STATUS OF

TIGERS

CO-PREDATORS AND PREY IN

INDIA

2022

Cover Photo: Mayank Sharma

Status of Tigers

Co-predators & Prey in India, 2022

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Content

मंत्री
पर्यावरण, वन एवं जलवायु परिवर्तन
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Minister
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सत्यमेव जयते

भूपेन्द्र यादव
Bhupender Yadav

India has a long standing and successful track record of protecting its tigers. The success of India in conserving and doubling its wild tiger population much before the targeted year of 2022 as per St. Petersburg Declaration, is commendable. India's exemplary efforts in tiger conservation and the increase in tiger numbers is not just a statistic but a testament to the determination and commitment of the nation. Under the ambit of tiger conservation, India has not only successfully safeguarded its tiger population, but also has secured the future of all life forms, truly in line with our philosophy of *'Vasudaiva Kutambakam'*.

India harbours approximately 75% global wild tiger population which is reflective of our conservation initiatives thoroughly supported by robust scientific approach. Monitoring tigers to keep a pulse on their numbers is imperative to understand the efficacy of our tiger conservation initiatives.

All India tiger monitoring is a herculean exercise being conducted every four years by National Tiger Conservation Authority in collaboration with State Forest Departments and with technical backstopping of the Wildlife Institute of India using the best available science. India is the only country in the world to have completed five cycles of estimation and the fifth cycle also demonstrates a rise in tiger numbers.

I compliment the National Tiger Conservation Authority, State Forest Departments and the Wildlife Institute of India for their relentless efforts in securing future of tigers in the country.

Bhupender Yadav
26/07/2023

राज्य मंत्री
पर्यावरण, वन एवं जलवायु परिवर्तन
उपभोक्ता मामले, खाद्य और सार्वजनिक वितरण

सत्यमेव जयते

Minister of State
Environment, Forest & Climate Change
Consumer Affairs, Food & Public Distribution

अश्विनी कुमार चौबे
Ashwini Kumar Choubey

बाघ भारतीय वनों के पारिस्थितिकी तंत्र का मुख्य हिस्सा है। यह वन खाद्य श्रृंखला पिरामिड के शीर्ष पर है। यदि बाघों का संरक्षण सफल होता है, तो संपूर्ण पारिस्थितिकी तंत्र की दशा में सुधार होता है। बाघ रेंज वाले देशों के लिए बाघों की बढ़ती आबादी, जलवायु परिवर्तन के विपरीत प्रभावों के लिए शमन रणनीति का एक प्रतीक है। बाघों का संरक्षण हमारे और हमारी आने वाली पीढ़ियों के लिए एक अच्छा भविष्य सुनिश्चित करने में बहुत मददगार साबित होगा।

"बाघ परियोजना" के 50 वर्षों की सफलता ने भारत के बाघ संरक्षण के अभूतपूर्व प्रयासों को पूरे विश्व पटल पर पर्यावरण संरक्षण की दिशा में एक नई पहल प्रदान की है। बाघ संरक्षण, केंद्र, राज्यों और देश के आम नागरिकों के बीच एक साझा जिम्मेदारी है। ऐसे सामूहिक प्रयासों के कारण पिछले कुछ वर्षों में बाघों की संख्या में काफी वृद्धि हुई है।

भारत दुनिया के उन गिने-चुने देशों में से एक है, जहाँ हर चार वर्ष के अंतराल पर बाघों, परभक्षियों, भक्ष्य आधारित प्राणियों (शाकाहारी वन्यप्राणी) की और उनके आवासों की संस्थागत निगरानी की जाती है। राज्य वन विभागों और भारतीय वन्यजीव संस्थान के सहयोग से राष्ट्रीय बाघ संरक्षण प्राधिकरण के नेतृत्व में दुनिया के इस सबसे बड़े वन्यजीव सर्वेक्षण ने ना केवल बाघों के लिए भविष्य सुरक्षित किया है, बल्कि बाघ संरक्षण नीतियों में भी बदलाव लाया है।

उत्कृष्ट विज्ञान पर आधारित यह **अखिल भारतीय बाघ, परभक्षियों, भक्ष्य आधार एवं उनके पर्यावास के आकलन का पांचवा चक्र** बाघ संरक्षण की गतिशीलता में महत्वपूर्ण अंतदृष्टि प्रदान करेगा।

(अश्विनी कुमार चौबे)

Preface

This report is a symbol of the hard work, persistence and commitment of our country to conserving the world we live in. With the establishment of 53 tiger reserves across the country, it has provided safe havens for tigers to thrive. This success is a testament to the serious efforts of the government, the on-ground untiring effort of the forest department coupled with the collaboration and support of scientists, have made India a global leader in tiger conservation. Our success has inspired other nations to follow suit and adopt similar approaches. By embracing science-backed conservation and management, we have set an example for the world. However, we must not rest on our laurels. Challenges such as habitat fragmentation, climate change, and poaching persist. It is imperative that we continue to prioritize scientific research, collaborate across borders, and engage local communities to ensure the long-term survival of tigers and their habitats. Through the Project Tiger's progress, and the indispensable role of science, we have become a global leader in this endeavor. I join all of you in congratulating all those involved in making this a resounding success. Let us continue to work together, hand in hand, to secure a thriving future for tigers and cement our position as torchbearers of conservation worldwide.

Virendra R. Tiwari
Director
Wildlife Institute of India


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Section I

Status of tigers in India

Yadvendradev V. Jhala, Qamar Qureshi, Vishnupriya Kolipakam, Ujjwal Kumar, Shikha Bisht, Ayan Sadhu, Deb Ranjan Laha, Amit Mallick, Satya P. Yadav

Section I

I.1 Introduction

Tigers are a vital aspect of India's wildlife heritage, culture, and country is proud to be home to more than 75% of the world's wild tiger population. Conserving tigers as top-predator is crucial for preserving biodiversity, a way of life, and a connection to nature.

The modern era of tiger conservation can be divided into three major phases. The first phase began in the 1970s with the enactment of the Wildlife Protection Act and establishment of protected areas that facilitated the conservation of tigers and tropical forests. However, late 1980s-1990's constitutes the second phase wherein, the trade in tiger parts began to decimate the population, leading to the shock of tiger extinction from the prestigious Sariska Tiger Reserve in 2004. Thus, began the third phase, wherein the Government innovated and implemented science backed ideas. In this phase, government adopted a landscape-level approach and implemented scientific monitoring for tiger conservation. This resulted in an increase in the tiger population from 1,411 in 2006 to 2,967 in 2018, occupying an area of 88,558 km^2. This effort to conserve tiger benefits ecosystems and human well-being, requiring attention, resources, and efforts from all sectors of society.

In 1973, Project Tiger was established with the objective of utilizing tiger's functional role and charisma to garner public support and resources for preserving representative ecosystems. Since its inception, the project has expanded from nine tiger reserves covering 18,278 km^2 to 53 reserves covering 75,796 km^2, which accounts for 2.3% of India's land area. Despite this, most tiger reserves and protected areas in India are similar to small islands in a vast sea of ecologically unsustainable land uses, and many tiger populations are confined to small protected areas. Although some habitat corridors exist that allow tiger movement between them, most of these habitats are not protected areas which are deteriorating due to unsustainable human use and developmental projects, and are thereby not conducive to animal movement. H.M. Patel (Union Minister and Chairman Steering Committee, Project Tiger, 1973) said, "Our objective is not to contrive glorified Safari parks for the tiger or, for that matter, our wildlife in general. Our endeavor, on the contrary, must be to retain the pristine or climax conditions of these areas with all the wonder and variety of their living forms, not just as a primordial relic of a distant past but as a dynamic and vital requirement for a quality of life that the most enlightened level of human thinking can conceive".

The information generated by the past four cycles has resulted in major changes in policy and the management of tiger populations. It has also provided scientific data to fully implement the provisions of the Wildlife (Protection) Act 1972, as amended in 2006, in letter and spirit. The major outcomes that were a direct or indirect consequence of information generated by the monitoring exercises were: 1) tiger conservation plans at landscape level, 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 importance of the corridors and their physical delineation, 5) integrating tiger conservation with developmental activities using the power of a reliable information system, 6) planning reintroduction and supplementation strategies for tigers and ungulates and 7) prioritizing conservation investments to target unique vulnerable gene pools (Qureshi *et al.* 2014, Kolipakam *et al.* 2019, Jhala *et al*. 2021). All of these provide an opportunity to incorporate conservation objectives supported by sound science-based data on an equal footing with economic, sociological and other values in policy and decision-making for the benefit of society.

Despite efforts to conserve tigers, there are still several challenges that need to be addressed. One of the major challenge is aligning the aspirations of large-scale economic development while safeguarding forests and their wildlife and mitigating human-tiger conflict. Other silent and surmounting threats are climate change-related impacts on habitats and the loss of the quality of forests over time. Out of approximately 5,83,278 km^2 of forests in the tiger states, only one-third

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are in relatively healthy condition. Another significant challenge is the illegal wildlife trade. Even though poaching is illegal, the demand for tiger products remains high, and poachers continue to kill tigers for profit. To combat this, the Indian government has implemented strict laws and increased surveillance to prevent poaching and illegal trade. The increase in the tiger population is a positive sign, but we must not become complacent, and continue our efforts to ensure the survival of this magnificent animal and safeguard our forested ecosystems in their entirety. Tigers are not just a part of India's wildlife heritage but also a symbol of the country's ecological richness and economic well-being.

The Prime Minister, Shri Narendra Modi, acknowledged the significant milestone of Project Tiger completing 50 years, highlighting that its success is not only a source of pride for India but also a matter of global importance. He emphasized that the commendable increase in India's tiger population, in contrast to declining numbers in other countries, is rooted in India's rich cultural heritage, deep respect for biodiversity, and its harmonious coexistence with the environment.

According to the Prime Minister, India firmly rejects the notion of a conflict between ecology and economy, instead prioritizing the coexistence of both. He emphasized that wildlife protection is a universal concern, transcending national boundaries. In 2019, he made a resolute call for a global alliance against poaching and illegal wildlife trade, underscoring the imperative for collective action. During India's G20 presidency, the Prime Minister underscored the motto "One Earth, One Family, One Future." This motto symbolizes the paramount significance of safeguarding the environment and fostering biodiversity to ensure a prosperous future for humanity. He added that this responsibility is shared by every individual and extends to the entire world. Expressing optimism, the Prime Minister affirmed India's ambitious goals in environmental protection and expressed confidence in international cooperation to accomplish these objectives.

I.2 Methodology

The tigers, ungulate, and habitat monitoring methods were adopted and implemented across almost 3,95,379 km^2 of India's forested habitat. Such large-scale data collection requires a large workforce, discipline, seamless data flow, and technology for analysis. As tigers inhabit diverse habitats across a vast geographical expanse in India, we have categorized the tiger-bearing habitats into five major landscapes based on biogeography and interconnectivity of the habitats: 1) Shivalik Hills and Gangetic Plains; 2) Central India and Eastern Ghats; 3) Western Ghats; 4) North Eastern Hills and Brahmaputra Flood Plains; and 5) Sundarbans. Each landscape is analyzed separately since environmental and habitat covariates differ in their relationship with tiger abundance in each of the landscapes. In addition, landscapes form logical and biological units wherein tiger populations can share common individuals and a common gene pool and can potentially disperse between populations. Given the landscape-scale management philosophy that is currently adapted, this division makes sense ecologically and for management inferences and implementation. However, tiger movement between landscapes is rare in recent times.

At the beginning of the first tiger monitoring exercise in 2006, India was divided into 100 km^2 cells, which were further divided into 25 km^2 and 2 km^2 cells, and since then, this sampling space has remained constant. Each grid was uniquely coded so that subsequent inferences could be compared on the same spatial scale and extent. The overall sampled space for Phase I remains constant; what changes within that is camera-trapped space vs. model-predicted space, over time with the availability of more camera traps and trained man power the proportion of the area sampled by camera traps has increased making the need for model based predictions smaller in each cycle.

Phase I - Countrywide field data collection: Frontline staff of State Forest Departments in 21 potential tiger-bearing States were trained to collect the Phase I data (Fig. I.2.1) in a digital format on the M-STrIPES mobile application. Field guides (Jhala *et al.* 2021) in nine regional languages were published and provided to each beat guard.

Data collection on each of the following components was implemented in 2022:

a. Carnivore and megaherbivore sign encounters (Form 1: multiple occupancy surveys in a beat)
b. Ungulate abundance (Form 2: Distance sampling on line transect(s) in a beat)
c. Vegetation (Forms 3A and 3C: Canopy cover, tree, shrub, and herb composition, weed infestation on plots on a transect in a beat)
d. Human disturbance (Form 3B: Multiple plots of 30m diameter on line transects in a beat) and
e. Dung counts (Form 4: count of all dung and pellets identified to species in multiple 40 m^2 plots on transects)

In Sundarbans, the above protocol was modified so as to allow sampling using a boat along river channels (*khals*), and in north-east India, barring Assam, the polygon search method was used (Efford, 2011, https://mstripes.wii.gov.in/publications/polygon-search-method/). Phase I sampling took a maximum of 10 days for each forest beat, with the sampling effort being done by two people.

Phase II - Remotely sensed spatial and attribute covariates: Distribution and abundance of wildlife are likely to be determined by habitat characteristics and anthropogenic impacts. These covariates were obtained from remotely sensed data and used to model tiger occupancy and abundance in combination with Phase I data. Habitat characteristics were surrogated by forest area, vegetation cover (Normalized Difference Vegetation Index (NDVI)), forest patch size, forest core areas, elevation, distance from protected areas, and drainage density. Human impacts were surrogated by human footprint, distance to night lights, night light intensity, distance to roads, and

Table I.2.1

Remotely sensed spatial data based on field sampling and secondary data used for modelling occupancy and abundance of tigers.

Data from Phase-1 Surveys			
S. No	Dataset	Source	Spatial Resolution
1.	Prey encounter rate (Chital, Sambar, Wild pig, Gaur)	Phase-1 Survey, AITE 2022	25 &100 km^2 *
2.	Prey faecal pellet (Chital, Sambar, Wild pig, Gaur)	Phase-1 Survey, AITE 2022	25 &100 km^2 *
3.	Human Disturbance –Human trail, Wood cutting, Lopping, Livestock trail, People seen)	Phase-1 Survey, AITE 2022	25 &100 km^2 *
Remotely sensed data			
4	Night time lights Intensity (2021)	C. D. Elvidge, K. Baugh, M. Zhizhin, F. C. Hsu, and T. Ghosh, "VIIRS night-time lights," International Journal of Remote Sensing, vol. 38, pp. 5860–5879, 2017.	500 m
5	Normalised Difference Vegetation Index-Pre and post monsoon	Vermote, E., Justice, C., Claverie, M., & Franch, B. (2016). Preliminary analysis of the performance of the Landsat 8/OLI land surface reflectance product. Remote Sensing of Environment, 185, 46-56.	30 m
6	Digital Elevation Model	NASA Shuttle Radar Topography Mission (SRTM)(2013). Shuttle Radar Topography Mission (SRTM) Global. Distributed by OpenTopography. https://doi.org/10.5069/G9445JDF.	30m

7	Global human modification Index (2016)	Kennedy, C. M., J. R. Oakleaf, D. M. Theobald, S. Baruch-Mordo, and J. Kiesecker. 2020. Global Human Modification of Terrestrial Systems. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/edbc-3z60.)	1000m
8	Forest Cover (2017)	India state of Forest Report (2017).Forest Survey of India, Ministry of Environment, Forest and Climate Change , Government of India	23.5 m
9	Ruggedness	Derived from Primary data	1000 m
10	Distance to Nightlights	Derived from Primary data	1000 m
11	Distance to water sources	Derived from Primary data	1000 m
12	Distance to Protected areas	Derived from Primary data	1000 m

**Data collected on 2-3 km line transects & plots laid at every 400 m were extracted at 25 &100 km^2 cell*

Phase III - Camera trap-based Capture-Mark-Recapture: Camera trap surveys are a well-established method for abundance and density estimation of carnivores. The development of spatial capture-recapture methods has led to greater clarity and precision in density estimation by integrating the spatial location information of animal photo-captures (Jhala *et al.* 2020).

Camera traps were placed at 32,803 locations spread across 175 sites for mark recapture analysis (Fig. I.2.2). These camera traps were systematically distributed within the sampling area in 2 km^2 cells, which are a subset of the aforementioned fixed 100 km^2 cells, deploying at least one pair of cameras within each cell. Within each 2 km^2 cells, locations are identified for the placement of cameras through extensive search during sign surveys so as to maximize photo-captures of tigers and leopards. Sampling was carried out simultaneously in a minimum block of 200 km^2. If a larger number of camera traps were available to cover, then sampling was done in larger blocks. A minimum spacing of ~ 1 km was maintained between camera trap locations. Cameras were usually operated between 25 and 45 days at each site, with an average effort of over 1000 trap nights per 100 km^2.

In areas where camera trapping was not possible (logistically or due to insurgency) and tiger densities were very low, molecular tools were used to determine the presence of tigers by extracting DNA from scats.

Table I.2.2

Country wide sampling effort for ground surveys during Phase I of each state, 2022.

State	Number of trails	Total length of trails (km)	Number of transect	Total length of transect (km)	Number of habitat plots	Camera trap numbers
Bihar	232	1775	499	981	1372	429
Uttar Pradesh	1270	6412	1237	2408	4396	1343
Uttarakhand	2735	12389	2522	4299	8256	2165
Shivalik	**4237**	**20576**	**4258**	**7688**	**14024**	**3937**
Andhra Pradesh	3456	16597	3430	6637	11090	989
Chhattisgarh	9855	46176	8422	16185	31664	459
Jharkhand	976	4600	732	1457	4570	323
Madhya Pradesh	26757	139651	26341	54256	96924	6894
Maharashtra	16331	78016	16124	31210	56512	4872
Odisha	9623	52633	9531	19522	33544	733
Rajasthan	988	4449	981	1911	3422	685
Telangana	6633	29188	5599	10502	18264	1578
Central India	**74619**	**371310**	**71160**	**141680**	**255990**	**16533**
Karnataka	8874	45323	10002	18297	31742	5163
Kerala	1522	7463	1201	2361	4156	1314
Tamil Nadu	1892	11019	1845	3681	5376	3650
Goa	174	765	165	324	526	95
Western Ghats	12462	64570	13213	24663	41800	10222
Assam	389	1816	483	856	1356	619
North Bengal	786	4011	586	1203	2174	329
Mizoram	87	330	NA	NA	8064	43
Arunachal Pradesh	309	840	NA	NA		407
Nagaland	178	568	NA	NA		NA
North-East	**1749**	**7565**	**1069**	**2059**	**11594**	**1398**
Sundarbans	**315**	**1339**	**NA**	**NA**	**595**	**713**
India Total	**93382**	**465360**	**89700**	**176090**	**324003**	**32803**

The spatial covariates of relative abundance of tigers, co-predators, and ungulates, human impact indices, and habitat characteristics across all potential tiger habitats in India are collected via remote sensing and on-ground surveys at a spatial resolution of a forest beat (average about 15 km^2). Subsequent to Phase I and II, an adequate area within each landscape was sampled using camera traps at a high density of one double-sided camera location per 2 km^2 (Phase III) (Fig. I.2.2). The spatially explicit capture recapture approach was used to estimate tigers calibrate estimation in camera-trapped area and extrapolate to areas where tigers are present but not camera-trapped.

Figure I.2.1

Spatial coverage of sampled forests for carnivore signs, ungulate abundance, habitat characteristics and anthropogenic impacts (Phase-1) in 2022. Tiger presence locations are depicted in orange

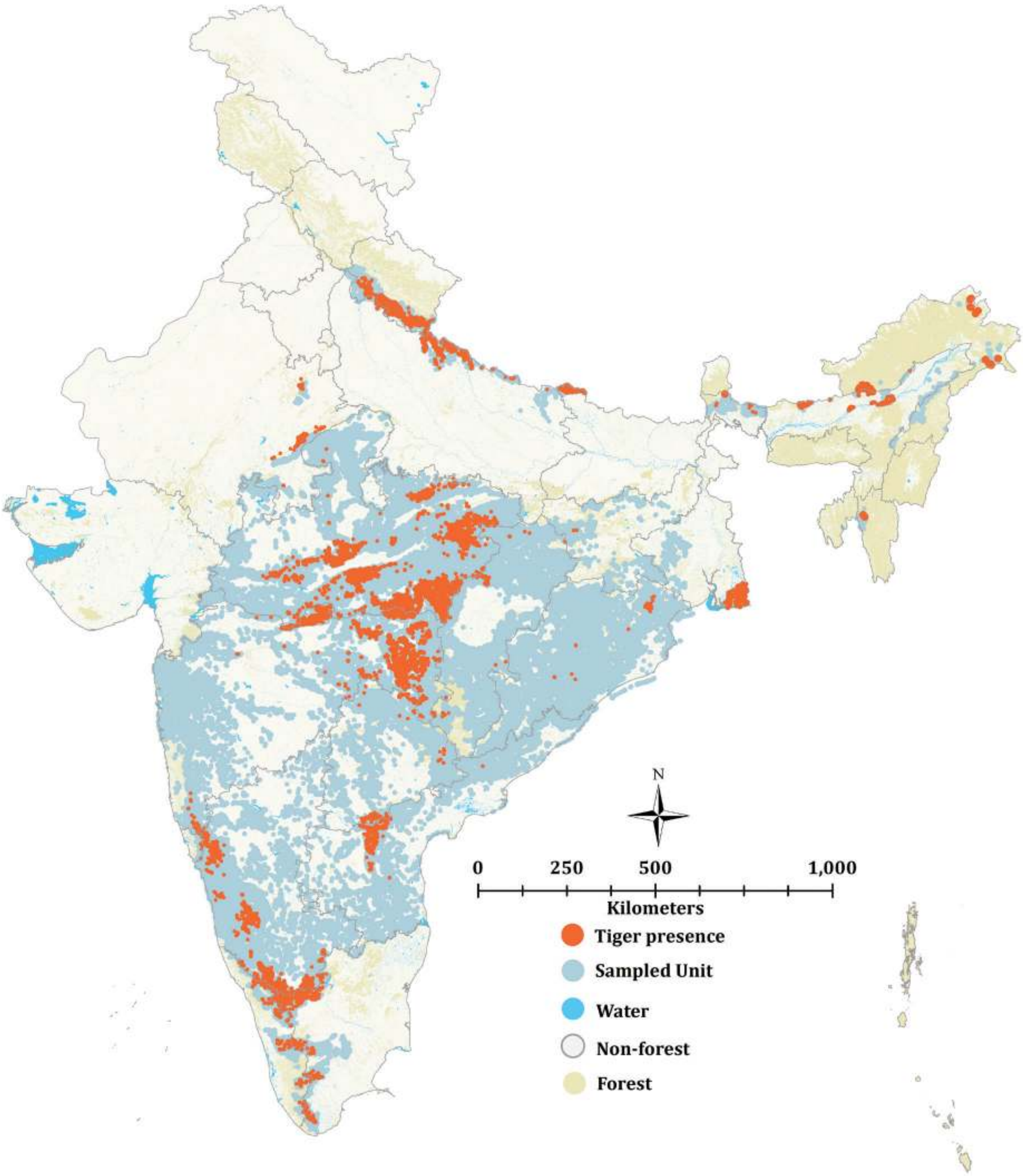
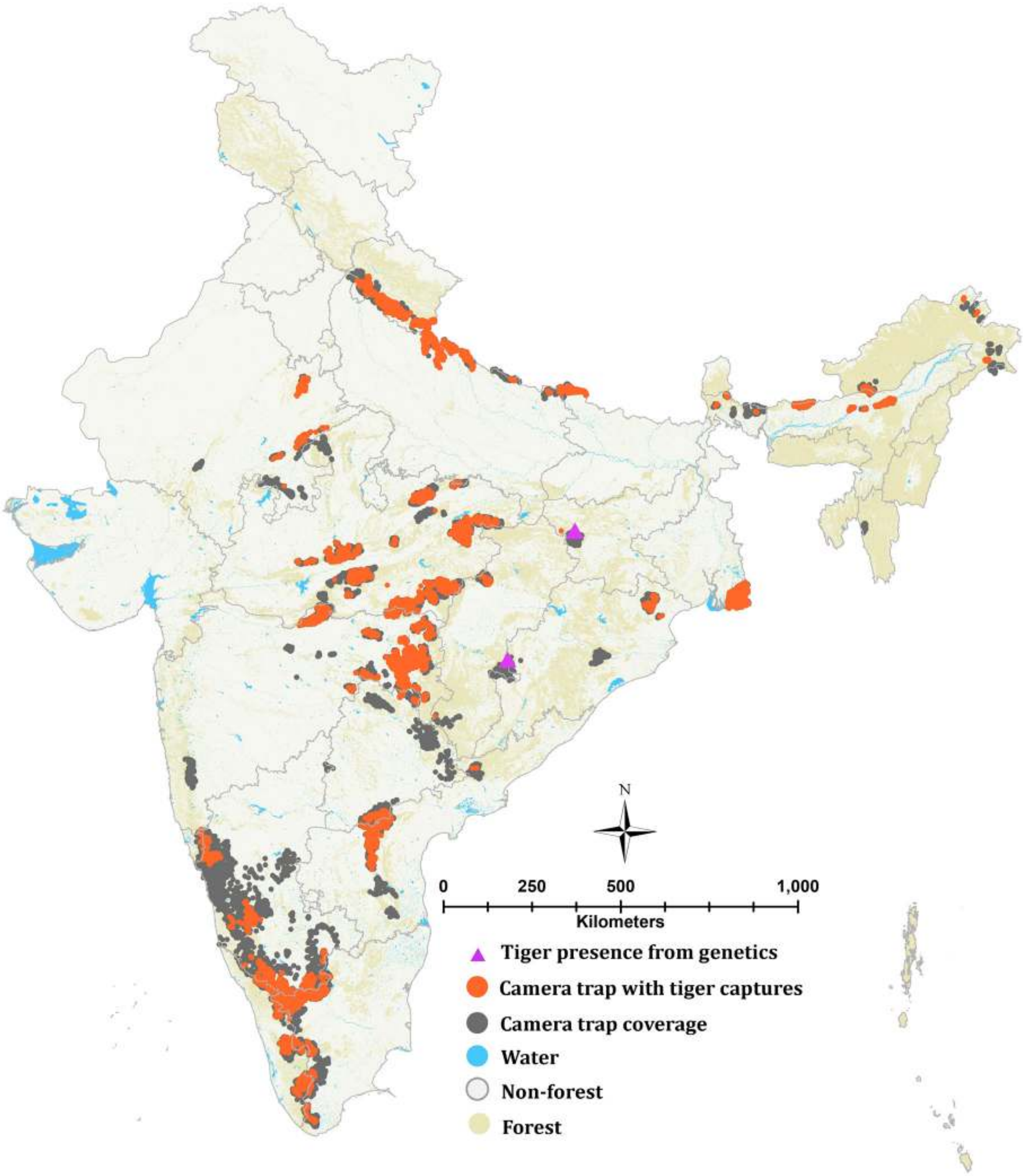


Figure I.2.2

Camera trap locations with tiger photo captures (orange) and tiger positive scat locations (purple triangles) from genetics across tiger bearing forests of India in 2022.



Processing of Phase I data in M-STrIPES desktop software: Phase I data was received from different States of India, and these were processed using M-STrIPES desktop software (Fig.I.2.3). Data entry errors, if any, were communicated back to the respective forest divisions for rectification. The M-STrIPES desktop software is capable of exporting the collected data into a data format that can be readily analyzed by existing quantitative analysis software. Data from the carnivore sign survey (Form 1) was used to model the occupancy of different species (single season, single species format), and herbivore abundance was estimated using the exported line transect data (Form 2). The data from habitat assessment, which includes information on different plant species (Forms 3 and 4), including invasive plants and ungulate dung was extracted for mapping.

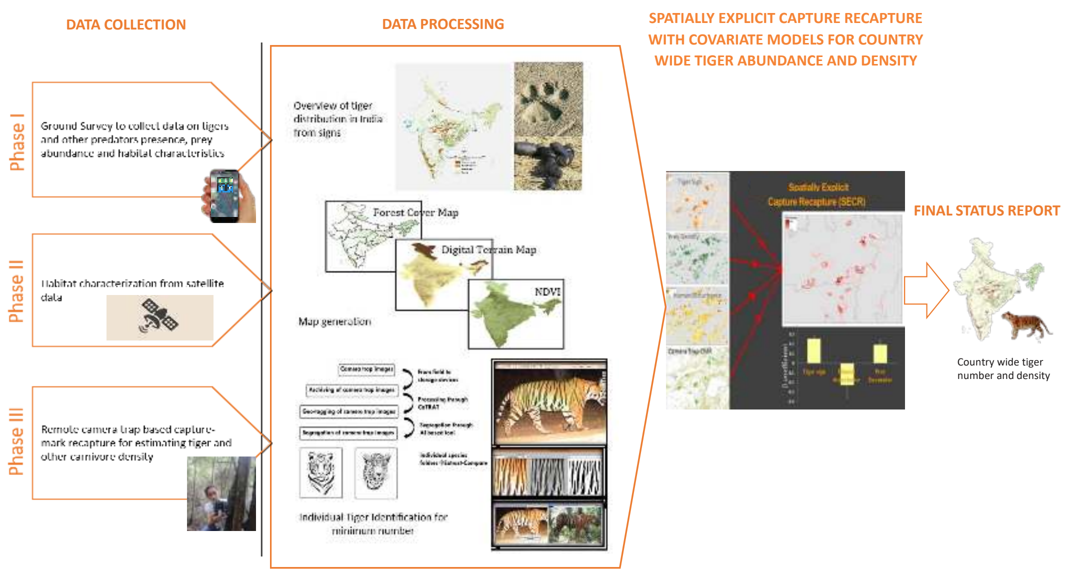
Phase II Remotely sensed spatial and attribute covariates: Remotely sensed data was extracted grid-wise and used as a covariate in occupancy and abundance models (Table I.2.1).

Processing of Phase III data: The image processing software CaTRAT (Camera Trap Data Repository and Analysis Tool), developed at the Wildlife Institute of India in collaboration with the Indraprastha Institute of Information Technology (IIIT), New Delhi, to analyze camera trap data, was used for organizing and geo-tagging (tagging individual pictures with the location of the camera trap site) of photo-captures obtained from the field. The geo-tagged images were further processed for segregation into species using an artificial intelligence tool (AI) (Fig. I.2.3). The AI-based image processing tool, developed in collaboration with IIIT, Delhi, helps automatically segregate the camera trap images of different species. This segregated data was subsequently processed for individual identification of tigers and leopards (Hiby *et al.* 2009).

In some areas, molecular tool-based confirmation of tigers was carried out. From the collected scats, DNA was extracted, and species confirmation was obtained by using a species-specific marker that can differentiate between tigers and other co-predators. A panel of eleven microsatellites was further used on tiger-positive scats to evaluate the minimum number of individuals in the sampled area (Kolipakam *et al.* 2019).

Figure I.2.3

Workflow of data collection and analysis, All India Tiger Estimation, 2022.



Individual identification of tigers: Individual identification is carried out using pattern recognition program ExtractCompare (Hiby *et al.* 2009). Using an automated process, pattern recognition software searches through the database of images to calculate similarity between digitized tiger coat patterns to recognize common and unique individuals (Figs. I.2.3 and I.2.4). Individual tigers were first identified from each camera trap site and subsequently, tiger photographs of adjoining sites and other sites within the landscape were compared using the National Tiger Database so as to remove duplicate or shared tigers, if any, and to understand tiger dispersal events. Once all unique individual tigers are identified, a matrix of spatial capture history for each tiger is developed for each site with camera trap IDs, their coordinates, and the deployment and operation history of each camera. This information is needed to estimate tiger abundance.

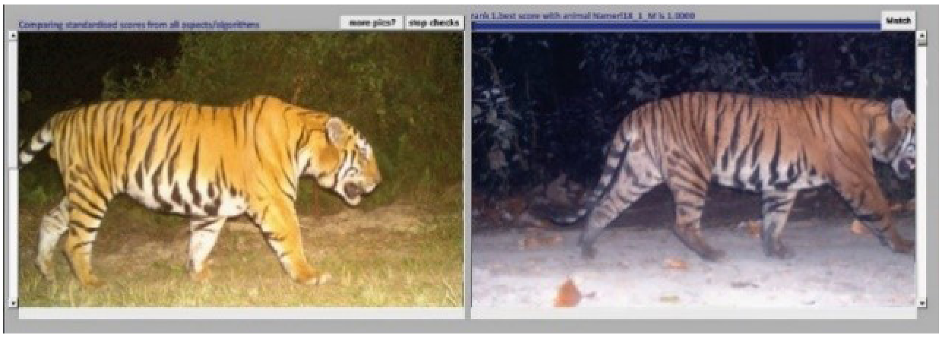
Figure I.2.4

Process of individual identification of tigers using ExtractCompare software. This has generated National Tiger Photo Database Library in India.

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

Abundance estimation through Spatially Explicit Capture Recapture (SECR): We used the likelihood-based SECR method (Efford *et al.* 2011, Borchers and Efford 2008), implemented in R (R Development Core Team 2010), to estimate tiger abundance from camera trap data. A habitat mask with a sufficiently realistic buffer (sufficient width around the camera trap array that excludes non-habitat) was used and density was modeled as a function of covariates. Tiger sign encounter rate, prey encounter or dung densities, and human footprint variables obtained from ground surveys and remotely sensed data are used within SECR as covariates in a likelihood framework to model tiger density (Fig. I.2.3).

I.3. A Comprehensive Abundance Assessment of Tigers in India

The fifth cycle of All India Tiger Estimation (2022-23) covered forested habitats in 19 states of India. A foot survey of 6,41,449 km was done for carnivore signs and prey abundance estimation (Table I.2.2). In these forests, 3,24,003 habitat plots were sampled for vegetation, human impacts and ungulate dung (Table I.2.2). Camera traps were deployed at 32,803 locations, resulted in 4,70,81,881 photographs of which 97,399 were of tigers. The total effort invested in the survey was 6,41,102 man-days. Tigers occupied a total of 1,03,408 km^2 of forests covering 16% of the total sampled grids. We believe that this is the world's largest effort invested in any wildlife survey till date, on all of the above counts.

Minimum tiger estimate is 3167 and a total of 3080 individual tigers (> 1 year of age) were photo-captured, which is more than the ones captured in 2018 (2461 tigers) (Table I.3.1). The SECR based estimate is 3682 and should be considered as the population estimate of the country.

Table I.3.1

Unique tiger individuals photo captured (2018 & 2022), minimum tiger population and population estimate in each landscape, 2022

Landscape	Unique tigers: Mt+1		Minimum Population: CMR*	Population Estimate: SECR# (SE)
	2018	2022		
Shivalik Hills & Gangetic Plains Landscape	598	804	816	819 (43)
Central Indian Highlands & Eastern Ghats Landscape	850	1161	1175	1439 (125)
Western Ghats Landscape	784	824	877	1087 (66)
North Eastern Hills & Brahmaputra Plains Landscape	144	194	199	236 (35)
Sunderbans Landscape	85	100	100	101 (10)
India	**2461**	**3080**	**3167**	**3682 (243)**

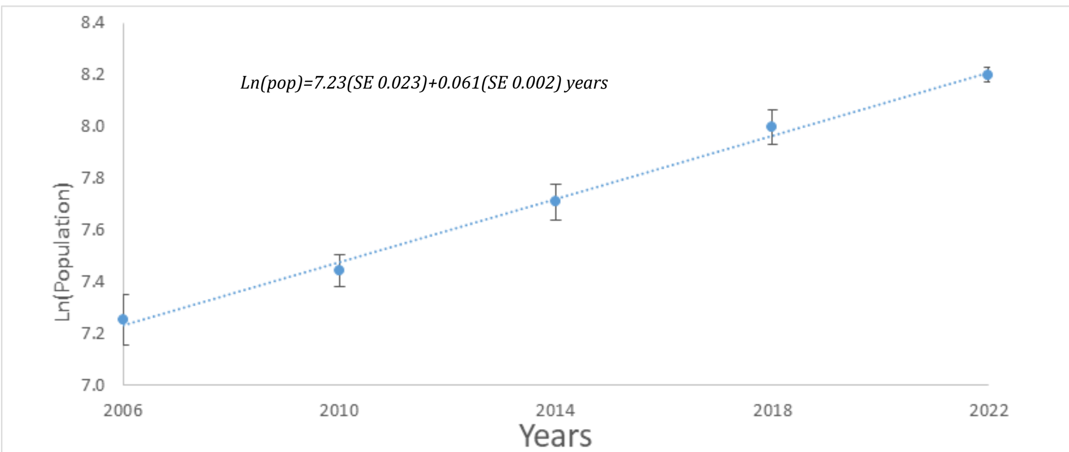
** The minimum population estimate is arrived using classical mark-recapture of camera trapped individual. This estimate is limited to Camera trapped area.*

 # The SECR based estimate is the population estimate of tiger occupied forest not limited to Camera trapped area.

The tiger number released by the Hon'ble Prime Minister is the population estimate within camera trapped areas and should be considered the minimum population estimate of the country. The spatial capture mark recapture (SECR) estimate applies to camera trapped areas, as well as areas where camera trapping was not carried out but tiger signs were detected during Phase I surveys and is the total population estimate of the country.

Figure I.3.1

Growth rate (6.1 %) of tigers in India estimated from 2006 to 2022



India's tiger population has experienced a growth of 6.1% (Fig. I.3.1). A significant portion of this assessment was conducted through the use of camera traps, which successfully captured 84% of individual tigers. Moreover, camera trap-based capture-mark-recapture methods accounted for 86% of the identified tigers, similar to proportion observed in 2018, (Jhala et al. 2020) (Fig. I.3.2). The estimated tiger population in India is 3,682 (SE 243) (Fig. I.3.3 & Table I.3.2). The abundance assessment of tigers in India reveals significant changes in their population distribution across various landscapes. The most notable increase in tiger population is observed in Central India and the Shivalik Hills and Gangetic Plains, which is primarily contributed by the states of Madhya Pradesh, Maharashtra, and Uttarakhand (Fig.I.3.3 & Table I.3.2). This surge in numbers is an encouraging sign for tiger conservation efforts in these regions. Additionally, Uttar Pradesh, Andhra Pradesh, Rajasthan and Bihar have also recorded notable increases in their tiger populations (Fig. I.3.3 & Table I.3.2).

However, the situation is not uniform across all regions. The tiger population in the Western Ghats has remained relatively stable, but there have been declines noted in specific areas such as Wayanad and Northern Karnataka. The localized declines in tiger populations in the Western Ghats highlight the need for more targeted monitoring and conservation efforts within this region. On the other hand, there are states that report alarming tiger population trends. Mizoram and Nagaland have reported zero tiger signs and sightings, raising concerns about the absence of tigers in these areas. Similarly, Jharkhand has documented only a single individual tiger, emphasizing the urgent need for conservation measures to protect and enhance tiger populations in these regions. Goa, Chhattisgarh and Arunachal Pradesh have relatively small tiger populations, which necessitates focused conservation strategies to ensure their long-term survival.

One particular area of concern is the survival of the tiger population in Odisha, which is currently under serious threat from poaching activities. Immediate action is required to combat poaching and protect the remaining tigers in Odisha, as failure to do so may lead to the extinction of this population. Efforts must be made to strengthen anti-poaching measures and raise awareness about the importance of conserving tigers in Odisha to ensure their survival for future generations.

Section I.3

Figure I.3.2

Proportion of total tiger population camera trapped and estimated by capture-mark recapture (CMR), 2022

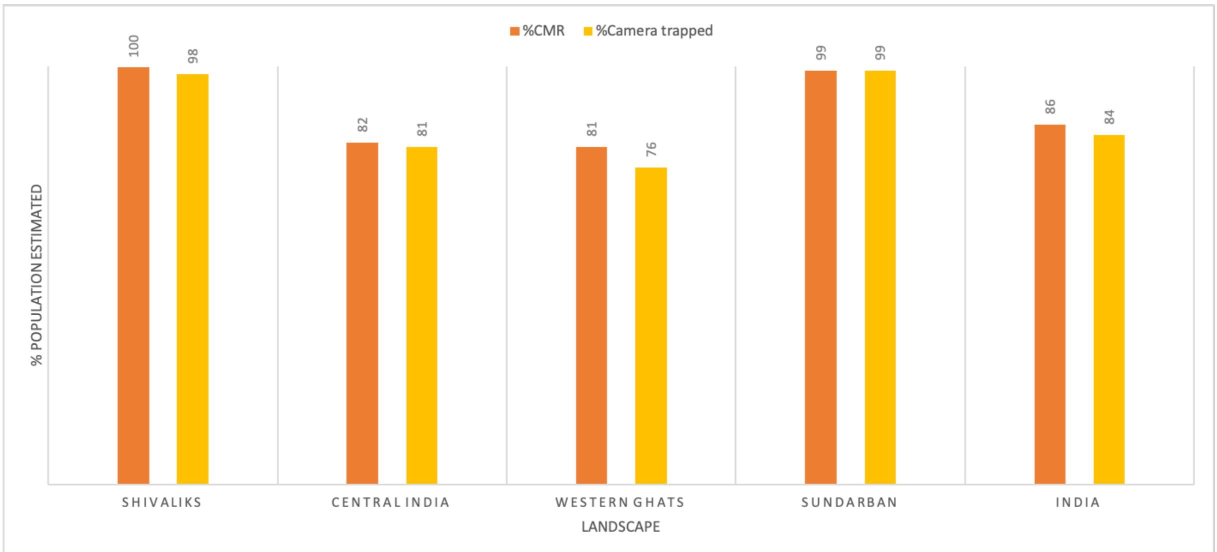


Table I.3.2

Estimated tiger numbers in each landscape from 2006 to 2022 (Number in parenthesis is Standard Error). State population estimate do not add up to the landscape estimate due to common tigers, tiger outside protected areas, and spatial distribution of tiger activity centers. Tigers common between sites are counted only once in the landscape/state. Lower limit of the estimates should be truncated at the minimum number of photo-captured tigers.

State	Tiger Population				
	2006	2010	2014	2018	2022
Shivalik Hills and Gangetic Plains Landscape					
Bihar	10	8	28	31	54(1)
Uttarakhand	178	227	340	442	560(24)
Uttar Pradesh	109	118	117	173	205(18)
Shivalik-Gangetic	**297**	**353**	**485**	**646**	**819(43)****
Central Indian Landscape and Eastern Ghats					
Andhra Pradesh	95	72	68	48	63(7)
Telangana	-	-	-	26	21(2)
Chhattisgarh	26	26	46*	19	17(2)
Jharkhand		10	3*	5	1*
Madhya Pradesh	300	257	308*	526	785(58)
Maharashtra	103	168	190*	312	444(43)
Odisha	45	32	28*	28	20(4)
Rajasthan	32	36	45	69	88(9)
Central India & Eastern Ghats	**601**	**601**	**688**	**1033**	**1439(125)**
Western Ghats Landscape					
Goa	-	-	5*	3	5
Karnataka	290	300	406	524	563(35)
Kerala	46	71	136	190	213(16)
Tamil Nadu	76	163	229	264	306(15)
Western Ghats	**402**	**534**	**776**	**981**	**1087(66)**
Northeast Hills and Brahmaputra Flood Plains					
Arunachal Pradesh	14		28#	29#	9
Assam	70	143	167	190	229(24)

State	Tiger Population				
	2006	2010	2014	2018	2022
Nagaland	-	-	-	0	0
Northern West Bengal	10	-	3*	0	2
North East Hills, and Brahmaputra	**100**	**148**	**201**	**219**	**236(35)**
Sundarbans		70	76	88	101(10)
TOTAL	**1411**	**1706**	**2226**	**2967**	**3682(243)**

**:scat DNA based population*
***:Ranipur(Uttar Pradesh) is added in Shivalik landscape for convenience*
#:MaxEnt predicted population, this should not be used to compare the trends
State population estimate does not add up to the landscape estimate due to common tigers, tiger outside protected areas, and model range limits.

The study utilized a spatially explicit framework to estimate tiger populations within individual tiger reserves, considering the dynamic movements of tigers and the absence of strict boundaries. Two estimates were provided: one based on tigers within the administrative boundaries of the reserves, and the other considering tigers that could potentially utilize the reserves.

Among the assessed tiger reserves, Corbett Tiger Reserve emerged with the largest population of 319 (SE 9.3) tigers. Reserves such as Bandipur, Nagarahole, Mudumalai, Bandhavgarh, and Dudhwa harbored 150 or more tigers. Additionally, Kaziranga, Kanha, Pench (MP), Tadoba, Sathyamangalam, and Sunderbans contained tiger populations ranging from 100 to 150. Fourteen reserves had populations ranging from 50 to 100 tigers. For reserves with smaller populations, implementing a metapopulation framework and establishing habitat corridors would be crucial for their long-term survival (Fig I.3.3 & Table I.3.3).

However, populations with around 20 tigers need to put in more effort to ensure survival of tiger populations. Reserves with no tigers, male-only populations, or fewer than 5 tigers were Nameri, Pakke, Achanakmar, Ranipur, Indravati, Mukundara, Ramgarh-Vishdhari, Namdapha, Kamlang, Udanti Sitanadi, Satkosia, Kawal, Palamau, Sahyadri, Buxa, and Dampa (Table 1.3.3).

Approximately 35% of the tiger reserves urgently require enhanced protection measures, efforts to reduce human dependence, habitat restoration, ungulate supplementation, and subsequent tiger reintroduction. For ungulate augmentation, predator-proof enclosures should be established within reserves, and chital and/or sambar should be appropriately quarantined and introduced for supplementation. When reintroducing or supplementing ungulates or tigers, individuals should be sourced from within the landscape. The implementation of these measures is crucial to ensure the conservation and growth of tiger populations within these reserves, guaranteeing their long-term viability and success.

Figure I.3.3

Tiger density, extent and population blocks in India, 2022.

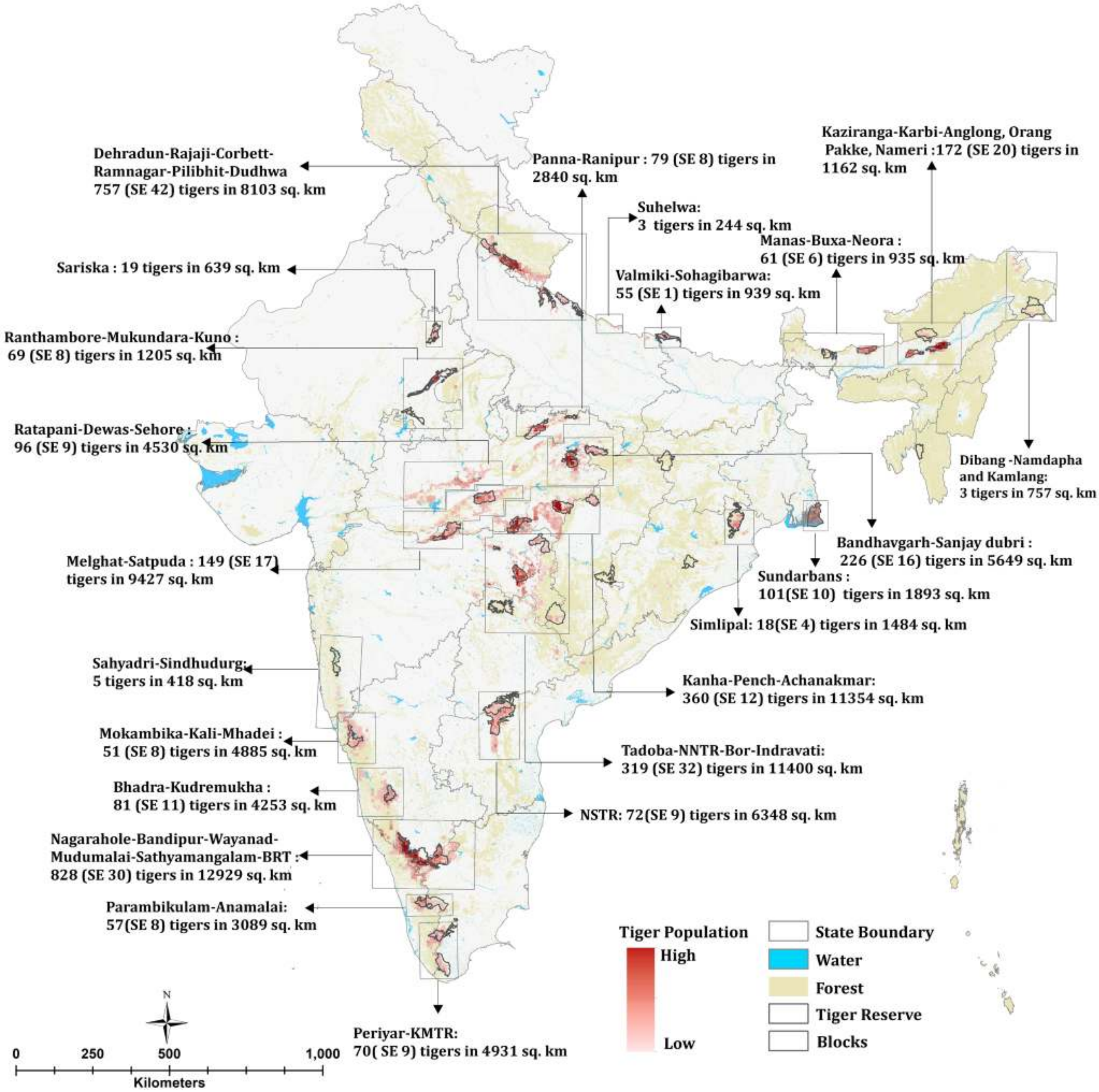


Table I.3.3

A comparative account of the estimated tiger numbers in Tiger Reserves and tigers utilizing Tiger Reserves in 2022.

State	Tiger Reserve	Tiger Number Within Tiger Reserves ± SE	Tiger Number utilising the Tiger Reserve ± SE
Uttarakhand	Corbett	260±0.4	319±9.3
	Rajaji	54±0.6	78±6.6
Uttar Pradesh	Pilibhit	63±0.01	71±3.3
	Dudhwa	135±0.07	153±14
	Ranipur	4	4
Bihar	Valmiki	54±0.2	55±1.8
Andhra Pradesh	NSTR	58±0.84	62±4.14
Chhattisgarh	Achanakmar	5	5
	Indravati*	1	1
	Udanti Sitanadi	1	1
Jharkhand	Palamau*	1	1
Madhya Pradesh	Bandhavgarh	135±1.07	165±6.27
	Kanha	105±0.49	129±5.58
	Panna	55±0.25	64±3.41
	Pench	77±0.31	123±8.7
	Satpura	50±0.05	62±4.1
	Sanjay Dubri	16±0.06	20±2.41
Maharashtra	Bor	9±0.14	11±2.01
	Melghat	57±0.28	68±3.89
	Navegaon Nagzira	11±0.12	13±1.92
	Pench	48±0.43	77±6.55
	Sahyadri	0	0
	TATR	97±0.22	122±5.67
Odisha	Satkosia	0	0
	Similipal	16±0.4	20±2.47
Rajasthan	Mukundara	1	1
	Ramgarh Vishadhari	1	1
	Ranthambhore	57±0.13	63±2.59
	Sariska	19	19
Telangana	Amrabad	12±0.6	16±2.56
	Kawal	0	0
Karnataka	Bandipur	150±0.5	191±7.3
	Bhadra	28±0.3	44±5.2
	BRT	37±0.5	60±6.3
	Kali	17±0.2	29±5.1
	Nagarhole	141±0.8	185±7.8

State	Tiger Reserve	Tiger Number Within Tiger Reserves ± SE	Tiger Number utilising the Tiger Reserve ± SE
Kerala	Parambikulam	31±0.3	42±4.4
	Periyar	30±0.2	43±4.5
Tamil Nadu	Anamalai	16±0.1	20±2.6
	Kalakad -Mundanthurai	5	5
	Mudumalai	114±0.4	167±9
	Sathyamangalam	85±0.6	114±6.4
	SMTR (Meghamalai)	12±0.5	18±3.1
Assam	Orang	16±0.31	26±4.32
	Manas	58±0.76	59±1.53
	Kaziranga	104±0.27	136±6.63
	Nameri	3	3
Mizoram	Dampa	0	0
Arunachal Pradesh	Pakke	6	6
	Kamlang	0	0
	Namdapha	1	1
West Bengal	Sundarban Biosphere Reserve#	-	101±10
	Buxa	1	1

**Minimum population through genetic analysis of tiger scat.*

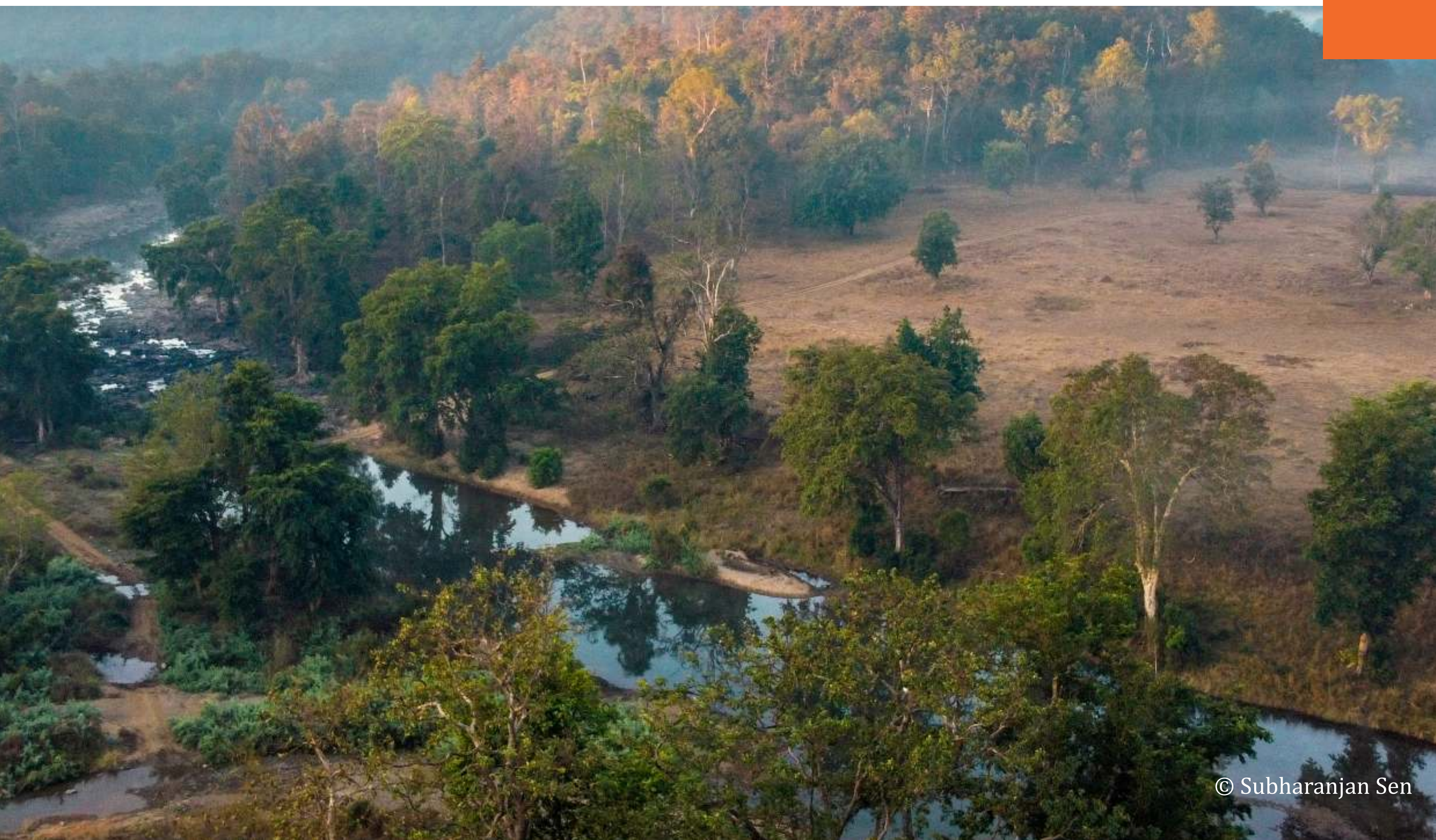
NSTR= Nagarjunasagar Srisailam Tiger Reserve

BRT= Biligiri Ranganatha Swamy Temple Tiger Reserve

TATR= Tadoba-Andhari Tiger Reserve

SMTR= Srivilliputhur-Meghamalai Tiger Reserve

#: Sundarban Biosphere Reserve includes Sundarban Tiger Reserve and adjoining South 24 Parganas division (see detail in Section II.5)

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Landscapes

Section II.1

Shivalik Hills and Gangetic Plains Landscape

Shikha Bisht, Anindita Bidisha Chaterjee, Kainat Latafat, Ujjwal Kumar, Swati Saini, Dhruv Jain, Monika Saraswat, Vishnupriya Kolipakam, Hemant Singh, Rajendra Garawad, Satya P. Yadav, Yadavendradev V. Jhala, Qamar Qureshi

Section II.1

Shivalik Hills and Gangetic Plains

The Shivalik Hills and Gangetic Plains landscape is comprised of Shivaliks, Bhabar tracts, and Terai plains. Shivaliks, present in both India and Nepal (known as the Churia Hills), are young fold mountains (elevation 1,000–1,500 meters) prone to erosion and characterized by loose boulders and ephemeral streams. Their eroded material gets deposited along the less steep slopes, giving rise to bouldery bhabar tracts, where most of the streams of Shivaliks go underground and re-emerge in the Terai plains (Mani 1974). Terai is characterized by a high water table, annual flooding, and shifting floodplains and is consequently dominated by tall grass species (Mathur 2000). Shivaliks have floral elements of both peninsular India and temperate regions of the western Himalayas, while the Bhabar tracts are dominated by moist deciduous forests, with Sal (Shorea robusta) being the predominant species. Terai plains have woodland-grassland-wetland forests dominated by graminoid species of *Saccharum narenga, Sclerostachya, Imperata, and Typha sp.* (Mathur 2000).

In India, this landscape spans across the states of Himachal Pradesh, Uttarakhand, Uttar Pradesh, Bihar, West Bengal, and Assam. For convenience in the assessment of tigers, 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 western portion of this landscape lies in Shivalik-Bhabar tracts and is characterized by a large number of seasonal streams called *raus* and perennial streams called *sots*. Two tiger reserves, *viz.,* Rajaji and Corbett Tiger, are situated in this region. In the eastern portion of this landscape, both *raus* and *sots* flow into the Terai and act as water sources throughout the year. This eastern portion is therefore composed primarily of Terai grasslands that thrive on the alluvial silts and clay deposits. Large swampy regions attract migratory waterfowl and support conditions conducive to the survival of species like the swamp deer, hog deer, and rhinoceros. The protected areas within this zone, namely Pilibhit, Dudhwa, and Valmiki Tiger Reserves, are embedded in a matrix of human use and sugarcane fields. These protected areas are connected with Nepal and are important for transboundary tiger conservation. The western portion has higher forest cover and low human disturbance, while the eastern part is characterized by intensive agriculture and low forest cover (Johnsingh *et al.* 2004).

With its high productivity and concentration of ungulates, this landscape has the ability to sustain some of the highest densities of tigers in the world (Bisht *et al.* 2019). This area 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 (the former two being in Nepal) (Wikramanayake *et al.* 1998). Most of the Terai forests (Pilibhit Tiger Reserve, Dudhwa Tiger Reserve, Suhelwa Wildlife Sanctuary and Valmiki Tiger Reserve) in India are connected with the Nepal, so trans-boundary cooperation is imperative to secure a single meta-population of tigers (Qureshi *et al.* 2006).

Apart from tigers, the landscape harbors subspecies of the endangered northern Swamp deer (barasingha) and the only surviving population of gaur and wild dog (in Valmiki Tiger Reserve) present in the Indian Terai. Indian Wolf was reported from Rajaji Tiger Reserve (Krishna *et al.* 2022) and Valmiki Tiger Reserve (Maurya *et al.* 2021). Among 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 for this representative endangered fauna.
Tigers were reintroduced in the western part of Rajaji Tiger Reserve in 2020, which can lead to the recolonization of the western Terai forests of Haryana and Himachal Pradesh. A tiger from Rajaji Tiger Reserve was photo-captured in Simbalbara National Park in Himachal Pradesh, on the border of Haryana state, in 2023. The Shivalik forests of Haryana and Himachal Pradesh need to increase protection and reduce forest conversion to provide a place for tigers to establish territory instead of just transient movements across them. Tiger related conflict is also on rise in this landscape. Active management efforts such as village relocation and prey supplementation followed by tiger reintroduction can lead to tiger movement in the fragmented forests of the western Shivalik and Bhabar tracts of this landscape.

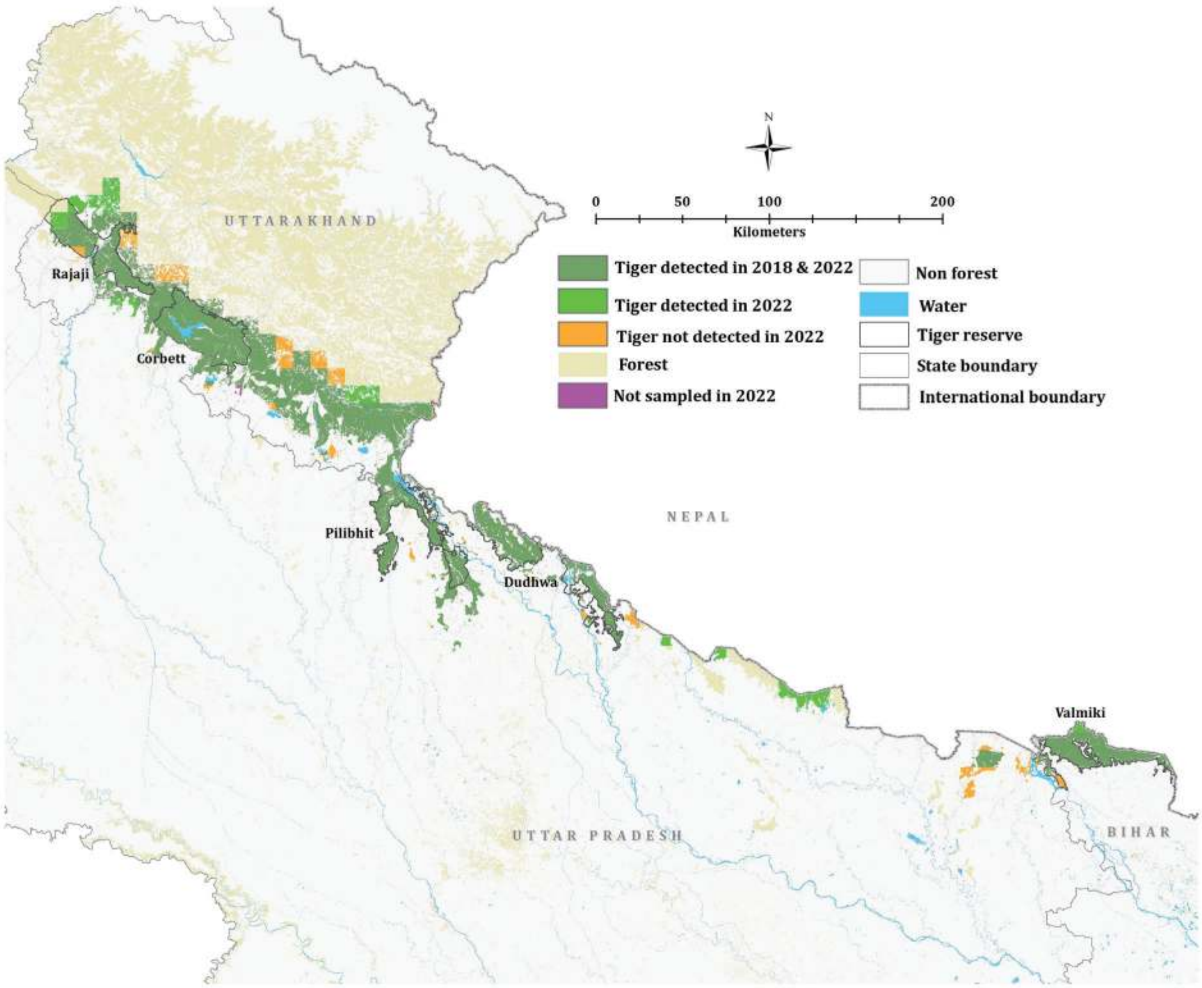

NTCA Tiger Cell

Tiger Distribution:

Sampling for tiger signs and camera trapping was carried out in 351 cells of 100 km^2 out of which tiger signs and photo-captures were detected in 192 cells (54.7%) covering an area of 9414 km^2 in 2022. Tiger-occupied area in the landscape has increased with new records of tigers from Dehradun Forest Division in the western limit of tiger distribution in the landscape (Fig. II.1.1). A tiger previously photo-captured in Rajaji Tiger Reserve was reported from Simbalbara Wildlife Sanctuary in Himachal Pradesh in 2023. Although such reports are encouraging, these forests need to improve protection and prey populations to encourage tigers to settle in the area. The initial occupancy of 2006 had tiger presence only in and around Tiger Reserves (Rajaji, Corbett, Pilibhit, Dudhwa, and Valmiki), but by 2014 and 2018, most of the habitats in the landscape were colonized (Jhala *et al.* 2020), with a 14% increase in occupancy. 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 (Jhala *et al.* 2020).

Figure II.1.1

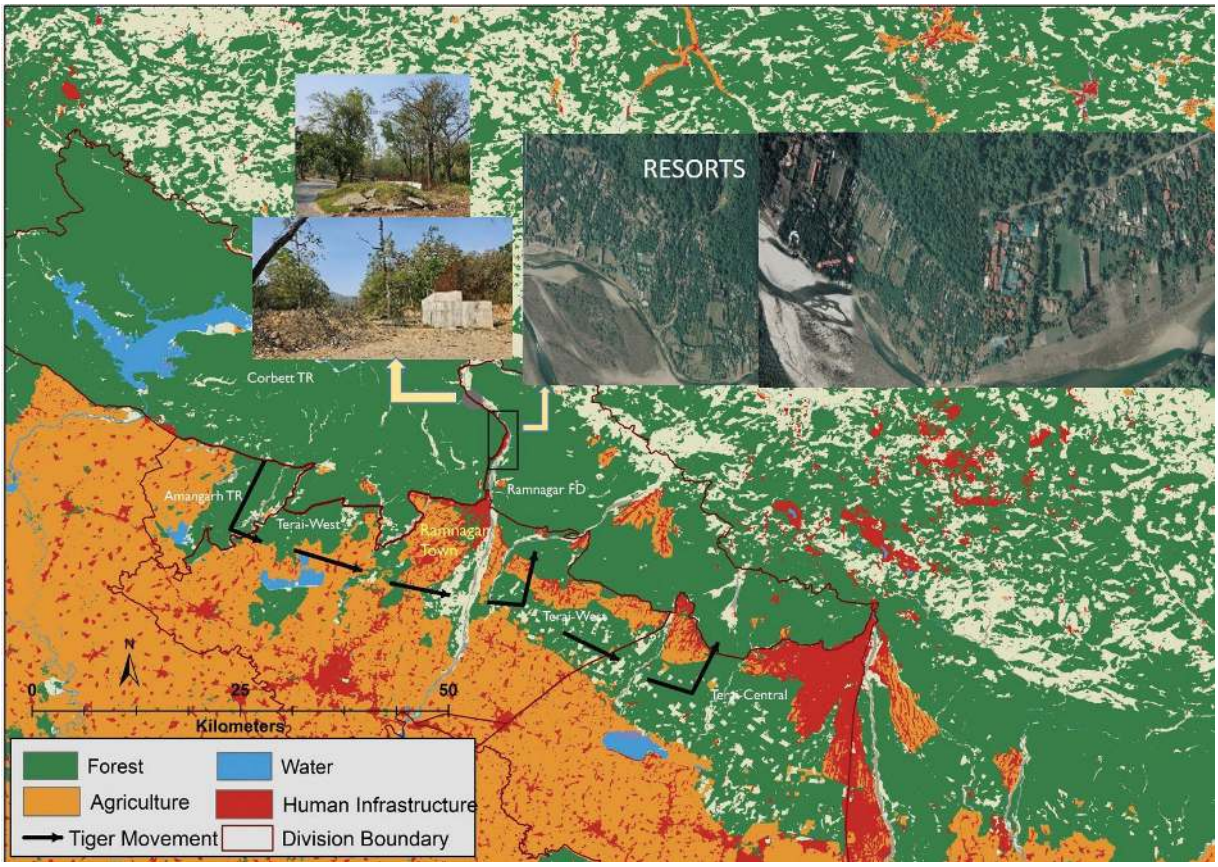
Change in tiger distribution in 2018 and 2022 in the Shivalik and Gangetic Plains landscape.



Despite constant occupancy, some crucial connectivity in the landscape seems to be under threat. Connectivity towards the east of Corbett Tiger Reserve is restricted by the township of Ramnagar and linear development along National Highway 121 of resorts, townships, and private farms along the banks of the Kosi River (Fig. II.1.2 inset (b)). The development of resorts and private farms has intensified over the years, leading to a hard boundary for animal movement. In this eastern part, only two corridors remain that connect Corbett forests with Ramnagar Forest Division. These are along the Garjia-Sunderkhal settlement on the northern side and the Bijrani range of Corbett in the southern part (Fig. II.1.2). In the Garjia-Sunderkhal stretch, currently, a developmental project lies abandoned, causing disturbance in this part of the corridor near the Dhanghari gate (Fig. II.1.2 inset (a)).

Figure II.1.2

Corbett Tiger Reserve and connected patches with blockage in tiger movement Sunderkhal along NH121 (see inset for details)



inset (a) Photographs showing the abandoned bridge project over Panod sot in the tiger corridor between Corbett TR and Ramnagar FD; inset (b) google earth imagery showing resorts leading to hard boundary for animal movement between Corbett TR and Ramnagar FD; Black arrows show current movement of tiger from Corbett TR through Amangarh and Terai West. These areas have agriculture and human habitation and leads to increased negative interaction of tigers with humans.

Such projects in important corridors for tigers and elephants need to be assessed more critically. These remaining linkages need to be fostered with restorative inputs wherein infrastructural development is mitigated with appropriate measures and encroachment is strictly controlled. Resorts and private landowners need to be sensitized to remove fences that are impermeable to wildlife at critical points to permit passage through their property. These issues have led to a loss of connectivity between Corbett and Ramnagar forest division. Tiger movement had been observed between the two areas in camera traps previously, but in 2022, no tiger was found to be common between the Corbett and Ramnagar forest division. Tigers are instead moving from Amangarh to Terai West and then onwards to Ramnagar forest division (Fig. II.1.2). This shift in tiger movement or corridor will lead to negative interactions since these areas south of Corbett are heavily populated areas with patches or islands of forests.

From Ramnagar Forest Division, forest connectivity is continuous until the township of Haldwani. Forest connectivity from Haldwani division to the Shuklaphanta National Park of Nepal is maintained by the Gola corridor forests along with Nandhaur Wildlife Sanctuary and Champawat forest division. However, this corridor is severely impacted by the urban sprawl of Haldwani township, proposed Jamrani Multipurpose Drinking Water Project, boulder mining, and human activities, along with National Highway 87 and the railway line to Kathgodam. This corridor connectivity is almost lost, and tigers possibly use the forests of the lower Himalayas to move eastward (as evidenced from camera trap data of tigers from Rajaji and Corbett being photo-captured east of Haldwani township in 2018). Restoring connectivity in the foothills and less hilly tracts of the Gola corridor is crucial for elephant movement, which 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.

Major roads are planned along the border of India and Nepal; these will traverse crucial international corridors that are vital linkages for the trans-boundary movement of wildlife, including tigers and elephants, between the Protected areas of India and Nepal (WII report, 2022). For some populations, this movement is crucial to maintaining genetic and demographic viability through meta-population dynamics. Alignment of these roads should avoid traversing Protected Areas and corridors and ensure appropriate and adequate animal passageways through mitigation where alternate alignment is not possible. These corridors are important for elephant and rhinoceros movement and if their movement is constrained then the human-wildlife conflict in the region will be exacerbated.

National and international efforts and coordination are required to maintain the permeability of these vital border corridors. We found tigers common between Pilibhit Tiger Reserves and Shuklaphanta National Park (n = 2), Katarniaghat Wildlife Sanctuary and Bardia National Park, Nepal (n = 4), and Banke, Nepal and Suhelwa (n = 1) (DNPWC and DFSC 2022). To maintain this connectivity and movement, it is imperative that these proposed roads adhere to the suggested alternate alignments and mitigation measures.

The tiger population in Valmiki Tiger Reserve has increased substantially over the years, which can be attributed to prey restoration within the park and an increase in the tiger population in the adjoining Chitwan National Park of Nepal (DNPWC and DFSC 2022), which acts as a source population for tigers in this landscape. We found 8 tigers to be common between Valmiki Tiger Reserve and Chitwan National Park, while 3 tigers were common between Valmiki Tiger Reserve and Parsa Wildlife Sanctuary, Nepal (DNPWC and DFSC 2022). This increase in tiger numbers in Valmiki has, in turn, facilitated colonization of Sohagibarwa Wildlife Sanctuary. Tiger cubs and juveniles photo-captured in Valmiki Tiger Reserve dispersed to Sohagibarwa and established territory in 2021, which is very encouraging for the eastern limit of this landscape's tiger population.

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 26 sites in the landscape (See section V for details), viz., Kalsi Forest Division, Dehradun Forest Division, Narendranagar Forest Division, Rajaji Tiger Reserve, Lansdowne Forest Division, Bijnore Forest Division, Corbett Tiger Reserve, Almora Forest Division, Ramnagar Forest Division, Terai East, Terai West, Terai Central, Nainital Forest Division, Champawat Forest Division, Haldwani Forest Division, Pilibhit Tiger Reserve, Katerniaghat Wildlife Sanctuary, Kishanpur Wildlife Sanctuary, Dudhwa National Park, Suhelwa Wildlife Sanctuary, Sohagibarwa Wildlife Sanctuary and Valmiki Tiger Reserve. Tiger densities in the Shivalik-Gangetic Plains ranged between 2 to 15 tigers per 100 km^2 (see section V). The best SECR model used to estimate tiger density had tiger sign intensity, prey abundance and human disturbance as co-variates (Fig. II.1.3). Total population in the landscape was 819 (SE 43) which has recorded a 27% increase since 2018 (Jhala *et al.* 2020). After joining contiguous grids with tiger presence, three tiger populations were identified within the Shivalik-Gangetic Plains (Fig II.1.3). These include:

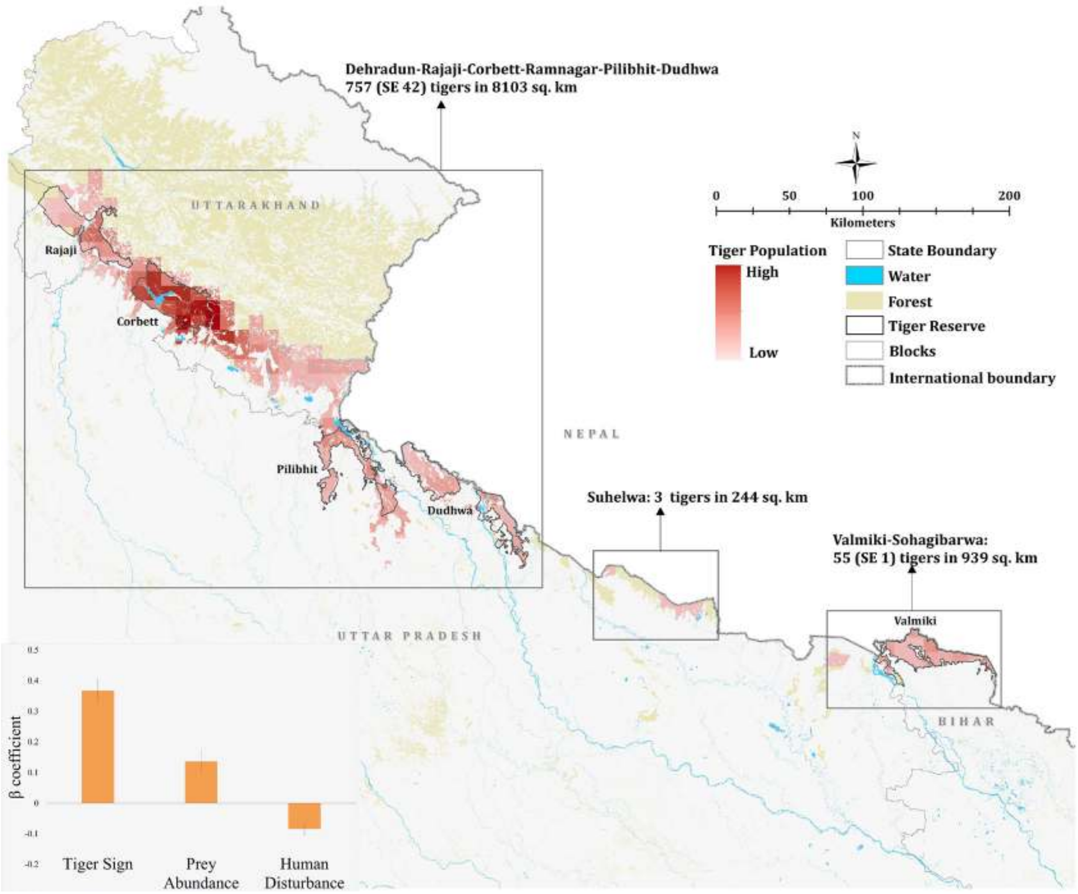
1. **Dehradun-Rajaji-Corbett-Ramnagar-Pilibhit- Dudhwa:** The western most population of tigers in Dehradun Forest Division, Rajaji Tiger Reserve along with Lansdowne Forest Division, Corbett Tiger Reserve, Amangarh, Terai West Forest Division, Ramnagar Forest Division, Haldwani Forest Division, Terai Central and East Forest Divisions, Pilibhit Tiger Reserve and Dudhwa Tiger Reserve having tiger occupancy in about 8103 km^2 of forested habitat with an estimated population size of 757 (SE 42) individuals. This contiguous population harbours one of the major source of tigers for Western Terai Arc Landscape (Corbett Tiger Reserve) and along with tigers of Bardia National Park (125) and Shuklaphanta National Park (36) in Nepal (DNPWC and DFSC 2022) constitutes one of the largest tiger population in the world. The tiger population has shown significant increase in the last four years in comparison to 604 (SE 74) tigers in 2018 (Jhala *et al.* 2020).

2. **Suhelwa Wildlife Sanctuary** recorded three tiger individuals in 244 km^2 area. These tigers did not match with the previous tigers recorded in the area (Sadhu *et al.* 2022). This points to transient tiger population and the area needs substantial active management efforts to ensure that the transient tiger population establishes territory in the area. There is no habitat connectivity between Katarniaghat and Suhelwa Wildlife Sanctuary on the Indian side, but the forests of Bardia National Park and Banke National Park along the Churia hill forests of Nepal form a connecting corridor to Suhelwa Wildlife Sanctuary. One tiger individual was found to be common between Banke National Park and Suhelwa Wildlife Sanctuary (DNPWC and DFSC 2022) emphasizing the role of this corridor. Efforts to increase prey and investment in protection of the sanctuary needs to be implemented.

3. **Valmiki- Sohagibarwa:** The Valmiki-Sohagibarwa continuum spans across parts of India and Nepal (Chitwan National Park) with 939 km^2 tiger occupancy on the Indian side with 54-55 individuals. Tigers were found to be common with Chitwan and Parsa National Park in Nepal. Together with Chitwan 128 (SE 12) tigers and Parsa National Park 41(SE 9) tigers (DNPWC and DFSC 2022) this population block harbours 213 (SE 21) tigers.

Figure II.1.3

Spatially explicit tiger density modelled from camera traps-based capture-mark-recapture and covariates of tiger sign, prey, and human disturbance index (inset graph) within the Shivalik-Gangetic Plains Landscape for 2022.



Statewise tiger population

Uttarakhand:

Fourteen sites were sampled in the state, and the tiger population was estimated at 560 (SE 24) which has seen an increase from 442 (SE 49) in 2018 (Jhala *et al.* 2020). The Shivalik-Bhabar tracts of the state are nearly full with tigers, and habitats that have the potential to increase tigers are the Himalayan areas of Almora, Nainital, and Champawat Forest Divisons. These areas need to be systematically sampled with more intensive effort to estimate the tiger and prey populations. Animal corridors in the state are getting fragmented or have become nonfunctional due to increase in linear infrastructure projects (for details see the Section IV). It is imperative to safeguard this tiger population, which is currently one of the densest in the world due to its productive and comparatively well-connected forest tracts. In view of increased tiger numbers and occupancy in the state, the department needs to invest in active management of negative interactions between humans and wildlife. Radio-collaring tigers and elephants and the development of an early warning system can help alleviate the ever-increasing conflict in the state. With photo-captures of tigers in Dehradun Forest Division and movement of tigers from Rajaji to Himachal Pradesh, Dehradun-Kalsi Forest Division can be brought under the ambit of Tiger Reserve to improve habitat, prey and provide corridor for tigers to occupy and extend their range in western terai forest. Terai forest division of the state currently harbor more tigers than some of the big tiger reserves in the country (see section V for details). Particularly Terai West which is connected to Corbett Tiger Reserve and Terai East which is connected to Pilibhit Tiger Reserve should be considered potential areas to be declared as tiger reserves.

Uttar Pradesh:

Six Protected areas were sampled in the state, and the tiger population was estimated at 205 (SE 18) an increase from previous estimate of 173 (SE 25) in 2018 (Jhala *et al.* 2020), Pilibhit and Dudhwa Tiger Reserves harbor nearly 99% of the tiger population in the state. These Tiger Reserves are also important from the point of view of transboundary tiger conservation with Nepal. Increased border road development will hamper animal movement across important corridors of this landscape, and therefore green infrastructure has to be adopted in such projects (WII report 2022). Lack of a functional buffer and surrounding sugarcane fields with prey that mimic tall grasslands around these Tiger Reserves is also a cause of the negative interaction of tigers with people, as tigers move to sugarcane fields outside the Protected Area. An early warning system is required to manage this conflict and minimize the threat to the lives of people living on the edges of these Protected Areas. Suhelwa and Sohagibarwa Wildlife Sanctuaries and Ranipur Tiger Reserve need to invest in protection and train ground staff to patrol the forests, ungulate augmentation and tiger reintroduction for effective conservation. Sohagibarwa can be managed as a tiger reserve, just as Amangarh (as interstate buffer of Corbett Tiger Reserve) has been.

Bihar:

The only Protected Area that was sampled in the state was Valmiki Tiger Reserve, and the estimated tiger population was 54 (SE 1). The tiger population here has increased from 31 (SE 6) in 2018 (Jhala *et al.* 2020). Kaimur Wildlife Sanctuary Wildlife Sanctuary need to be monitored and developed as potential tiger introduction sites. After substantial habitat and prey improvement, the state can bring the sanctuary under the ambit of tiger reserves. With increasing negative interactions between humans and tigers, this is a step that the department should take seriously.

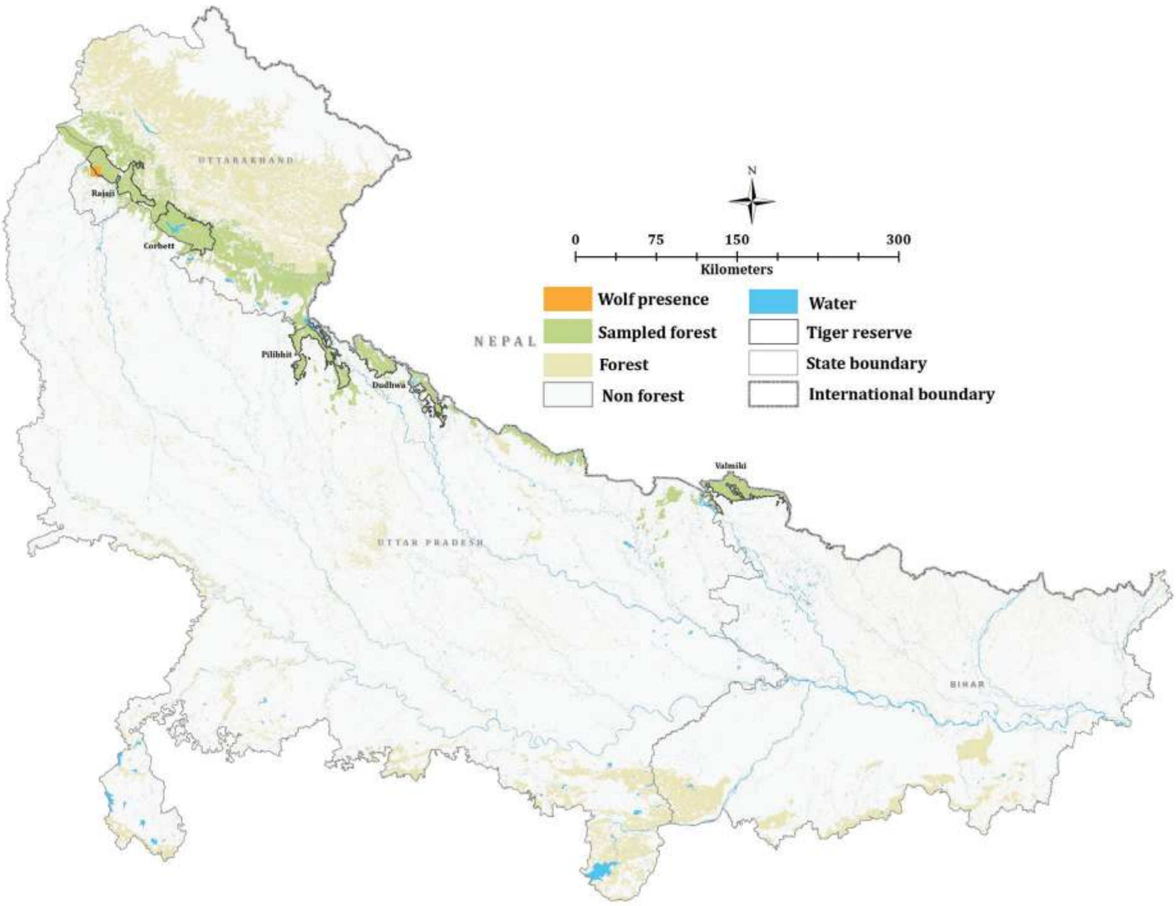
Distribution of carnivores and omnivores in Shivalik Gangetic Plains landscape, 2022

Indian wolf *(Canis lupus pallipes)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Least Concern]*

Indian wolf has not been recorded from this landscape in previous cycles. However, it was recorded in the western part of Rajaji Tiger Reserve (60 km^2) in 2019 (Krishna *et al.* 2022). Indian wolf was also recorded in 2017 in Valmiki Tiger Reserve but has not been reported from there since (Maurya *et al.* 2021). In the north India, Indian Indian wolf is well documented form the states of Uttar Pradesh, Rajasthan and Bihar and was thought to be absent from north of the river Ganges (Krishna *et al.* 2022). Rajaji Tiger Reserve is in 50 km radius of the places (Saharanpur, Roorkee and Muzaffarnagar) of Indian wolf's known distribution (Jhala *et a.* 2022a).

Figure II.1.4

Indian wolf distribution in Shivalik Gangetic Plains landscape, 2022

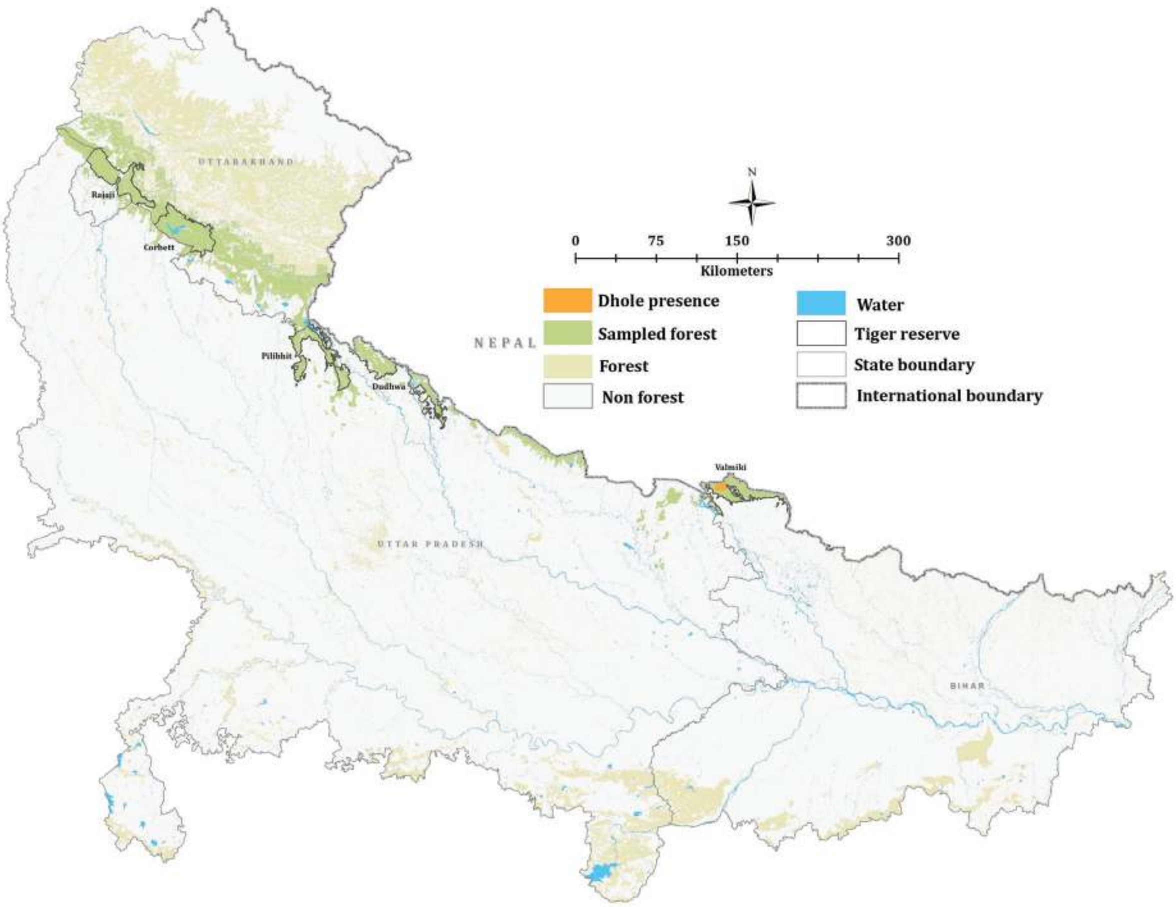


Dhole (Wild dog) ***(Cuon alpinus)*** *[Wildlife (Protection) Act, Amended 2022 Schedule I; IUCN Red List: Endangered]*

Dholes were only recorded from Valmiki Tiger Reserve in Bihar in this landscape in 76 km^2 (Fig. II.1.5). However, they were previously recorded from Valmiki Tiger Reserve, the Mirzapur forests of southeastern Uttar Pradesh, and Suhelwa Wildlife Sanctuary in Uttar Pradesh (Jhala *et al.* 2020). Wild dogs were found to occur across this landscape in the past (Champion 1927), but they were likely exterminated from western Terai due to bounty-driven persecution (Fox 1984). It would be pertinent to attempt to reintroduce this important large carnivore to parts of its historic range, as it plays a role as a selective predator and can help restore historical biodiversity that has been extirpated by recent intentional actions of humans (Jhala 2019).

Figure II.1.5

Dhole distribution in Shivalik Gangetic Plains landscape, 2022

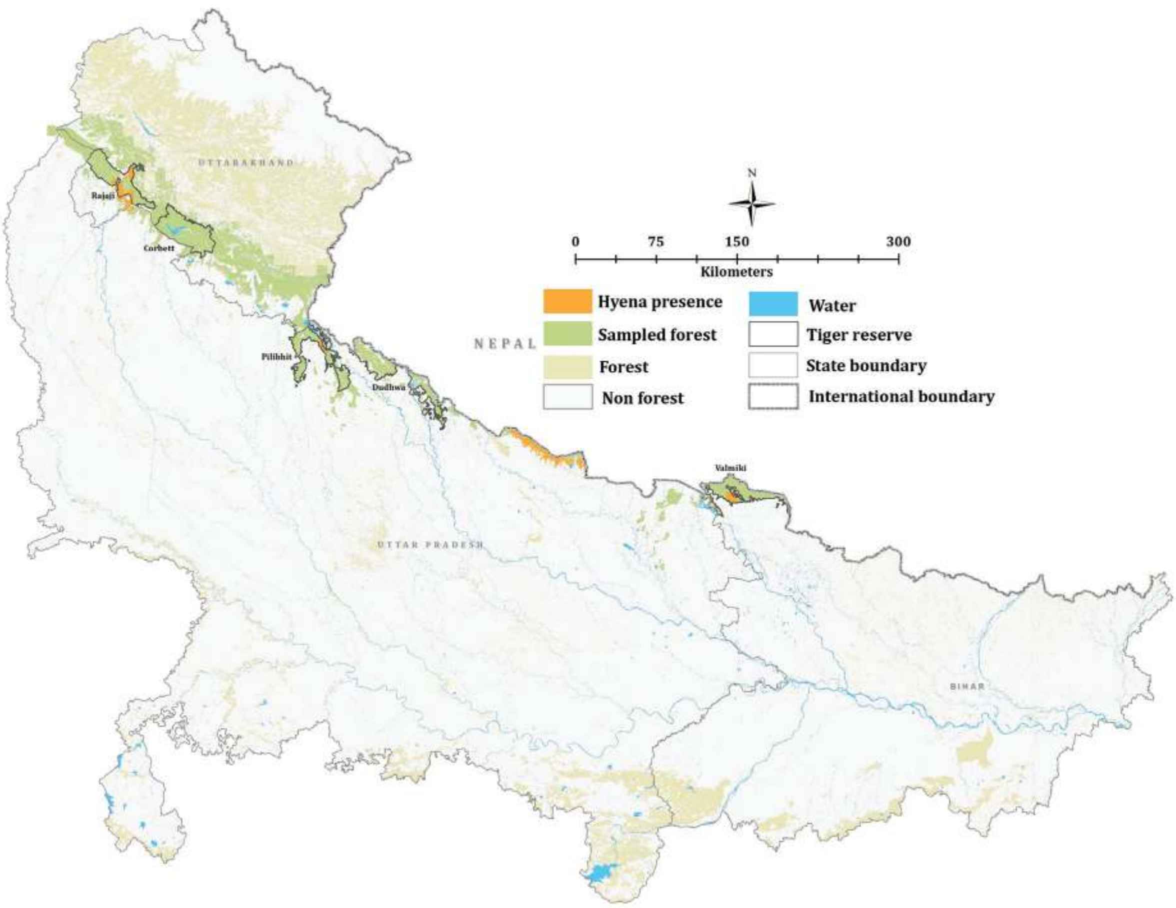


Striped hyena ***(Hyaena hyaena)*** *[Wildlife (Protection) Act, Amended 2022 Schedule I; IUCN Red List: Near Threatened]*

The distribution of striped hyenas was limited to the peripheral parts of the Chilla and Gohri ranges of Rajaji Tiger Reserve in Uttarakhand (Fig. II.1.6). Some parts of Pilibhit had hyena presence, while Suhelwa Wildlife Sanctuary had hyena presence across the entire sanctuary (Fig. II.1.6). Hyenas were also recorded on the periphery of Valmiki Tiger Reserve. Hyena presence in Dudhwa was last recorded in 2010 (Jhala *et al.* 2011), but there have been no records since then. Hyena presence was recorded in the periphery of Corbett Tiger Reserve in 2018, but not in 2022. Since hyena distribution and abundance coincide with those of livestock, they are more common on the peripheries of protected areas than within the core areas. The total recorded occupancy within forested areas of this landscape was 885 km2 (Fig. II.1.6). Since hyaenas use agro-pastures and scrubby areas, awareness amongst the agro-pastoralist communities about scavenging nature of the species needs to be highlighted and livestock carcass sites need to be made free from harmful chemicals. Such conservation actions for hyenas are required in this landscape.

Figure II.1.6

Hyena distribution in Shivalik Gangetic Plains landscape, 2022

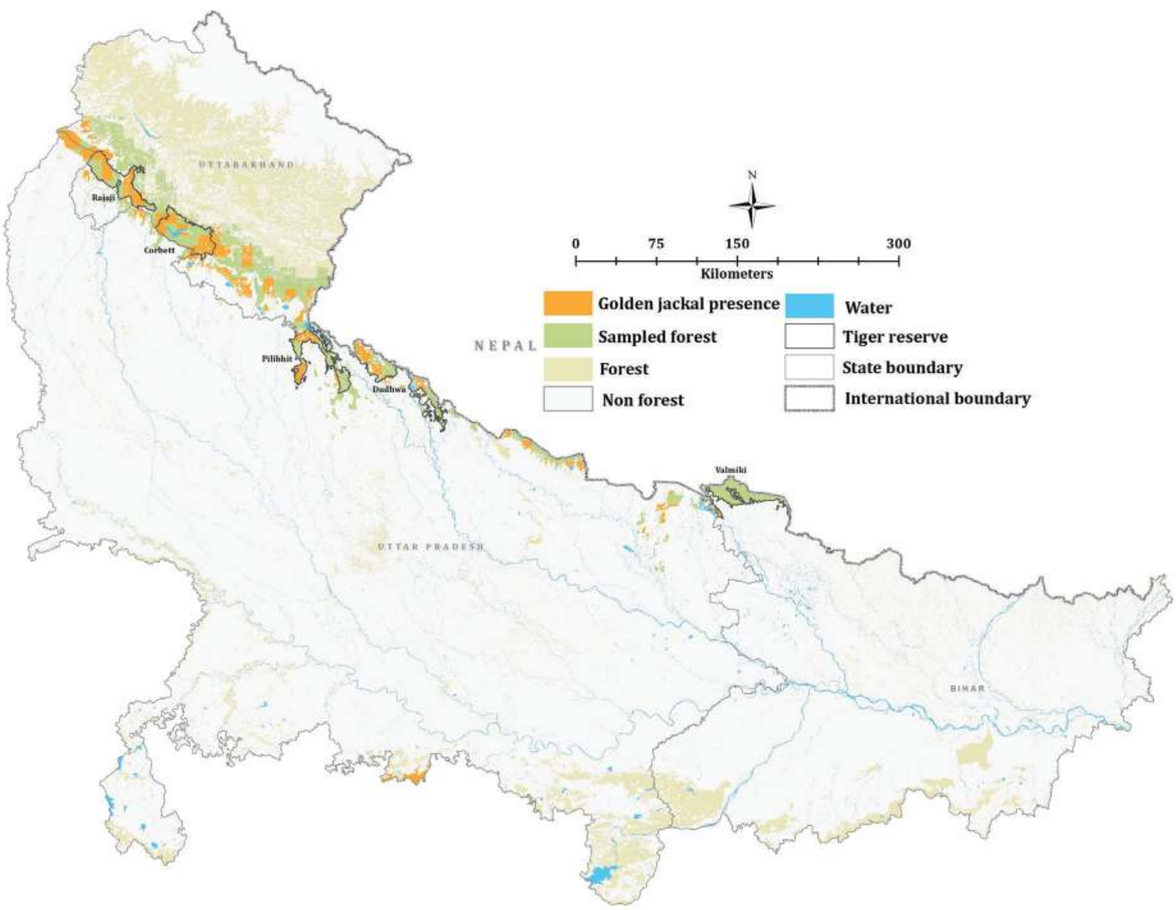


Golden Jackal *(Canis aureus)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Least Concern]*

Golden jackals were found to be distributed throughout the landscape, with an occupancy of 4245 km^2. They occupy forested areas, as well as rural areas and agricultural fields in this landscape (Fig. II.1.7). It is important to note that the distribution and occupancy of golden jackals may vary over time due to factors such as habitat changes, human activities, and ecological dynamics. Therefore, ongoing monitoring and research are essential to better understand their population dynamics and conservation status in the landscape.

Figure II.1.7

Golden jackal distribution in Shivalik-Gangetic Plains landscape, 2022



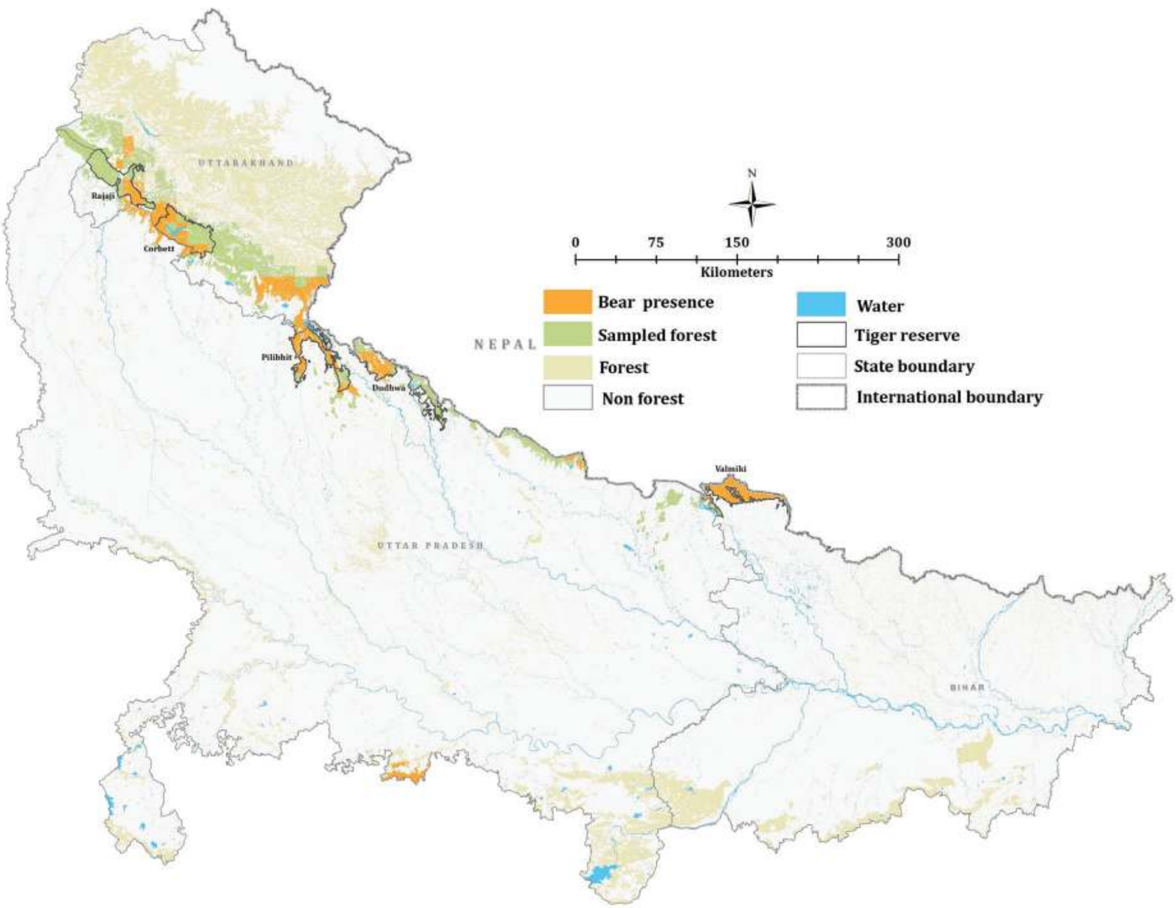
Bear *(Melursus ursinus and Ursus thibetanus)* *[Melursus ursinus -Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Vulnerable and Ursus thibetanus- Wildlife (Protection)Act, Amended, 2022: Schedule I; IUCN Red List: Vulnerable]*

In this landscape, Uttarakhand is home to two species of bears, the sloth bear and the Asiatic black bear. During winter, the Asiatic black bear migrates to the foothills and Terai habitats. Distinguishing between signs of these two bear species requires genetic analysis of their faeces, and as a result, their distributions were not segregated based on signs alone. Uttar Pradesh and Bihar also have significant forested areas that provide suitable habitats for bears, and their shared borders with Nepal contribute to the connectivity of bear populations in the region. In the higher elevations, black bears were likely found exclusively, while in the Shivaliks, Bhabhar, and Terai regions, sloth bears are predominantly present, with occasional sightings of black bears during winter, particularly in locations such as Rajaji Tiger Reserve, Corbett Tiger Reserve, and Lansdowne Forest Division.

The total forested area occupied by bears in this landscape was estimated to be 4833 km^2 (Fig. II.1.8). It is important to note that the distribution and presence of these bear species may vary over time due to various factors, including habitat changes, food availability, and human activities. Continual monitoring and research is necessary to gain a better understanding of the population dynamics and using this information to improve protection is conservation need of both sloth bears and Asiatic black bears in this landscape.

Figure II.1.8

Bear distribution in Shivalik Gangetic Plains landscape, 2022



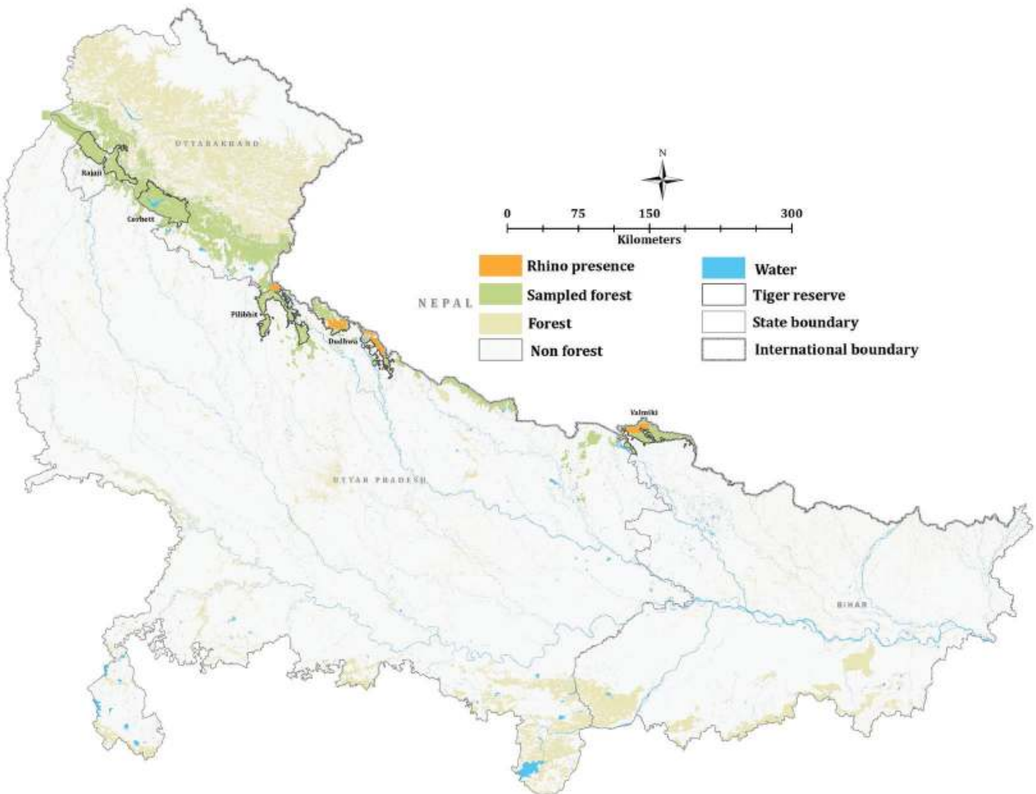
Distribution of mega herbivores and ungulates in Shivalik Gangetic Plains landscape, 2022

Greater one horned rhinoceros *(Rhinoceros unicornis)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Vulnerable]*

Rhinoceros sightings have been reported in various locations in Uttar Pradesh and Bihar occupying an area of 647 km^2. Notable areas include Pilibhit Tiger Reserve which is connected with Suklaphanta of Nepal, Dudhwa National Park (where a reintroduced population exists), and Katarniaghat Wildlife Sanctuary, which is connected to Bardia National Park in Nepal (Fig. II.1.9). In Bihar, the northern parts of the Valmiki Tiger Reserve have reported rhinoceros presence. This region shares connectivity with Chitwan National Park in Nepal, highlighting the cross-border movement of rhinoceros populations (Fig. II.1.9). Rhinoceros can be re-introduced in Valmiki, contingent upon investing in park protection and creating safe passages, potentially involving realigning railway tracks (Jhala *et al.* 2020). These reports emphasize the importance of conservation initiatives and habitat connectivity between India and Nepal. The Uttarakhand Government was considering the reintroduction of rhinoceros in Corbett National Park and this initiative needs to be brought to fruitification so as to create safety-net populations across the range of this species vulnerable to poaching and local extinctions (Jhala *et al.* 2021). Protecting these regions, establishing safe corridors, and implementing collaborative efforts are crucial for the preservation of this iconic species.

Figure II.1.9

Greater one horned rhinoceros distribution in Shivalik Gangetic Plains landscape, 2022

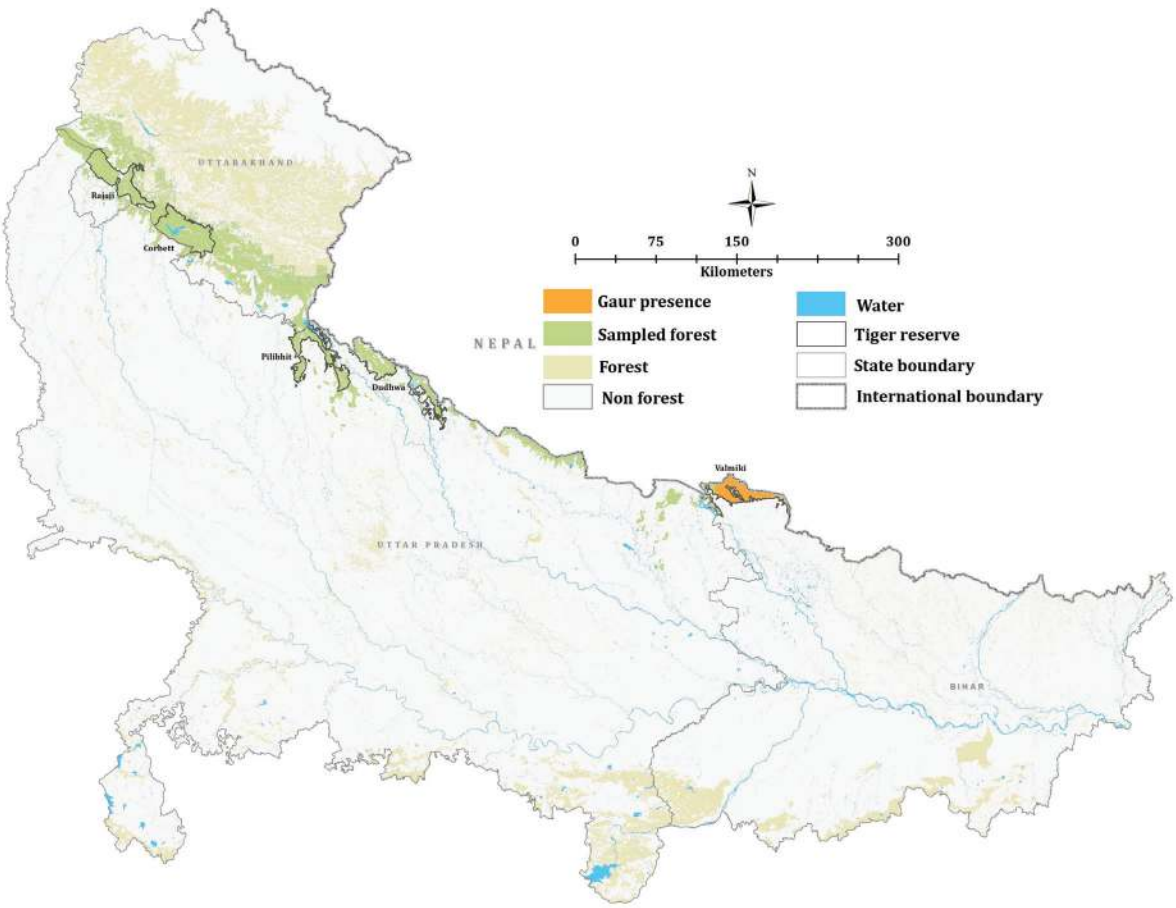


Gaur *(Bos gaurus)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Vulnerable]*

Gaur is present only in Valmiki Tiger Reserve in this landscape (691km^2) (Fig. II.1.10). There has been an impetus for mega-herbivore reintroduction in their historic range (Jhala *et al.* 2022b). After a scientific feasibility study, such efforts should be extended to this landscape as well to repopulate the historic range of gaur in the Terai of Uttar Pradesh.

Figure II.1.10

Gaur distribution in Shivalik Gangetic Plains landscape, 2022

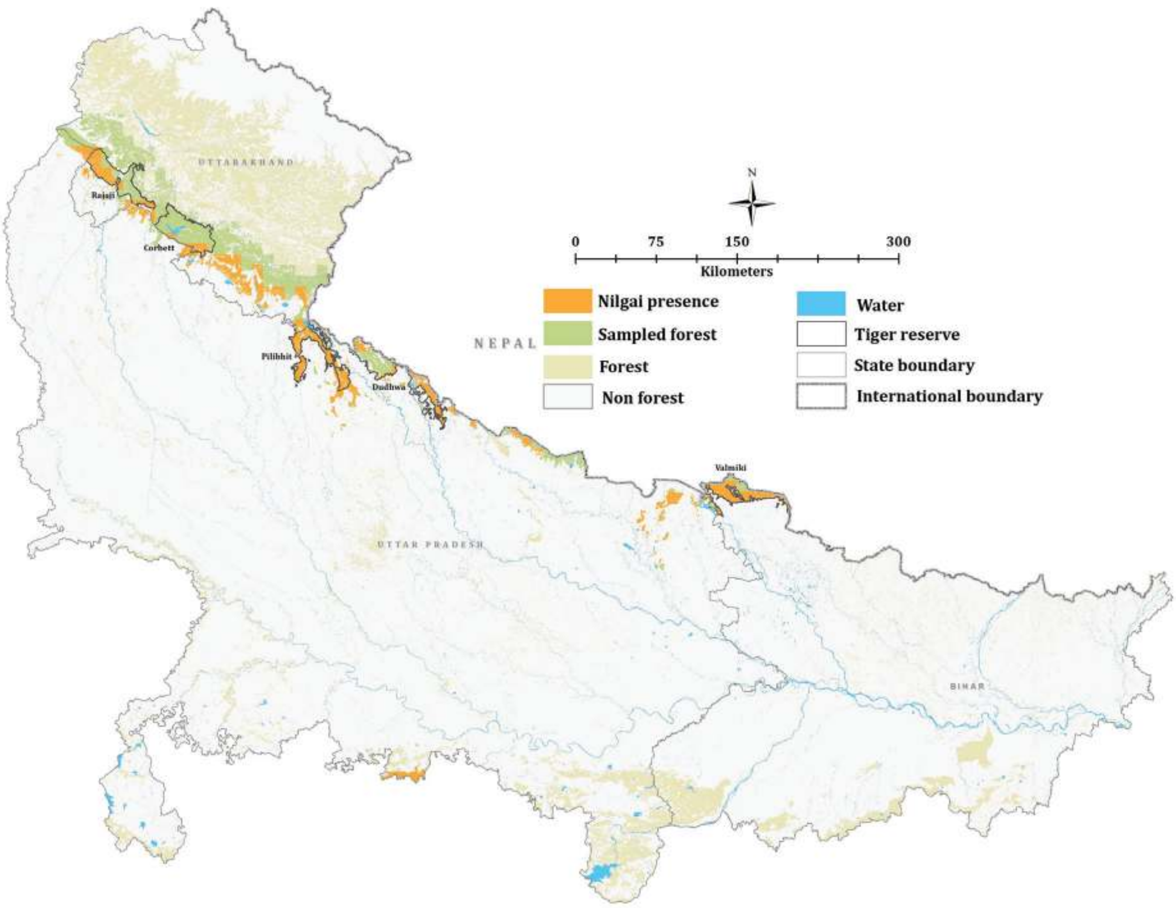


Nilgai *(Boselaphus tragocamelus)* *[Wildlife (Protection) Act, Amended, 2022: Schedule II; IUCN Red List: Least Concern]*

The Nilgai, also known as the blue bull, is a widespread ungulate found in the plain areas of Uttarakhand, Uttar Pradesh, and Bihar. It occupies approximately 5327 km^2 of the landscape (Fig. II.1.11). Nilgai is commonly observed in the fringes of forested areas and agricultural regions. It demonstrates adaptability to human-modified habitats and can be found in agricultural fields, grasslands, and scrublands. These herbivores consume a diverse diet of grasses, crops, and leaves. Conservation efforts should focus on preserving their habitats and minimizing human-wildlife conflicts to ensure their continued presence in the landscape.

Figure II.1.11

Nilgai distribution in Shivalik Gangetic Plains landscape, 2022



Section II.1

Barasingha (Swamp Deer) *(Rucervus duvaucelii duvaucelii)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Vulnerable]*

This landscape is the last remaining stronghold of the northern swamp deer population in the world (Paul *et al.* 2018). Their distribution was limited to grassland mosaics along the flood plains of the Ganga, Sharda, and Suheli rivers (418 km^2) (Fig. II.1.12). Barasingha habitats (that mostly lie outside protected areas) are being rapidly converted into agriculture, and this risks severing migratory routes for the species (Paul *et al.* 2023). The Sharda block population in Pilibhit and Dudhwa Tiger Reserves has better chances of long-term survival since it is present in a protected area (Rastogi *et al.* 2022). But the Ganga flood plain population (Islands and Khadar along Ganga till Kanpur, Jhilmil Jheel, Hastinapur WLS, and Afzalgarh) mostly occurs outside protected areas with rapid grassland conversion (Paul *et al.* 2020). Four priority conservation areas, were suggested by Paul *et al.* 2020,

1) along Ganga between Jhilmil Jheel Conservation Reserve, Uttarakhand and Hastinapur Wildlife Sanctuary, Uttar Pradesh

2) lower part of Hastinapur Wildlife Sanctuary downstream to Bijnor Barrage

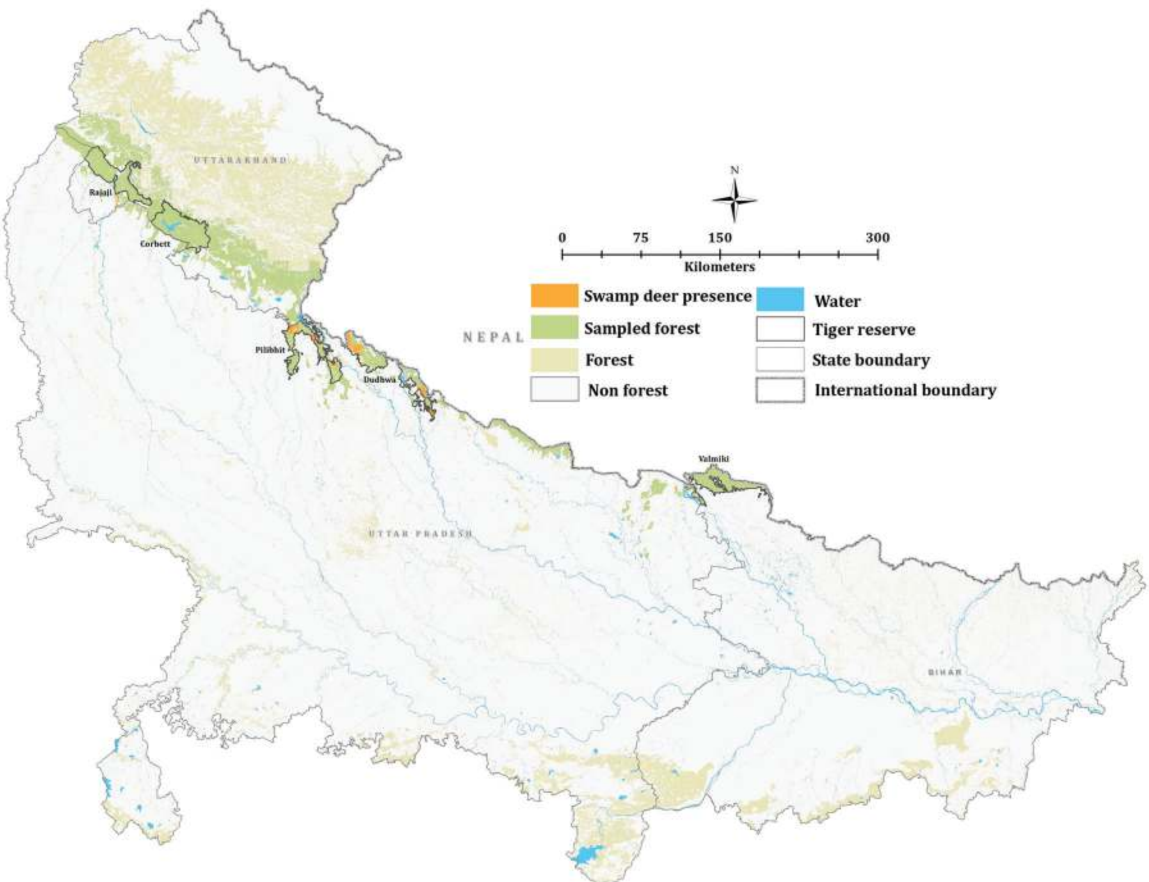
3) Along the Ramganga river in Jamanpur, Afzalgarh, Uttar Pradesh and

4) unprotected riverine landscape along Sharda river that connects Shuklaphanta Wildlife Sanctuary in Nepal with Kishanpur Wildlife Sanctuary in Uttar Pradesh.

These areas need to be established in this landscape for the survival of this obligate grassland herbivore in the country.

Figure II.1.12

Barasingha (Swamp Deer) distribution in Shivalik Gangetic Plains landscape, 2022

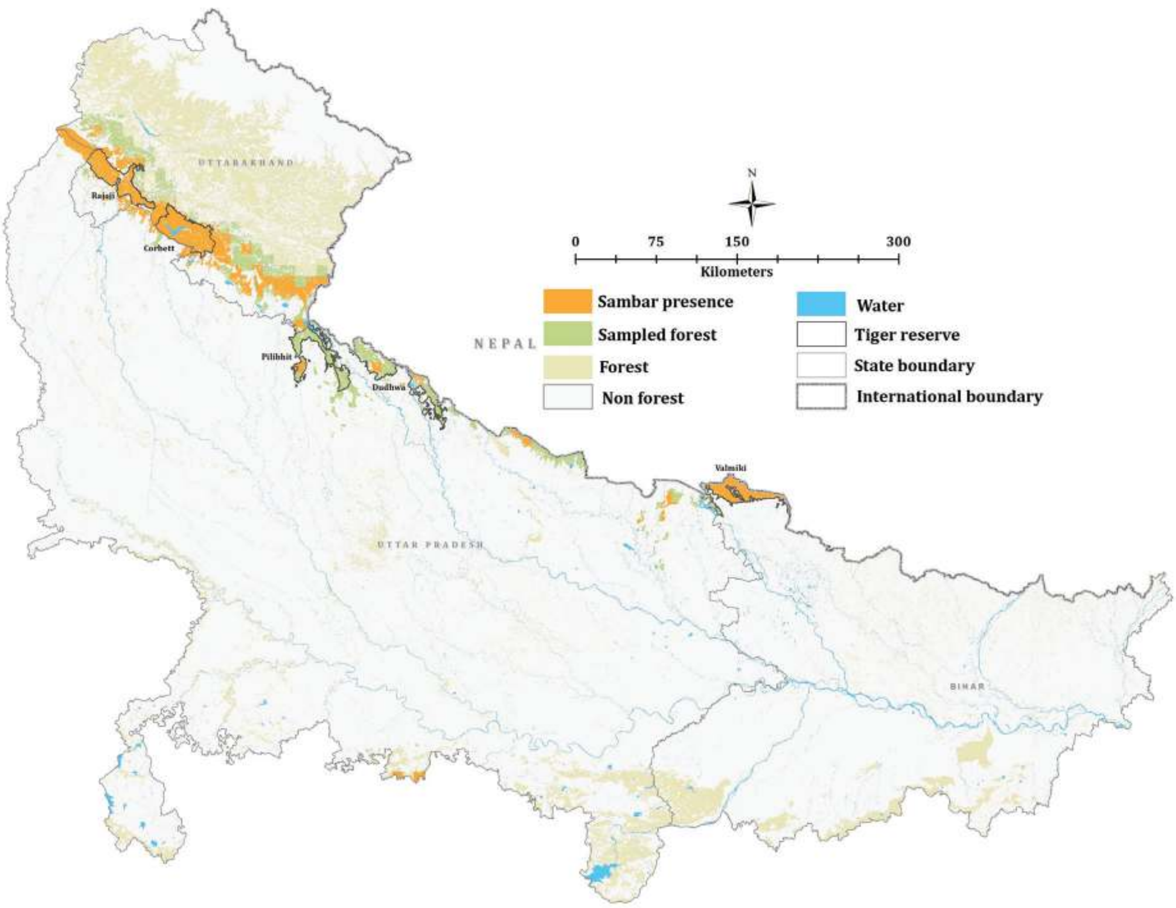


Sambar *(Rusa unicolor)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Vulnerable]*

Sambar deer is one of the most widespread cervid species in the Shivalik-Gangetic Plains landscape, occupying an area of approximately 6918 km^2 (Fig. II.1.13). It serves as an important prey species for tigers, particularly in the higher elevations of the Himalayas in Uttarakhand. Presence of Sambar, as the only large ungulate in alpine regions, significantly influences tiger occupancy. The adaptability of Sambar to various habitats, including forests and grasslands, contributes to its widespread distribution. Conservation efforts are crucial to maintain healthy Sambar populations and preserve their habitats, as they play a vital role in the predator-prey dynamics, especially as a significant food source for tigers in the Shivalik-Gangetic Plains landscape.

Figure II.1.13

Sambar distribution in Shivalik and Gangetic Plains landscape, 2022



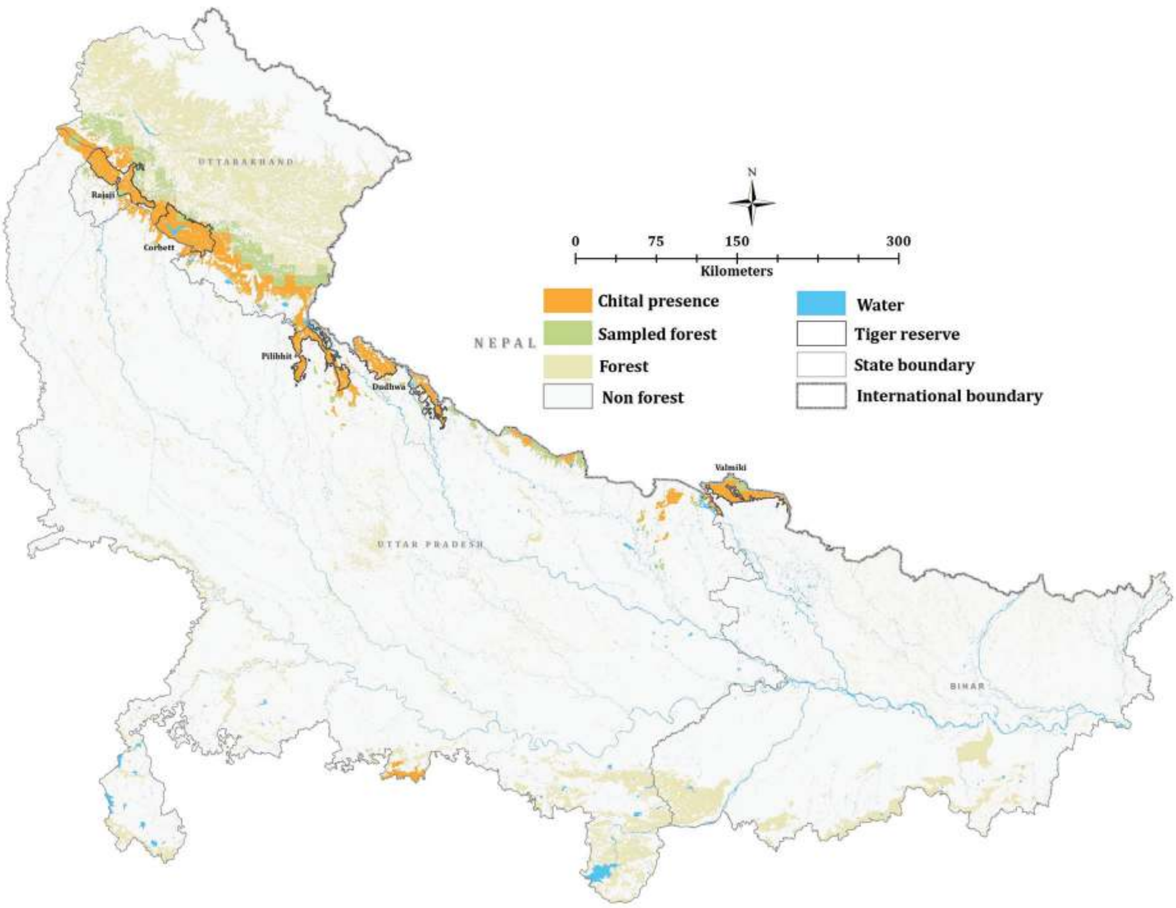
Chital ***(Axis axis)*** *[Wildlife (Protection) Act, Amended, 2022: Schedule II; IUCN Red List: Least Concern]*

The Chital is a vital prey species for tigers in the Shivalik-Gangetic Plains landscape. It occupies approximately 8449 km^2 of forested habitat along the Shivalik foothills and within the Terai region (Fig. II.1.14). Chital populations are present in all Protected Areas within this landscape, highlighting their adaptability to various conservation zones.

Chital are relatively abundant and widespread making them a reliable indicator of tiger population in an area. Studies have shown that tigers are more likely to be found in areas with higher chital densities and thus conserving chital population is crucial for the conservation of tigers in the Shivalik-Gangetic Plains landscape. Maintaining the ecological balance and protecting Chital habitats are integral aspects of tiger conservation efforts in this landscape.

Figure II.1.14

Chital distribution in Shivalik Gangetic Plains landscape, 2022

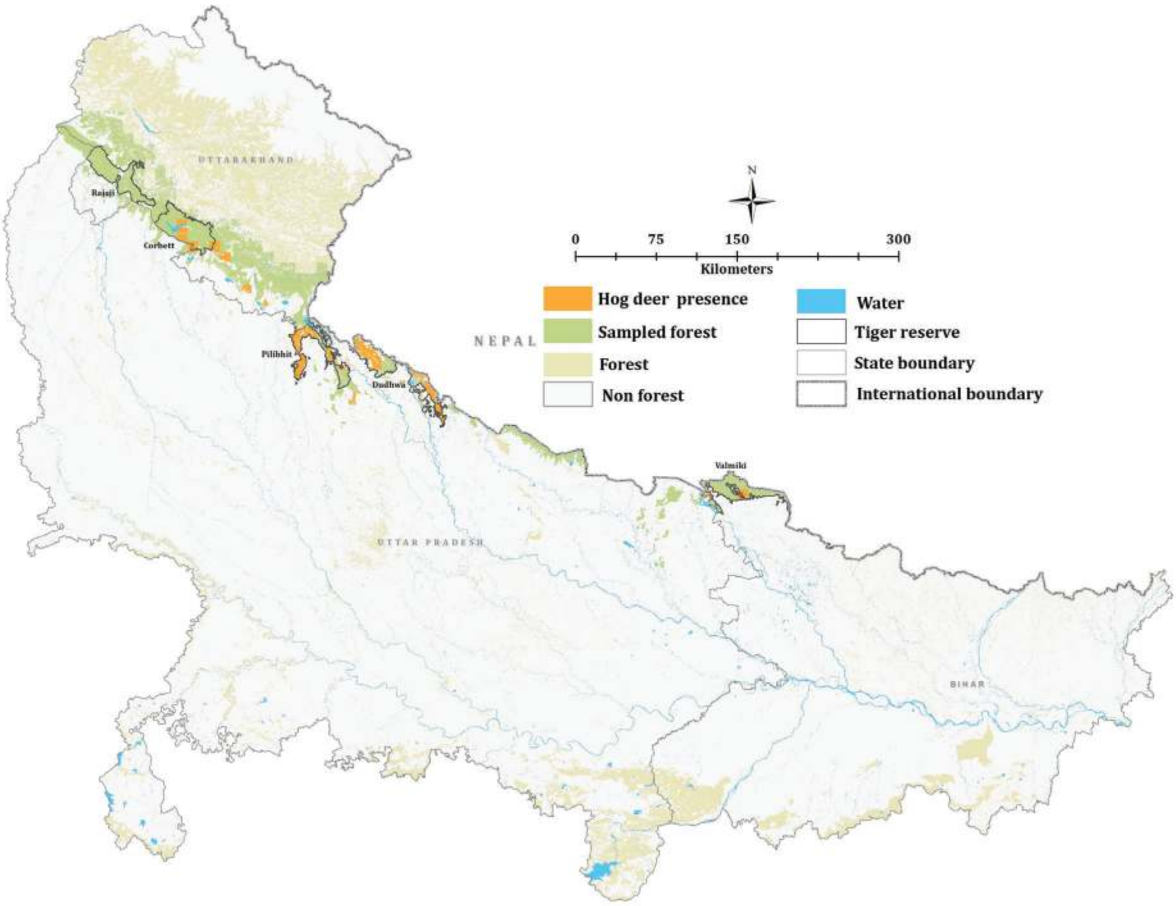


Hog deer ***(Axis porcinus)*** *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Endangered]*

The Hog deer in the Shivalik-Gangetic Plains landscape primarily inhabit floodplain habitats within protected areas, covering approximately 1792 km^2 of areas (Fig. II.1.15). The area between Corbett to Dudhwa Tiger Reserves is important with significant Hog deer populations. However, many of the hog deer habitats outside protected areas have been converted to agricultural lands. The floodplain dynamics within protected areas have been disrupted due to vegetation succession and improper grassland management practices such as harrowing and burning. These disturbances have negatively impacted Hog deer habitat suitability. The species is currently facing a decline in population, emphasizing the need for urgent intervention. To conserve Hog deer, it is essential to focus on proper management of their remaining habitats and implement measures to control poaching, particularly around the periphery of Protected Areas. Restoring and maintaining suitable floodplain habitats, preventing encroachment and agricultural expansion, and implementing effective anti-poaching strategies are crucial for their conservation.

Figure II.1.15

Hog deer distribution in Shivalik Gangetic Plains landscape, 2022

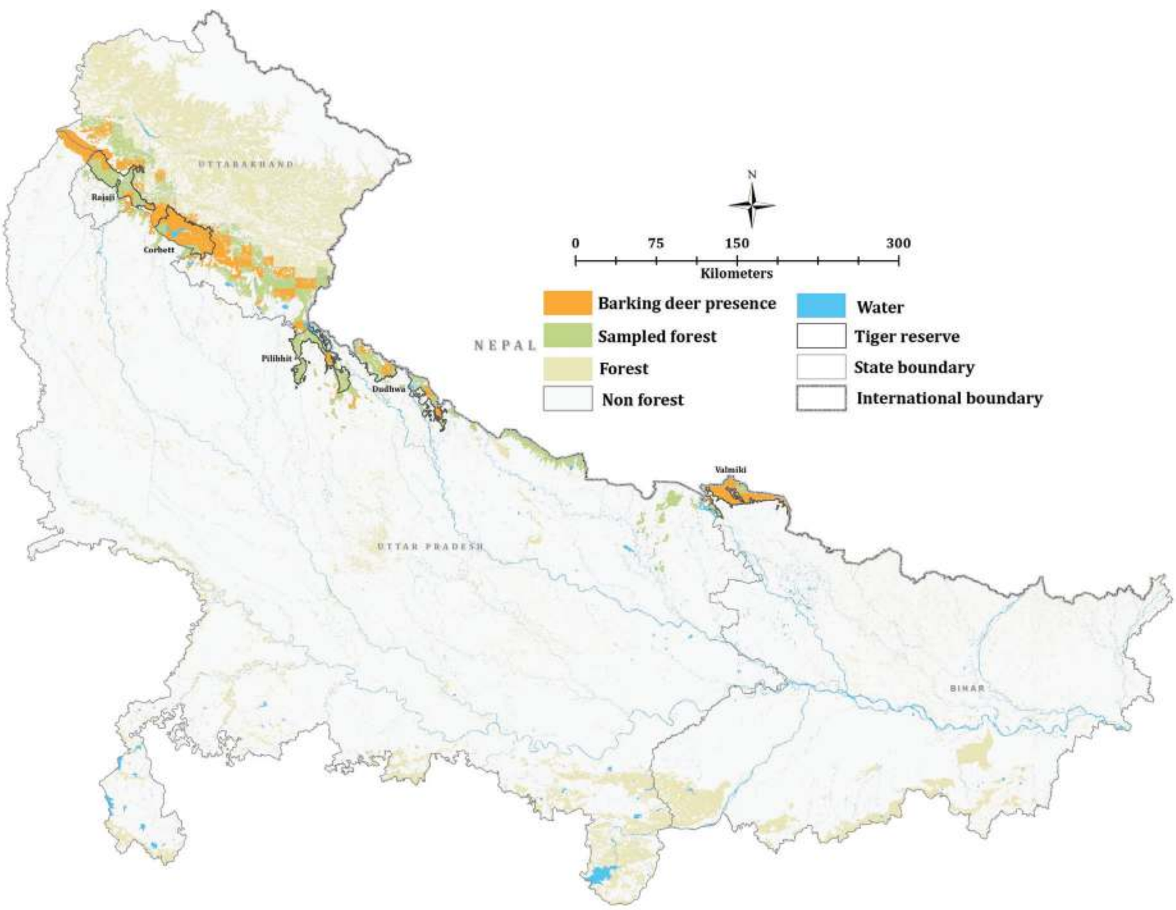


Barking Deer *(Muntiacus vaginalis)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Least Concern]*

The Barking deer, also known as the Indian Muntjac, is one of the most widely distributed deer species in India. Within the Shivalik-Gangetic Plains landscape, the Barking deer was found to have a continuous distribution throughout the Shivalik hills and the Himalayan foothills. It primarily inhabits dense forests and wooded areas, often found near the edges of forests or in areas with thick undergrowth. The recorded occupancy of Barking deer in the forested landscape was approximately 5652 km^2 (Fig. II.1.16). It is important to note that while Barking deer do occur at higher elevations as well, these areas were not included in the sampling exercise since they fall outside the ambit of Project Tiger. Their continuous distribution in the Shivalik hills and the Himalayan foothills highlights their adaptability to various habitats within the landscape. Protecting their habitats from habitat loss, fragmentation, and human disturbances is crucial for the long-term survival of this widely distributed deer species in the Shivalik-Gangetic Plains landscape.

Figure II.1.16

Barking deer distribution in Shivalik Gangetic Plains landscape, 2022



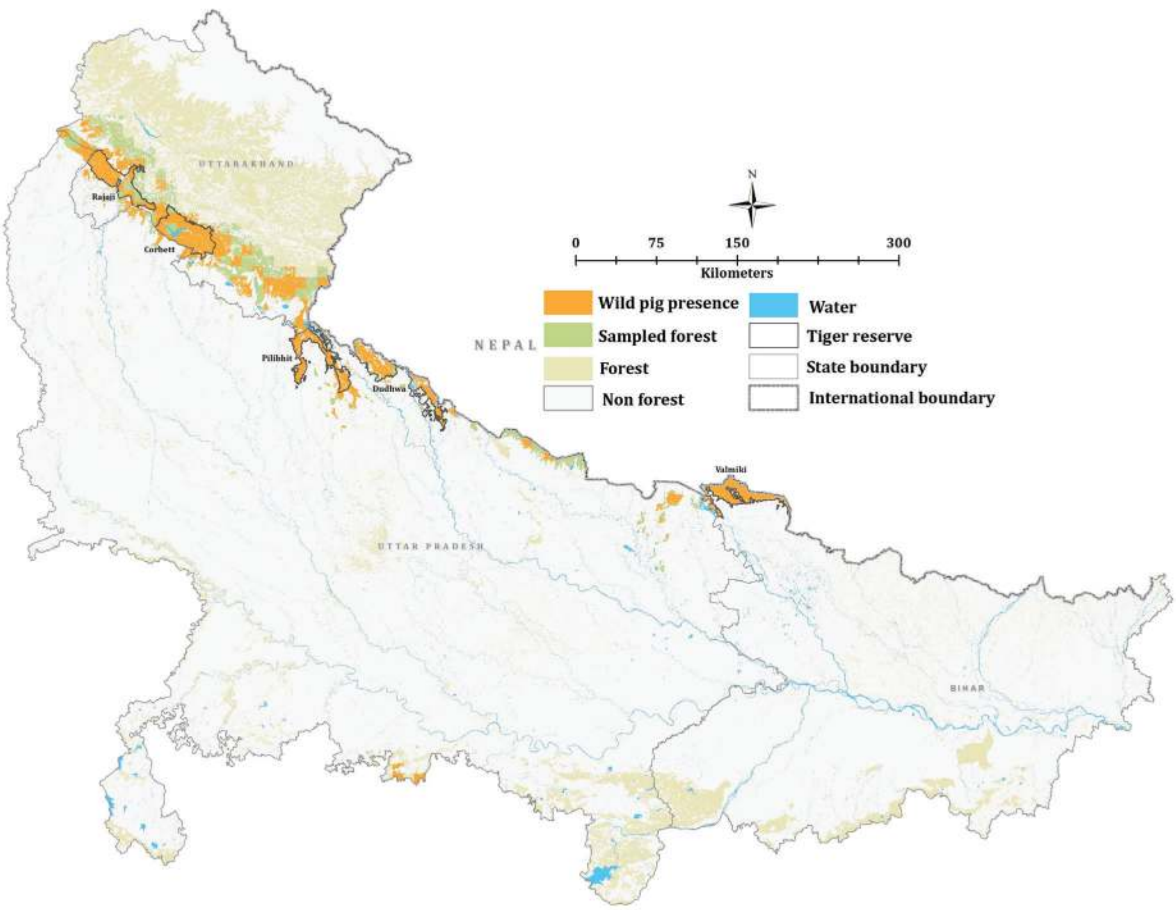
Wild pig *(Sus scrofa)* *[Wildlife (Protection) Act, Amended, 2022: Schedule II; IUCN Red List: Least Concern]*

Wild pig is widely distributed throughout the Shivalik and Gangetic hill landscapes, occupying an area of approximately 8163 km^2 (Fig. II.1.17). Unlike Nilgai, their distribution is not limited by the presence of Shivalik hills. However, wild pigs pose a significant concern in terms of human-wildlife conflict due to crop raiding in this landscape. It is also an important prey for large carnivores.

Crop raiding by wild pigs can result in significant damage to agricultural fields, leading to conflicts between local communities and wildlife. Managing these conflicts requires effective strategies that balance wildlife conservation and address the concerns of farmers. Implementing measures such as crop protection, fencing, and population control measures for wild pigs can help mitigate conflicts.

Figure II.1.17

Wild pig distribution in Shivalik Gangetic Plains landscape, 2022

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Section II.2

Central India and Eastern Ghats Landscape

Ujjwal Kumar, Krishna Mishra, Rutu J Prajapati, Ayan Sadhu, Ashish Prasad, Swati Saini, Dhruv Jain, Manish A. Singanjude, Anup Pradhan, Hemant Kamdi, Rajendra Garawad, Satya P. Yadav, Vishnupriya Kolipakam, Yadvendradev V. Jhala, Qamar Qureshi

Section II.2

Central India and Eastern Ghats Landscape

Central India and the Eastern Ghats house India's largest tiger population. Additionally, this landscape is home to a significant population of scheduled tribes who rely on forest lands for their livelihoods. Central India have the highest genetic diversity among tiger populations, featuring a distinct lineage found in the Similipal Tiger Reserve (Kolipakam *et al.* 2019). This landscape spans across the semi-arid region of Rajasthan and the central Indian plateau, covering Maharashtra, Madhya Pradesh, Chhattisgarh, Jharkhand, and Odisha. It also includes portions of the Eastern Ghats in Telangana, Andhra Pradesh, and Odisha. To maintain regional integrity, certain parts of the Northern Western Ghats (Sahyadri) in Maharashtra is included here.

The hill ranges surround the central region of India, including the Aravalli range to the northwest, the Satpura Range to the south, the Chota Nagpur plateau to the northeast, and the Orissa hills to the southeast, Within this landscape, numerous other hill ranges exist, ranging in elevation from 200m to 1300m. Notable ranges include the Vindhyas, Mahadeo Hills, and Maikal Range. The Vindhyas and Satpuras act as geographical dividers between the peninsular region of India and the Indo-Gangetic Plains. The Chota Nagpur plateau in this landscape features the Hazaribagh, Ranchi, and Koderma plateaus, forming a step-like formation. The Ranchi plateau, situated in the west and at the highest elevation, seamlessly connects with the Sarguja plateau, averaging 1000m in height. The majority of the landscape is covered by forests due to hilly terrains and plateaus with shallow and infertile soils, limiting extensive cultivation.

The Eastern Ghats extend parallel to India's east coast, spanning from the Mahanadi valley in the north to the Krishna valley in the south. The Godavari and Krishna rivers cut across the Eastern Ghats, resulting in a fragmented range of hills. Notable ranges within the Eastern Ghats include Nallamala, Erramala, Palakonda, Velikonda, Seshachalam, Papi Kondalu, Maliya, Madugula Konda, and Garhjat hills. While historically connected to the forests of Central India and the Chota Nagpur plateau, this connection has largely been lost over time.

This landscape encompasses an extensive network of protected areas (PAs), including nearly half (25 out of 53) of India's designated tiger reserves, along with several other PAs supporting significant tiger populations. The eastern region of Rajasthan and a portion of north-western Madhya Pradesh within this landscape fall within the semi-arid zone. Serving as a transitional zone between the Indian peninsula's forests and the Thar desert, this region experiences lower rainfall compared to the peninsular forest regions. The peninsular region within this landscape, comprising Madhya Pradesh, Maharashtra, Chhattisgarh, Odisha, Telangana, and Andhra Pradesh states, represents the largest landmass in India and acts as a unique transition zone between the Gangetic plains and the forested Western Ghats. The region's diverse habitats, ranging from moist to dry deciduous forests and from valleys to hilly terrains, support rich biodiversity.

This region has undertaken several initiatives to reintroduce locally extinct mammals within their historic ranges. Notable successes include the reintroduction of tigers in Panna and Sariska Tiger Reserves, Nauradehi Wildlife Sanctuary, and Madhav National Park, reintroduction of Gaur in Bandhavgarh and Sanjay-Dubri Tiger Reserve, and reintroduction of Barasingha in the Satpuda and Bandhavgarh Tiger Reserves. Additionally, cheetah introduction has occurred in Kuno National Park, with potential relocation sites identified as Mukundara National Park, Gandhisagar, and Noradehi Wildlife Sanctuary. Tiger translocations from high-density to low-density regions, such as Kanha and Bandhavgarh to Satpuda and Sanjay Tiger Reserve and Brahmpuri to Navegaon Nagzira Tiger Reserve, have also taken place.

The forest departments of Madhya Pradesh and Maharashtra have made significant progress in ensuring the protection of core areas in tiger reserves through incentivized village relocations. Unfortunately, this landscape also experiences the highest concentration of mining activities, which possess a considerable challenge to conservation efforts. Within this landscape, two endangered species, the central Indian wild buffalo and the hard ground barasingha, are now confined to the tiger reserves. Despite their high biodiversity value and conservation significance, the forests of this region face immense threats from mining, linear infrastructures, livestock grazing, non-timber forest product collection, and insurgency.

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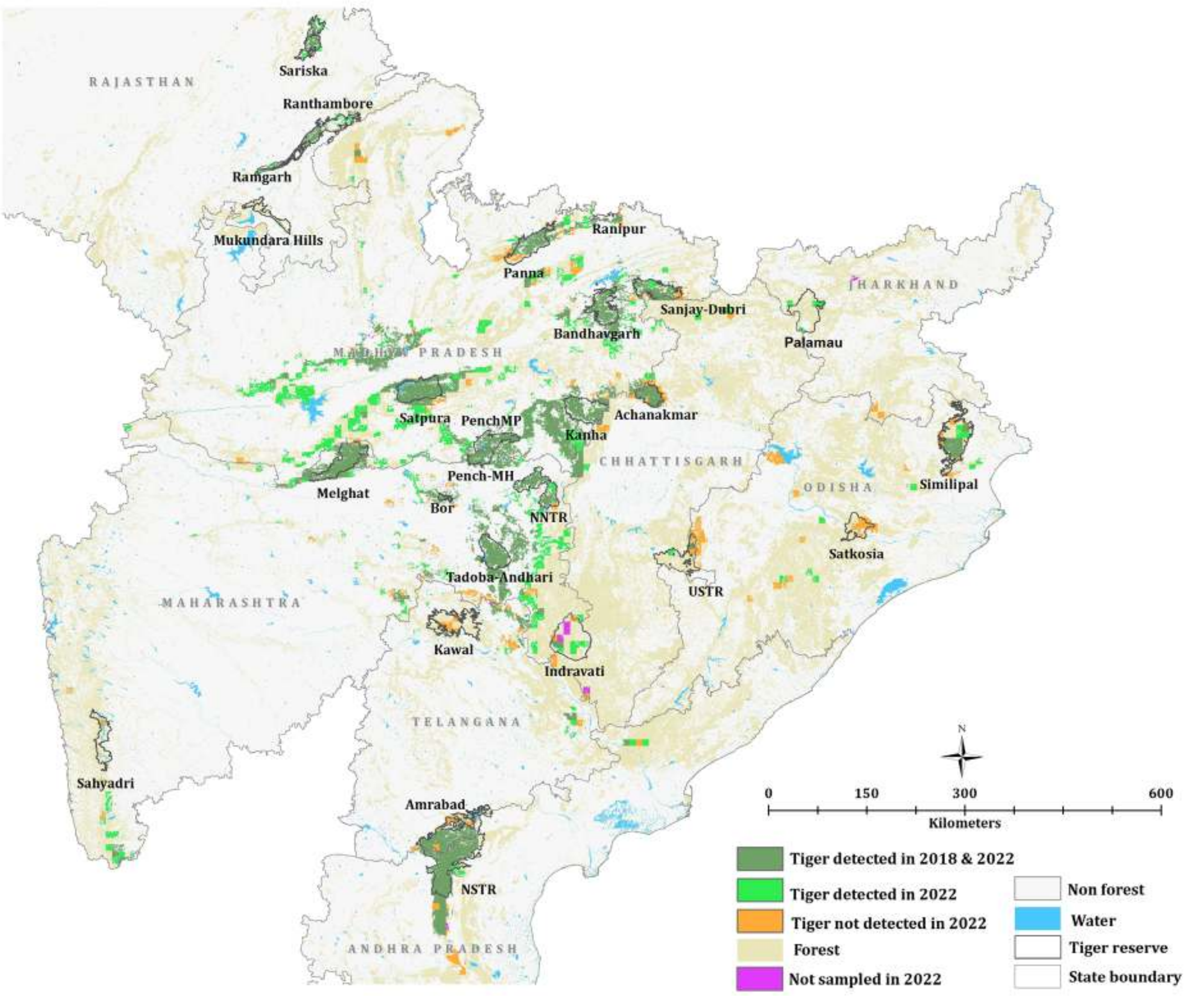
Tiger Distribution

In 2022, tiger presence was observed in an area of 59,011 km^2,occupying 1046 cells (12 %) out of 8652 sampled (Fig.II.2.1). Ranthambhore, as the sole source population in Western India, has played a crucial role in expanding the tiger distribution across the semi-arid landscape. This expansion includes areas like Dholpur, Kuno-Shivpuri, and Ramgarh Visdhari. However, there has been a decline in tiger occupancy in Jharkhand, Odisha, Chhattisgarh, Andhra Pradesh, and Telangana. On the other hand, tiger occupancy has expanded to various territorial regions in Madhya Pradesh and Maharashtra, linking several tiger reserves and previously unoccupied protected areas since 2018.

Satkosia, Kawal, and Sahyadri tiger reserves did not report tiger presence, but Palamau and Udanti-Sitanadi tiger reserves recorded tiger presence in one or two grids. These reserves hold potential for reintroduction efforts through measures such as ungulate recovery, enhanced protection, and continued management of reintroduced populations through supplementation. Initially, tiger occupancy in 2006 was limited to tiger reserves and specific territorial regions, which were remnants of historic populations. The conservation implications and tiger occupancy are discussed in more detail in the state-specific section of this chapter.

Figure II.2.1

Change in tiger distribution in 2018 and 2022 in the Central India and Eastern Ghats landscape.



Tiger population extent and abundance across the Central India & Eastern Ghats Landscape:

The Central Indian and Eastern Ghats landscapes are characterized by having the largest tiger population in India (1439, SE-126), but they also face significant fragmentation of wildlife habitats. This fragmentation has led to fluctuations in the tiger population of the states, resulting in numerous local extinctions and colonizations (Jhala *et al.* 2020). The best SECR model used in estimating tiger density incorporated tiger sign intensity, prey abundance and human disturbance as co-variants (Fig. II.2.2) To better understand population connectivity and extent, the Central Indian and Eastern Ghats landscape population is divided into 11 sub-units or blocks. These blocks consist of individual or multiple protected areas, some of which may or may not currently have tiger populations. Among these sub-units, there are four population blocks that each harbor more than 200 adult tigers. Additionally, smaller sub-units exist within this landscape, encompassing individual or multiple protected areas, regardless of whether they currently have tiger populations. These sub-units play a critical role in the long-term survival of the species in the region. These population blocks include:

1) Sariska: Sariska Tiger Reserve, situated in the Aravali hill ranges of Rajasthan, has a significant history regarding tiger conservation. It experienced a local extinction of tigers, officially declared in 2004, due to poaching. However, this unfortunate incident prompted a shift in the tiger conservation approach in India, leading to the era of evidence-based tiger conservation. To address the absence of tigers, reintroduction efforts were initiated in Sariska in 2008, and the department began actively monitoring all reintroduced individuals. The recent camera trapping exercise conducted in 2021-22 recorded 19 adult tigers residing in Sariska.

The dry deciduous forests of Sariska face substantial human disturbance, which has led to degradation in the prime tiger habitats within the reserve. Nevertheless, the reintroduced tigers have successfully bred in Sariska, resulting in a population increase over the years. It is essential to actively manage the Sariska population as a metapopulation, along with nearby tiger reserves such as Ranthambhore, Ramgarh, and Mukundara. This management approach involves periodically exchanging individuals among these reserves to maintain genetic diversity and promote a healthy tiger population.

2) Ranthambore-Mukundara-Kuno: This cluster represents the westernmost distribution of tigers and has been isolated from the rest of the central Indian landscape for a considerable period. Ranthambhore is the largest population within this landscape, with dispersing males from Ranthambhore establishing themselves in different sink populations in the greater Ranthambhore ecosystem, including Kuno, Datia, Mukundara, and Ramgarh (Sadhu *et al.* 2017). These smaller populations are largely comprised of dispersing males, and therefore breeding females need to be reintroduced to establish resident viable populations. A study by Kolipakam *et al.* (2019) demonstrated that the genetic structure of tigers in the semi-arid region differs from the rest of the central Indian population. However, due to limited connectivity in the landscape, dispersal events are rare.

The dispersal corridors within this landscape comprise forests, ravines of the Chambal River and its tributaries, pasturelands, and agricultural fields. The tributaries of the Chambal River provide convenient passages for tigers to move through this human-dominated landscape. Madhav National Park is connected to Kuno National Park through the upper Vindhya region and serves as a sink population within the greater Ranthambhore ecosystem. The development of linear infrastructures poses a threat to wildlife habitats in this landscape, compromising the long-term persistence of tigers. Additionally, the flattening of ravines for agriculture poses another risk to this unique landscape. Government of Madhya Pradesh has initiated projects to reclaim ravines and convert them into agricultural land. Such reclamation efforts have the potential to impede tiger movement across the corridors and will adversely impact the biodiversity of this region. Mining activities are also widespread in the landscape, representing a major cause of wildlife habitat destruction. The current estimated population of tigers in this block is 69 individuals (SE 8) occupying an area of 1205 km^2 (Fig. II.2.2).

3) Panna-Ranipur: The Panna block, located within the Vindhya range, has become geographically separated from the Bandhavgarh-Guru Ghasidas complex in recent times. However, there have been reports of collared tigers navigating the human-dominated landscape between the two reserves, undertaking a risky journey from Panna Tiger Reserve to Sanjay-Dubri Tiger Reserve. Panna Tiger Reserve serves as the source population within this block. After facing local extirpation, the tiger population in Panna has been successfully restored through reintroduction efforts and the effective enforcement of laws by the Madhya Pradesh forest department.

Panna Tiger Reserve is connected to the newly established Ranipur tiger reserve in Uttar Pradesh through the territorial forest divisions of North Panna and Satna. Habitat improvement, ungulate augmentation, and protection is needed to establish tiger population. In the south, the fragmented habitat of the South Panna Territorial Division acts as a stepping stone for dispersing tigers from Panna Tiger Reserve towards Bandhavgarh and Noradehi Wildlife Sanctuary. The current estimated population of tigers in this block is 79 individuals (SE 8) occupying an area of 2840 km^2 (Fig. II.2.2). This represents a significant increase of tiger population and range expansion. Unfortunately, a substantial portion of the biodiverse Panna Tiger Reserve is currently under threat of submersion due to the proposed Ken-Betwa river-linking project, which poses a significant risk to the conservation efforts in the area

4) Bandhavgarh-Sanjay-Guru Ghasidas: The population block consists of Bandhavgarh Tiger Reserve as a significant source population, along with the territorial forest divisions of Shahdol and Rewa circles in Madhya Pradesh. It is located in the Vindhyan hills and shares contiguous borders with Guru Ghasidas National Park, Timor Pingla and Semarsot Wildlife Sanctuaries, Surajpur and Balrampur divisions in Chhattisgarh. These connections eventually lead to Palamau Tiger Reserve situated in the Chota Nagpur plateau of Jharkhand. Notably, a recent migration of a small group of elephants from Guru Ghasidas National Park to Bandhavgarh using these corridors has been observed.

The current estimated population of tigers in this block is 226 individuals (SE 16) tigers within an area of 5649 km^2 (Fig. II.2.2). The tiger population in this block has shown increase compared to the previous estimation cycle. This landscape exhibits great potential for accommodating the growing tiger population of Central India. With the recovery of ungulate species in the area, it has the capacity to support a tiger population of more than 500 individuals.

5)Kanha-Pench-Achanakmar: This population block represents the largest tiger population in the Central Indian landscape, with an estimated 360 individuals (SE 12) within an area of 11,400 km^2 (Fig. II.2.2). It encompasses the forested landscape of Kanha Tiger Reserve, Mandla, Balaghat, and Dindori territorial divisions, Pench Tiger Reserve in Madhya Pradesh, Pench Tiger Reserve in Maharashtra, and Achanakmar Tiger Reserve in Chhattisgarh. Together, these areas form the largest connected tiger population in the Central Indian landscape.

The Bhoramdeo Wildlife Sanctuary in Chhattisgarh, which shares a contiguous border with Kanha Tiger Reserve, requires restorative efforts and should be integrated as a transboundary part of the tiger reserve. The connectivity between this population block and the adjacent Bandhavgarh-Gurughasidas, Satpuda-Melghat, and Tadoba-NNTR-Indravati blocks is functional, with documented tiger movements occurring between these areas.

6) Tadoba-NNTR-Bor-Indravati-Kawal: This population block has demonstrated remarkable recovery, compared to the countrywide estimation in 2018. The tiger population is currently estimated at 319 individuals (SE 32) within an area of 11,400 km^2 (Fig. II.2.2). The inclusion of the Indravati Tiger Reserve in Chhattisgarh within this block is a result of increased tiger occupancy in the connecting corridors between Indravati and Tadoba Andhari Tiger Reserves, facilitated through the forests of Gadchiroli and Allapali divisions. However, several forest grids in this area remain unsampled due to left-wing extremism.

The Kawal Tiger Reserve and Adilabad forest circle in Telangana are also incorporated into this block due to frequent tiger movement within the region. The primary source population in this block is the Tadoba Tiger Reserve and its neighboring forest divisions, including Brahmpuri, Central Chanda, and Chandrapur. The smaller tiger populations in Bor Tiger Reserve and Tipeshwar Wildlife Sanctuary have limited capacity to accommodate additional tigers.

The Umred Karhandla Paoni Wildlife Sanctuary and Navegaon Nagzira Tiger Reserve require restorative efforts to enhance prey availability. This population block in Maharashtra experiences the highest level of conflict between humans and tigers, with instances of livestock predation and attacks on humans. To ensure the long-term survival of tigers in this landscape, it is crucial to restore wild ungulate availability in forested areas. Problematic individual tigers should be removed following the protocols set by the National Tiger Conservation Authority (NTCA).

The low-density area of Telangana within this block, including Kawal Tiger Reserve, Adilabad, Chennur, and Kagaznagar, has the potential to accommodate the increasing tiger population of Maharashtra if ungulate recovery and improved protection measures are achieved. However, the corridor connecting these two tiger areas faces threats from anthropogenic pressures such as mining activities and the expansion of road and rail networks. To address these challenges, it is necessary to implement wildlife-friendly and permeable infrastructure to facilitate safe wildlife movement.

7) Satpura-Melghat: Melghat and Satpura tiger reserves are situated in the scenic Satpura hills of the Central Highlands. These two reserves are interconnected through the forests of Betul and Narmadapuram forest divisions in Madhya Pradesh. This population block has exhibited remarkable recovery, in comparison to countrywide estimation in 2018. Currently, the population is estimated to be 149 tigers (SE 17) within an area of 9,427 km^2 (Fig. II.2.2).

One of the key factors contributing to this recovery is the availability of large and undisturbed spaces, which were achieved through the incentivized voluntary village relocations. This has created favourable conditions for tiger recovery in the region. Furthermore, this area has significant potential to sustain a population of approximately 500 tigers if ungulate recovery efforts are implemented through measures such as supplementation, habitat management, and increased protection.

The combination of these factors, including ample space and potential for prey recovery, bodes well for the long-term survival and growth of the tiger population in Satpura Tiger Reserve.

8) Ratapani-Bhopal-Dewas: This block is situated on the northern side of the Narmada River. It is separated from the Satpura Tiger Reserve landscape by the city of Narmadapuram, Obedullaganj, and the Narmada river. Notably, this tiger population block includes the urban area of Bhopal, the capital city of Madhya Pradesh. It encompasses the Ratapani Wildlife Sanctuary, along with the adjacent territorial areas of Obedullaganj forest division, the Kheoni Wildlife Sanctuary, and the territorial areas of Dewas forest division. Additionally, it includes the territorial areas of Bhopal and Sehore forest divisions of Madhya Pradesh.

This area holds great potential to be established as a tiger reserve. The tiger population in this block has witnessed a significant increase, with a doubling of numbers. The current estimated population stands at 96 tigers (SE 9) within an area of 4,530 km^2 (Fig. II.2.2).

9) Similipal: Similipal is the sole tiger population in the state of Odisha and is notable for its unique lineage of tigers (Kolipakam et al. 2019). Previously, this population block also included the Satkosia Tiger Reserve, but as tigers have been locally extirpated from Satkosia, it is not considered in the current assessment. The Similipal Tiger Reserve, along with the Kuldiha Wildlife Sanctuary, constitute this population block. However, the tiger population in this block faces significant challenges and is severely depleted, with an estimated count of only 18 tigers (SE 4) across an area of 1,484 km^2 (Fig. II.2.2). Urgent efforts are required to restore and recover this population. It is crucial to effectively combat tiger poaching and address the issue of snaring, which negatively affects both tigers and their prey. Conservation measures must be prioritized to ensure the revival and long-term conservation of this vulnerable tiger population in Similipal.

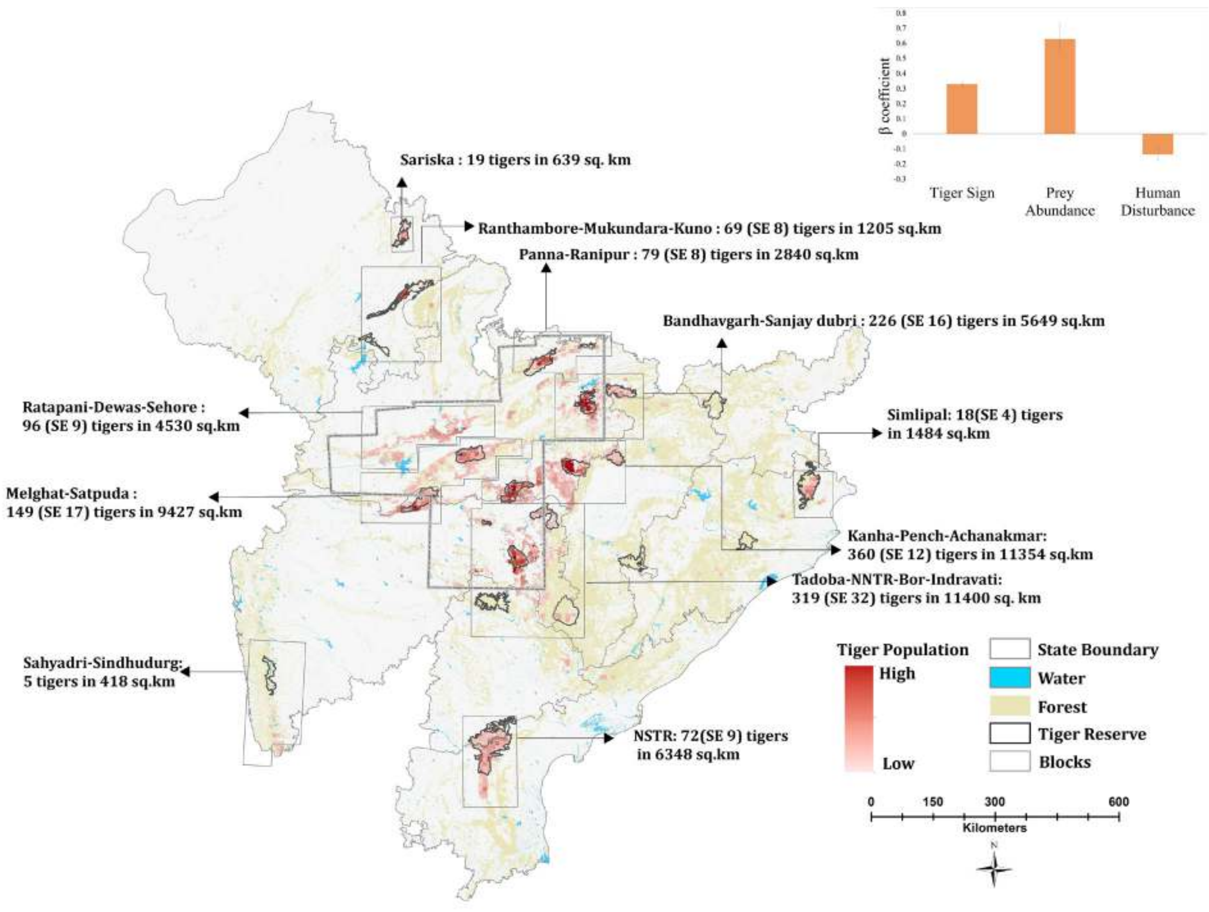
10) Nagarjunsagar Srisailam-Amrabad: The population in this block has witnessed an increase compared to the previous countrywide estimation, with the current estimate of 72 tigers (SE 9) within an area of 6,348 km^2 (Fig. II.2.2). Following the reorganization of Andhra Pradesh state in 2016, the former Nagarjunsagar-Srisailam Tiger Reserve was divided into Amrababad and Nagarjunsagar-Srisailam Tiger Reserves. The corridor connecting Nagarjunsagar-Srisailam Tiger Reserve and Sri Venkateswara National Park, known as the Nagarjunsagar-Sri Venkateswara NP Corridor, primarily passes through forested habitats and includes three protected areas: Gundla Brahmeswaram Wildlife Sanctuary, Sri Lankamalleswaram Wildlife Sanctuary, and Sri Penusila Narasimha Wildlife Sanctuary. Various state highways (31, 34, 56, and 57) intersect the corridor, highlighting the need for wildlife passageways and appropriate mitigation measures. In particular, the township of Sidhavatam, which poses a significant bottleneck in this corridor due to development activities, requires restorative management.

The tiger density within the Nagarjunsagar-Srisailam Tiger Reserve is on the rise, and tigers will naturally disperse to recolonize Sri Venkateswara National Park. Therefore, it is crucial to maintain the functionality of the corridor to facilitate this natural dispersal. This population block encompasses one of the largest continuous forest areas, with the potential to sustain approximately 400 tigers if the wild ungulate population is restored.

11) Sahyadri-Sindhudurg: This population block represents the northernmost extent of the Western Ghats population, including the Koyna Wildlife Sanctuary, Chandoli National Park, Radhanagri Wildlife Sanctuary, and the forests of Sindhudurg in the Maharashtra. The prey base in this block is currently poor, but there is potential for tiger population recovery once the prey base is restored. The Sahyadri Tiger Reserve and Radhangari Wildlife Sanctuary are connected to the tiger habitats in Goa, which, in turn, are contiguous with the Kali Tiger Reserve in Karnataka. Currently, there are no significant source populations of tigers in this region. There was no tiger record from Sahyadri tiger reserve however Sawantwadi-Kolhapur forest divisions has reported small population of dispersing tigers from Goa and Kali Tiger Reserve of Karnataka state. The estimated population is 5 tigers in 518 km^2 (Fig. II.2.2).

Figure II.2.2

Spatially explicit tiger density modelled from camera trap based capture-mark-recapture and co-variates of tiger sign, prey abundance and human disturbance (inset graph) within the central India and eastern ghats landscape, 2022.



State-wise tiger population

Andhra Pradesh: Andhra Pradesh has 37,258 km^2 of forest, which makes up 22.86% of the state's total area. Phase I sampling was done in 23 forest divisions, camera traps were set up in Papikonda National Park, Nagarjuna Srisailam Tiger Reserve, and adjacent sanctuaries like Sri Lankamalleshwara, Sri Penusila Narasimha Wildlife Sanctuaries, Sri Venkateshwara National Park, and the Kadapa forest divisions. The estimated tiger population in Andhra Pradesh in 2022 is 63 (SE 7). However, tiger occupancy has been declining. In 2018, tigers were present in Gundla Brahmeswaram, Sri Lankamalleshwara, Sri Penusila Narasimha Wildlife Sanctuaries, and Sri Venkateshwara National Park, but they were not recorded in these areas in 2022. Only one tiger was photographed in the Papikonda Wildlife Sanctuary. In 2006, there were sporadic tiger sightings in the east Godavari and Vishakhapatnam regions, but these have now disappeared and are restricted to Papikonda. The connectivity between the Nagarjuna Srisailam Tiger Reserve and the Sri Venkateswara National Park passes through forested habitats and the Gundla Brahmeswaram, Sri Lankamalleswaram, and Sri Penusila Narasimha wildlife sanctuaries. State Highways 31, 34, 56, and 57 intersect the corridor at various points, highlighting the need for appropriate mitigation measures such as wildlife passageways. The township of Sidhavatam is a major bottleneck within this corridor and is facing development activities that require restorative management to ensure the connectivity and functionality of the corridor.

Chhattisgarh: The state of Chhattisgarh encompasses a substantial forest area, covering 59,816 km^2, which accounts for 44.25% of the total geographic area of the state (State of the Forest Report 2021). However, the tiger population in the state is facing a decline. As of 2022, the estimated tiger population is 17 (SE 2) tigers. Urgent attention is needed to address this decline.

The Udanti-Sitanadi Tiger Reserve is currently experiencing a deteriorating situation, and significant investments are required to enhance protection measures and facilitate prey recovery in the reserve. Similarly, the Achanakmar Tiger Reserve is in a recovery stage, but long-term sustainability of the tiger population in the reserve depends on adequate investments in protection and prey recovery efforts. Indravati Tiger Reserve has the potential for recovery; however, it is influenced by left-wing extremism, which poses challenges to conservation efforts in the area. On a positive note, the Guru-Ghasidas National Park has received principal approval for declaring it as a tiger reserve. The park is contiguous with the Sanjay-Dhubri Tiger Reserve in Madhya Pradesh and has the potential to receive dispersing tigers from Bandhavgarh Tiger Reserve. To support the tiger population in Guru-Ghasidas National Park, supplementary translocation of prey from high-density areas of is necessary, along with improvements in the protection regime.

Efforts aimed at conservation and restoration, such as prey supplementation, enhanced protection measures, and addressing the challenges posed by left-wing extremism, are vital for the recovery and long-term survival of tigers in Chhattisgarh.

Jharkhand: Jharkhand, with a forest area covering 25,118 km^2, accounts for 31.51% of the total geographic area of the state (State of the Forest Report 2021). The tiger population in Jharkhand currently faces a precarious situation, with only one tiger reported from the Palamau Tiger Reserve. To address this critical situation, the state needs to focus on several key areas. Firstly, there is a need to enhance the skills and capacity of forest staff through comprehensive capacity building programs. This will enable them to effectively carry out conservation efforts and protection measures in the national parks and sanctuaries of Jharkhand. Additionally, it is crucial to mitigate the impact of mining operations near forest areas by implementing innovative methods that prioritize conservation. This will help minimize disturbances to the habitats of wildlife, including tigers.

Despite the challenges, the Palamau Tiger Reserve remains significant as it maintains corridor connectivity both to the west, with Bandhavgarh Tiger Reserve through Semarsot-timor Pingla Guru Ghasidas Sanjay Tiger Reserve and to the east, with Gautam Buddha and Koderma through Lawalong Wildlife Sanctuaries. This connectivity positions Palamau as a potential source population for the future revitalization of the landscape with tigers and other endangered species. While implementing restorative management is essential, it is vital to prioritize the protection of core habitats and critical connectivity. Regaining lost prey and tiger populations is feasible, but restoring densely populated areas plagued by poverty is a challenging task. Therefore, ensuring the preservation of core habitats and critical corridors becomes crucial for the long-term conservation of tigers in Jharkhand. Efforts should be directed towards improving the ground situation, protecting core habitats, and facilitating connectivity, as these factors are key to the future revival of tiger populations and the conservation of other endangered species in Jharkhand.

Madhya Pradesh: Madhya Pradesh, with a forest area covering 94,689 km^2, accounts for 30.72% of the total geographic area of the state (State of the Forest Report 2021). The tiger population in Madhya Pradesh is estimated to be 785 (SE 58) in 2022. The state is renowned for its conservation efforts and is home to six Tiger Reserves, including two proposed Tiger Reserves - Ratapani and Durgawati-Noradehi. Additionally, Madhya Pradesh have nine National Parks, 25 Wildlife Sanctuaries, and 81 Forest Divisions, all contributing to the Central Indian Tiger Landscape.

The forest department of Madhya Pradesh has demonstrated remarkable commitment and success in active management practices. They have effectively restored low-density areas through incentivized voluntary village relocations, prey supplementation, reintroduction of species such as Barasingha to new habitats like Satpuda and Bandhavgarh, and the reintroduction of Gaur to Bandhavgarh and Sanjay-Dubri Tiger Reserves. Prey species like chital have been successfully supplemented in Satpuda, Sanjay Tiger Reserves, Nauradehi, Kuno, and Gandhisagar Wildlife Sanctuaries through translocation from high-density areas such as Pench and Bandhavgarh Tiger Reserves.

As a result of these efforts, the tiger population in Madhya Pradesh has shown a significant increase since the last countrywide estimate in 2018. All the tiger reserves in the state have witnessed population growth since the previous estimation. There is still potential for accommodating more tigers in reserves such as Satpuda and Sanjay Tiger Reserves.

Notably, the forested area of East Nimar (Harda-Betul-Khandwa divisions) south of the Narmada River, forming the Melghat-Satpuda corridor, is now being colonized by tigers dispersing from both tiger reserves. The forest corridor between Pench and Satpuda Tiger Reserves also reports continuous tiger presence. However, the expanding linear infrastructure poses a major threat to these corridors, leading to habitat fragmentation if appropriate mitigation measures are not implemented. The Balaghat forest division, which connects Kanha and Pench Tiger Reserves, has the potential to become a protected area due to its large forested areas and significant tiger population. The Madhya Pradesh government has proposed declaring a 182 km^2 area of the Warasoni range in Balaghat as the Sonewani Wildlife Sanctuary, reflecting the state's commitment to wildlife conservation.

Madhya Pradesh's conservation efforts have yielded positive results, and continued dedication to protecting habitats, mitigating threats, and expanding protected areas will ensure the long-term survival and growth of the tiger population in the state.

Maharashtra: Maharashtra, have a forest area of 20.13% of the state's total geographic area (State of the Forest Report 2021). The tiger population in Maharashtra is estimated to be 444 (SE 43) tigers in 2022. The state have six Tiger Reserves: Tadoba Andhari, Pench, Navegaon Nagzira, Bor, Melghat, and Sahyadri.

Maharashtra has made significant strides in tiger conservation, with a increase in the tiger population since the last countrywide estimation in 2018. The Chandrapur District, encompassing Brahmpuri, Chandrapur, Central Chanda, and Tadoba-Andhari Tiger Reserves, has witnessed substantial growth in the tiger population. However, this area faces challenges such as increasing tiger numbers, dispersal and a scarcity of wild prey, leading to potential human-wildlife conflicts. Efforts should be directed towards prey recovery in low-density areas like Navegaon Nagzira Tiger Reserve (NNTR) and Melghat Tiger Reserve. Capacity building initiatives for forest veterinary officers and staff are essential to minimize conflict situations and effectively conduct rescue operations.

Notably, the Sahyadri Tiger Reserve did not record any tiger presence during the sampling for the countrywide estimation in 2022. The Sahyadri population was once connected to the tiger population in Goa through the Radhangiri Wildlife Sanctuary. Further south, it was connected to the Kali Tiger Reserve (formerly Anshi-Dandeli) in Karnataka via the ridge-top forests of the Western Ghats. Once the population in Kali is recovered, dispersing tigers from Kali can potentially replenish the Sahyadri Tiger Reserve. However, the connectivity between Kali and Sahyadri is threatened by mining activities and road expansion projects. It is crucial to implement appropriate mitigation measures to restore and preserve the tiger population in the Sahyadri Tiger Reserve.
Maharashtra's efforts in tiger conservation have yielded positive outcomes, but continued focus on prey recovery, conflict mitigation, and habitat protection is necessary to ensure the long-term survival and growth of the tiger population in the state.

Odisha: Forests of Odisha accounts for 39.31% of the state's total geographic area (State of the Forest Report 2021). The tiger population in Odisha is estimated to be 20 (SE 4) tigers in 2022. The state is home to two Tiger Reserves, namely Similipal and Satkosia, as well as a proposed Sunabeda Tiger Reserve. Additionally, it has two National Parks and 18 Wildlife Sanctuaries.

However, the tiger occupancy in Odisha has significantly declined since the countrywide estimation in 2006. Notably, tiger presence was not recorded at Sunabeda and Kotagarh Wildlife Sanctuaries, which were previously occupied. The majority of the tiger population in the state is concentrated in the Similipal Tiger Reserve, where effective management practices have led to remarkable growth in both the tiger and prey populations. However recent poaching and operation of armed poacher gangs is a cause of concern. Two forest staff were martyred in the process of safeguarding the reserve. Similipal's large size and favorable habitat conditions offer the potential to sustain a viable tiger population for long-term conservation. Moreover, it has the possibility of connecting with the forests of Saranda in Jharkhand, further enhancing conservation efforts.

In contrast, Satkosia Tiger Reserve has witnessed a local extirpation of tigers. Reintroduction efforts have been made, but they have not yielded successful results thus far. The corridor between Similipal and Satkosia is endangered due to large-scale mining and linear infrastructural projects, posing a significant challenge to connectivity.

There have been reports of one tiger being photographed in the Hirakud Wildlife Division, which was also captured on camera in the Udanti-Sitanadi Tiger Reserve. Wild ungulate recovery and stringent protection measures are crucial for the revival of the tiger population in Satkosia Tiger Reserve and Sunabeda Wildlife Sanctuary. Deploying armed special tiger protection forces in Similipal is necessary to effectively combat poaching activities and ensure the safety of wildlife and personnel within the reserve.

Rajasthan: The state of Rajasthan has a forest area constituting 39.31% of the total geographic area of the State (State of the Forest Report 2021). The tiger population is estimated at 88 (SE 9) tigers in 2022. Ranthambhore has the largest population in the state, followed by Sariska. Recently, dispersed tigers from Ranthambhore recolonized Ramgarh, Kailadevi, Mukundara, and Dholpur. These sink populations need to be monitored with the aim of establishing a metapopulation in the greater Ranthambhore ecosystem. Reintroduction of females needs to be done after creating suitable habitat for tigers and recovering their prey.

Recently, the Rajasthan Forest Department took a commendable initiative to extend the existing Tiger Reserve network by declaring new tiger reserves in different parts of the greater Ranthambhore ecosystem (e.g., Ramgarh-Visdhari, Dholpur). This will safeguard the existing wildlife habitats and facilitate maintaining a viable metapopulation in the landscape. In the last few decades, tigers went extinct from the Kumbhalgarh-Sitamata landscape, primarily due to poaching (including hunting) and prey depletion. Since these forests are not connected with the only source population (i.e., Ranthambhore), natural recolonization was not possible. However, parts of these systems still hold intact forest patches. Conservation investments should focus on the recovery of prey populations and securing large, inviolate core areas for tigers. With such active management, the reintroduction of tigers in their historical range can be considered.

Telangana: Telangana, with approximately 24.70% of its total geographic area covered by forests (State of the Forest Report 2021), is home to an estimated tiger population of 21 tigers (SE 2) in 2022. However, there has been a noticeable decline in tiger occupancy within the state. Previously, forests such as Kawal and Eturnagarm were known to have tiger populations, but in 2022, no tiger presence was recorded in these areas. The Telangana tiger population can be categorized into two regions. The first region is northern Telangana, which shares boundaries with Chhattisgarh and Maharashtra. These populations are part of a larger tiger-occupied landscape known as Tadoba-NNTR-Indravati, spanning across Chhattisgarh, Maharashtra, and Telangana. To ensure the conservation of these populations, it is essential to manage them through interstate cooperation and the implementation of comprehensive landscape management plans. Currently, the tiger population in this area is severely depleted and heavily relies on dispersing tigers from Maharashtra. Kagaznagar holds only a few individuals, while no tigers were detected in Kawal Tiger Reserve.

The second region is the southern region of Telangana, which includes the Amrabad Tiger Reserve, contiguous with the Nagarjunasagar Srisailam Tiger Reserve. This region hosts the largest tiger population in Telangana and requires effective interstate cooperation with Andhra Pradesh for its management. However, even within the Amrabad region, tiger presence has been declining. A significant threat to the tiger landscape in the state of Telangana is the poaching of prey, mining operations, and the development of linear infrastructure. To mitigate these threats, it is crucial to adopt environmental protection measures, establish wildlife passageways, and promote environmentally friendly mining methods. Safeguarding the tiger population in Telangana will require concerted efforts in conservation, habitat protection, and collaboration among states to ensure the long-term survival and thriving of these majestic animals in the region.

Distribution of carnivores and omnivores in the Central India and Eastern Ghats landscape, 2022

Dhole (Wild dog) ***(Cuon alpinus)*** *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Endangered]*

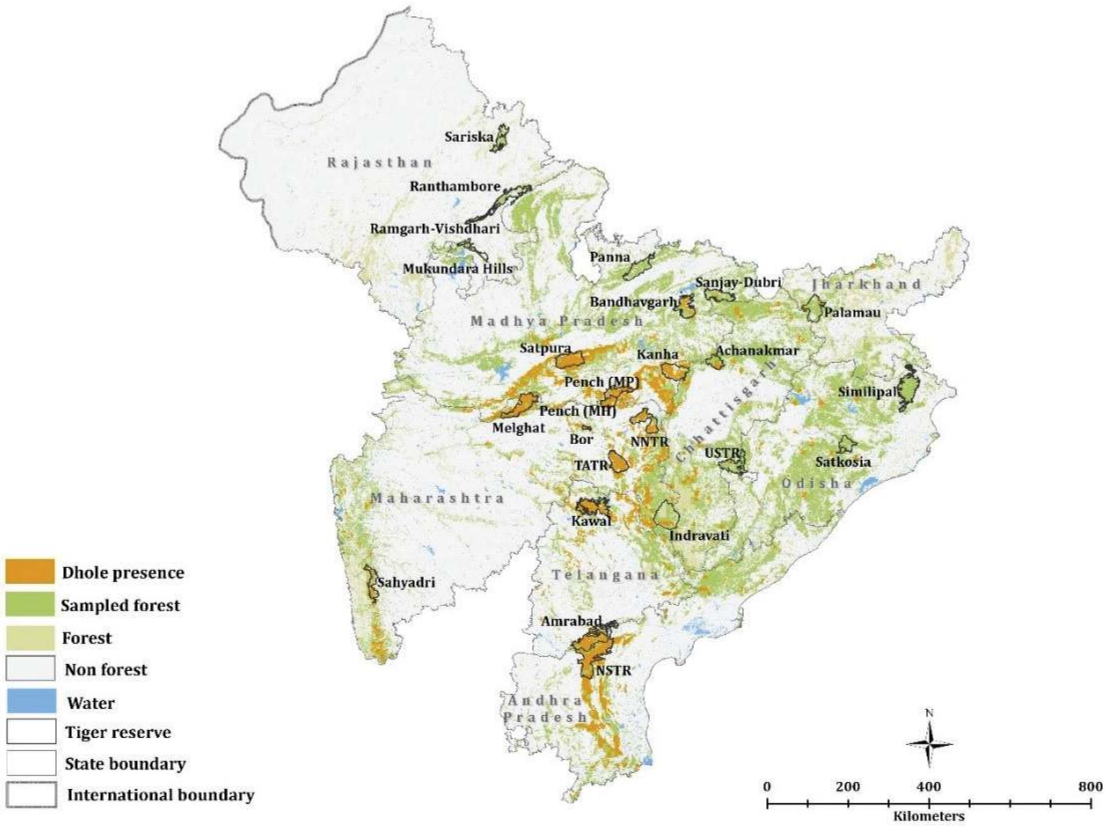
Dhole has been observed across a wide area of 28,473 km^2 in the forested regions of the central Indian landscape (Fig. II. 2.3). Signs of Dholes have been documented in tiger-occupied forests spanning across Madhya Pradesh, Maharashtra, Telangana and Andhra Pradesh. Within this landscape, Dhole occupancy can be categorized into four primary patches:

(a) The central block includes areas in Madhya Pradesh, Chhattisgarh, Palamau in Jharkhand, Eastern Maharashtra, and Northern Telangana, (b) The southern block encompasses Amrabad, Nagarjunsagar-Srisailam Tiger Reserve, and extends into Sri Venkateshwara Wildlife Sanctuary (c) The western block consists of the Western Ghats of Maharashtra, Sahyadri, and Sindhudurg (d) The eastern block comprises southern Jharkhand and parts of Odisha.

The majority of Dhole occupancy was observed within tiger reserves. However, it is worth noting that the northern block, which includes forests in Sheopur, Kuno, Madhav, Ranthambhore, Mukundara, and Sariska, seems to have lost its Dhole population and is now considered extinct in those areas.

Figure II.2.3

Dhole distribution in Central India and Eastern Ghat landscape, 2022

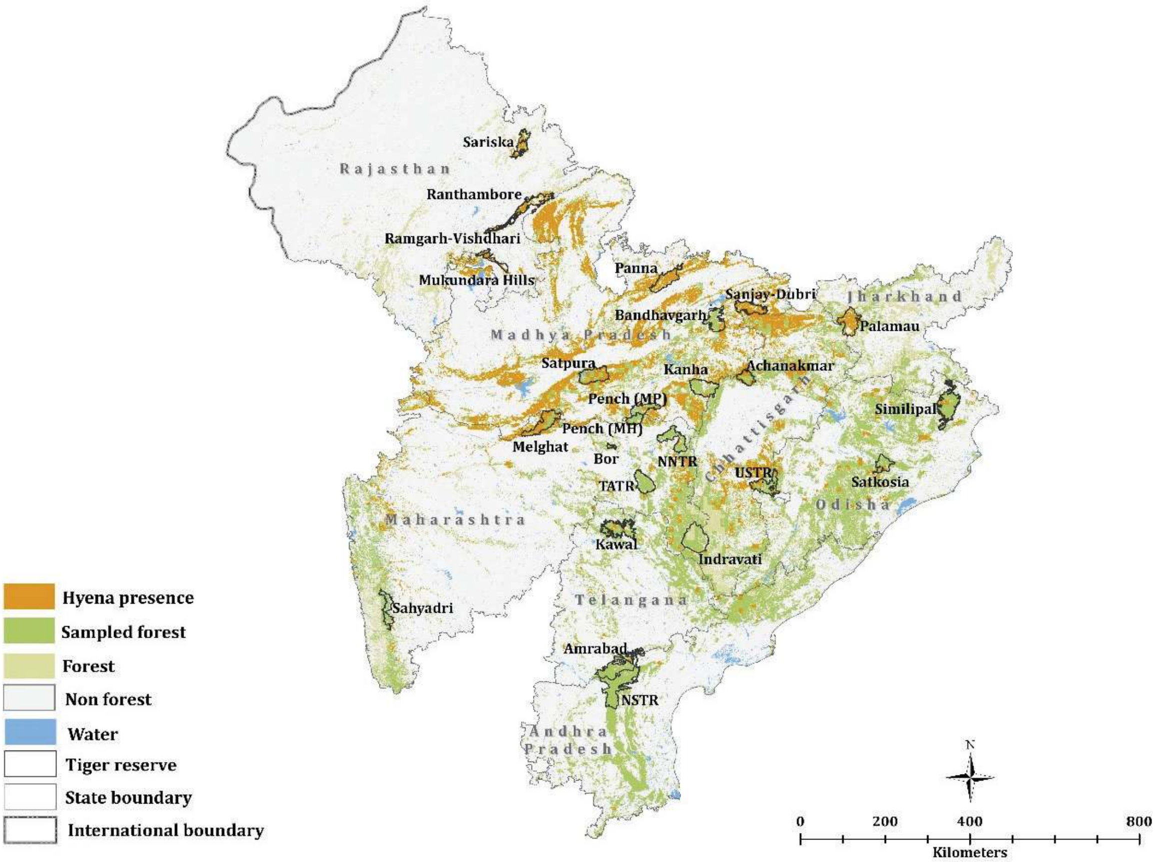


Striped hyena *(Hyaena hyaena)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Near Threatened]*

Hyenas were primarily found in the dry deciduous and semi-arid forests of this landscape, which spans an area of 92,902 km^2 (Fig. II. 2.4). Interestingly, Hynenas were not observed in the high-tiger-density reserves such as Kanha, Bandhavgarh, Pench, and Tadoba. Instead, hyenas occupied the dry forests of Betul and Bhopal forest circles in Madhya Pradesh, the high tiger density Ranthambore tiger reserve in Rajasthan, Palamau Tiger Reserve, and Hazaribag in Jharkhand. The drier forests of eastern Rajasthan and northern Madhya Pradesh, including Sariska and Panna Tiger Reserves, showed a continuous presence of hyenas. Hyena population and distribution is expanding in Central India.

Figure II.2.4

Striped hyena distribution in Central India and Eastern Ghat landscape, 2022

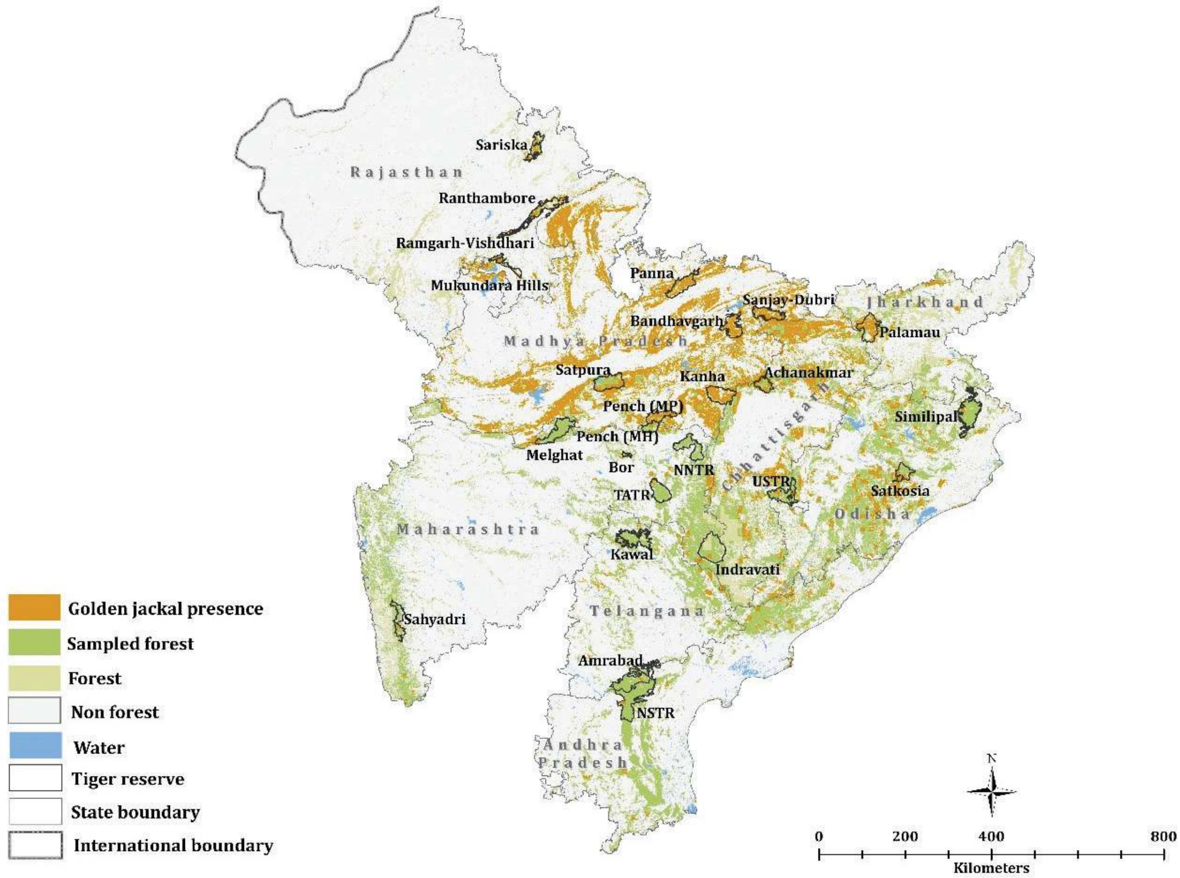


Golden Jackal *(Canis aureus)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Least Concern]*

The jackal, a widespread carnivore, occupies a substantial area of the Central Indian landscape, spanning across 115,689 km^2 (Fig. II.2.5). Its presence was observed in the majority of sampled forests in Madhya Pradesh and Rajasthan, with only a few ranges in Satpura Tiger Reserve being an exception. Jackals were also documented in various protected areas and adjacent territorial forests in Jharkhand, Odisha, and Chhattisgarh. However, their occupancy in Maharashtra, Andhra Pradesh, and Telangana was relatively low.

Figure II.2.5

Golden Jackal distribution in Central India and Eastern Ghat landscape, 2022



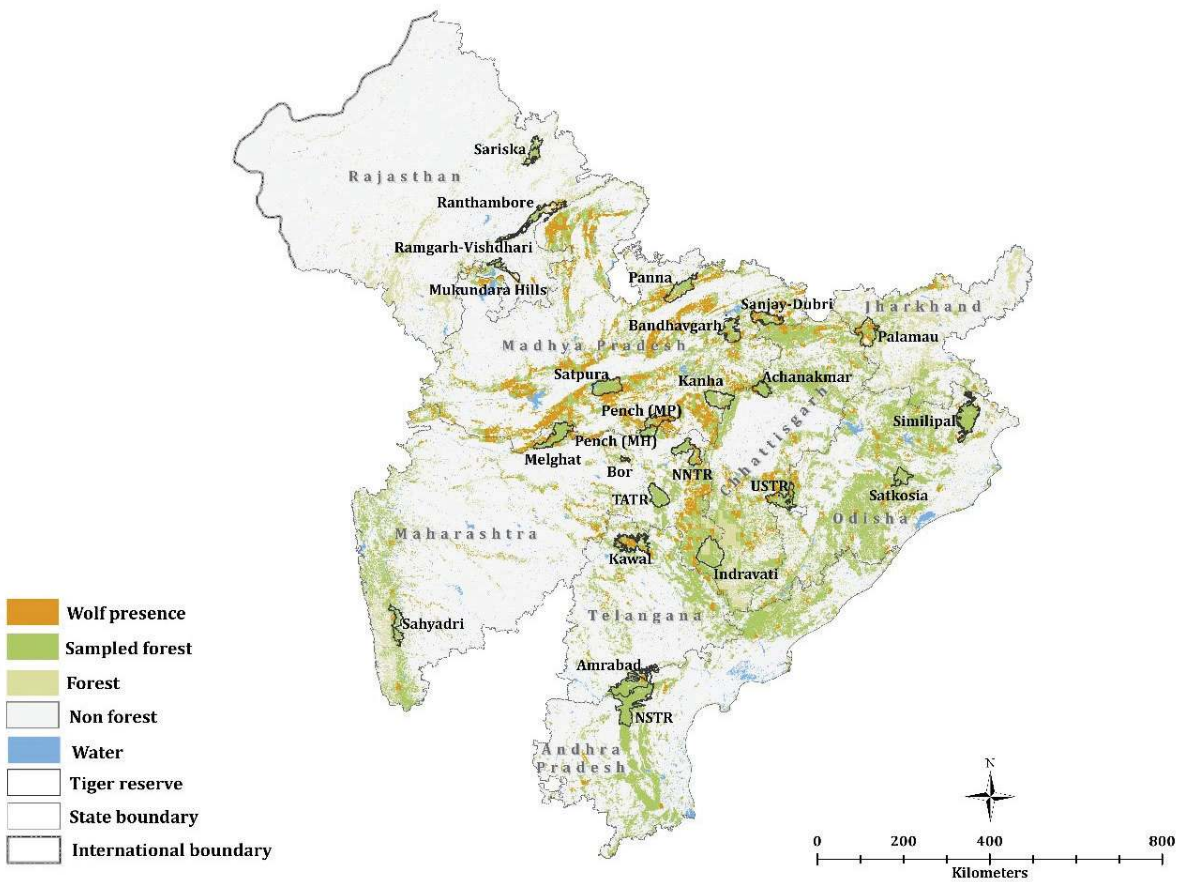
Indian wolf *(Canis lupus pallipes)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Least Concern]*

Wolves, primarily inhabiting the dry deciduous forests of the central Indian landscape, occupy an extensive area of approximately 60,372 km^2 (Fig. II. 2.6). Their presence within tiger reserves is relatively low, mainly restricted to the territorial divisions with agro-pastoral landscapes on the outskirts. The distribution of wolves can be categorized into four distinct population blocks:

a. The northern block, encompassing Ranthambore and Mukundhara Tiger Reserves, along with the northern regions of Madhya Pradesh.
b. The central block, comprising Madhya Pradesh, Maharashtra, and the northern parts of Telangana.
c. The eastern block, consisting of Chhattisgarh, Odisha, and Jharkhand.
d. Isolated forest areas in Andhra Pradesh and southern Maharashtra.

Figure II.2.6

Indian wolf distribution in Central India and Eastern Ghat landscape, 2022



Sloth Bear *(Melursus ursinus)* *Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Vulnerable]*

Sloth bears were found across a vast forested area of approximately 151,114 km^2 within the central Indian landscape (Fig. II.2.7). Their distribution spanned all tiger-occupied forests in Madhya Pradesh, Maharashtra, and Rajasthan, with the exception of Sariska Tiger Reserve. However, the Rajasthan Forest Department has recently reintroduced three sloth bears from the Mount Abu region into the Sariska Tiger Reserve, aiming to restore their presence.

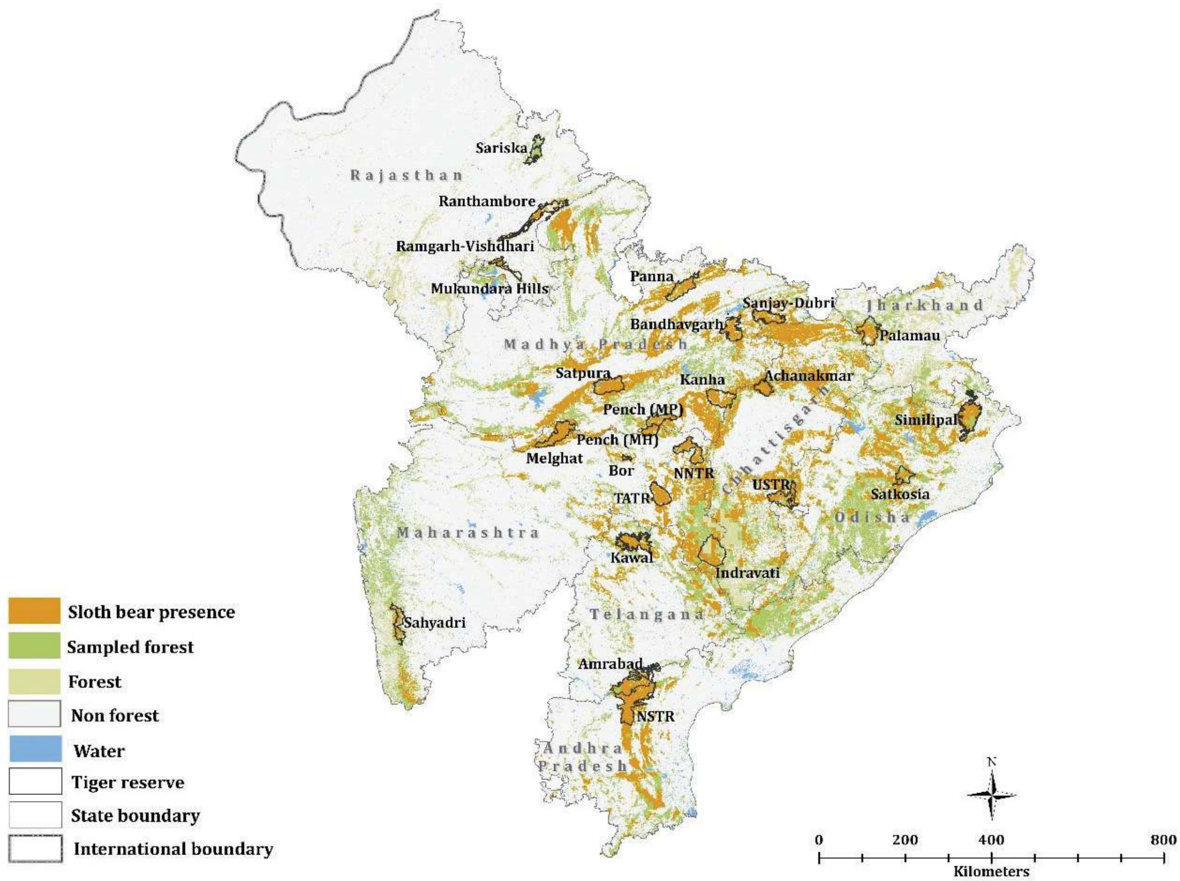
The occupancy of sloth bears within this landscape can be categorized into five distinct subunits:

a. The northern block, which includes Ranthambhore and Mukundara Tiger Reserves, as well as northern regions of Madhya Pradesh, covering Kuno, Madhav National Parks and Sheopur forests.
b. The central block, encompassing Madhya Pradesh, Chhattisgarh, Maharashtra, and Jharkhand.
c. The southern block, consisting of Amrabad and Nagarjunsagar-Srisailam Tiger Reserves, extending upto Sri Venkateswara National Park.
d. The Western Ghats of Maharashtra and the forested areas of the adjoining Deccan region.
e. The eastern block, formed by the protected areas and forests of Odisha.

Section II.2

Figure II.2.7

Sloth Bear distribution in Central India and Eastern Ghat landscape, 2022



Distribution of mega herbivores and ungulates in Central India and Eastern Ghats landscape, 2022

Wild Water Buffalo *(Bubalus arnee)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Endangered]*

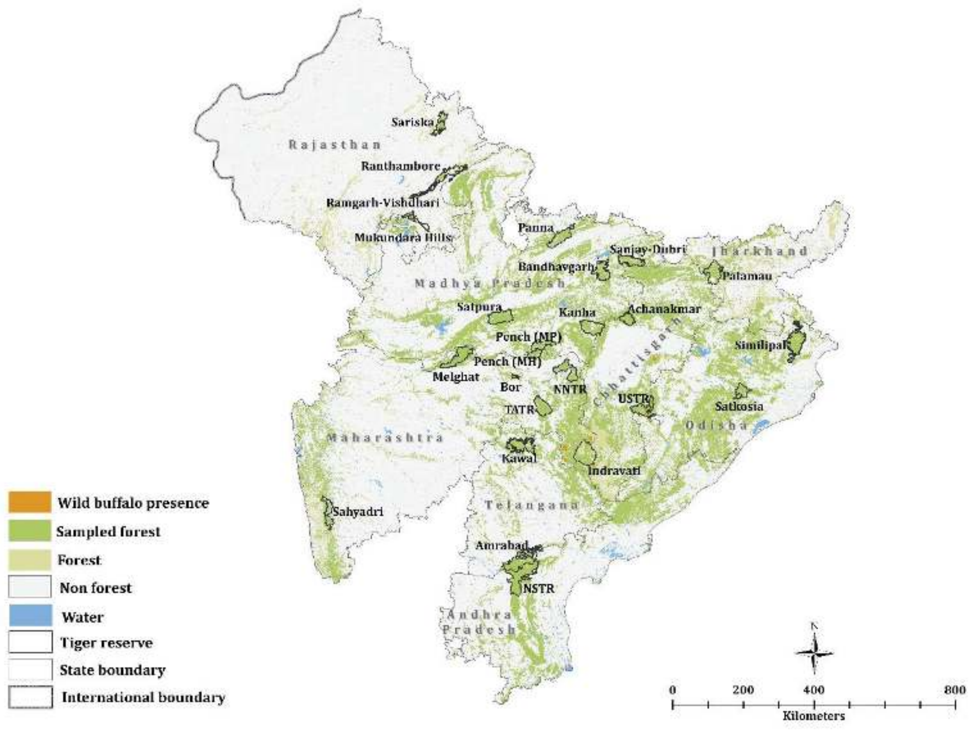
The Wild Buffalo, India's third-largest terrestrial mammal after the elephant and rhino, once had a wide distribution in Central India. However, it is now confined to the Gadchiroli-Allaplly-Indravati forest divisions and the Udanti-Sitanadi tiger reserve, both of which face challenges related to left-wing extremism. This species has experienced a significant decline in recent decades, primarily due to human activities (Choudhury, 2014; Kaul *et al.* 2019).

The Central Indian population of Wild Buffalo represents a distinct geographic unit. These animals have adapted to the harsh ground conditions and limited water availability in the dry deciduous forests with a grassy understory, interspersed with patches of moist Sal (*Shorea robusta*) forests (Kotwal & Mishra, 2004; Ranjitsinh *et al*. 2004). Currently, there are ongoing efforts to reintroduce a few individuals from the Manas Tiger Reserve to the Barnawapara Wildlife Sanctuary. Additionally, plans are underway for the reintroduction of Wild Buffalo in the Kanha Tiger Reserve, aiming to restore the species to its historic range.

Preserving and restoring the population of Wild Buffalo in Central India is crucial for the conservation of this iconic species and the overall biodiversity of the region. It requires coordinated efforts to address the anthropogenic pressures, promote habitat conservation, and ensure effective management of the protected areas where the remaining populations reside.

Figure II.2.8

Wild Buffalo distribution in Central India and Eastern Ghat landscape, 2022



Gaur *(Bos gaurus)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Vulnerable]*

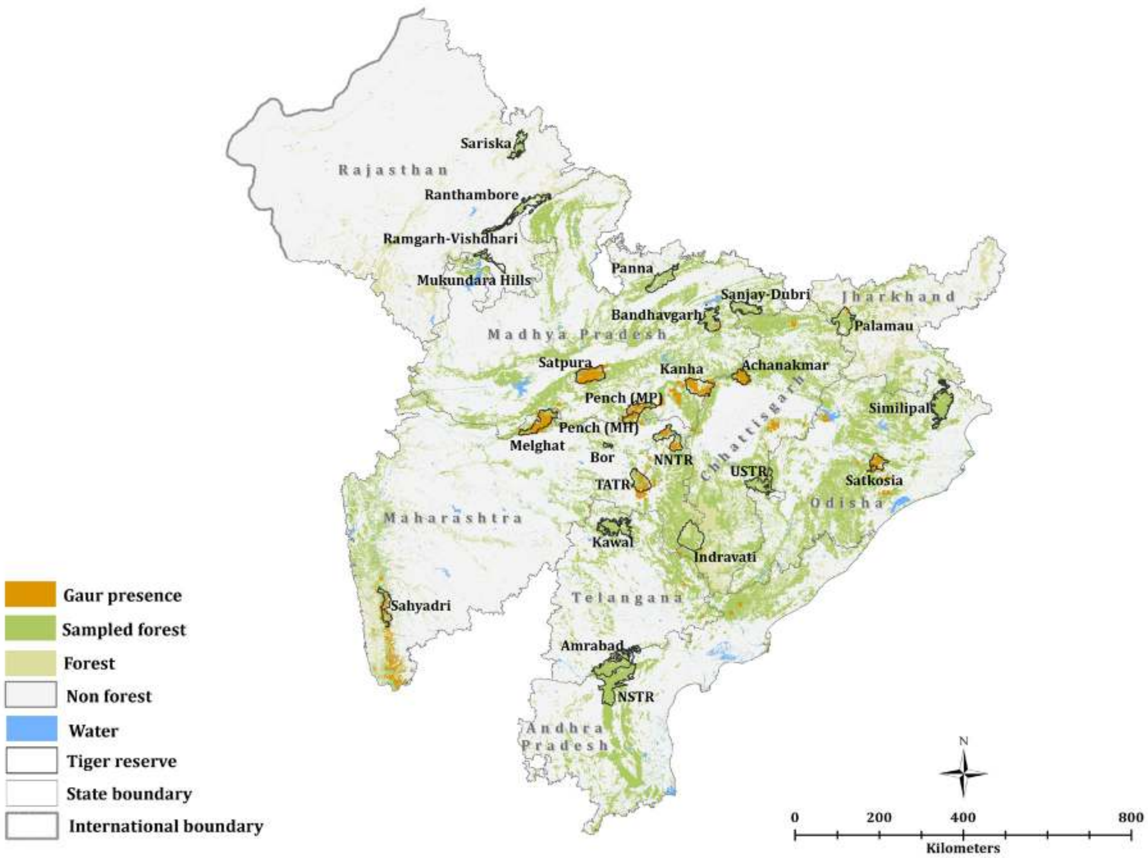
Gaur primarily occupies the protected areas of Central India and the Eastern Ghat landscape. The forested area where Gaur's presence was recorded spans approximately 16,776 km^2 (Fig. II.2.9). In addition to the protected areas, Gaur has also been observed in the Kanha Pench corridor, which includes the Balaghat and Seoni forest divisions. There have been reports of Gaur presence in certain territorial areas of Maharashtra, Chhattisgarh, Northern Telangana, and Andhra Pradesh.

It is important to note that Gaur went locally extinct in Bandhavgarh in 1995 and in Sanjay Dubri tiger reserves. Madhya Pradesh Forest Department introduced 50 gaurs (60% females) in Bandhavgarh (Pabla *et al.* 2011, Sankar *et al.* 2013) and they are doing well. Fourty four(28 from Kanha and 16 from Satpura Tiger Reserve) were translocated to Sanjay Dubri Tiger Reserve.

Section II.2

Figure II.2.9

Gaur distribution in Central India and Eastern Ghat landscape, 2022

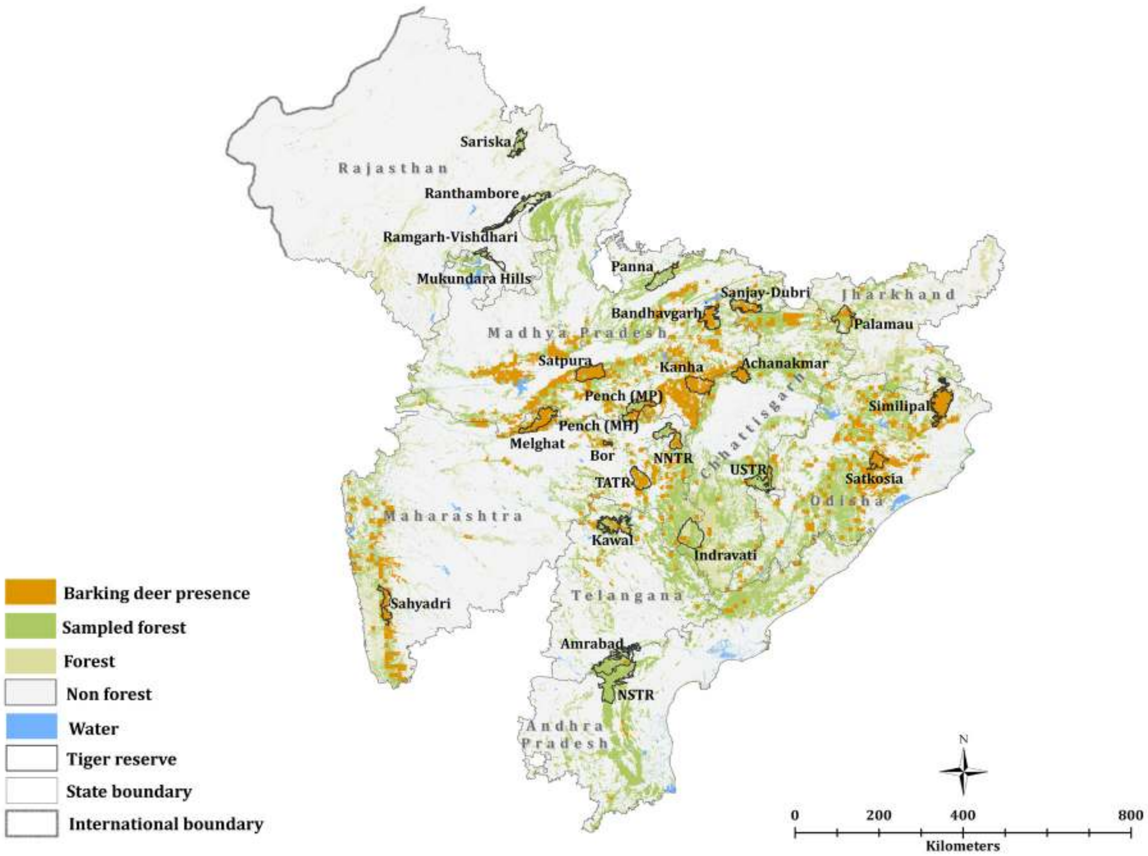


Barking Deer *(Muntiacus vaginalis)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Least Concern]*

Barking deer, also known as Indian muntjac, were observed across the entire Central Indian landscape, except in the semi-arid regions of Rajasthan and Northern Madhya Pradesh. Their occupancy spanned a forested area of approximately 65,468 km2 (Fig. II.2.10). Barking deer tend to prefer moist regions within this landscape.

Figure II.2.10

Barking Deer distribution in Central India and Eastern Ghat landscape, 2022

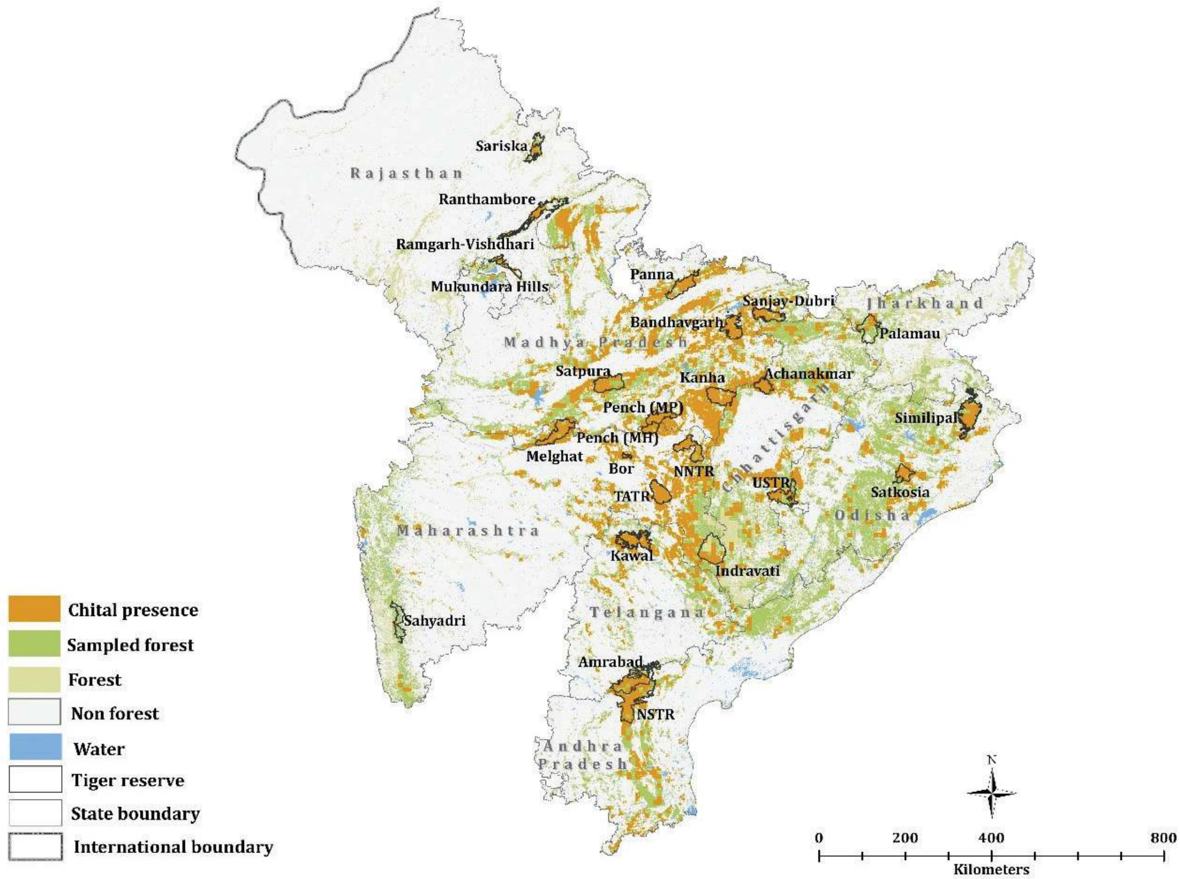


Chital *(Axis axis)* *[Wildlife (Protection) Act Amended, 2022: Schedule II; IUCN Red List: Least Concern]*

The chital, or spotted deer, occupy a significant area within the expansive forested landscape, spanning approximately 1,01,737 km^2 (Fig. II.2.11). Their presence was consistently intertwined with the occupancy of tigers, exhibiting a contiguous distribution pattern. In Rajasthan, chital occupancy was predominantly observed within the Tiger Reserves due to limited sampling. Conversely, in other parts of the landscape, chital populations flourished in the forests surrounding protected areas, including numerous crucial corridor habitats. Vast tracts of the Central and Eastern Ghats landscape are devoid of chital due to poaching, specifically forests outside Protected Areas.

Figure II.2.11

Chital distribution in Central India and Eastern Ghat landscape, 2022

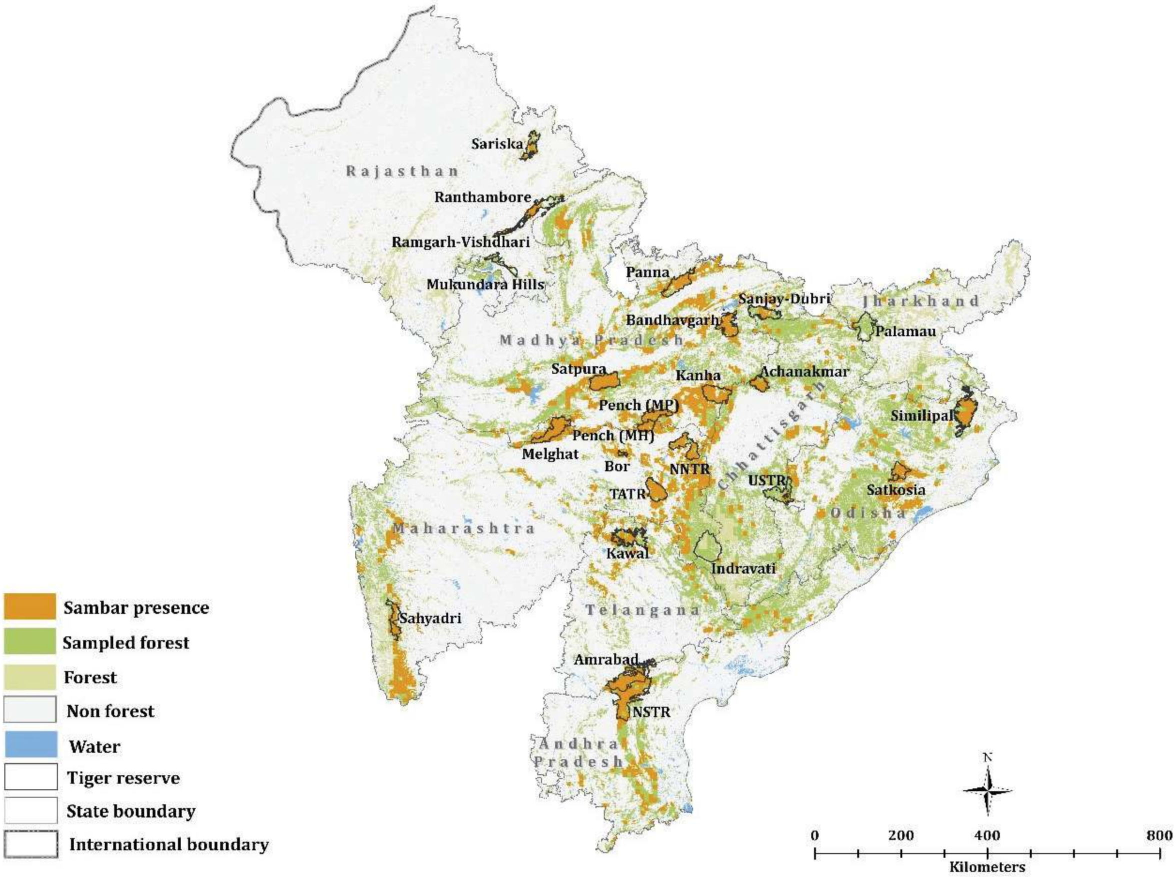


Sambar *(Rusa unicolor)* *[Wildlife (Protection) Act, Amended, 2022: Schedule III; IUCN Red List: Vulnerable]*

The sambar, a large deer species, exhibits a notable distribution across a forested area of approximately 77,110 km^2 within the landscape (Fig. II.2.12). Its occupancy is predominantly observed in protected areas and interconnected forest corridors spanning Madhya Pradesh and Maharashtra. In Odisha, sambar presence is confined to designated protected areas and adjacent forest divisions, while in Jharkhand, sightings are primarily recorded within the Hazaribag Wildlife Sanctuary and Betla National Park, both located within the Palamau Tiger Reserve. The range of sambar occupancy extends from the Amrabad to Nagarjunsagar Srisailam Tiger Reserves, encompassing the expansive Sri Venkateshwara Wildlife Sanctuary. Compared to chital, sambar distribution appears to be more restricted, with a higher likelihood of occurrence within or in close proximity to protected areas, benefiting from the conservation measures provided to these forest habitats.

Figure II.2.12

Sambar distribution in Central India and Eastern Ghat landscape, 2022

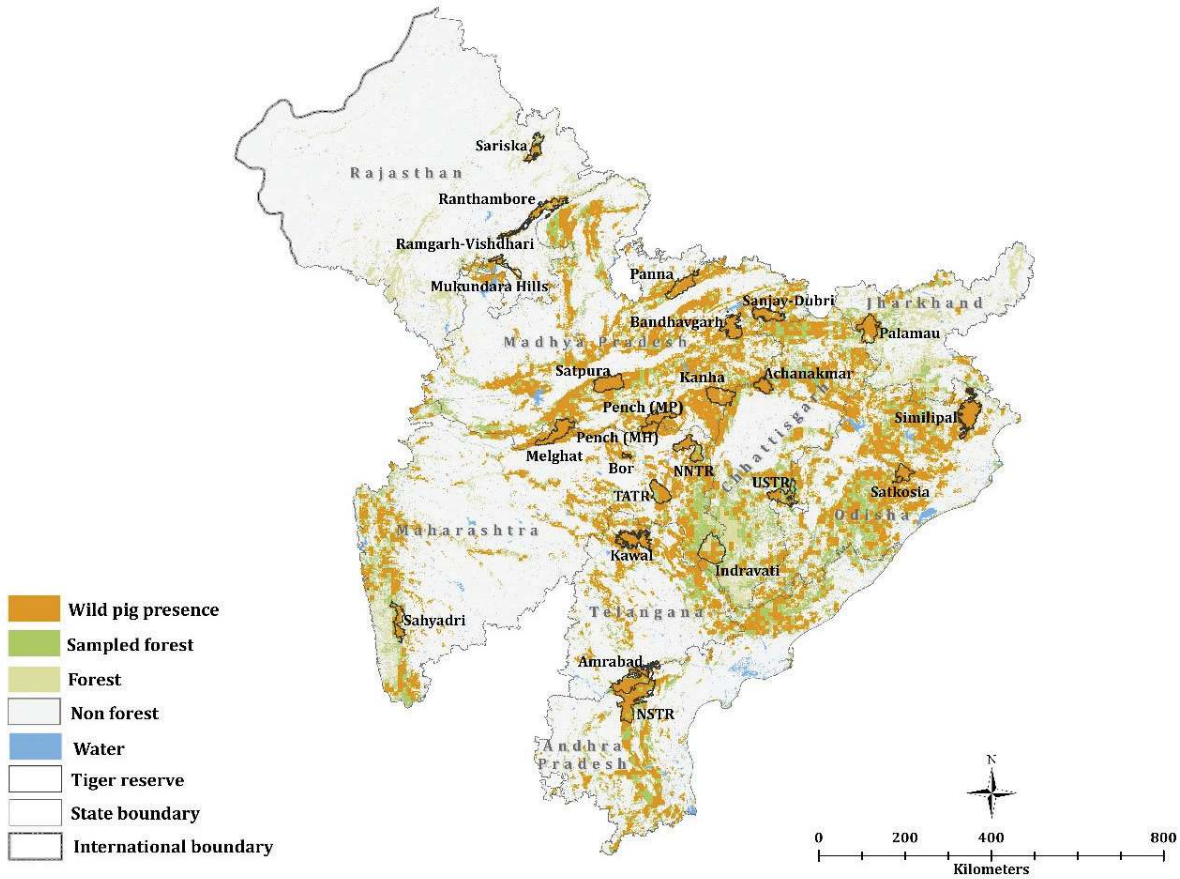


Wild pig *(Sus scrofa)* *[Wildlife (Protection) Act Amended, 2022: Schedule I; IUCN Red List: Least Concern]*

The Wild Pig exhibits a widespread distribution and is considered one of the most prominent ungulate species in the landscape. It occupies an extensive area of approximately 1,17,1012 km^2 (Fig.II.2.13). As a preferred prey species for carnivores, the Wild Pig plays a crucial role in the predator-prey dynamics within the ecosystem. Although not officially classified as pests in this landscape, it is worth noting that in specific regions, wild pigs have been associated with substantial crop damage, posing challenges for local communities and agriculture.

Figure II.2.13

Wild Pig distribution in Central India and Eastern Ghat landscape, 2022



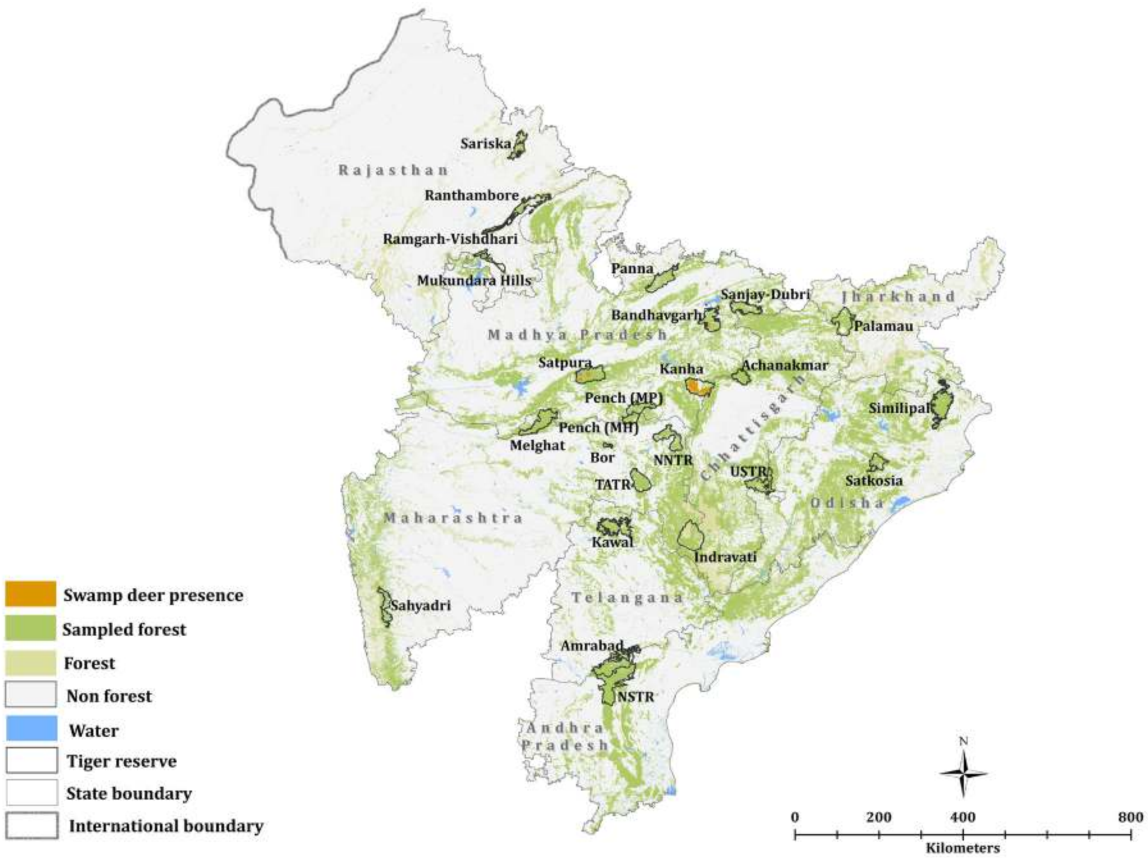
Barasingha *(Rucervus duvaucelii branderi)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Vulnerable]*

The Hard Ground Barasingha, a subspecies found in Central India, is confined to the Kanha, Satpura, and Bandhavgarh Tiger Reserves. Their hooves are specifically adapted to navigate the rugged terrain of the open savanna forest. This species is highly dependent on grasslands and plays a crucial role in their conservation.

Initially, Barasingha was only present in the Kanha Tiger Reserve until 2014. However, in 2015, efforts were made to reintroduce barasinghas in the Satpura Tiger Reserve. Since then, a total of 98 individuals have been successfully reintroduced, resulting in a current population of 178 individuals in the Satpura. In 2023, 50 individuals were reintroduced in the Bandhavgarh Tiger Reserve, extending their occupancy to an area of 1192 km^2 (Figure II, 2.14). The reintroduction initiative will secure the long-term survival of the Barasingha species.

Figure II.2.14

Barasingha distribution in Central India and Eastern Ghat landscape, 2022

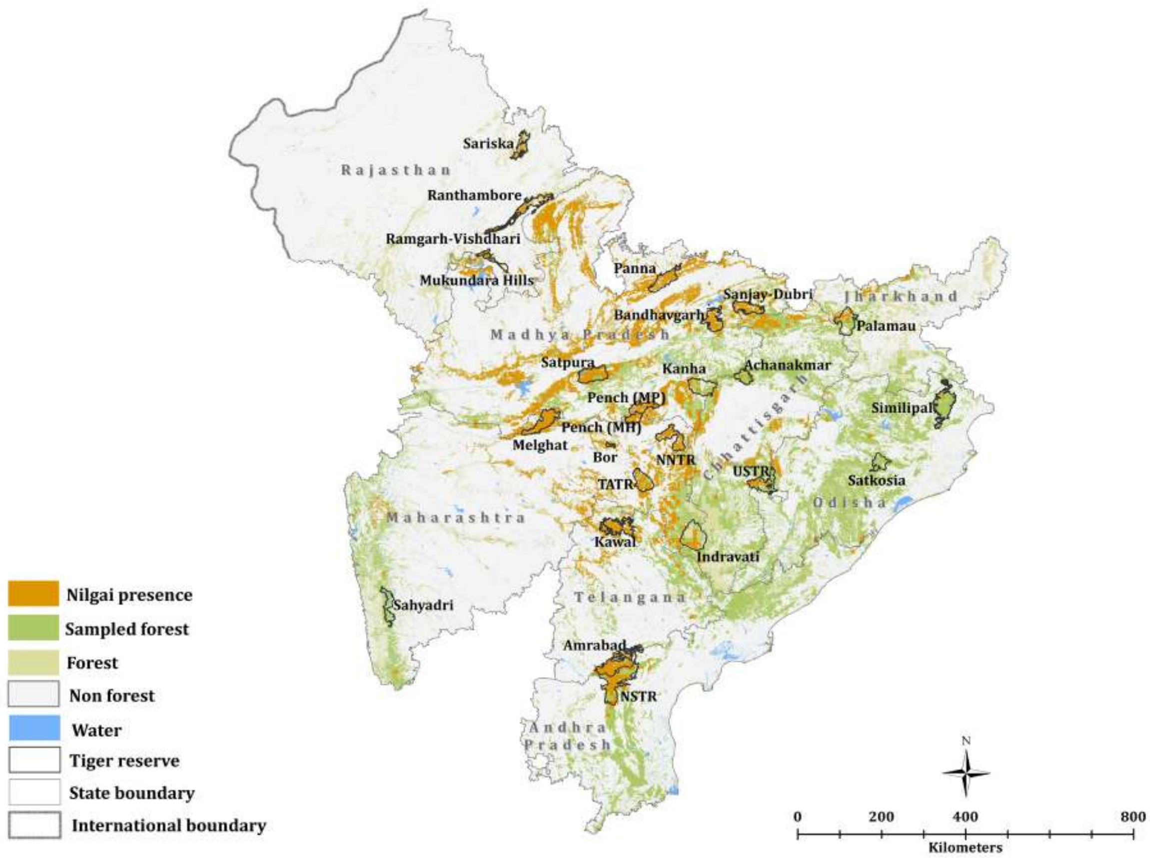


Nilgai *(Boselaphus tragocamelus)* *[Wildlife (Protection) Act, Amended, 2022: Schedule II; IUCN Red List: Least Concern]*

The Nilgai was found in various agro-pastoral patches within the landscape, and it was also observed in the forested regions of Central India. The recorded presence of Nilgai covered an area of approximately 1,00,316 km^2 (Fig. II.2.15). In Odisha, it was documented in the Sunabeda Wildlife Sanctuary and the surrounding forests. However, its occupancy in Achanakmar, Kanha, Similipal, and Palamau Tiger Reserves was comparatively lower than in other protected areas within the same landscape.

Figure II.2.15

Nilgai distribution in Central India and Eastern Ghat landscape, 2022



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Section II.3

Western Ghats Landscape

Ayan Sadhu, Genie Murao, Kausik Banerjee, Ujjwal Kumar, Swati Saini, Ashish Prasad, Monika Saraswat, Vaishnavi Gusain, Vishnupriya Kolipakam, N.S Murali, Harini Venugopal, Amit Mallick, Satya P. Yadav, Yadvendradev V. Jhala, Qamar Qureshi

Section II.3

Western Ghats

Section II.3

The Western Ghats, along with its extension in the wet zone of Sri Lanka, is recognized as one of the eight "hottest hotspots" of biodiversity in the world (Myers *et al.*, 2000) spanning from south of Tapti river to Kanyakumari in the south. The Western Ghats traverse through Kerala, Tamil Nadu, Karnataka, Goa, Maharashtra, and Gujarat (Daniels 1992). However, the Western Ghats is the one of the most populated biodiversity hotspots in the world and face numerous threats pertaining to human-induced activities (Cincotta *et al.* 2000). These threats have contributed to the ongoing decline of biodiversity in the region. Encompassing an area of around 140,000 km^2, the Ghats extend for about 1600 km along the west coast of India. The continuity of this landscape interrupted only by Palghat gap (the largest), Shencottah gap, and Goa gap (the newest), which act as major drivers shaping the distribution of species (Biswas and Karanth 2021). The broad geographical range, bioclimatic conditions, and topographic gradients of Western Ghats system, resulting in exceptionally high levels of biological diversity and endemism. The Western Ghats encompass a range of diverse vegetation types, including tropical wet evergreen forest, montane stunted evergreen forest (shola), grassland, lateritic plateaus, moist deciduous and dry deciduous forest, dry thorn forests, and grassland. It is home to approximately 5,800 species of flowering plants, many of which are endemic, making up around 27% of the total species in India (Gunawardene *et al.*, 2007; Krishnan *et al.*, 2011; Subashree *et al.*, 2021). The region also hosts significant populations of birds, mammals, invertebrates, amphibians, and reptiles, including endangered species such as tigers, Asian elephants, and caecilians.

The major threats to contiguous natural landscapes in the Western Ghats Landscape are mining, hydroelectric projects, and infrastructure development. These activities, especially within and near Protected Areas, result in irreversible habitat loss, disruption of habitat corridors, and long-lasting impacts on gene flow, metapopulation structure, and population persistence of species at the landscape scale. The human-related threats include livestock grazing, illegal hunting, human-wildlife conflicts, extraction of non-timber forest products, fuelwood and fodder harvesting, conversion of natural habitats to monoculture plantations, and the unrestricted use of agrochemicals. These threats have contributed to the ongoing decline of biodiversity in the Western Ghats, with several biological communities and species facing the risk of extinction. In Karnataka alone, nearly 12% of the forests in the Western Ghats have been lost in the past decades (Ramesh, 2001). Estimates by Gadgil and Meher-Homji (1986) suggest that only between 5,288 km^2 (8.5 percent) and 21,515 km^2 (34.7 percent) of the potential area of evergreen forests remain along the ranges of the Western Ghats. A more recent assessment by Myers *et al.* (2000) indicates that only about 6.8 percent (12,450 km^2) of the original 182,500 km^2 of primary vegetation in the Western Ghats and Sri Lanka still exist today. Another pervasive issue is the illegal hunting driven by tradition or the demand for wild meat. Hunters employ various methods, including guns, poisoning, snaring, and trapping (Kumara and Singh 2004, Karanth *et al.* 2013). Human-wildlife conflicts are also common in the Western Ghats due to its landscape dominated by human activity. The presence of dense human populations in several parts of the region further exacerbates the intensity of these conflicts (Madhusudhan 2003).

Efforts to conserve the Western Ghats' biodiversity are crucial to safeguard its unique ecosystems and endemic species. Conservation strategies should focus on sustainable land use practices, community involvement, and the establishment of protected areas. Strict enforcement of wildlife protection laws and raising awareness about the importance of biodiversity conservation are essential steps towards preserving the Western Ghats' natural heritage.

Tiger Distribution

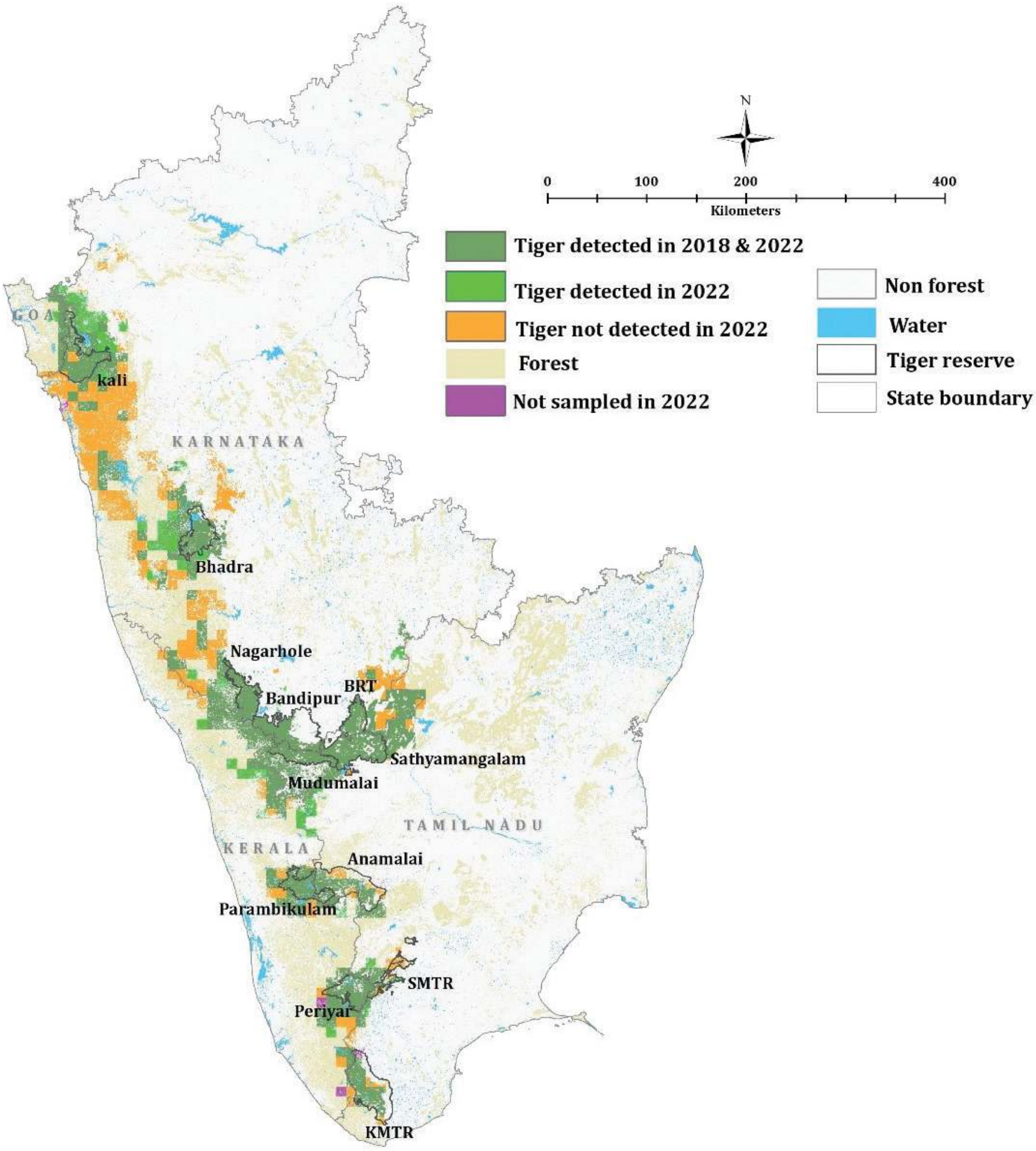
The forests of Western Ghats have the potential for contiguous tiger occupancy, extending from the Dang forests in Gujarat to the Palakkad (Palghat) gap in Kerala, and from the Parambikulum-Anamalai complex to the Periyar-Kalakad-Mundanthurai-Kanyakumari complex (Fig. II.3.1). In the All India Tiger Estimation Exercise 2021-22, tigers were detected in 400 grid cells (25.67%) out of 1558 grid cells surveyed covering an area of 29,263 km^2. The tiger populations of Western Ghats landscape are better connected with each other when compared to 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 with the potential for long distance dispersal. The present assessment depicted scope of tiger population expansion in the northern part of the Western Ghats landscape. Although the TRs and PAs within the Western Ghats landscape are well connected, densely populated matrices within the ecological boundaries of protected areas are a major concern for tiger dispersal.

The habitat connectivity in the Western Ghats landscape is facing the wrath of expanding human land uses, and mushrooming developmental activities. The apparently conducive plantations and agricultural fields which were not barriers to movement are now getting fenced, disrupting the connectivity within the landscape. Industrial and infrastructural development pose additional barriers to the once continuous landscape. 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. As most of these corridors are not within the legal domain of protection, it would be prudent to legitimize the potential corridors between PAs for ensuring uninterrupted gene flow.

The above sections depicted the present status of tigers in Western Ghats and scope of increasing the distribution range for tigers in the landscape. The northern Western Ghats (Kali – Bhadra landscape) harbors a low density tiger population, most likely due to unavailability of inviolate core areas and the very low abundance of wild prey. The landscape model showed the importance of prey availability and negative influence of human disturbance for tiger recovery. It seems the Nilgiri cluster (Nagarahole to BRT Hills TR) has reached or about to reach carrying capacity, and tiger populations have started colonising neighbouring forested areas. These forest divisions are mostly human-dominated with low wild prey. While planning for the tiger recovery, the ecological as well as the social carrying capacity should be taken care of. Areas in the Southern Western Ghats (south of the Palghat gap) harbour low tiger density most likely due to the naturally occurring low prey density. Deliberate habitat management and prey augmentation (to achieve a higher density of tigers) should not be done without assessing the ground situations. The wildlife corridors in the Western Ghats need legal sanctity in order to safeguard them from the upcoming developmental activities and degradation, an in-depth analysis at high spatial resolution is required to assess the vulnerability and threats for each habitat corridor.

Figure II.3.1

Tiger distribution in 2022 and 2018 with comparison of occupancy in the Western Ghats Landscape.



Tiger population extent and abundance across the Western Ghats Landscape

Field surveys and camera trapping were conducted in the Western Ghats, covering a significant portion of the region in Karnataka, Tamil Nadu, and Kerala. A total of 10,222 camera traps were deployed, resulting in 19,181 tiger images and the identification of 824 individual tigers. The best SECR model used in estimating tiger density incorporated tiger sign intensity, prey abundance, forest fragmentation, and human disturbance as covariates (Fig. II.3.2) The model revealed that tiger density increased with higher tiger signs and prey abundance but declined with increasing forest fragmentation and human disturbance. The Western Ghats have recorded impressive tiger population growth since 2006. The estimated population within the Western Ghats Landscape is 1087 (SE 66) tigers in 2022 (Fig II.3.1 and 2), a marginal increase compared to the 2018 estimate (981, SE 112, Jhala *et al.* 2020). Karnataka supports the highest number of tigers, followed by Tamil Nadu and Kerala. Tiger densities varied across different areas of the Western Ghats, ranging from 11 tigers per 100 km^2 in Nagarahole Tiger Reserve to 0.19 tigers per 100 km^2 in Koppa. Based on the presence of tigers in contiguous grids, five distinct tiger population blocks were identified within the Western Ghats landscape. These include:

1) Nagarhole-Bandipur-Wayanad-Mudumalai-Sathyamangalam-BRT complex:

The Nagarahole-Bandipur-Sathyamangalam-BRT-Mudumalai-Wayanad population, spanning across Karnataka, Tamil Nadu, and Kerala, is considered the most crucial source population within the Western Ghats landscape. While the protected areas and tiger reserves in the Nilgiri clusters are well connected, the presence of sizable human populations in villages within these areas pose a significant concern for tiger dispersal. In the southern part, the Wayanad landscape is connected to the Silent Valley National Park through Mudumalai and Mukurti. However, the NH67 road passing through this corridor experiences heavy vehicular traffic, necessitating the construction of wildlife passages such as underpasses and overpasses. A comprehensive study focusing on mitigating human disturbances in the landscape is essential to ensure connectivity between tiger populations.

The contiguous network of Tiger Reserves and Protected Areas in the Western Ghats harbours the largest tiger population in the world, estimated at 828 (SE 30) tigers (Figs. II.3.1 & 2). This (Nilgiri) cluster also supports one of the highest densities of wild tigers in India. The presence of large inviolate areas, abundant large-bodied prey, and excellent landscape connectivity create an ideal environment for a thriving tiger population. However, the expanding human population and the growing range of tigers have led to increased negative interactions between humans and tigers across the landscape. Additionally, the Western Ghats landscape is a significant hotspot for tiger poaching. If wildlife officials are not vigilant against poachers, these significant gains in tiger numbers can be depleted in a short episode of poaching.

2) Mokambika–Kali–Mhadei complex:

The greater Kali landscape, encompassing the Mollem-Netravali cluster in Goa, Anshi-Dandeli-Sharavathi Valley-Mookambika, and the Reserve Forests of Haliyal and Yellapura in Karnataka, shows consistent tiger presence and indicates the potential for expanding tiger distribution in the entire landscape. In the 2021–22 estimation, tiger presence was recorded in 5000 Km^2, except in the Mokambika landscape, which had sparse population records in the previous cycle.

The landscape has shown signs of recovery in recent cycles. The population of tigers in this landscape was estimated to be 51 (SE 8) (Fig. II.3.2). The Kali Tiger Reserve (Anshi-Dandeli) is the primary source population in the area, and tigers from this reserve have started to disperse and recolonize neighbouring forests in Goa and northern Karnataka. The main challenge for the recovery of tigers in this landscape is the potential impact of unplanned development projects, particularly linear infrastructure and mining activities. However, with proactive management and strategic conservation measures, there is potential for a substantial tiger population to thrive in this landscape in the future. This landscape includes protected areas with intermittent tiger occupancy and is characterized by a mix of plantations and agricultural areas. The presence of linear infrastructure, such as highways, poses a threat to connectivity between protected areas. It is crucial to mitigate these threats by providing wildlife passages and implementing appropriate measures to ensure the long-term survival of tigers in the landscape.

3) Bhadra–Kudremukha complex: The Bhadra Kudremukha landscape is home to a tiger population that spans across 5000 Km^2. However, a significant portion of the landscape did not have any tiger presence. The source population of tigers, located in Bhadra Tiger Reserve, is connected to other areas through human habitations and agricultural land. Small patches of ridge-top forests act as crucial "stepping stones" for connectivity but are fragile. The forested landscapes of Bhadra Tiger Reserve, Kudremukha National Park, and adjacent divisions support medium to low-density tiger populations. The recent assessment estimated the abundance of 81 (SE 11) tigers. In this cycle, the tiger distribution was reduced outside the Bhadra TR, especially towards Bhadravathi, which is a conservation concern. The areas outside protected areas are predominantly influenced by human activities and exposed to various anthropogenic disturbances. Therefore, it is crucial to enhance protection measures and potentially implement active management practices to ensure the sustainability of a viable tiger population in the landscape.

The state highway (SH 65) between Sheetur and Shedagaru poses a threat to the connectivity between Bhadra Tiger Reserve and Shettihalli Wildlife Sanctuary, weakening their link. While the habitat matrix allows wildlife movement, the presence of agricultural developments may become barriers in the future. The connectivity in the northern Karnataka landscape, including Kudremukh, Pushpagiri, Talakaveri, and Brahmagiri, extending to Wayanad, is in a precarious state. This linkage is vital, as dispersing tigers from the Nilgiri cluster are likely to recolonize the northern Western Ghats through this habitat connectivity. Linear infrastructures such as NH 234, NH 48, and several state highways (SH 8, 27, 37, 85, 88, 89, 91, and 114) intersect the corridors, posing a threat to connectivity. Further development activities in these areas could jeopardize connectivity and hinder gene exchange between tiger populations. Additionally, the expansion of the urban sprawl of Kutta township poses a risk to the habitat connectivity between Wayanad, Brahmagiri, and Nagarhole.

4) Parambikulam–Anamalai complex: The Parambikulum-Anamalai complex, is the first major tiger population south of the south of the Palghat (Palakkad) gap (Fig.II.3.1). While the tiger occupancy remains consistent within the PAs (Fig.II.3.2), the peripheral areas recorded shrinking distribution of tigers compared to 2018. The recent AITE (2021-22) exercise recorded tiger presence in ~3000 Km^2 area of the landscape (Fig.II.3.2). This complex supports a medium-to-low density tiger population that is sparsely distributed across the larger landscape. The estimated tiger population for this cluster is 57 (SE 8), and it has remained consistent over multiple assessment cycles.

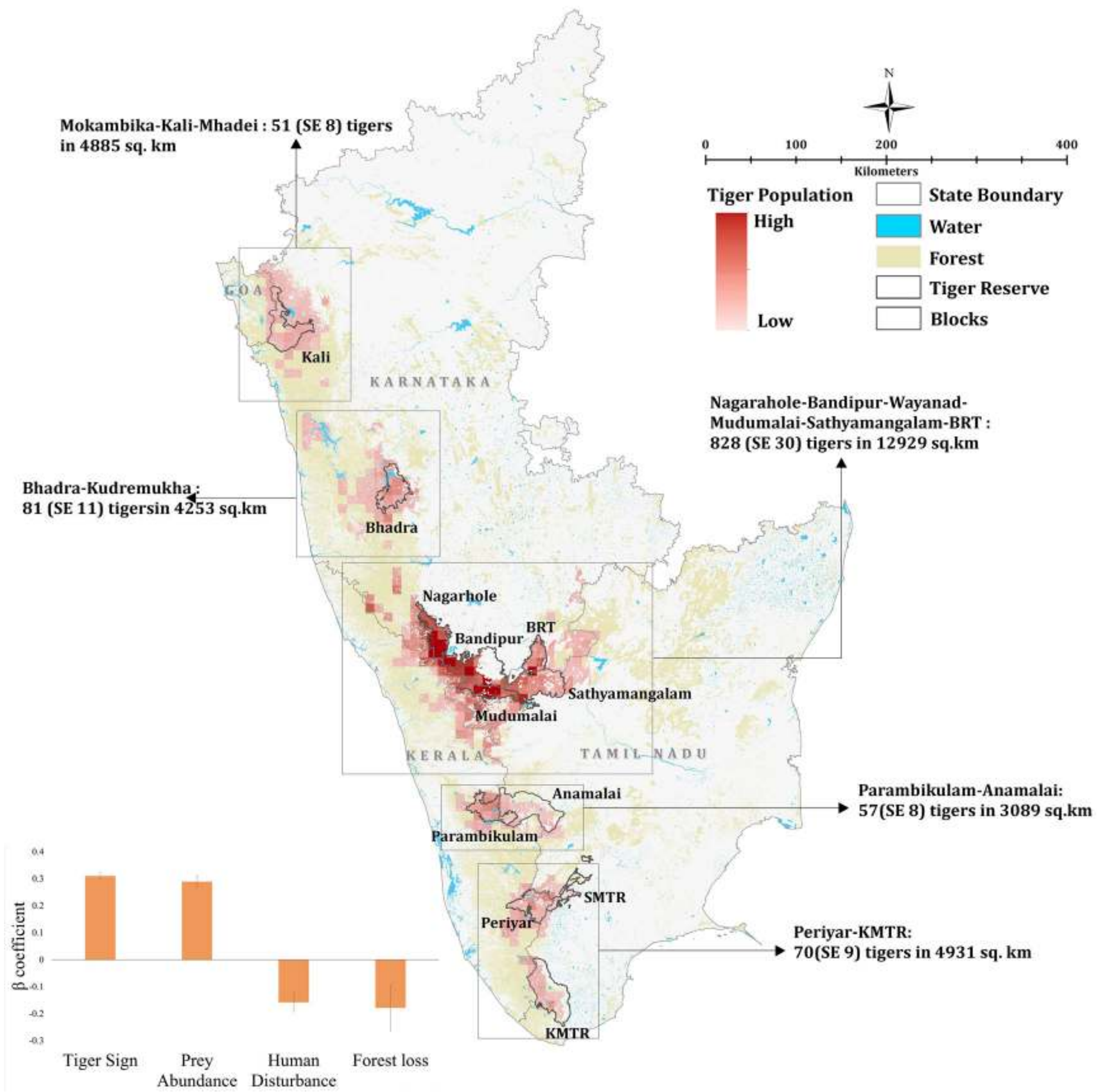
The densely populated Palghat gap acts as a significant barrier to gene flow between the northern and southern Western Ghats, resulting in local structuring among long-ranging mammals. The connectivity between Parambikulum, Eravikulum, and Anamalai is established through a combination of plantations, ridge-top forests, and Shola forests. While the plantations and agricultural fields facilitate wildlife movement at present, there is a possibility of them becoming barriers in the future, especially if they are fenced off.

5) Periyar–Kalakad Mundanthurai complex: The southern Western Ghats population encompasses Periyar Tiger Reserve, Kalakad Mundanthurai Tiger Reserve, and adjacent forested areas. This cluster, characterized by semi-evergreen to evergreen patches, supports a low to low-medium density of tiger populations. According to the recent assessment, the estimated tiger population in this region is 70 (SE 9) tigers (Fig. II.3.2).

Tiger occupancy extends from Periyar Tiger Reserve through the forest divisions of Ranni and Konni into Kalakad Mundanthurai Tiger Reserve, covering a total area of 5000 km^2. Although tiger presence was not recorded in Kanyakumari Wildlife Sanctuary during the 2022 exercise, it has the potential to support a low-density tiger population. While the landscape exhibits good connectivity, the presence of linear infrastructures, such as NH 208, poses significant threats to wildlife movement. To ensure the connectivity between protected areas and wildlife habitats, appropriate wildlife-friendly structures should be implemented to mitigate the impacts of such developmental activities.

Figure II.3.2

Tiger abundance modelled from camera traps-based Spatially Explicit Capture Recapture with covariates of tiger sign, prey, forest loss and human disturbance index (inset graph) within the Western Ghats Landscape for 2022.



State wise tiger population

Goa: A total of five protected areas in the North Goa and South Goa divisions were surveyed, with a population estimate of five tigers in the state. The tiger populations in Goa have consistently remained low since 2014 (5 in 2014, 3 in 2018, Jhala *et al.* 2020). However, recent records of breeding tigress have sparked hope for an improvement in the conservation of tigers. The connectivity between the tiger-bearing forests in Karnataka and Goa, known as the Kali-Mhadei landscape, plays a crucial role in establishing tiger population in Goa.

Karnataka: The Karnataka Forest Department conducted extensive camera trapping and Phase I sampling, ensuring that all potential tiger-bearing areas were covered. Additionally, the department extended the camera trapping to important wildlife habitats in the eastern part of the state, including Kalburgi, Ballari, Davangere, Tumkur, Ramanagara, and others. However, it is necessary to sample these areas more comprehensively with a larger number of camera traps deployed in a systematic manner. The camera trapping, conducted primarily from December 2021 to February 2022, resulted in an estimated tiger population of 563 (SE 35) tigers in the state, slightly higher than the 2018 estimate of 524 (SE 49) tigers (Fig II.3.2) Karnataka shares a significant tiger population with Kerala (Wayanad landscape), Tamil Nadu (Nilgiri landscape), and Goa (Mhadei). Nagarahole and Bandipur Tiger Reserves have the highest number of tigers in the state, followed by BRT Hills, Bhadra, and Kali Tiger Reserves. While the Nagarahole-Bandipur cluster is reaching its saturation point in terms of tiger density, there is potential to increase tiger numbers in the northern part of the state (Kali-Belagavi area) and the Bhadra-Bhadravathi-Kudremukha region. However, the growing populations of tigers and other wildlife, such as elephants and gaurs, in the protected areas have led to increased negative interactions between humans and wildlife, posing a significant management concern.

Kerala: The camera trapping and Phase I sampling efforts covered a significant portion of the tiger-bearing forests in Kerala. The recent camera trapping exercise estimated the tiger population at 213 (SE 16), not different from 2018 estimate of 190 (SE 25) tigers. Kerala shares a substantial tiger population with Karnataka (Nagarahole-Bandipur landscape) and Tamil Nadu (Nilgiri landscape, Anamalai landscape, SMTR landscape). The tiger populations in Kerala also overlap with those in neighboring states. Although Wayanad still holds the largest tiger population in the state, there has been a significant decline in tiger numbers compared to 2018 (2018 – 120 unique tiger, 2022 – 80 unique tiger), which is a concerning trend that needs immediate attention and assessment by the state forest department. On a positive note, the tiger populations in Periyar and Parambikulam have remained stable since 2018.

Tamil Nadu: The Tamil Nadu primarily focused on the Western Ghats region of the state, while the eastern region was not sampled, similar to the 2018 survey. The state forest department conducted systematic camera trapping and Phase I exercises in the tiger-bearing areas; however, there is a need to survey the forests outside the current tiger-bearing regions in the state. The recent camera trapping exercise in 2021-22 estimated the tiger population at 306 (SE 15), which is higher than the 2018 estimate of 264 (SE 38) tigers. The Nilgiri cluster in Tamil Nadu shares tigers with Karnataka and Kerala, and the Anamalai and Srivilliputhur clusters share tigers with Kerala (Parambikulam and Periyar, respectively). Tigers in the state also move across different clusters, such as Sathyamangalam, Nilgiri, and Mudumalai. Mudumalai and Sathyamangalam have the largest tiger populations in the state, and these populations have started spreading to neighboring divisions like Coimbatore, Erode, and Gudalur. However, there is potential for increasing the tiger population in the Srivilliputhur Megamalai Tiger Reserve (SMTR) landscape, while the Kalakkad Mundanthurai Tiger Reserve (KMTR) landscape has maintained a consistent tiger population over the years, similar to the Anamalai Tiger Reserve.

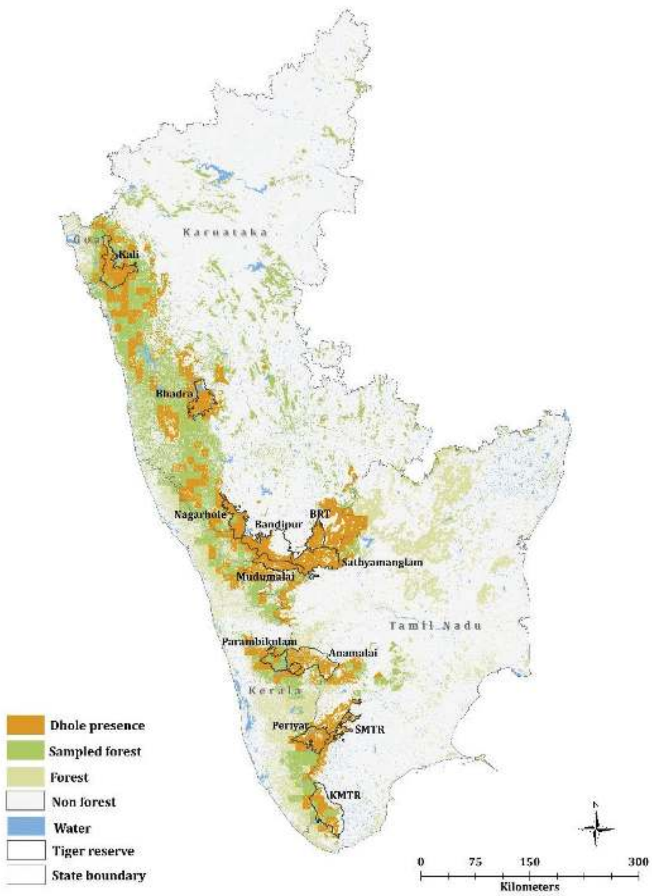
Distribution of carnivores and omnivores in Western Ghats Landscape, 2022

Dhole (Wild Dog) ***(Cuon alpinus)*** *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Endangered]*

Dhole signs were observed in most areas of the landscape, excluding the fragmented forests of central Karnataka. The species occupied an extensive area of 28,500 km^2 (Fig. II.3.3). The only gaps in their distribution were observed between Bhadra and Anshi-Dandeli, Bhadra and Bandipur-Mudumalai-Sathyamangalam forest block, the Palghat gap, and between Anamalai-Parambikulam and Periyar cluster. In 2014, dholes were present in the forested landscapes of northern Tamil Nadu; however, no sampling was conducted in 2022 in that region. The occurrence of dholes outside the protected areas is encouraging and demonstrates the functional connectivity of their populations. As dholes have a tendency to prey on livestock, conflicts with humans often arise. Conservation efforts should focus on raising awareness, providing compensation, and enforcing legal measures to mitigate these conflicts. Additionally, there is an urgent need to understand the dynamics of diseases and their impacts on dhole populations, particularly in relation to human modifications of the landscape, in order to effectively conserve this species.

Figure II.3.3

Dhole distribution in the Western Ghats Landscape, 2021-22.

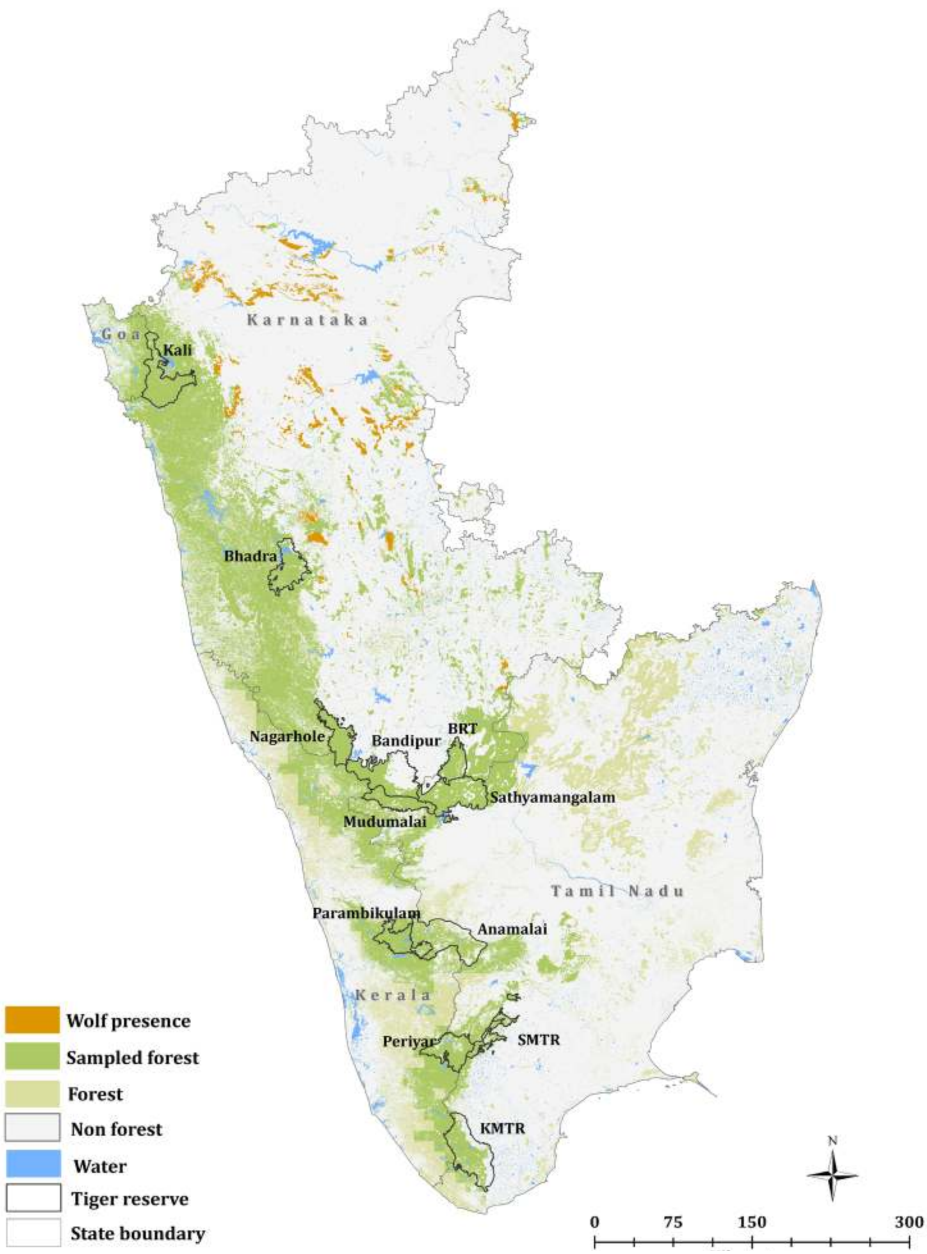


Indian wolf *(Canis lupus pallipes)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Least Concern]*

Wolves are commonly found in agro-pastoral and scrub forests, while they tend to avoid dense forests with thick canopies. Within the sampled forests, wolves occupied an area of 3700 km^2 (Fig. II.3.4). Their distribution was primarily observed in flat scrub forests of Karnataka and drier regions of north-western Tamil Nadu. However, the species faces significant threats in the landscape. The loss of grasslands and scrublands outside the forested areas, which are critical for denning and pup rearing, are threatened due to development activities. Additionally, wolves are often persecuted by local communities due to conflicts with livestock predation. These factors contribute to the high vulnerability of Indian wolves in the landscape.

Figure II.3.4

Indian Indian wolf distribution in the Western Ghats Landscape, 2021-22.

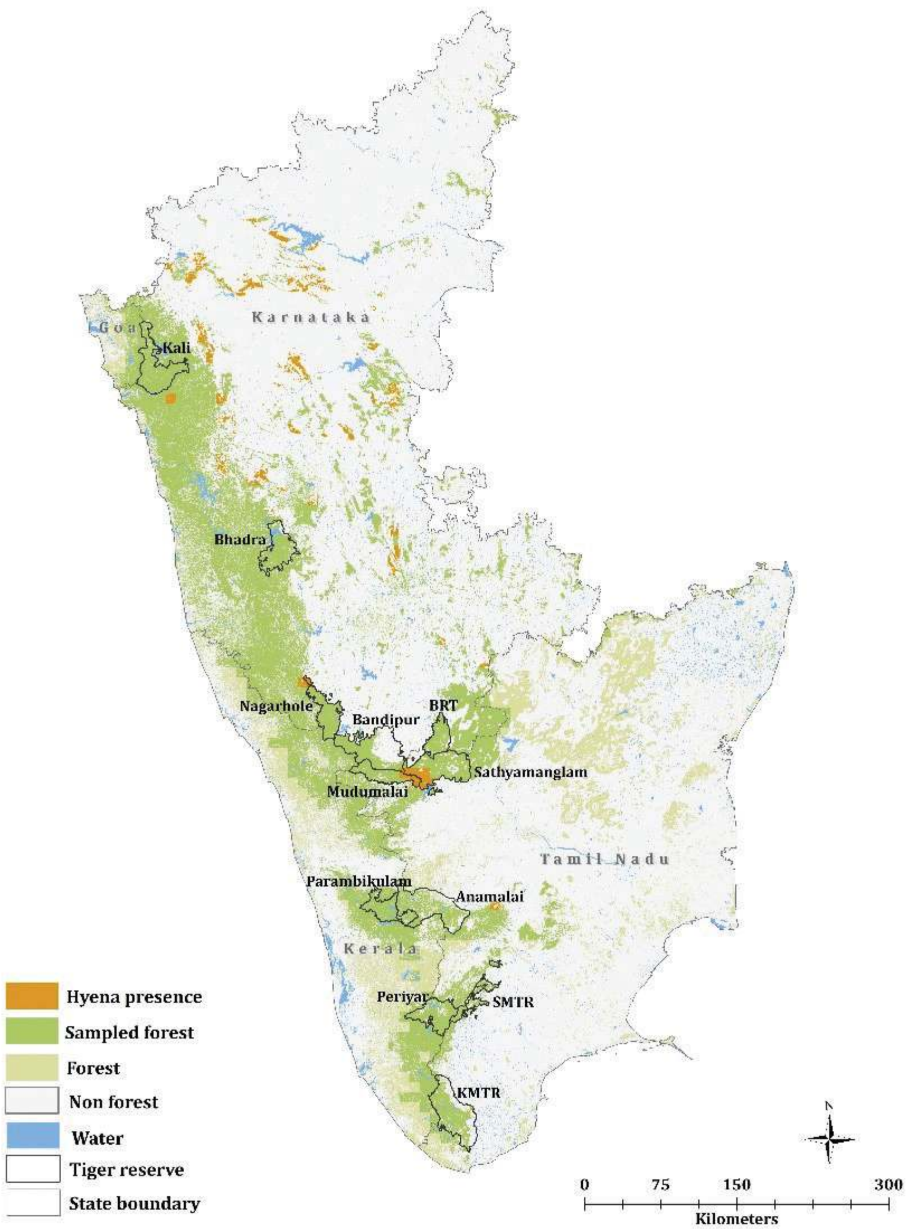


Striped Hyena *(Hyaena hyaena)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Near Threatened]*

Striped hyenas were found in isolated patches of dry forests in Tamil Nadu and Karnataka. Their presence was recorded in an area of approximately 3,100 km^2 within the landscape (Fig. II.3.5). The species mainly occupied areas such as the Haliyal Forest Division, the dry forests of Bandipur-Mudumalai-Sathyamangalam, and the fragmented forests of Central and Northern Karnataka. However, hyenas were not reported south of the Palghat gap, except for isolated relics. It's important to note that the recorded occupancy is a conservative estimate as the exercise did not cover semi-urban or rural areas near human settlements where hyenas are known to frequently occur. Conservation efforts for this species pose challenges as their range extends beyond the network of protected areas. It is crucial to involve local communities in conservation initiatives to ensure the long-term survival of the striped hyena population in the landscape.

Figure II.3.5

Striped hyena distribution in the Western Ghats Landscape, 2021-22.

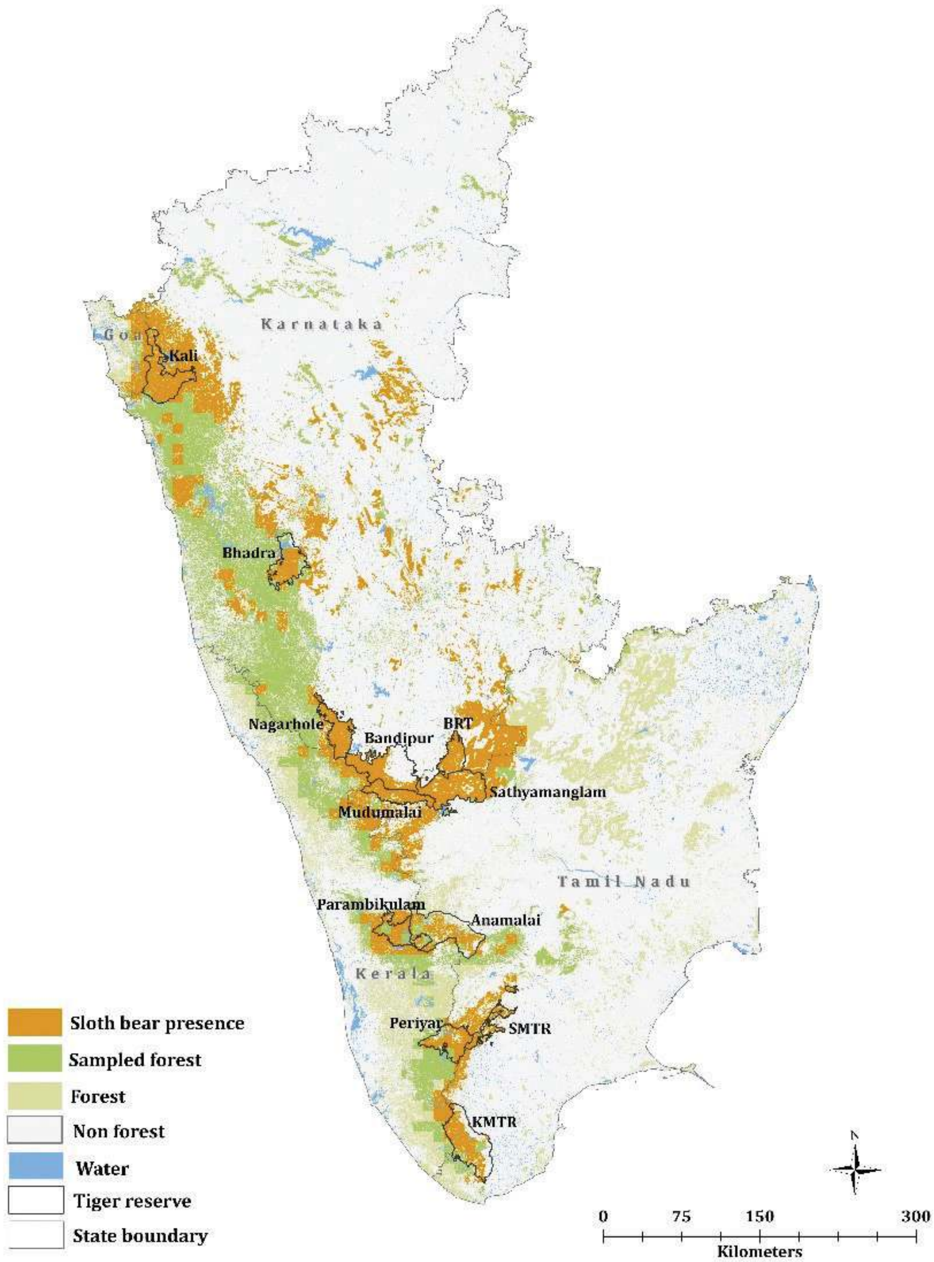


Sloth Bear *(Melursus ursinus)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Vulnerable]*

Sloth bear signs were observed across an area of approximately 32,400 km^2 within the Western Ghats landscape (Fig. II.3.6). The distribution of sloth bears was found in five main population blocks, including Anshi-Dandeli, Bhadra, Nagarhole-Mudumalai-Wayanad-BRT Hills-Cauvery Wildlife Sanctuary, Peechi-Vazhani-Perambikulam-Indira Gandhi WLS, and Periyar-Kalakad Mundanthurai. Additionally, sloth bears were reported in forest patches in Central Karnataka, and they were found in many forested areas in rural Bengaluru. While it is encouraging to observe the presence of bears outside protected areas and in suburban landscapes, it also raises concerns about human-bear conflicts. Efforts are needed to address this issue and minimize conflicts between humans and sloth bears for the safety of both species.

Figure II.3.6

Sloth bear distribution in the Western Ghats Landscape, 2021-22.

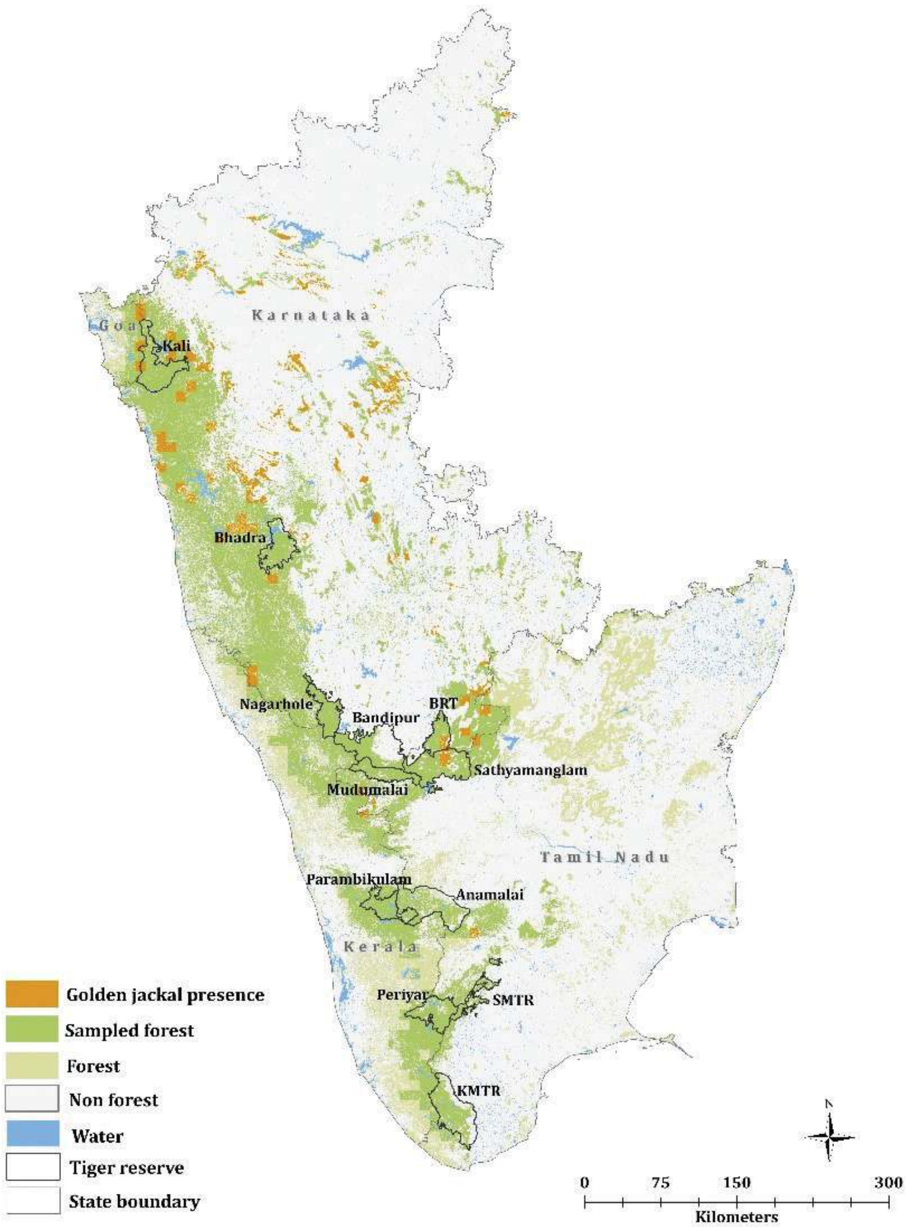


Golden Jackal *(Canis aureus)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Least Concern]*

The golden jackal population in the Western Ghats landscape was found to be sparsely distributed. Occupying an area of approximately 6,000 km^2 (Fig. II.3.7), the recorded presence of jackals is a conservative estimate that only applies to the forested areas surveyed. Jackals are known to occur not only in forests but also in plantations, rural, and semi-urban areas, which were not specifically sampled. Additionally, jackals were observed outside protected areas and in forest patches of coastal Karnataka and drier parts of Karnataka and Tamil Nadu. The Jackal presence below Palghat gap was not recorded except for an isolated record from the Kodaikanal-Theni area. It is worth noting that jackal signs were not found in areas with high tiger density, such as the Nagarhole-Bandipur Tiger Reserves. The declining distribution of the golden jackal highlights the need for immediate attention and conservation efforts.

Figure II.3.7

Golden jackal distribution in the Western Ghats Landscape 2021-22.



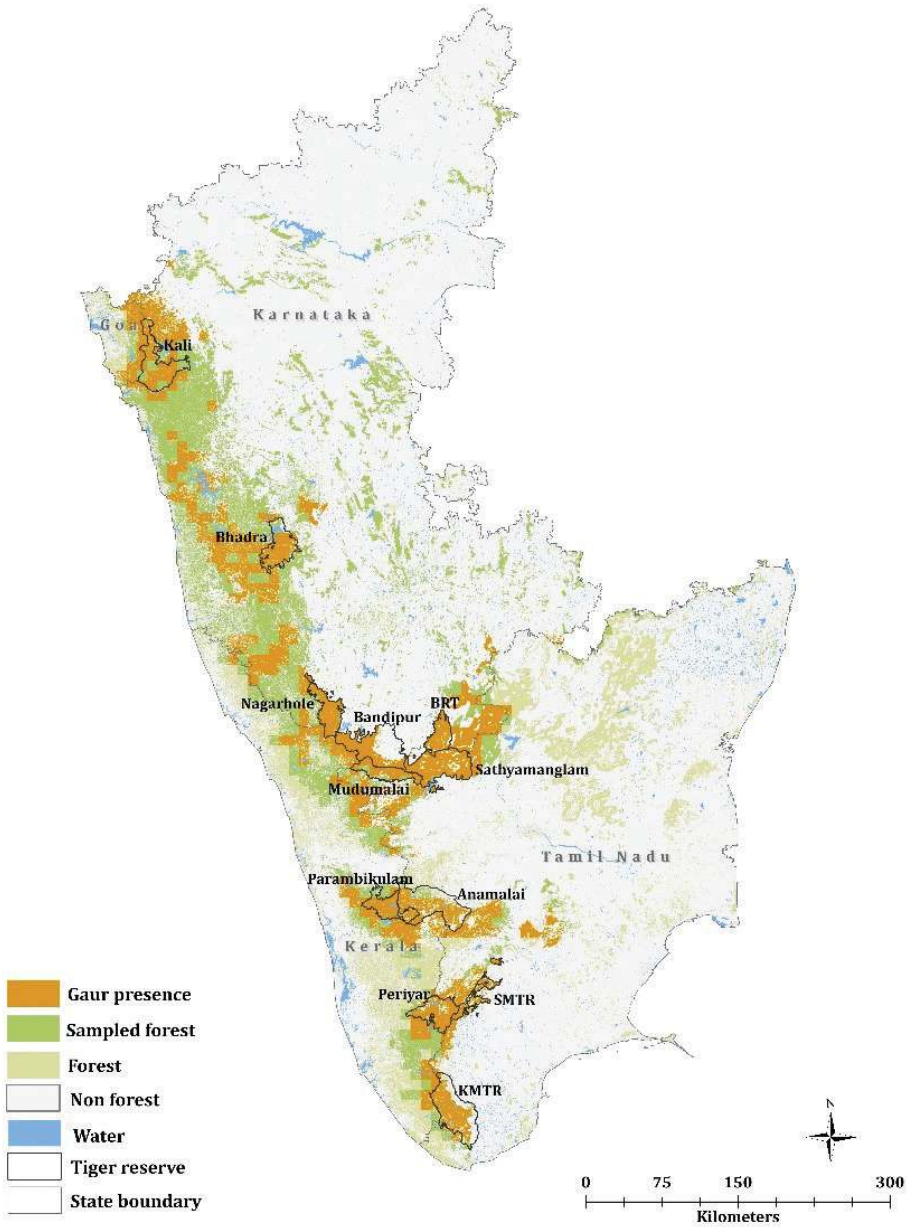
Distribution of Mega-herbivores and Ungulates in Western Ghats Landscape, 2022

Gaur *(Bos gaurus)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Vulnerable]*

The gaur, exhibited one of the widest distribution among herbivores in the Western Ghats Landscape, occupying an area of approximately 30,100 km2 (Fig. II.3.8). There appear to be five major populations: 1) the Kali-Belagavi landscape, 2) the Bhadra-Kudremukha landscape, 3) the Nilgiri cluster, 4) the Anamalai-Parambikulam landscape, and 5) the Periyar-KMTR cluster. Although there is an increase in area occupied by the species, there are concerns regarding habitat connectivity in the landscape due to expanding human population and land uses. Maintaining and enhancing habitat connectivity in these areas is crucial for the conservation of gaur populations.

Figure II.3.8

Indian bison (Gaur) distribution in the Western Ghats Landscape 2021-22.

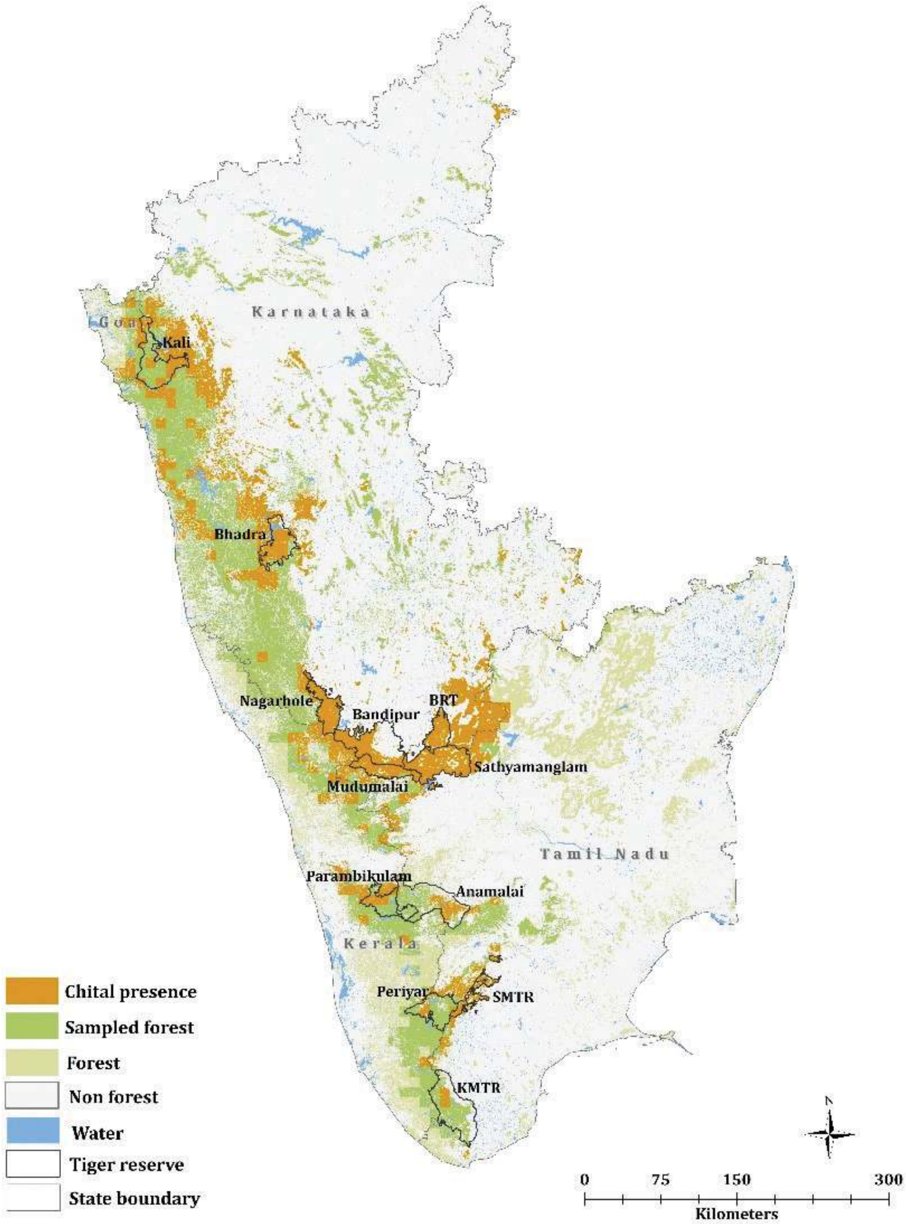


Chital ***(Axis axis)*** *[Wildlife (Protection) Act, Amended, 2022: Schedule II; IUCN Red List: Least Concern]*

The chital occupied approximately 25,000 km2 of forested landscape (Fig. II.3.9). Its distribution within the Western Ghats landscape can be categorized into five distinct populations: the Anshi-Dandeli complex, the Bhadra-Kudremukh complex, the Nagarhole-Cauvery complex, the Anamalai-Cardamom Hill complex, and the Periyar-Kalakad Mundanthurai complex. These populations can be largely found in Protected Areas or their immediate vicinity, highlighting the habitat suitability and poaching that has limited their distribution in the Western Ghats.

Figure II.3.9

Spotted deer (Chital) distribution in the Western Ghats Landscape 2021-22.

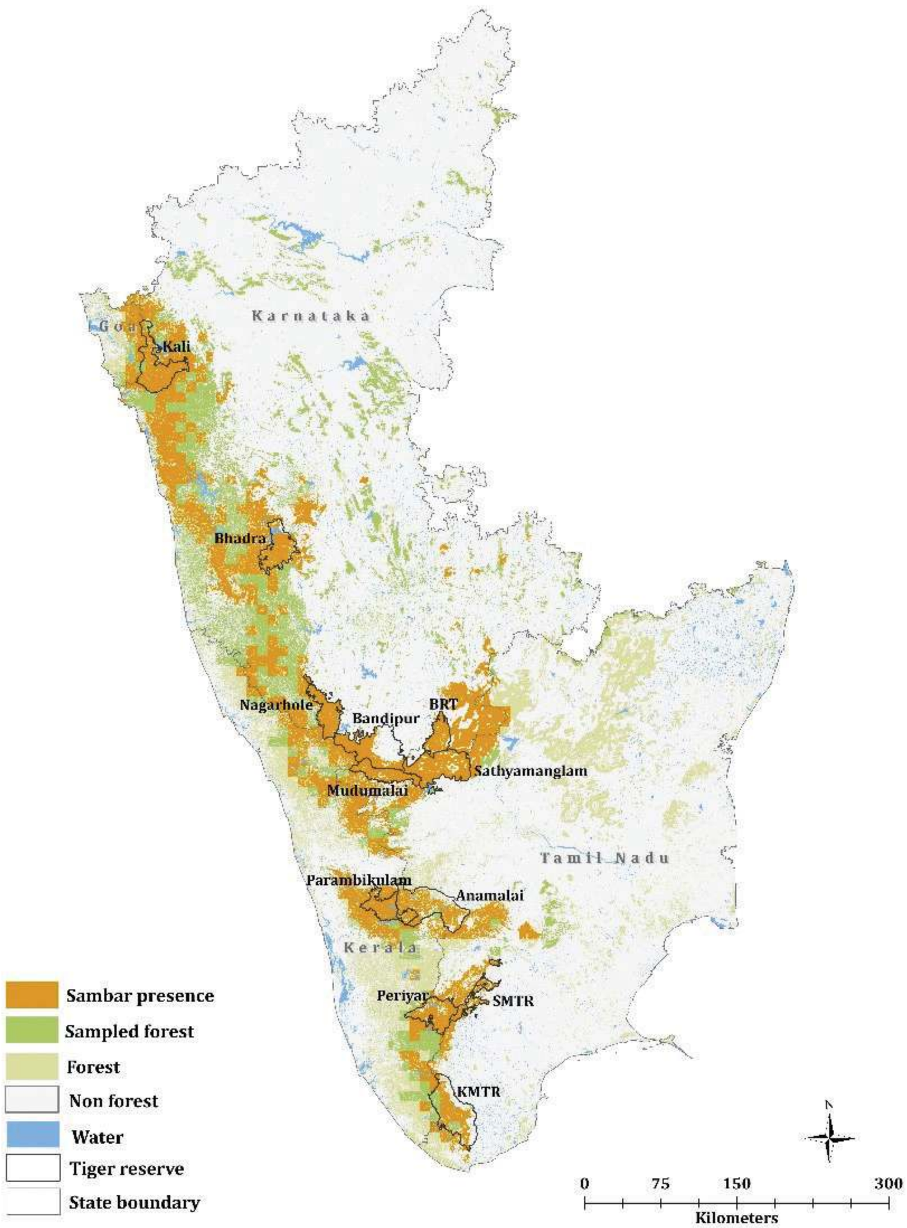


Sambar *(Rusa unicolor)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Vulnerable]*

The sambar, a large deer species, was recorded to occupy approximately 38,100 km2 of forested landscape (Fig. II.3.10), which has declined in comparison to 2018. Its distribution is continuous throughout most of the Western Ghats, with only breaks at the Palghat gap and in the central Western Ghats below Bhadra Tiger Reserve. South of the gap, the distribution is further divided into the Anamalai hills and Cardamom hills, which are connected by the population in Idukki Wildlife Sanctuary, serving as a stepping stone for connectivity in this part of the landscape. The distribution of sambar also extends eastward to the Cauvery Wildlife Sanctuary and into the forested patches of eastern Karnataka. This wide-ranging distribution showcases the adaptability and habitat preference of the sambar across the Western Ghats landscape. Sambar distribution is restricted to Protected Areas and complex terrain.

Figure II.3.10

Sambar distribution in the Western Ghats Landscape, 2021-22.

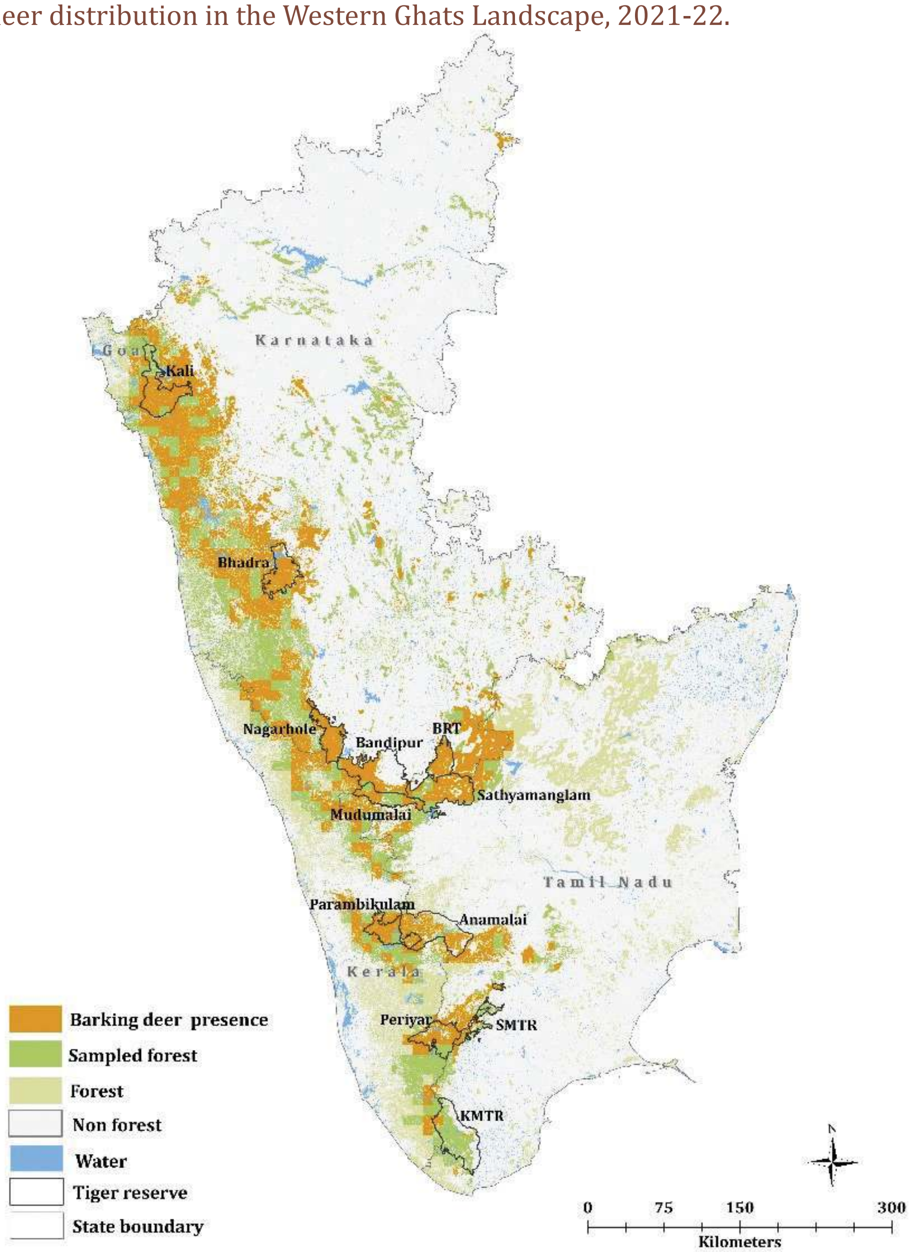


Barking Deer *(Muntiacus vaginalis)* *[Wildlife (Protection) Act, Amended, 2022: Schedule I; IUCN Red List: Least Concern]*

The barking deer, also known as the muntjac, has a continuous distribution across the Western Ghats, occupying approximately 34,200 km^2 of forested landscape (Fig. II.3.11). The Western Ghats population forms different lineages, is paler in color, has smaller antlers (Martins *et al.*, 2017), and is the oldest in India and Sri Lanka. They are found throughout most of the Western Ghats, including in the Northern and Central Karnataka regions, where they occur in scattered forest patches. However, they are not recorded in the semi-evergreen patches located south of the Palaghat gap. This distribution pattern highlights the adaptability of the barking deer to various forested habitats within the Western Ghats landscape.

Figure II.3.11

Barking deer distribution in the Western Ghats Landscape, 2021-22.

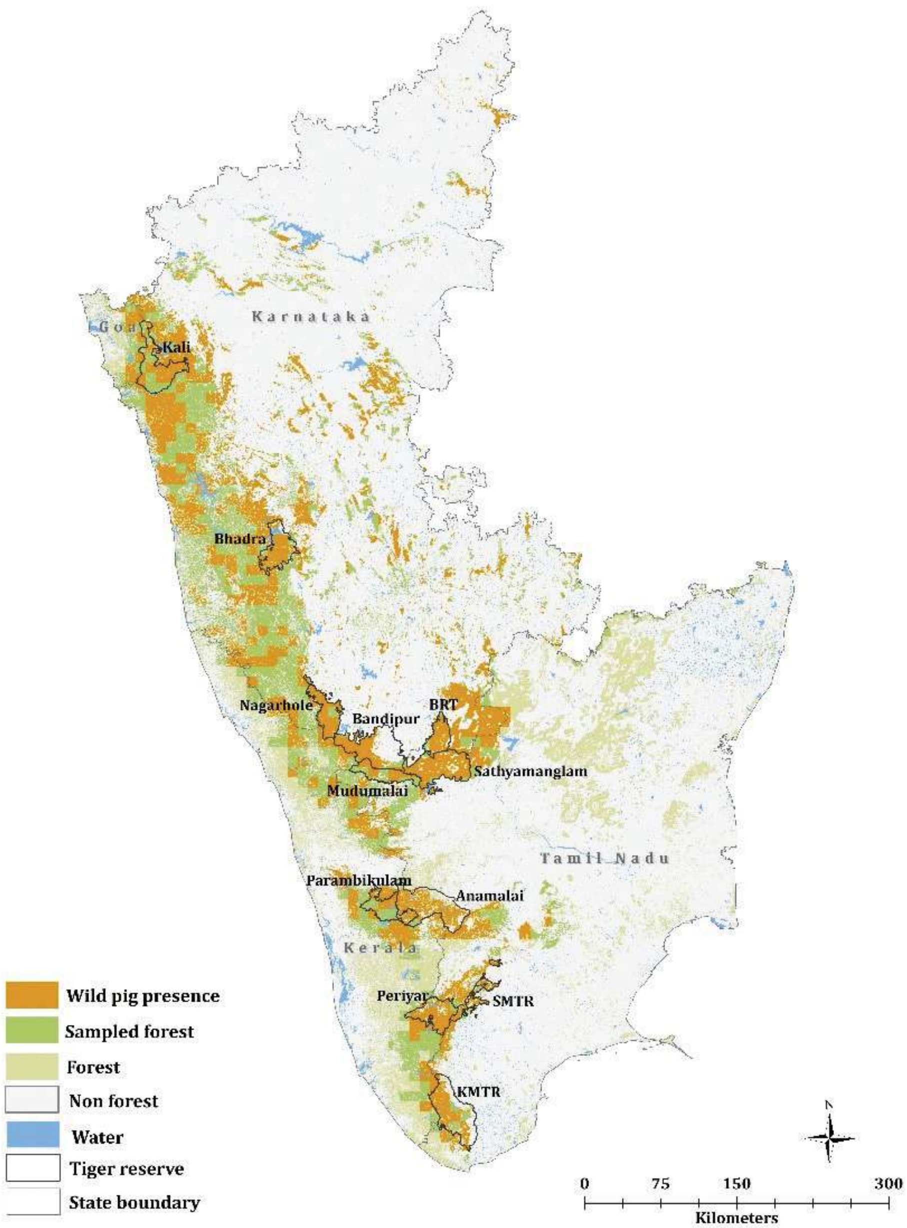


Wild pig ***(Sus scrofa)*** *[Wildlife (Protection) Act, Amended, 2022: Schedule II; IUCN Red List: Least Concern]*

The wild pig exhibits a wide distribution across various forest types in the Western Ghats landscape, occupying approximately 34,900 km2 of forests (Fig. II.3.12). It was found to be present in most of the surveyed forests in the Western Ghats, as well as in the plain areas of central Karnataka and northern Tamil Nadu. However, it should be noted that wild pigs are also commonly found in plantations, rural areas, and semi-urban environments, which were not included in the survey. Therefore, the recorded occupancy represents a conservative estimate applicable only to the forested areas of this landscape. It is important to exercise caution as feral or domestic pigs can sometimes be mistaken for wild pigs. Additionally, the damage caused by wild pigs to crops is a significant concern in this landscape.

Figure II.3.12

Wild pig distribution in the Western Ghats Landscape, 2021-22.



Section II.4

The North East Hills and Brahmaputra Flood Plains Landscape

Deb Ranjan Laha, Shikha Bisht, Ujjwal Kumar, Swati Saini, Monika Saraswat, Vishnupriya Kolipakam, W. Longvah, Rajendra Garawad, Yadvendradev. V. Jhala, and Qamar Qureshi

Section II.4

The North East Hills and Brahmaputra Flood Plains Landscape

North East landscape of India comprises the states of Arunachal Pradesh, Assam, Manipur, Mizoram, Nagaland, Sikkim, Tripura, and hilly districts of northern West Bengal. This landscape can be further classified as North Bengal Dooars, Brahmaputra flood plains, and North East hill region. It is situated alongside international borders with Nepal, Bhutan, People's Republic of China, Myanmar, and Bangladesh, and connected to peninsular India through a narrow strategic stretch, Siliguri Corridor. As the landscape shares 90% of its boundary with neighboring countries, it is one of the most important geo-strategic locations of the country. This landscape also is home to more than 200 ethnic and indigenous communities. Other than the cultural plurality, North East and Brahmaputra flood plains landscape is diverse with natural resources.

Historically, this landscape has experienced extensive land-use changes, which in turn caused severe loss of natural habitat available. Recognizing the potential of growing tea plants in the favorable climatic and edaphic conditions, and the potential for enormous revenue generation, large forested tracts were cleared. In the present scenario, India is the largest producer of tea and produces around one-third of tea of the world (Tea Board, 2004). Also, game hunting of species like tiger, elephant, wild buffalo, and one-horned rhinoceros by British officials and local affluent led to the near extirpation of these species from much of their historical distribution in the landscape (Jhala *et al.* 2020). Direct exploitation of wildlife in terms of game hunting also resulted in historical low abundance of wildlife species in this landscape.

Although predominantly mountainous, the landscape is spread between a mosaic of various geographical features including snow-capped mountains, plateaus, foothills, and vast alluvial flood plains. Three major rivers, Brahmaputra, Barak and Teesta and their tributaries crisscross the landscape. Wide topographical variation of the landscape also governs edaphic and climatic variation. These factors influence the unique faunal assemblage and high degree of endemism in terms of biodiversity in this landscape. Birdlife International (Sattersfield *et al.* 1998) identifies this landscape as an "Endemic Bird Area (EBA)".

Located at the juncture of three biogeographic realms, Indian, Indo-Malayan, and Indo-Chinese

(Mani 1974), the landscape represents diverse habitats associated with wide altitudinal and climatic variation. This landscape has the richest floral diversity in the country among other landscapes (Shukla 2012). Due to the climatic contrast, this landscape has tropical, temperate, and alpine vegetation. Most of the tropical forests are located in the Assamese valley, foothills of the Himalayas, parts of Naga Hills and Manipur Hills. The deciduous forests are dominated by *Shorea robusta* in areas with less than 2000 millimeters of rainfall. The temperate vegetation is found at elevations from 1300 to 2500 meters in Shillong plateau, Naga Hills, Lushai Hills, Mikir Hills, and parts of Arunachal Pradesh. Beyond elevations of 4500 meters, alpine vegetation predominates with several species of rhododendron and meadows.

The fauna of the region is extremely diverse with 13 species of primates; four large cats, viz., tiger, leopard, snow leopard, clouded leopard, along with three species of ursidae, the Asiatic black bear, sloth bear, and the Malayan sun bear, along with two canid species, the jackal and the wild dog. Recently, Sela macaque, a new mammalian species was described in Arunachal Pradesh and named after Sela pass (Ghosh *et al.* 2022), was discovered. The region has the highest diversity of small carnivores, which includes five species of small cats and several species of viverrids and mustelids. In addition, assemblage of four mega herbivorous viz. Asiatic elephant, gaur, one horned rhinoceros and wild buffalo are also found this landscape.

Tiger population extents and abundance across the North-East Hills and Brahmaputra Flood Plains Landscape:

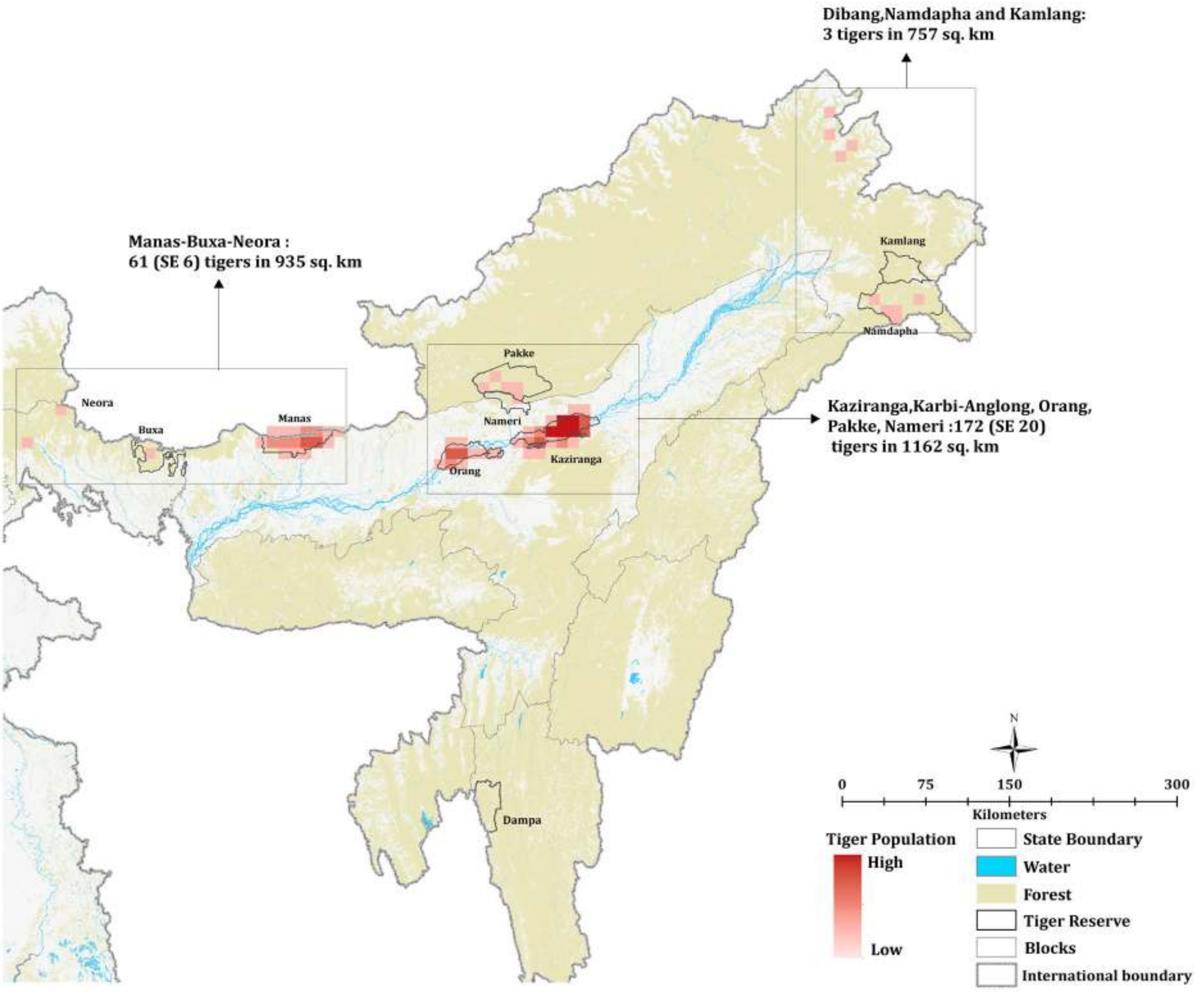
A total of 15 sites were sampled using the camera trap-based mark-recapture method, and tigers were photo-captured from 11 sites across the landscape. The landscape has an estimated population of about 236 (SE 35) tigers (Fig. II.4.1). However, due to inadequate sample sizes, density estimates were obtained only for three sites, namely Kaziranga, Manas and Orang tiger reserves in Assam. The population of tigers in the Brahmaputra flood plains is almost stable as compared with the previous cycle, with Kaziranga having the largest population in this entire landscape. The spread of phase I sampling has drastically reduced in the state of Assam, with many divisions where tigers were reported earlier not being sampled in this cycle. However, phase I sampling effort has increased in Bengal Dooars as compared to previous cycles. Due to phase I sampling being restricted to a few Protected Areas, tiger density could not be extrapolated in this landscape and is limited to these reserves. Phase I sampling was done by the polygon search method in the north-east hill regions.

A few forested areas of Nagaland were also sampled during the exercise by the forest department. However, no tiger signs were obtained from Nagaland. Tigers were photo-captured for the first time in Buxa Tiger Reserve, Neora Valley National Park, and Mahananda Wildlife Sanctuary in West Bengal. Also, after quite a few years, a tiger was photo-captured in the Namdapha Tiger Reserve of Arunachal Pradesh.

1) Kaziranga- Orang- Pakke- Nameri block: This block is the largest population block in this landscape and has an estimate of 172 (SE 20) tigers. Kaziranga has the highest tiger population in this landscape, followed by Orang. Karbi-Anglong Forest Division in the south of Kaziranga acts as an ecological extension of the reserve. However, both divisions differ in terms of protection, and NH 715 (earlier NH 37) and numerous built-up areas bordering road act as a physical barrier to the free movement of wildlife species in this block. Though individual tiger numbers increased in Pakke Tiger Reserve from the previous cycle, density estimate could not be done for the Pakke-Nameri block due to very small sample size. Two individual tigers were common between Pakke Nameri Tiger Reserves. Pakke and Nameri could potentially harbor more tigers with some adaptive management measures such as habitat restoration, augmentation of prey, and improved law enforcement monitoring. The tiger population of Pakke and Nameri could further move towards Tale, Kane, D'Ering Memorial, and Mehao Wildlife Sanctuaries through the network of several Reserve Forests situated alongside the borders of Arunachal Pradesh and Assam. Kaziranga acts as source population of tigers in this landscape and islands of the river Brahmaputra act as biological corridors and natural extensions to the population to maintain gene flow between tiger population in this landscape. However, these river islands are also favourable for agriculture and pastures for livestock, and are heavily encroached by human settlements. Connectivity to the Nameri-Pakke population through Biswanath should be restored by protecting those river islands. Karbi Anglong forest areas act as refuge for tigers and other wildlife species during the floods. However, the movement of wildlife species are heavily impacted by NH 715 (earlier known as NH 37) and appropriate mitigation measure need to be implemented to increase habitat connectivity

Figure II.4.1

Spatially explicit tiger density modelled from camera trap based capture-mark-recapture in North East Hills and Brahmaputra Flood Plains,2022



(Habib *et al.* 2020). Also, numerous built-up areas in the southern part of Kaziranga, tea estates, and mining and stone quarrying activity in Karbi Anglong areas act as major barriers for further movement of animals in the landscape. Floods are responsible for a major death toll, and it's crucial to have policies in place to provide enough safe passages for animals to move across to higher regions in Karbi-Anglong. Appropriate compensation should be provided to people to assist in providing safe movement corridors. Unlike earlier cycles, no surveys to record the presence of wildlife have been done in Karbi Anglong in this cycle.

Situated on the north eastern bank of the Brahmaputra River, Dibru-Saikhowa National Park has the potential to serve as a refuge for tigers in the future. Active management strategies such as reducing anthropogenic pressure, restoring habitats, and augmenting prey populations should be implemented to establish a sustainable tiger population in the park.

2) Manas- Buxa- Neora- Mahananda block: This block had an estimated tiger population of 61 (SE 6) tigers, showing a steady increase since the previous cycle. This population block is

connected to the tiger population of Bhutan through across the shared border. In Bhutan, the estimated tiger population was 91, with 60 adult females captured, and density estimates of 2-3 tigers per 100 km^2 in the adjacent Royal Manas National Park (Tempa *et al.* 2019).
If the corridor maintains connectivity and protection, the tiger population in Manas can expand towards the west, reaching the Buxa Tiger Reserve via. Raimona National Park and Ripu-Chirang Elephant Reserve. It can also extend towards the east, encompassing Bornadi Wildlife Sanctuary and eventually reaching Sonai Rupai Wildlife Sanctuary. Additionally, the population can spread to Territorial Divisions in the south. The western extension forms a sub-block known as the Buxa-Jaldapara-Neora-Mahananda block, which connects to the larger Manas block through forest patches or Biological Corridors in Bhutan (Tempa *et al.* 2019).

In the 2018 cycle (Jhala *et al.* 2020), no tigers were photo-captured in the Buxa-Jaldapara-Neora-Mahananda block. However, tiger presence was confirmed in 2014 in Buxa Tiger Reserve through scat DNA analysis. Two male tigers were photo-captured in this block. The tiger captured in Mahananda Wildlife Sanctuary and Buxa Tiger Reserve was determined to be the same individual, suggesting connectivity between these forests through tea plantations and fragmented forest areas. Another individual tiger was photo-captured in Neora Valley National Park within the Gorumara Wildlife Division. Both Mahananda Wildlife Sanctuary and Neora Valley National Park are part of the greater Khangchendzongha landscape. In 2019, a tiger was also photo-captured in Pangolakha Wildlife Sanctuary in east Sikkim, which is adjacent to Neora Valley National Park, as reported by the media.

3) Dibang- Kamlang- Namdapha block: Three tigers were photo-captured in this block. No tiger was photo-captured in Kamlang Tiger Reserve during the cycle, and no tiger-positive scat was obtained from the tiger reserve. Earlier tiger density obtained through camera-trapped tiger images and scat DNA locations was extrapolated to suitable habitats to get a potential tiger population in this block. As the spread of both Phase I and III is very sparse in this landscape only the minimum number of tigers is reported, which could be an underestimation of the tiger population in this block. Though the abundance of tigers is low in this block, it holds significant importance in terms of historical evolutionary aspects and the unique genetic signature of the tiger population (Kolipakam *et al.* 2019) compared to the Southeast Asian tiger population (Jhala *et al.* 2011).

Tiger reserves and protected areas in Arunachal Pradesh are connected through large forested tracts and a number of reserve forests situated along the interstate border between Arunachal Pradesh and Assam. This landscape is further connected to Intanki National Park in Nagaland and Dampa Tiger Reserves in Mizoram through some weak linkages of degraded forest (Jhala *et al.* 2020). Several indigenous forest communities dependent on bush meat and forest resources for subsistence inhabit this landscape; hence, the prey base is almost depleted in many of the forests (Jhala *et al.* 2021a). In addition, due to its strategic location, several highways are planned in Arunachal Pradesh to provide faster access to international border areas. Arunachal Pradesh gets three national highways: the Frontier Highway, the Trans-Arunachal Highway, and the East-West Industrial Corridor Highway, and six vertical and diagonal interstate highways of about 2178 km will be built (The Quint, PIB). Development activities in this landscape should be executed with appropriate mitigation measures to retain gene flow through habitat connectivity and safeguard this fragile ecosystem. Fragmentation of habitat by this rapid infrastructure development will eventually destroy the weak linkages between the tiger habitats and might lead to the local extinction of tigers in this landscape. The tiger population of the North East Hills has been prioritized for conservation (Kolipakam *et al.* 2019); however, the abundance of tiger and prey is substantially low in tiger habitats in this landscape (Jhala *et al.* 2020). Active management initiatives such as participatory community conservation, improved protection, and habitat restoration should be carried out in this landscape to restore prey and thereafter the tiger population.

Substantial poaching for the illegal trade of tiger body parts and ungulates constantly threatens the tiger population in this landscape. Since the landscape shares porous international borders in many parts with neighboring Southeast Asian countries, it is comparatively easy for poachers to operate in this landscape. In the recent past, the skin and body parts of two tigers were seized from Dibang Valley in Arunachal Pradesh and Itakhola on the Assam-Arunachal Pradesh border (NE Now, NTCA). Direct exploitation of tigers from this already low abundant population, coupled with habitat fragmentation and biotic pressure, could eventually deplete the tiger population in this landscape. Other than rapid development causing habitat fragmentation and the poaching of wild tigers and prey, the invasion of weeds in the natural habitat is a severe threat to this landscape. Although lesser areas are recorded to be invaded by *Lantana camara* in this landscape (Mungi *et al.* 2020), grasslands of terai dooars and flood plains are heavily threatened by invasive alien species like *Mikania micrantha and Chromolaena odorata* (Nath *et al.* 2019).

State-wise tiger population:

Arunachal Pradesh: Three tiger reserves, namely Pakke, Kamlang, Namdapha Tiger Reserve, and Dibang Wildlife Sanctuary, were sampled in the state. No tiger was recorded from Kamlang Tiger Reserve, either from camera trap images or through scat DNA. Due to the small sample size, tiger density estimates could not be obtained for Arunachal Pradesh. A total of nine tigers were photo-captured in the state of Arunachal Pradesh. However, this could be an underestimation of tigers in the state.

Assam: Camera trapping was done in all the four tiger reserves and Nagaon Wildlife Division of Assam, and the tiger population was estimated at 227 (SE 24) for the state. The tiger population of Assam has increased from 190 (SE 25) in 2018 (Jhala *et al.* 2020). After prolonged periods of armed conflicts that hampered conservation efforts, the tiger population of Manas steadily increased with better management. However, the Kaziranga-Orang tiger population is almost stable as compared with earlier cycles. Safeguarding river island corridors from encroachment and increasing protection in Nagaon Wildlife Division will help to maintain the genetic flow of tigers in this block. Also, a thorough Phase I sampling across the forested patches of the state to record tiger, co-predators, and other important wildlife presences is very much needed. Protected areas like Dibru-Saikhowa National Park and protected areas of Karbi Anglong hold potential to harbor tigers, and notifying those areas as part of Tiger Reserve would secure habitat connectivity in the same way as the landscape. However, before implementing such management initiatives, proper scientific study of the status of prey and habitat, capacity building of frontline staff, and sensitization of local communities are solicited.

Mizoram: Dampa was the only tiger reserve or protected area that was sampled in the state of

Mizoram. No tiger was photo-captured during the sampling cycles of 2018 and 2022. However, as per media reports, a tiger was photo-captured in 2021 in Dampa Tiger Reserve during an opportunistic monitoring exercise (Times Now). Although tiger abundance in Dampa continues to be low, this tiger reserve serves as an important forest block due to its proximity and connectivity to Myanmar and the Chittagong hill tracts of Bangladesh and its excellent faunal assemblage. Dampa Tiger Reserve reportedly has the highest density of clouded leopards (*Neofelis nebulosa*) in the country (Singh *et al.* 2017).

Nagaland: Camera trapping was not done in the state in this cycle, and tiger presence was also not confirmed through scat DNA or reported.

West Bengal (North Bengal Dooars): This landscape has undergone severe land-use pattern changes. Five protected areas were sampled in this landscape, and tiger presence was confirmed through photo captures from three protected areas, namely Buxa Tiger Reserve, Neora Valley National Park, and Mahananda Wildlife Sanctuary. Only two individual tigers were photo-captured during the sampling, as Buxa and Mahananda share a common individual tiger. Although a number of protected areas are present in this block, it experiences severe anthropogenic pressure in terms of exploitation of forest resources, a mosaic of human habitation and agricultural lands, tea plantations, and an extensive rail and road network. As relocation of tigers in Buxa Tiger Reserve is in the process, active management interventions such as incentivized voluntary relocation of human settlements from the core of the tiger reserve, restricting tourism activities as per guidelines of the NTCA, weed and invasive plant management, habitat restoration, and prey augmentation need to be done prior to that.

The Dooars and hilly districts of West Bengal have a network of protected areas, and a few of them are part of the Greater Khangchendzonga landscape as well. Chhaparamari Wildlife Sanctuary, Gorumara and Jaldapara National Parks, and Buxa Tiger Reserve are closely situated and connected through contiguous but patchy forest areas. As several glacier-fed and rain-fed rivers drain the north Bengal Dooars, the floodplain is extremely productive and favorable for agriculture and tea plantations, and therefore densely populated. In addition, due to its strategic geo-political location and being the only entry point to the eastern part of the country and neighboring countries, this area encounters heavy traffic load and development activities, which, in terms of fragmenting those natural habitats into islands, result in frequent negative human-wildlife interactions and restrictions in the movement of megafauna.

Distribution of carnivores and omnivores in North East Hills and Brahmaputra Flood Plains landscape, 2022

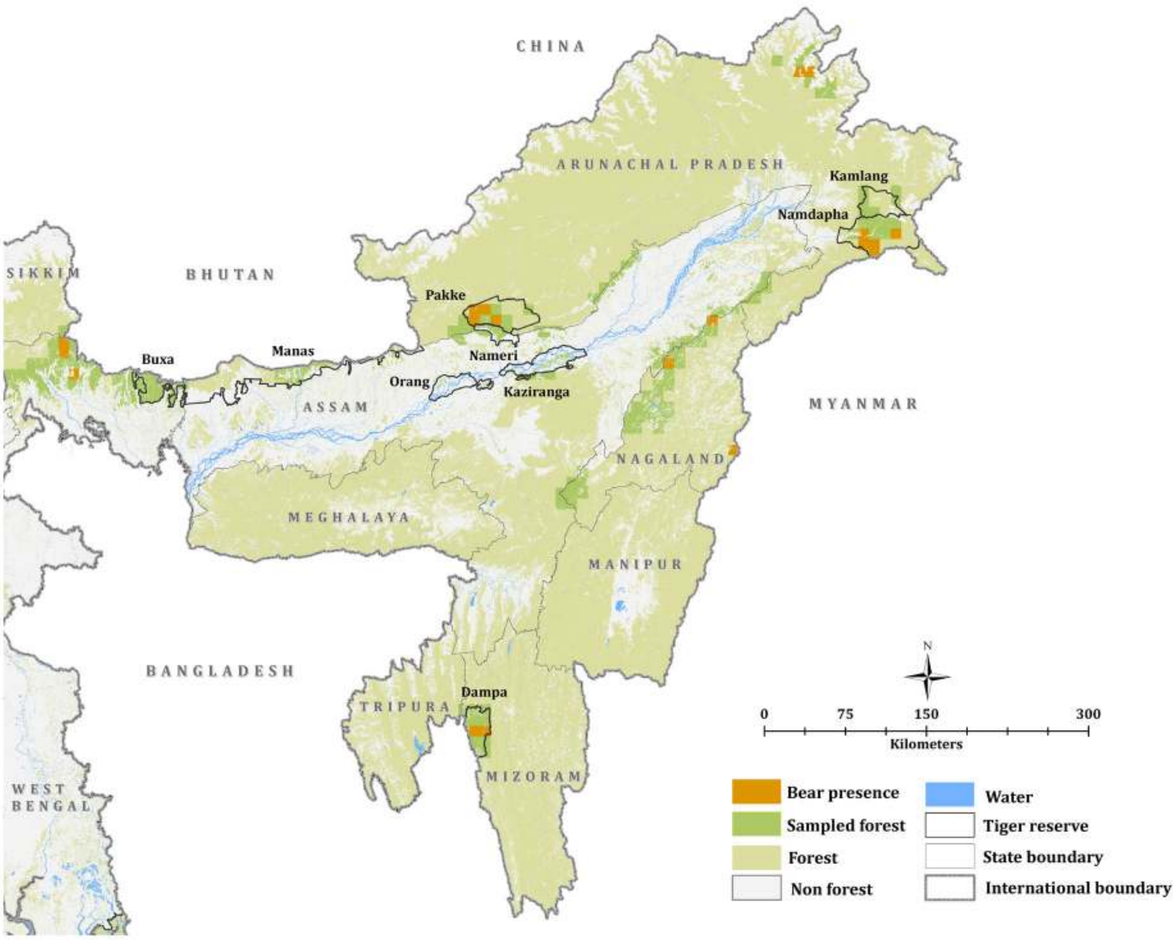
Spatial occupancy of carnivores and ungulates in North East Hills and Brahmaputra Flood Plains landscape is derived from Phase I sampling, and limited to sampled forest only.

Bear: (*Melursus ursinus, Ursus thibetanus, Helarctos malayanus*) *(Wildlife Protection Act, Amended, 2022: Schedule I, IUCN: Vulnerable)*

Due to their uncertain identities, signs of Asiatic black bear, sloth bear and sun bear were co-founded to record bear occupancy in this landscape. Bear presence was recorded in Neora Valley National Park of West Bengal, Pakke, Kamlang, and Namdapha Tiger Reserves, and Dibang Wildlife Sanctuary of Arunachal Pradesh. Dampa Tiger Reserve of Mizoram and Dimapur, Kiphire, Mokokchung, and Wokha districts of Nagaland also recorded bear presence. Even though bear presence was not recorded in Phase I, the species is known to be present in Manas and Kaziranga Tiger Reserves. Occupancy of bear was recorded from approximately an area of 2006 km^2 in this landscape (Fig. II.4.2).

Figure II.4.2

Bear distribution in North East Hills and Brahmaputra Flood Plains landscape, 2022



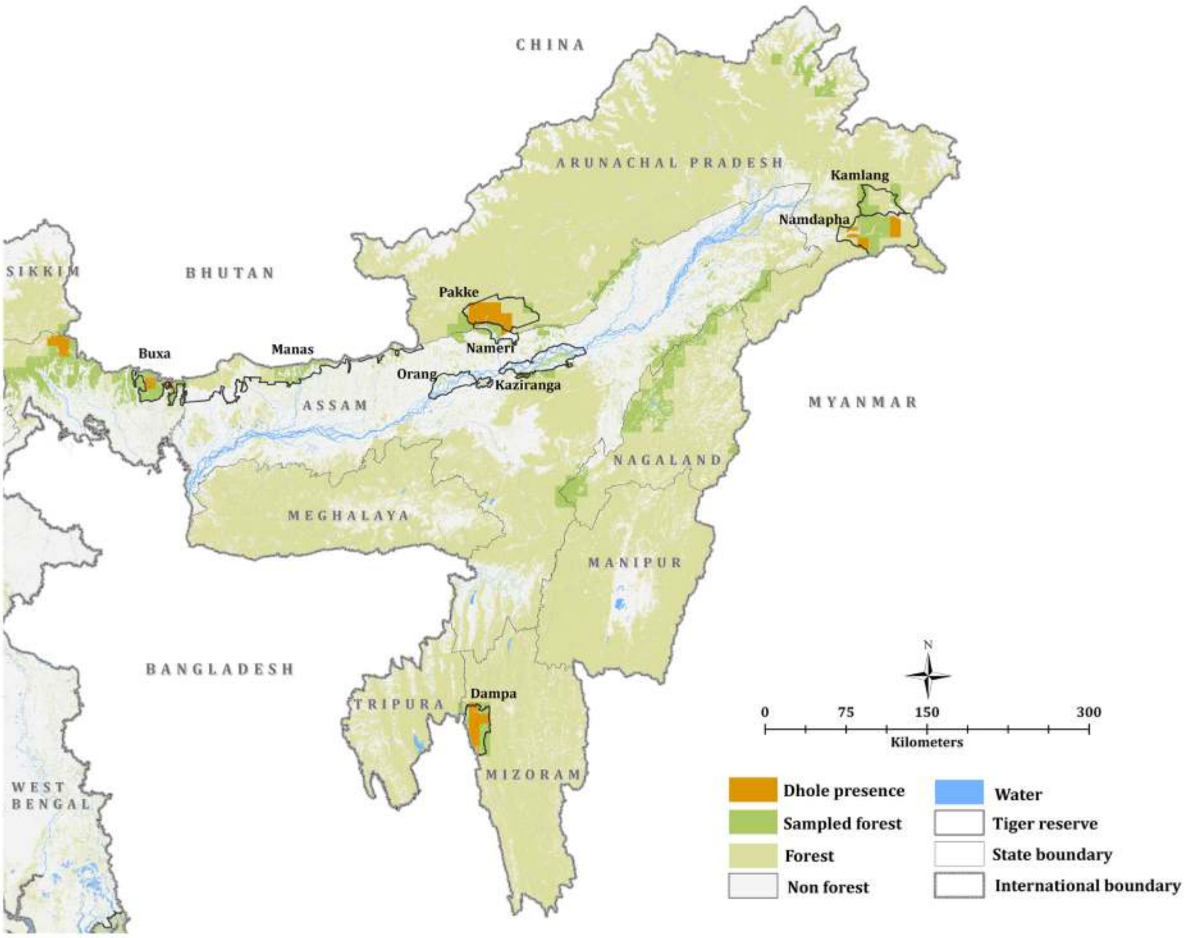
Section II.4

Dhole (Wild Dog) (*Cuon alpinus*) *(Wildlife Protection Act, Amended, 2022: : Schedule I, IUCN: Endangered)*

Dhole presence was obtained from Neora Valley National Park and Buxa Tiger Reserve in West Bengal, Pakke and Namdapha Tiger Reserves in Arunachal Pradesh, and Dampa Tiger Reserve in Mizoram. Dhole is known to be present in the Eastern Himalayas and foothills of this landscape. Occupancy of dhole was recorded from approximately an area of 2186 km^2 (Fig. II.4.3).

Figure II.4.3

Dhole distribution in North East Hills and Brahmaputra Flood Plains landscape, 2022

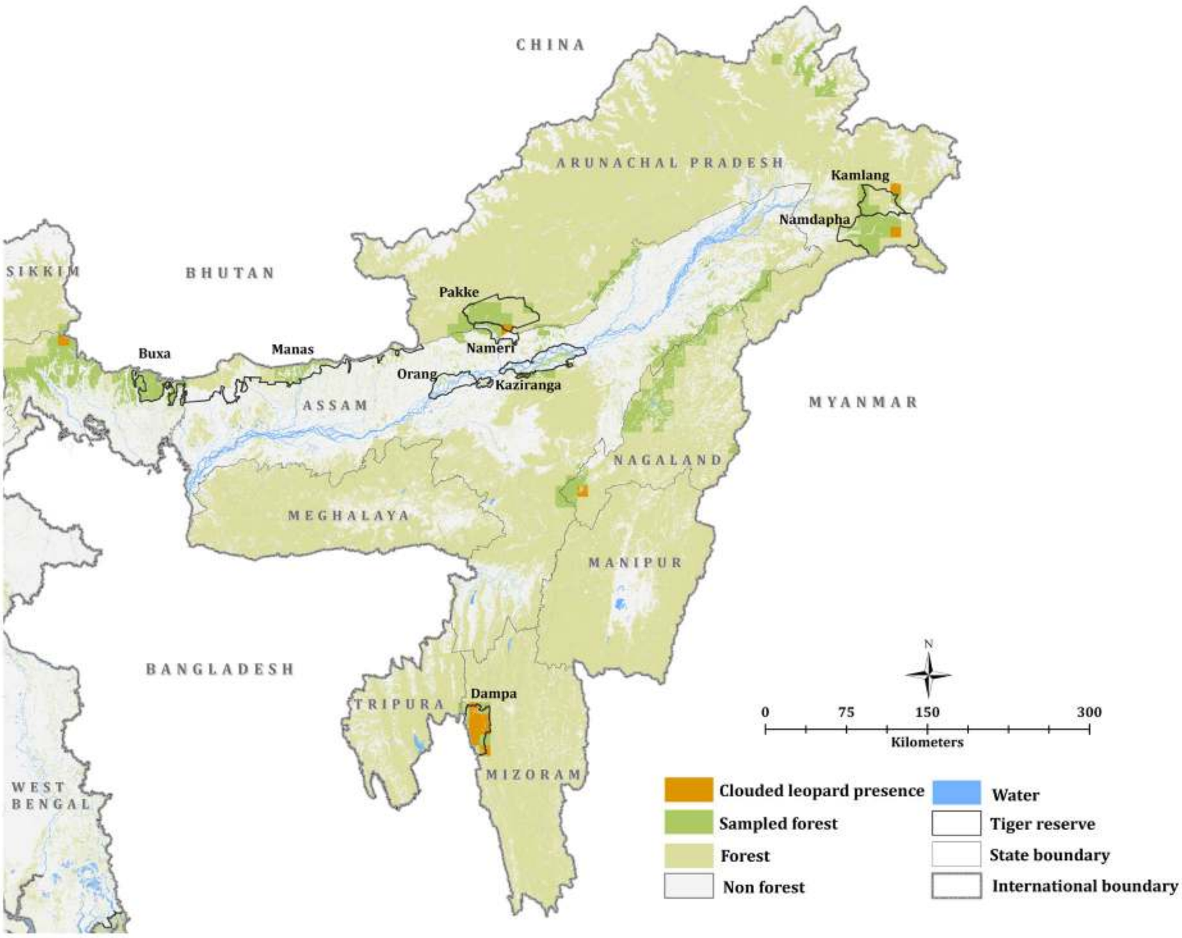


Clouded leopard: (*Neofelis nebulosa*) *(Wildlife Protection Act, Amended, 2022: Schedule I, IUCN: Vulnerable)*

Except in Dampa Tiger Reserve in Mizoram, clouded leopard presence is very patchy in this landscape. Other than Dampa, clouded leopard presence was recorded in Neora Valley National Park of West Bengal, Pakke, Kamlang, and Namdapha tiger reserves of Arunachal Pradesh, and Dimapur districts of Nagaland. Occupancy of clouded leopard was recorded from approximately an area of 1098 km^2 in this landscape (Fig. II.4.4).

Figure II.4.4

Clouded leopard distribution in North East Hills and Brahmaputra Flood Plains landscape, 2022



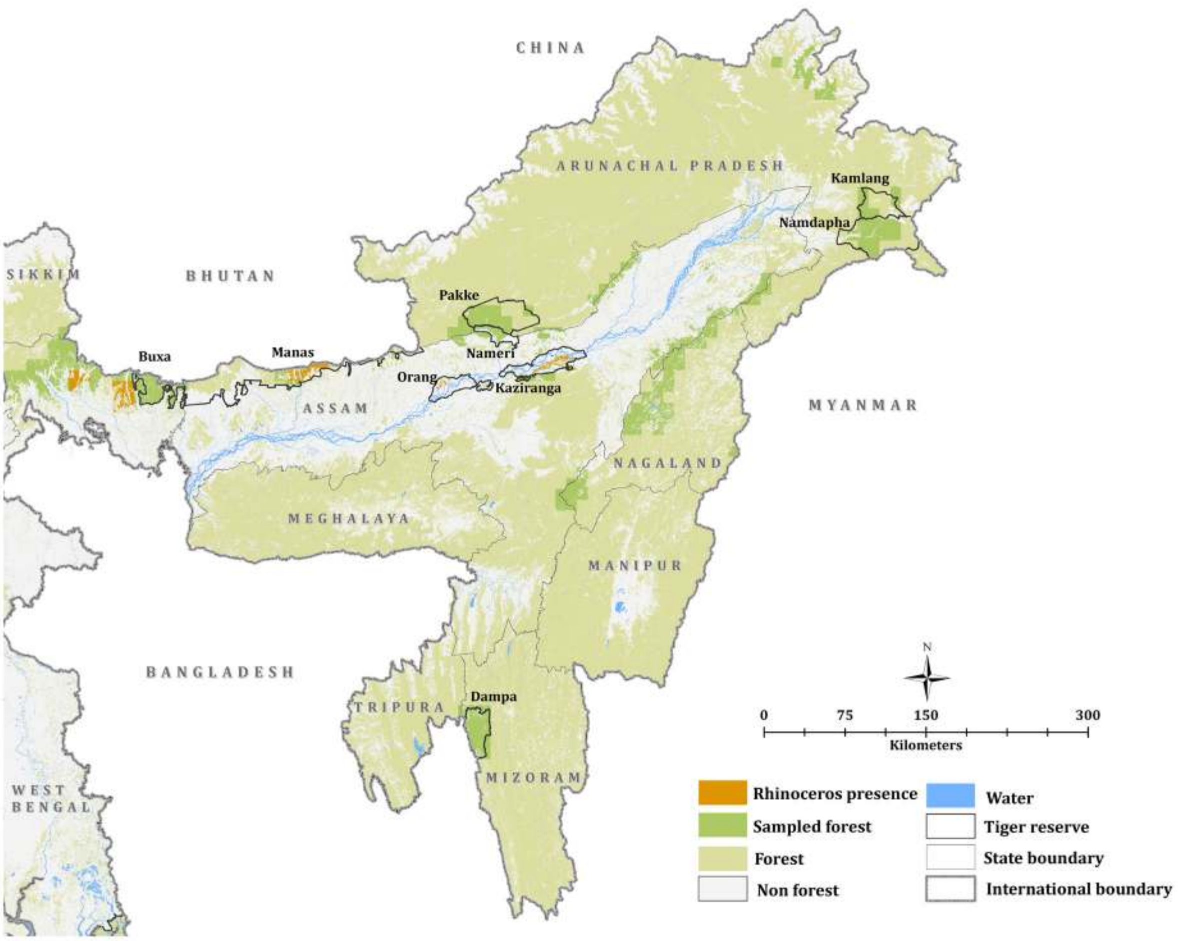
Distribution of mega herbivores and ungulates North East Hills and Brahmaputra Flood Plains landscape, 2022

One horned rhinoceros: (*Rhinoceros unicornis*) *(Wildlife Protection Act, Amended, 2022: Schedule I, IUCN: Vulnerable)*

As a flagship species of floodplains, rhino's presence was limited to floodplains of the north Bengal Dooars and floodplains of the River Brahmaputra. Rhino presence is obtained from Gorumara and Jaldapara national parks in West Bengal and Manas, Orang, and Kaziranga Tiger Reserves in Assam. After the local extinction of rhinoceros in Manas, they were reintroduced in the reserve from Kazirnaga Tiger Reserve and Pobitora Wildlife Sanctuary. Kaziranga holds the highest population of one-horned rhinos in the world. There is a plan to reintroduce rhino in Dibru-Saikhowa National Park (Rhino Vision Plan 2020). Approximately an area of 1093 km^2 was occupied by one horned rhinoceros (Fig. II.4.5).

Figure II.4.5

One horned rhinoceros distribution in North East Hills and Brahmaputra Flood Plains landscape, 2022

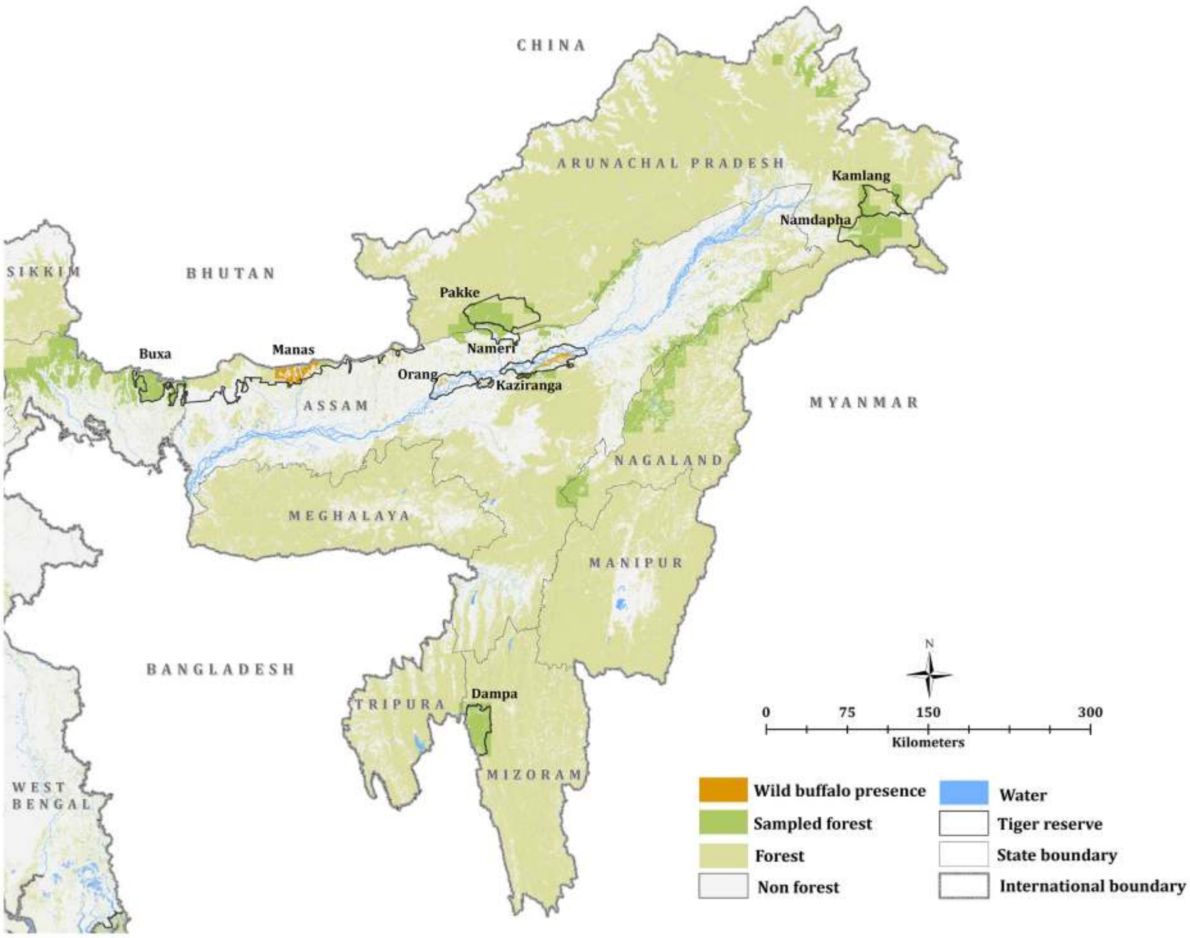


Wild Water Buffalo: (*Bubalus arnee*) *(Wildlife Protection Act, Amended, 2022: Schedule I, IUCN: Endangered)*

Wild buffalo population in this landscape was restricted in Kaziranga, Manas and Orang Tiger Reserves and Dibru Saikowa National Park of Assam, occupying an area of approximately 717 km^2. Wild buffalos are present mostly in the swampy grasslands and marshes. At present, wild water buffalo population are restricted in two states only, namely Assam and Chhattisgarh. However, Chhattisgarh population is very small, and need conservation attentions. In Assam, Laokhowa and Burachhapori wildlife sanctuaries have favourable habitat for this species. Restorative measures such as removal of biotic pressure followed by reintroduction of wild water buffalo should be implemented in these sanctuaries (Fig. II.4.6).

Figure II.4.6

Wild water buffalo distribution in North East Hills and Brahmaputra Flood Plains landscape, 2022

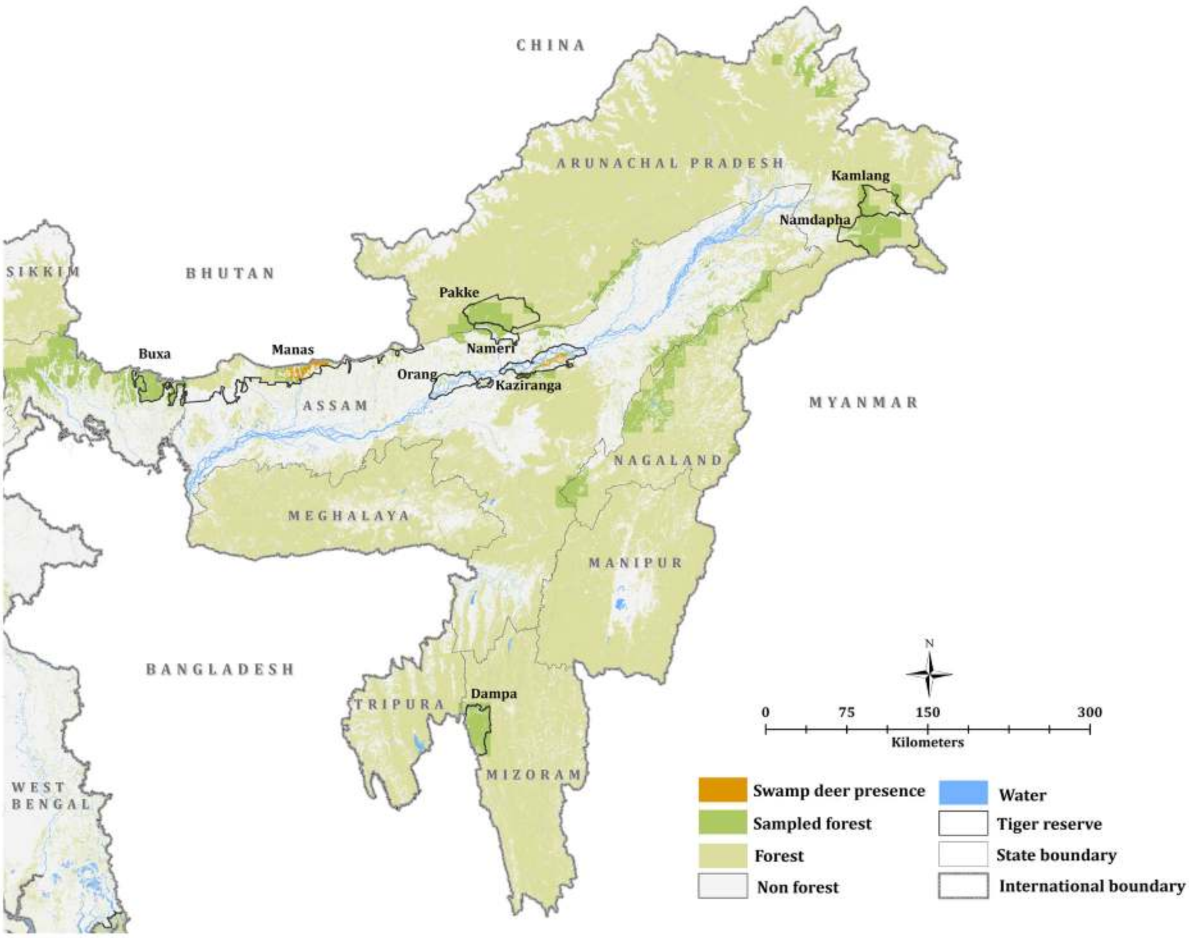


Eastern Barasingha or Swamp deer: (*Rucervus duvaucelli ranjitsinhii*) *(Wildlife Protection Act, Amended, 2022: Schedule I, IUCN: Vulnerable)*

Barasingha, or *Dol Horina* in Assamese, is recorded only in Kaziranga and Manas tiger reserves in Assam. This species is found in the alluvial floodplains and swampy grasslands around the river Brahmaputra. This subspecies of swamp deer is known to occur only in these two tiger reserves only with an approximate area of 492 km^2 (Fig. II.4.7). However, with increased protection and reduced anthropogenic pressures, swamp deer could also be translocated to Dibru-Saikhowa and Nagaon Wildlife Divisions of Assam.

Figure II.4.7

Eastern barasingha distribution in North East Hills and Brahmaputra Flood Plains landscape, 2022

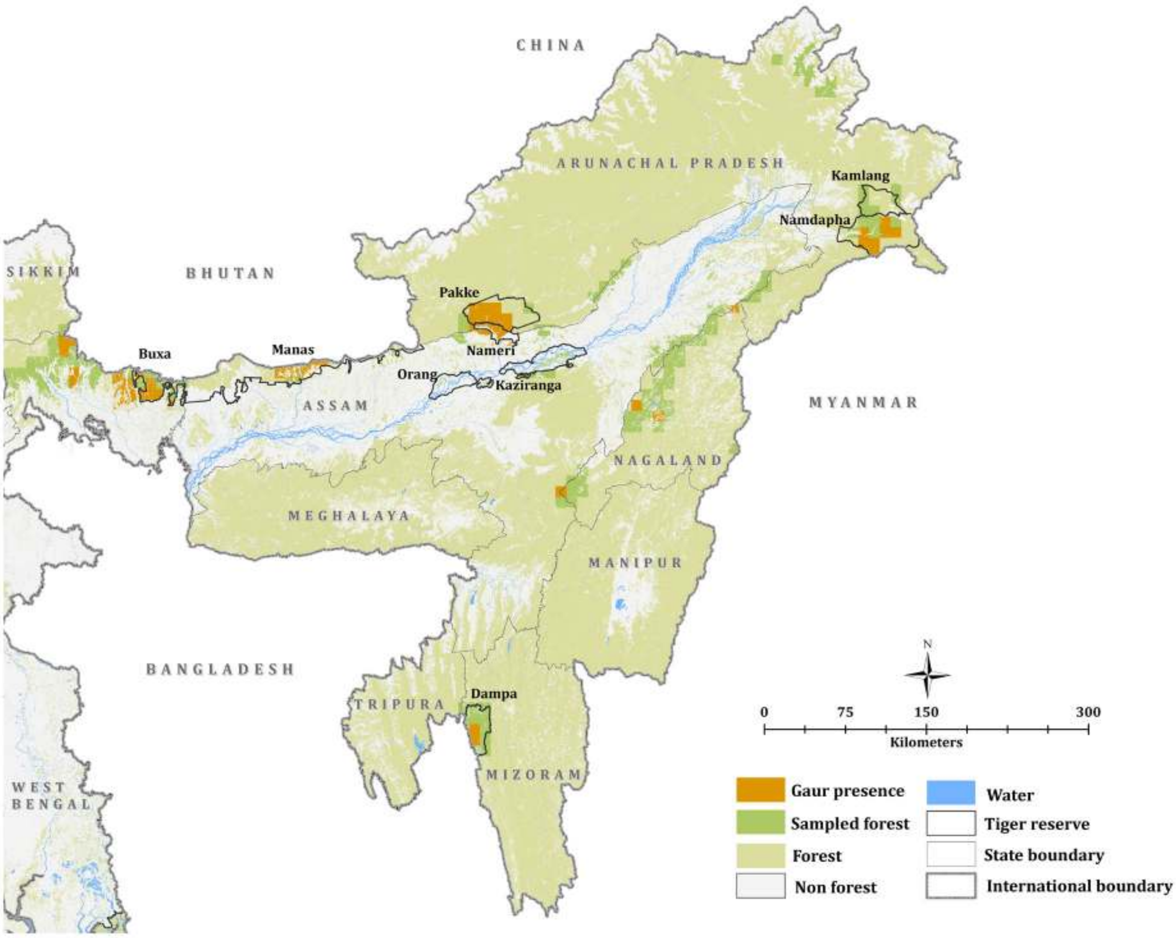


Gaur: (*Bos gaurus*) *(Wildlife Protection Act, Amended, 2022: Schedule I, IUCN: Vulnerable)*

Gaur distribution in this landscape is mostly restricted to the foothills of the eastern Himalayas. Gaur presence was recorded in Kalimpong district, Neora Valley, Gorumara, and Jaldapara national parks, Buxa Tiger Reserve of West Bengal, Manas and Nameri tiger reserves of Assam, Pakke and Namdapha tiger reserves of Arunachal Pradesh, Longleng, Peren, and Dimapur districts of Nagaland, and Dampa Tiger Reserve in Mizoram in this landscape. Approximate an area of 3583 km^2 (Fig. II.4.8) was occupied by gaur in this landscape.

Figure II.4.8

Gaur distribution in North East Hills and Brahmaputra Flood Plains landscape, 2022

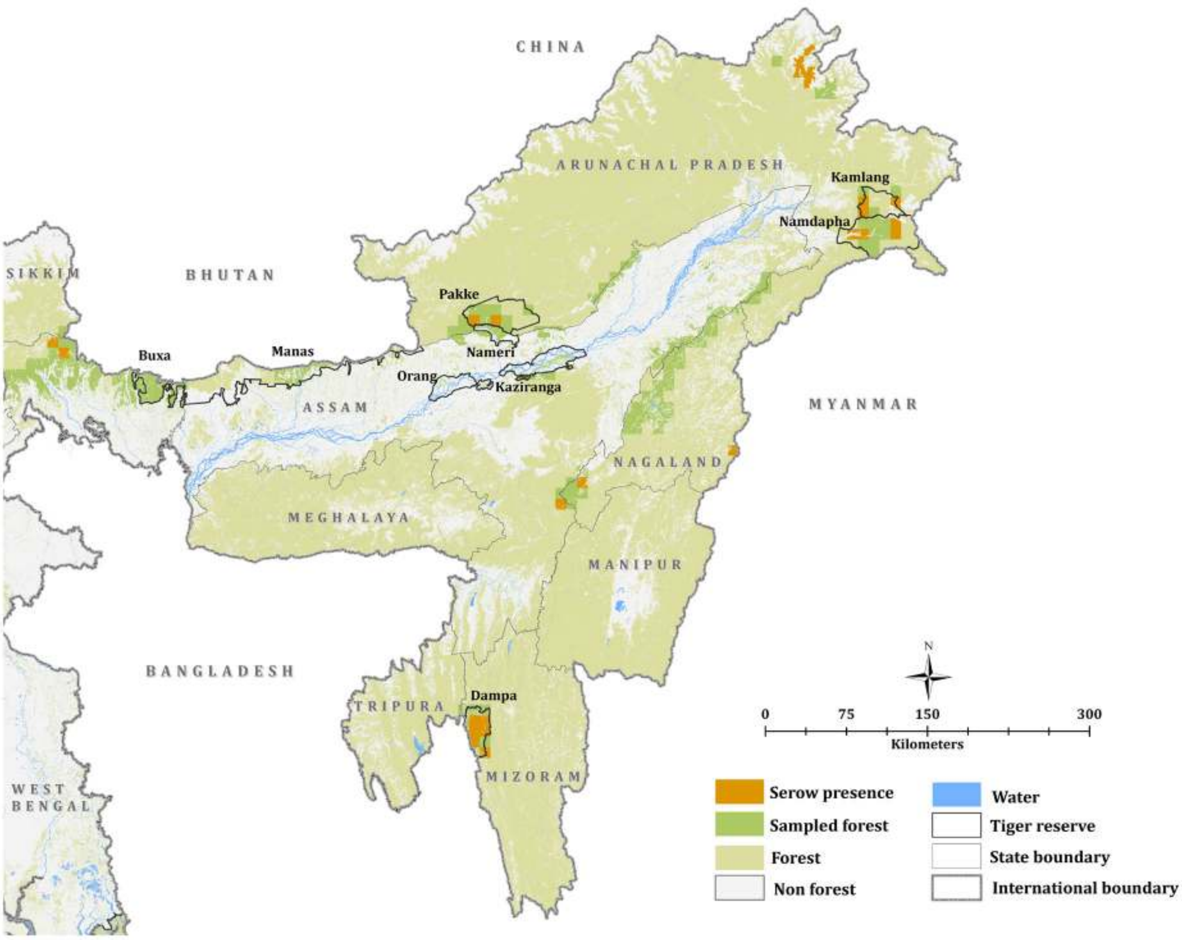


Serow: (*Capricornis sumatraensis*) *(Wildlife Protection Act, Amended, 2022: Schedule I, IUCN: Vulnerable)*

Presence of serow was recorded mostly in the eastern Himalayas. Serow presence was recorded from Neora Valley National Park of West Bengal, Pakke, Kamlang, and Namdpha tiger reserves, Dibang Wildlife Sanctuary of Arunachal Pradesh, Peren and Kiphire districts of Nagaland, and Dampa Tiger Reserve of Mizoram. Occupancy of serow was recorded from approximately an area of 2203 km² (Fig. II.4.9) in this landscape.

Figure II.4.9

Serow distribution in North East Hills and Brahmaputra Flood Plains landscape, 2022

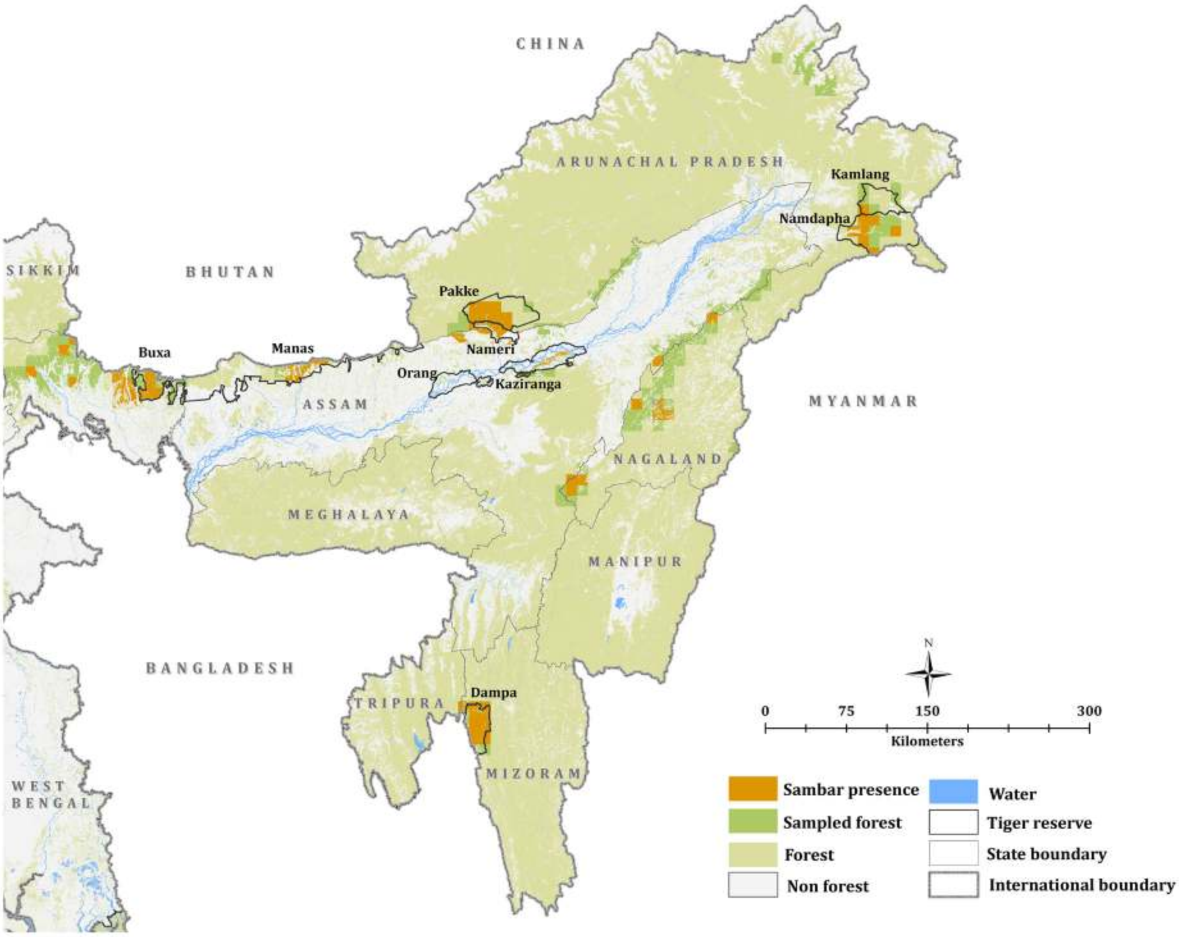


Sambar: (*Rusa unicolor*) *(Wildlife Protection Act, Amended, 2022:Schedule I, IUCN: Vulnerable)*

Except in the high-altitude areas of Dibang Wildlife Sanctuary in Arunachal Pradesh and Orang Tiger Reserve in Assam, sambar presence was recorded in all the protected areas of this landscape. Longleng, Wokha, Dimapur, and Peren districts of Nagaland also recorded sambar presence. Approximately an area of 4878 km^2 (Fig. II.4.10) was occupied by sambar in this landscape.

Figure II.4.10

Sambar distribution in North East Hills and Brahmaputra Flood Plains landscape, 2022

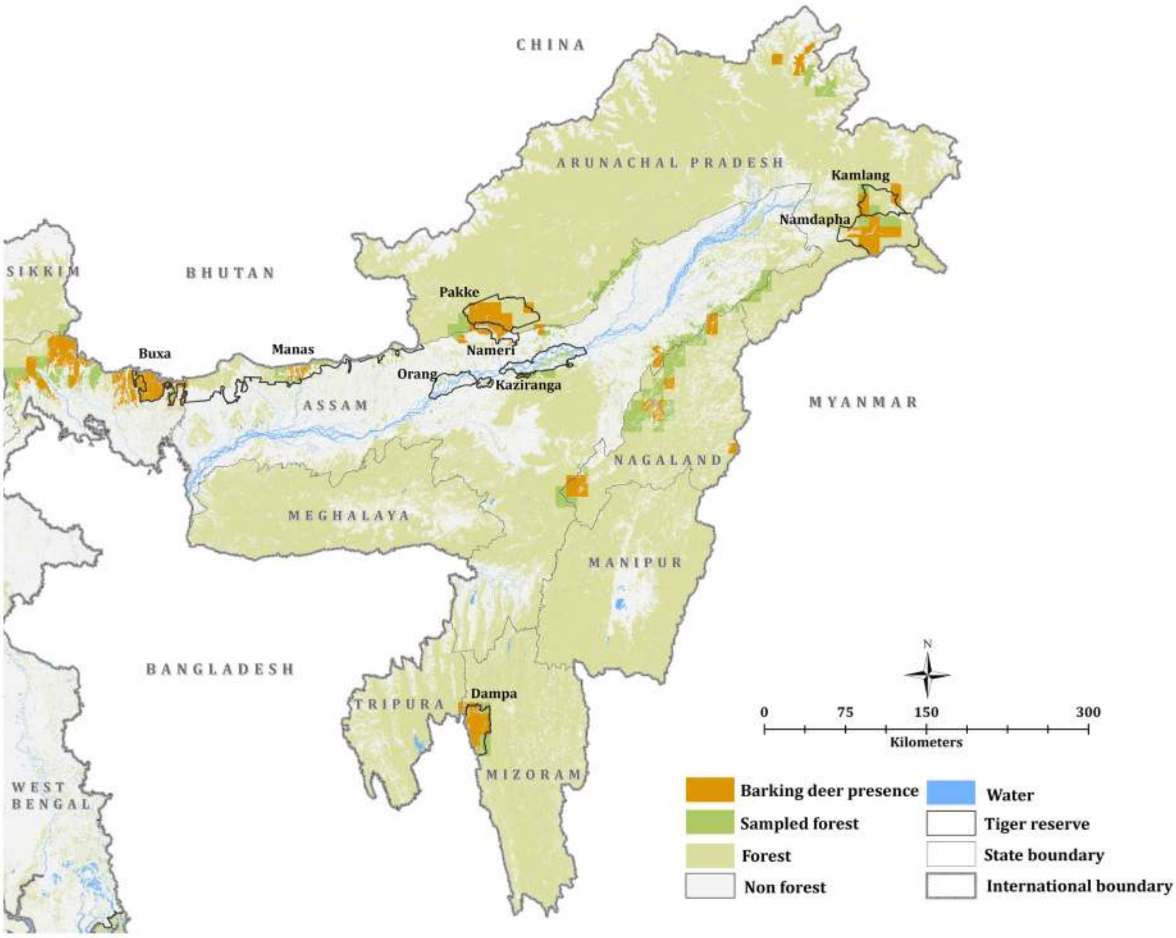


Barking deer: (*Muntiacus spp*) *(Wildlife Protection Act, Amended, 2022: Schedule I, IUCN: Least Concern)*

Barking deer were omnipresent in all the sampled forest areas except Orang tiger reserves in Assam. Occupied forest area by barking deer in this landscape was approximately 7137 km^2 (Fig. II.4.11). The distribution of barking deer is continuous in this landscape and serves as an important prey base for tigers in the eastern Himalayas. However, barking deer are also heavily harvested for bush meat consumption in this landscape (*Pers.obs. D.R. Laha* and Aiyadurai 2011).

Figure II.4.11

Barking deer distribution in North East Hills and Brahmaputra Flood Plains landscape, 2022

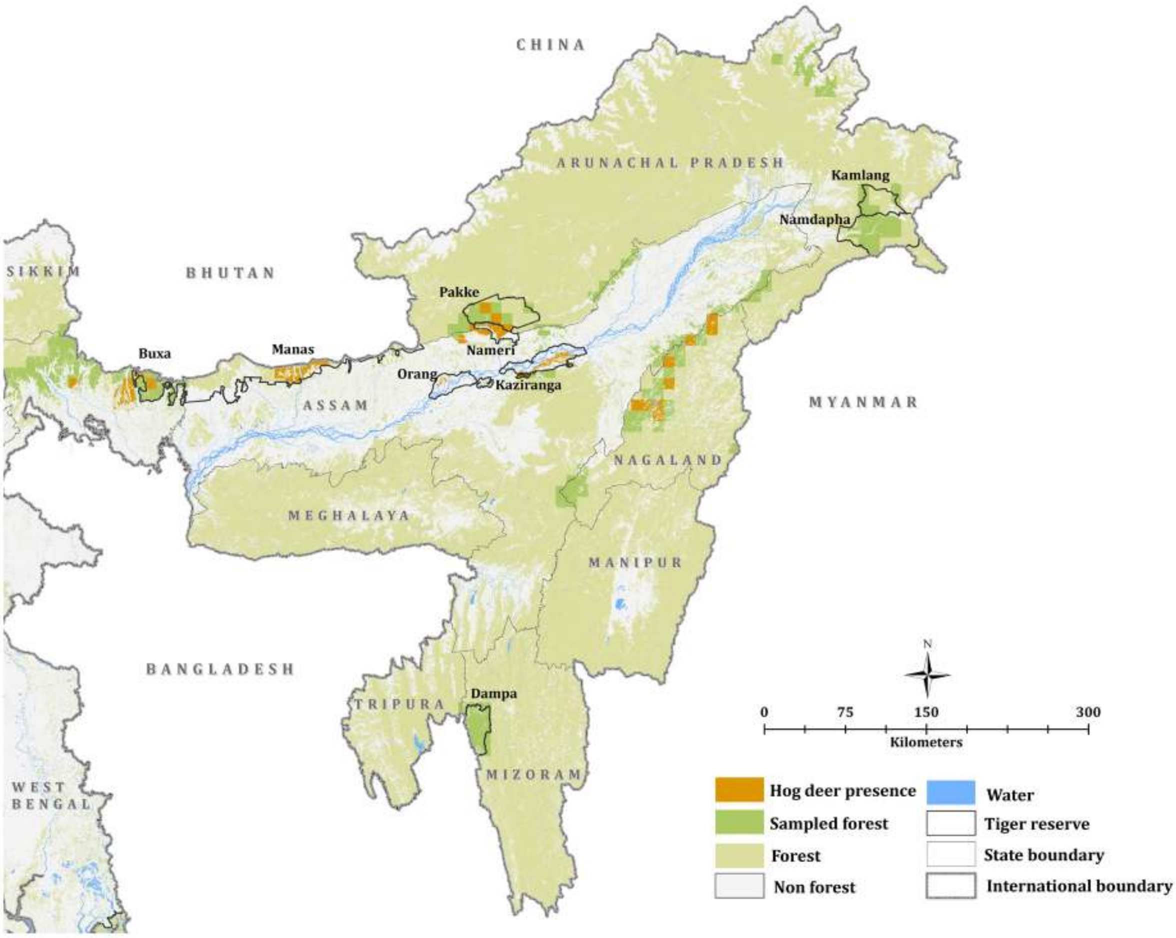


Hog deer: (*Axis porcinus*) *(Wildlife Protection Act, Amended, 2022: Schedule I, IUCN: Endangered)*

Presence of hog deer was mostly restricted to the floodplains and valleys in the landscape. Most of the hog deer presence was recorded in Assam, hog deer presence was also recorded in Mahananda Wildlife Sanctuary, Jaldapara National Park, and Buxa Tiger Reserve in West Bengal, Pakke Tiger Reserve in Arunachal Pradesh, and Mokokchung, Wokha, and Dimapur districts of Nagaland. In the absence of Chital, hog deer act as the major prey base for tigers in floodplains. Occupied forested area by hog deer in this landscape was approximately 2445 km^2 (Fig. II.4.12).

Figure II.4.12

Hog deer distribution in North East Hills and Brahmaputra Flood Plains landscape, 2022



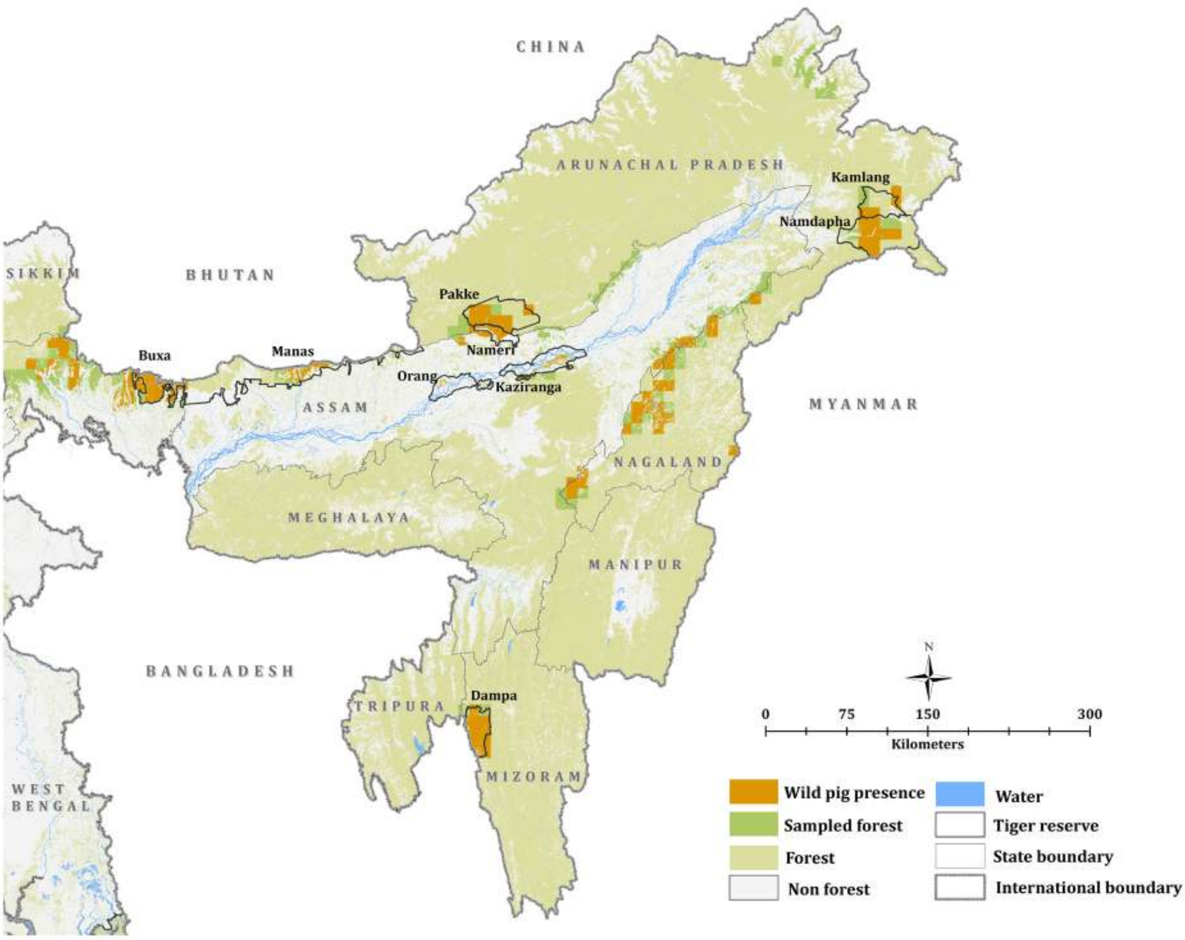
Section II.4

Wild pig: (*Sus scrofa*) *(Wildlife Protection Act, Amended, 2022: Schedule II, IUCN: Least Concern)*

Wild pigs were present throughout the landscape; however, wild pig presence was not recorded from Dibang Wildlife Sanctuary in Arunachal Pradesh. Distribution of wild pigs was almost similar with hog deer in this landscape, except hog deer were not recorded in Dampa. Although wild pigs are known for negative human-wildlife interactions, this species forms one of the major prey bases for tigers in this landscape. Recorded occupancy of wild pig in this landscape was approximately 7163 km^2 (Fig. II.4.13).

Figure II.4.13

Wild pig distribution in North East Hills and Brahmaputra Flood Plains landscape, 2022



Section II.5

Sundarbans Landscape

Deb Ranjan Laha, Ujjwal Kumar, Swati Saini, W. Longvah, Amit Mallick, Vishnupriya Kolipakam, Yadvendradev V. Jhala, Qamar Qureshi

Section II.5

Sundarbans Landscape

The Sundarbans is the largest continuous mangrove habitat in the world, situated at the delta of the Ganges, Brahmaputra and Meghna rivers. It is the only mangrove habitat known to have tigers. These mangrove forests span an area of approximately 10,000 km^2 and are located between two different political entities, namely India, which accounts for 42% of the total area and Bangladesh that has the majority 58%. Sundarbans is also recognized as a UNESCO World Heritage site and a wetland of global importance. The conservation history of Sundarbans can be traced back to 4 BC when settlement began, and it continued through the Mughal, British eras and post-independence. In the early 1875, the forests were declared as Reserved Forests by the British colonial government, which led to the establishment of several forest reserves in the area. However, it wasn't until the 1970s that serious conservation efforts started in the Sundarbans. Sundarbans landscape in India is situated in the South 24 Parganas district of West Bengal and covers an area about 4,266 km^2 area. Entire Sundarbans landscape of India falls under the Sundarbans Biosphere Reserve which comprises Sundarbans Tiger Reserve and mangrove forests of South 24 Parganas Forest Division. Sundarbans tiger reserve encompasses national park as core, and Sajnekhali wildlife sanctuary and Basirhat range as buffer zone. Indian part of Sundarbans is delineated by Ichamati- Raimangal river in the east, Hooghly river in the west, and the north by the Dampier-Hodges line drawn in 1830 (Dhar *et al* 2023).

Sundarbans is crisscrossed by numerous rivers, channels and creeks and mosaic of innumerable flat islands, which are highly influenced by the natural phenomena of tidal cycles. Gradient of salinity in these rivers are changing over the years (Mallick 2011). Mangrove forests of Sundarbans is classified under the sub-group tidal swamp forest with subdivisions of mangrove , saltwater mixed forest, brackish and palm and swamp (Champion & Seth 1968). Climate of Sundarban is sub-tropical with average rainfall of 1763 mm (Mallick 2011). High humidity (over 80%) retains throughout the year. The region is often exposed to cyclones and thunderstorms known as nor'westers or *Kalbaisakhi* which are common during April and can often be accompanied by tidal waves as high as 7.5m (Seidensticker & Hai 1983).

Sundarbans is situated in the vicinity of Kolkata, one of the world's most densely populated metropolitan area. Indian Sundarbans area was sparsely populated before 19th Century, and the lands were divided into plots to lease out for timber extraction and collection of revenue by the

British Government in 1771. After that, within two centuries almost 5364 km^2 tidal mangrove forest area of Sundarbans decreased owing to the conversion of forest to agriculture land and settlements, before extreme south-eastern part of this landscape brought under legal framework as tiger reserve in 1973 (Das 2014).

Geographical location of Sundarbans makes it extremely vulnerable to global warming and subsequent coastal squeezes under ever rising sea levels. The entire Sundarban landscape including the Bangladesh part is very susceptible to tropical cyclones which in turn result into storm surge-induced floods, embankment breaching, and saline water intrusion. On an average each year 4.8 storms occur in the North Indian Ocean out of which 80% of storm landfalls occur in Bay of Bengal (Bandopadhyay *et al* 2021). In recent past, super cyclone Amphan in 2020, and Yaas in 2021 devastated the Sundarbans landscape.

These natural calamities also bring in the conditions for human and tiger conflicts. Though the incidents of tigers venturing into human habitation in Sundarbans had reduced in 2015-16 as reported by authorities, there were sudden increase in tigers straying outside the mangrove forests, and at least seven such incidents have been recorded in 2021-22.

Despite the hostility of the landscape, threat of poaching is another major concern in Sundarbans. Poaching and hunting of spotted deer, wild pig and other prey species could lead to depletion of natural prey of tigers in this landscape, and will adversely affect the tiger population.

Tiger Distribution and Density:

Sampling protocol of Sundarban and mangrove landscape differ from peninsular India. To estimate herbivores and prey species, boat transect were done during low tides, and *khal* (water channel) surveys were done for occupancy of tigers and other species. For the very first time the entire landscape was sampled using android based Polygon Search application of MSTrIPES.

In Sundarbans, tigers occupy 1895 km^2 in 2022. A total of 713 camera trap stations were active for 25264 trap nights across the tiger bearing mangrove habitat of Indian Sundarbans. This yielded 849 photographs of tigers from which 100 individual tigers were identified. 81 tigers were photo-captured in Sundarban Tiger Reserve, and 20 tigers were photo-captured in adjoining South 24 Parganas. However, one tiger was common between two divisions. 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 as 4.27 (SE 0.43) tigers per 100 km^2. The g0 (detection at activity centre) for females was 0.009 (SE 0.0006) while for males it was 0.007 (SE 0.0005). The σ (movement/scale parameter) for females was 4.1 (SE 0.1) km while for males it was 6.4 (SE 0.2) km. The detection corrected sex ratio was 2 females per male.

Section II.5

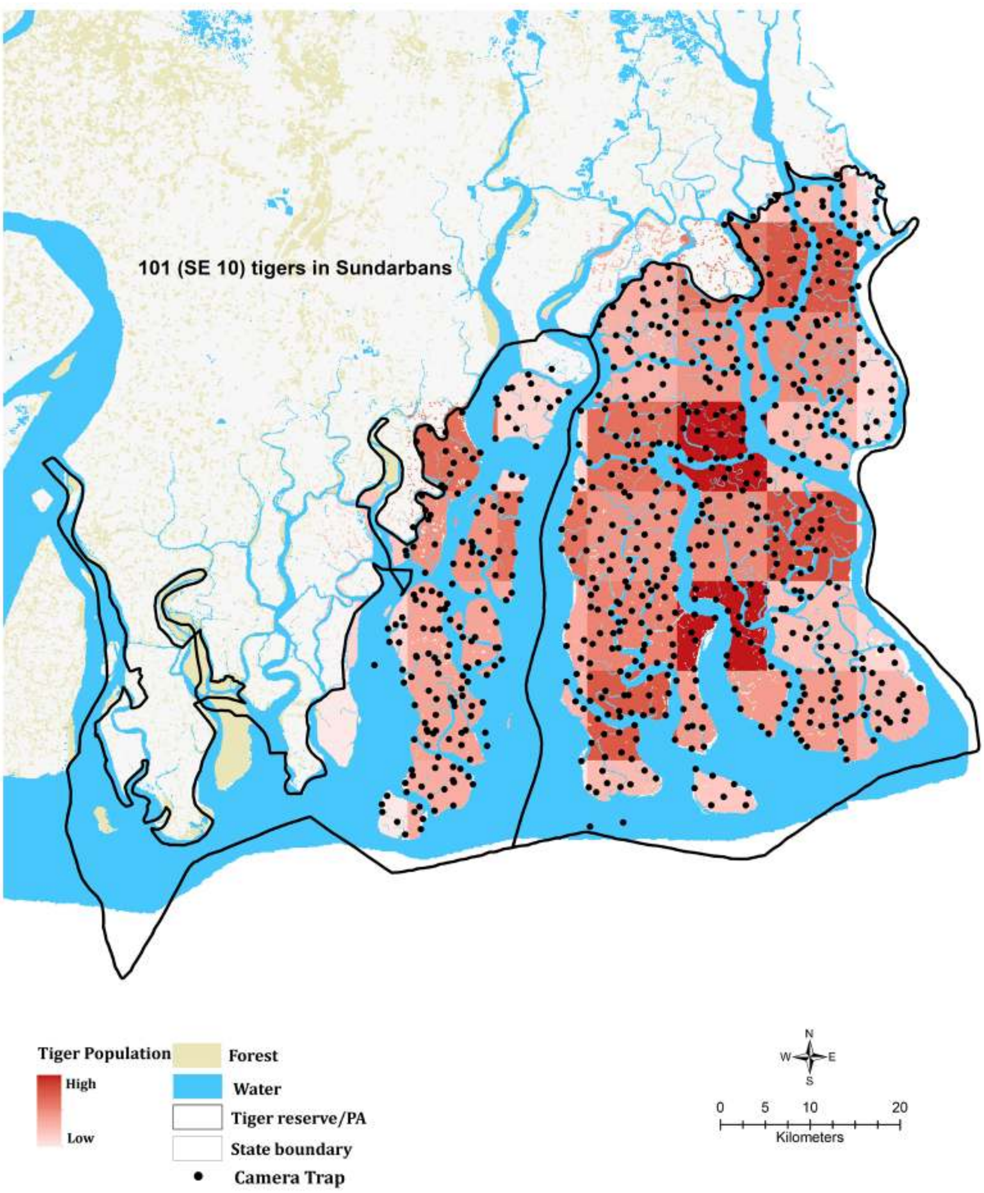
Table II.5.1

Tiger abundance in Indian Sundarban over past cycles of All India Tiger monitoring:

Year	Tiger abundance (Range)
2006	NA
2010	74 (SE 16)
2014	76 (SE 20)
2018	88 (SE 2)
2022	101 (SE 10)

Figure II.5.1

Camera trap locations and spatial tiger density of tigers in Sundarbans, 2022



Southern part of Sajnekhali wildlife sanctuary and parts of National Park East and West ranges have high tiger density. However, the northern part of South 24 Parganas forest division and Basirhat range of Sundarbans tiger reserve have moderate density of tigers. With all the three sides of this landscape is bordered by human habitation, the tiger population can extend only towards the east i.e. towards the Bangladesh part of Sundarbans. Possible conduit for the tigers towards east would be the channels which are less than 400m wide (Naha *et al.* 2016) and situated at the northern part of Basirhat range. However, the protection parameters of adjacent Bangladesh part differ from Indian Sundrabans (Jhala *et al.* 2020).

Population density of tigers in Sundarbans remain almost constant since 2010. Density of principal prey such as spotted deer or chital was estimated as 3.65 (SE 0.73) per km^2 in Sundarbans (Jhala *et al.* 2020). Carrying capacity of tigers in Sundarban was estimated at 4.68 tigers/ $100km^2$ (Roy *et al.* 2016). However, together Sundarbans landscape belongs to the one of the largest tiger population blocks of the world and holds utmost significance owing to unique morphological characteristics, and adaptations of these mangrove tigers.

Last estimation exercise in the Bangladesh part of Sundarbans was carried out in 2018 in three blocks namely Satkhira, Khulna and Sarankhola. The estimated tiger population in Bangladesh Sundarbans was 114 (SE 32) and overall density was 2.55 (SE 0.32)/ 100 km^2. A total of 63 tigers were photo-captured during the exercise (Aziz *et al.* 2018).

Due to the uniqueness of the landscape, geographical extent of the tiger population is limited to the available mangrove habitat. Tigers use mangrove habitats of Tiger Reserve and adjoining South 24 Parganas, however, the tiger bearing mangrove habitats should be brought under jurisdiction of Sundarban Tiger Reserve to garner more resources and protection. The ever increasing biotic interference in the form of livelihood forest exploitation, fishing, palm and timber extractions, and growing national and international waterways make this landscape and the tiger population vulnerable. Trans-boundary cooperation and knowledge sharing between India and Bangladesh are important to maintain ecological integrity of the landscape. There is a need to explore areas within India and Bangladesh for tiger relocation as well as prey augmentation as the population is nearing carrying capacity of current prey density. However, to protect mangrove habitat, Govt. of India within Ministry of Environment and Forest in 1979. On 5^{th} June 2023, the Govt.of India launched, Mangrove Initiative for Shoreline Habitats & Tangible Income (MISHTI) to explore possible area for development of mangrove habitats. Objective of this initiative is to share best practices on plantation techniques, conservation measures and resource mobilization through Public Private Partnership.

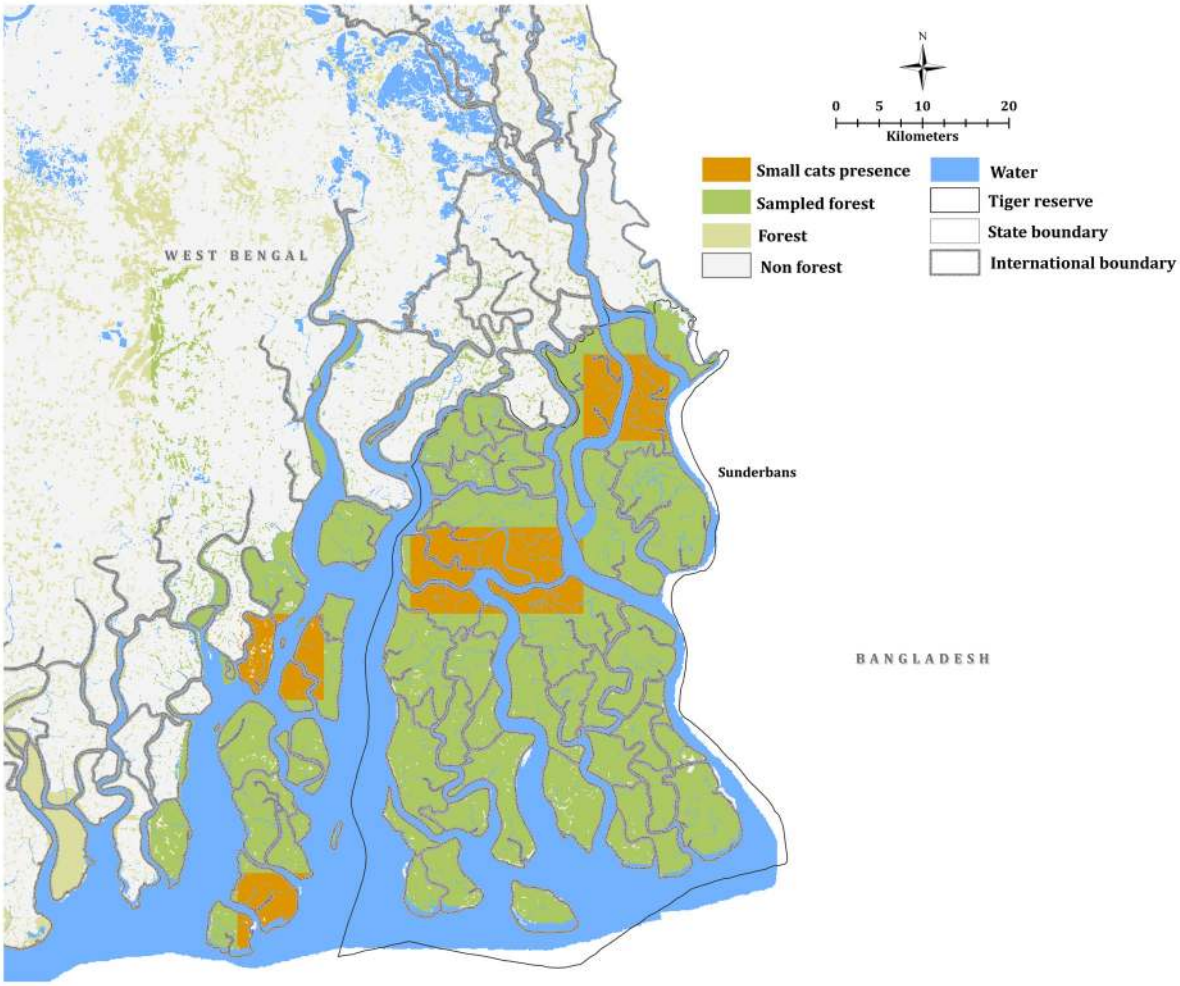
Distribution of carnivores and omnivores in Sundarbans, 2022

Small cats: *Prionailurus viverrinus, Prionailurus bengalensis* *(Wildlife Protection Act, Amended, 2022: Schedule I, IUCN:Vulnerable)*

Small cat (fishing cat and leopard cat) signs are difficult to identify in the mudflats, thereafter all the small cat signs were cumulated to get the occupancy. Small cat presence was mostly recorded from Sajnekhali and Basirhat ranges, and southern part of biosphere reserve. Occupancy of small cats in Sundarbans was approximately 322 km^2 (Fig II.5.2).

Figure II.5.2

Small cat distribution in Sundarbans, 2022

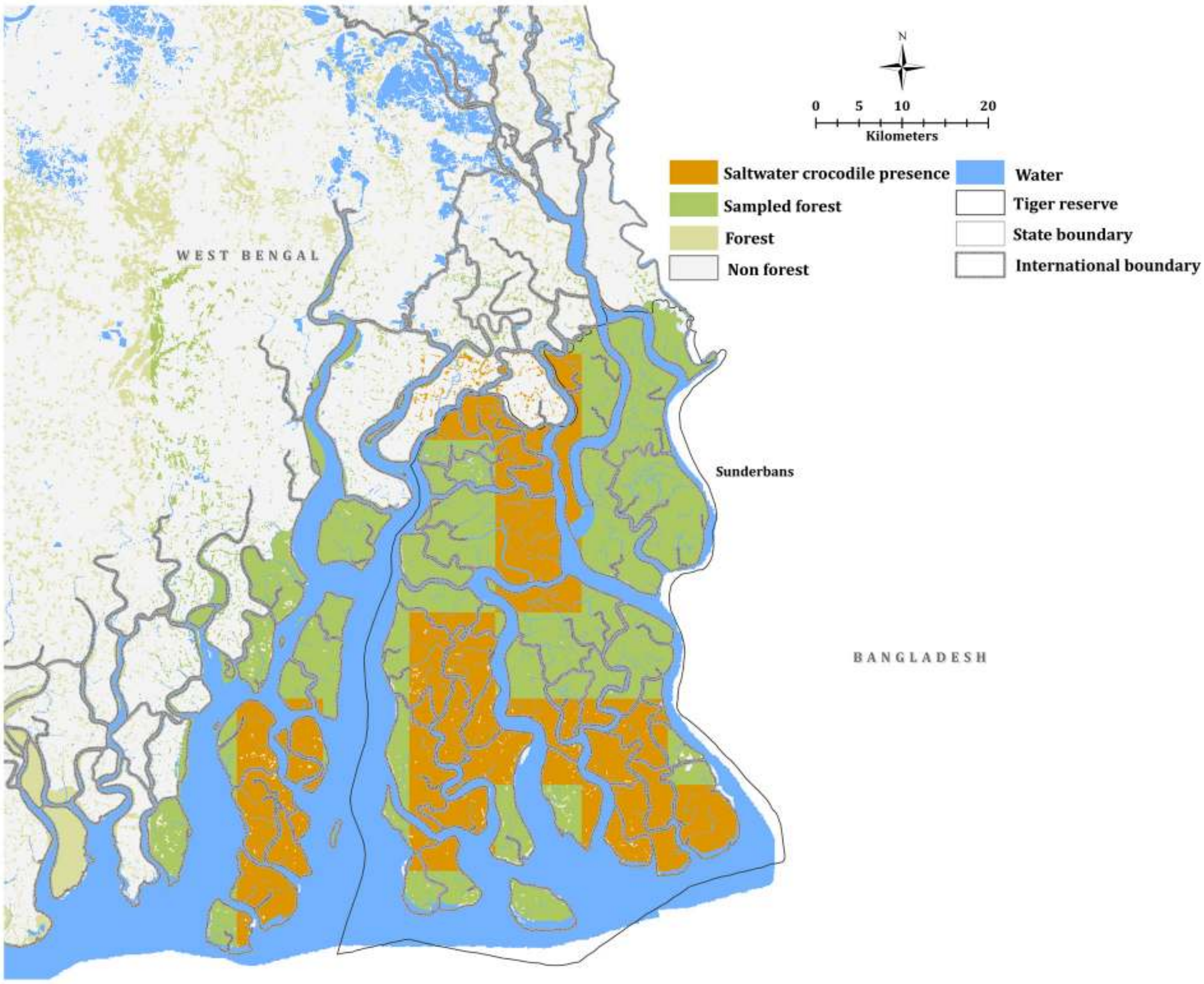


Salt water crocodile: *Crocodylus porosus* *(Wildlife Protection Act, Amended, 2022: Schedule I, IUCN: Least Concern)*

Salt water crocodile presence is recorded from Sajnekhali, National Park East and West ranges of tiger reserve. Salt water crocodile was also recorded from biosphere reserve. This species is observed to use inland water channels. Occupancy of salt water crocodile was recorded from approximately an area of 866 km^2 (Fig II.5.3).

Figure II.5.3

Salt water crocodile distribution in Sundarbans,2022

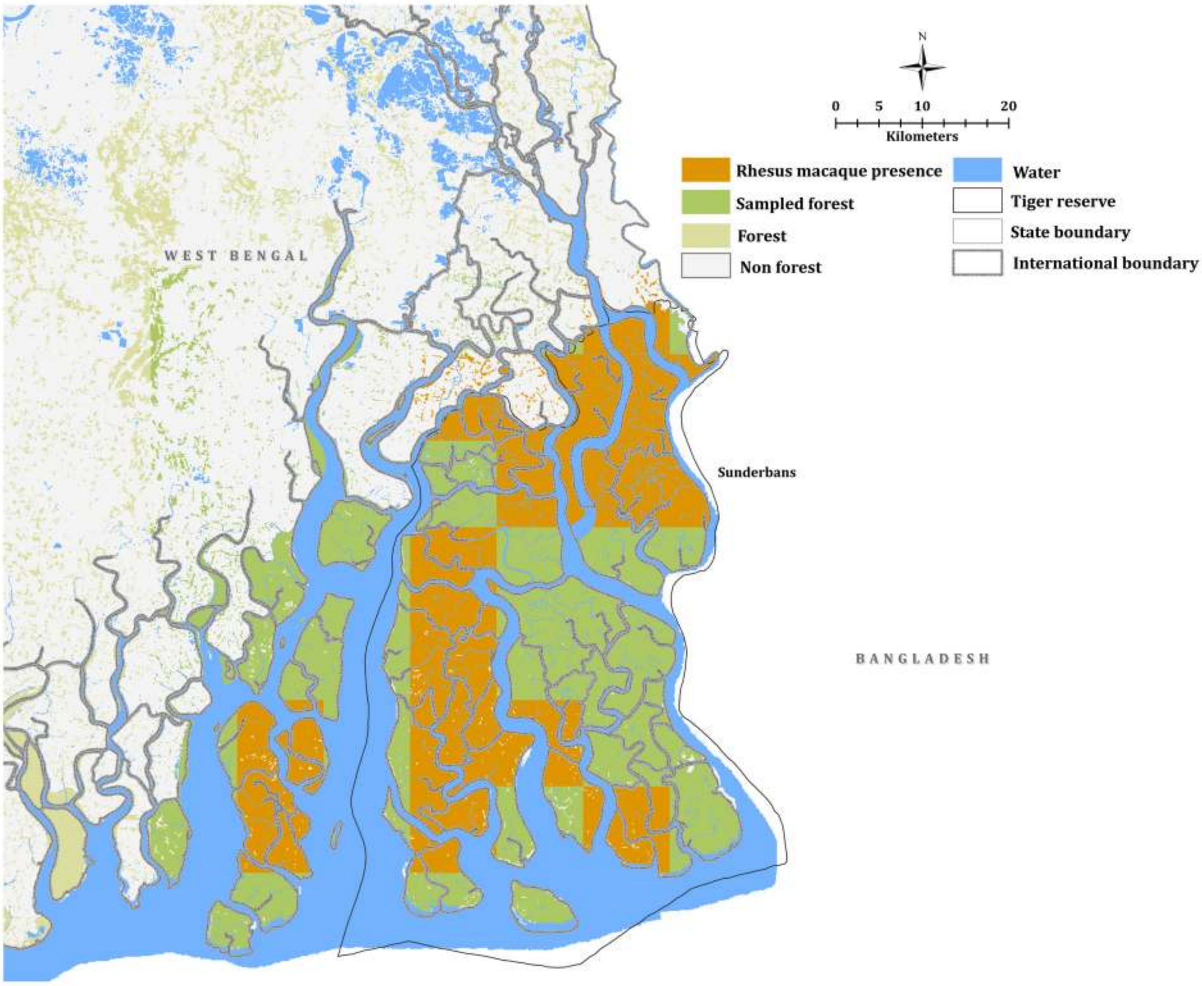


Rhesus macaque: *Macaca mullata* *(Wildlife Protection Act, Amended, 2022: Schedule IV, IUCN: Least Concern)*

Rhesus macaque presence was recorded mostly in Sajnekhali and Basirhat ranges, and in few patches of National Park East and West Ranges. Occupied area by rhesus macaque in Sundarbans was approximately 930 km^2 (Fig II.5.4).

Figure II.5.4

Rhesus macaque distribution in Sundarbans, 2022



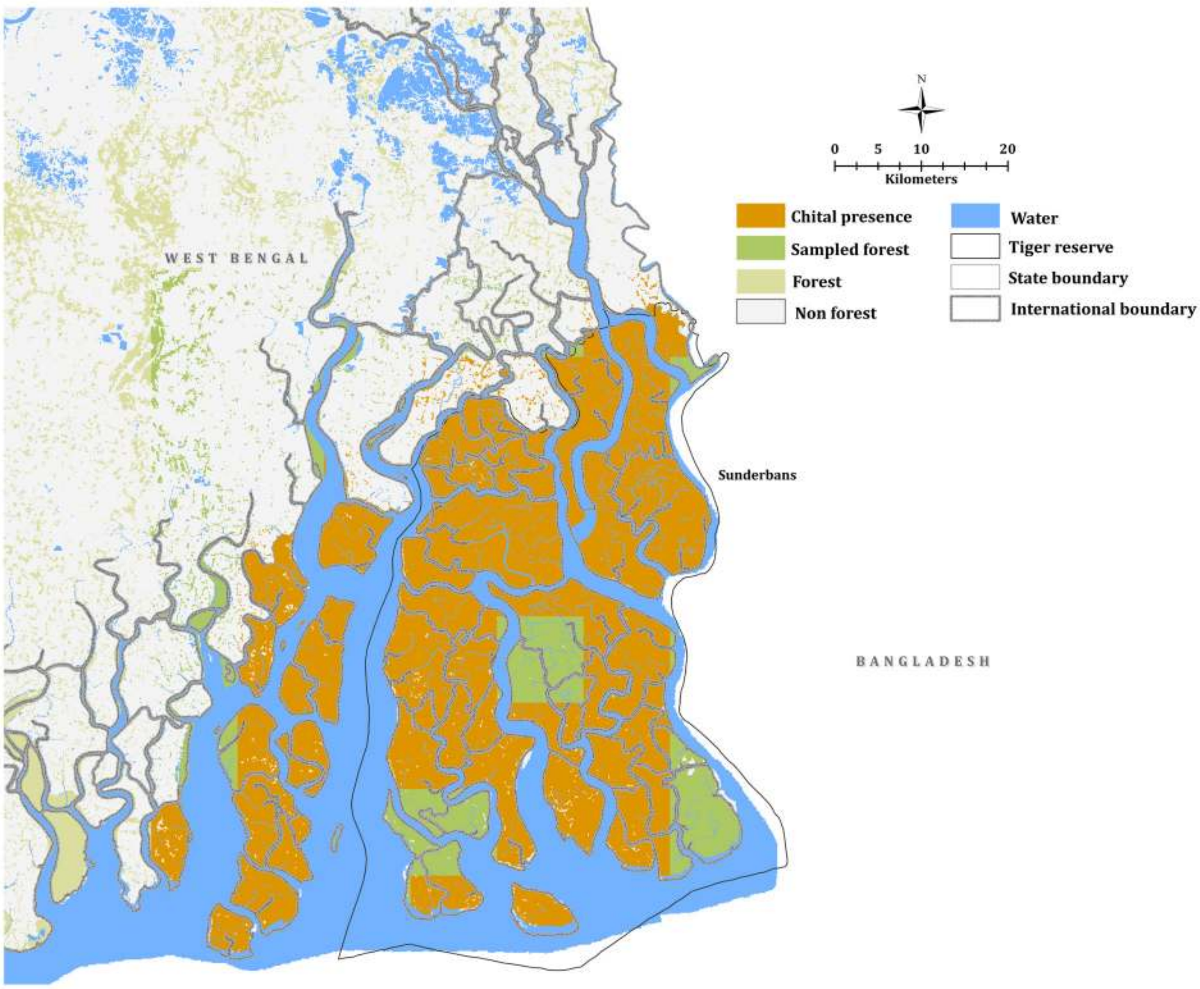
Distribution of ungulates in Sundarbans, 2022

Chital: ***Axis axis*** *(Wildlife Protection Act, Amended, 2022: Schedule II, IUCN: Least Concern)*

Chital presence is recorded from every sampled area of Sundarbans except few islands of National Park East and West ranges. This could be an artefact of the Phase I sampling. Chital occupies approximately 1653 km^2 (Fig II.5.5) area of Indian Sundarbans part. Chital forms the major prey base of tiger in this landscape.

Figure II.5.5

Chital distribution in Sundarbans, 2022

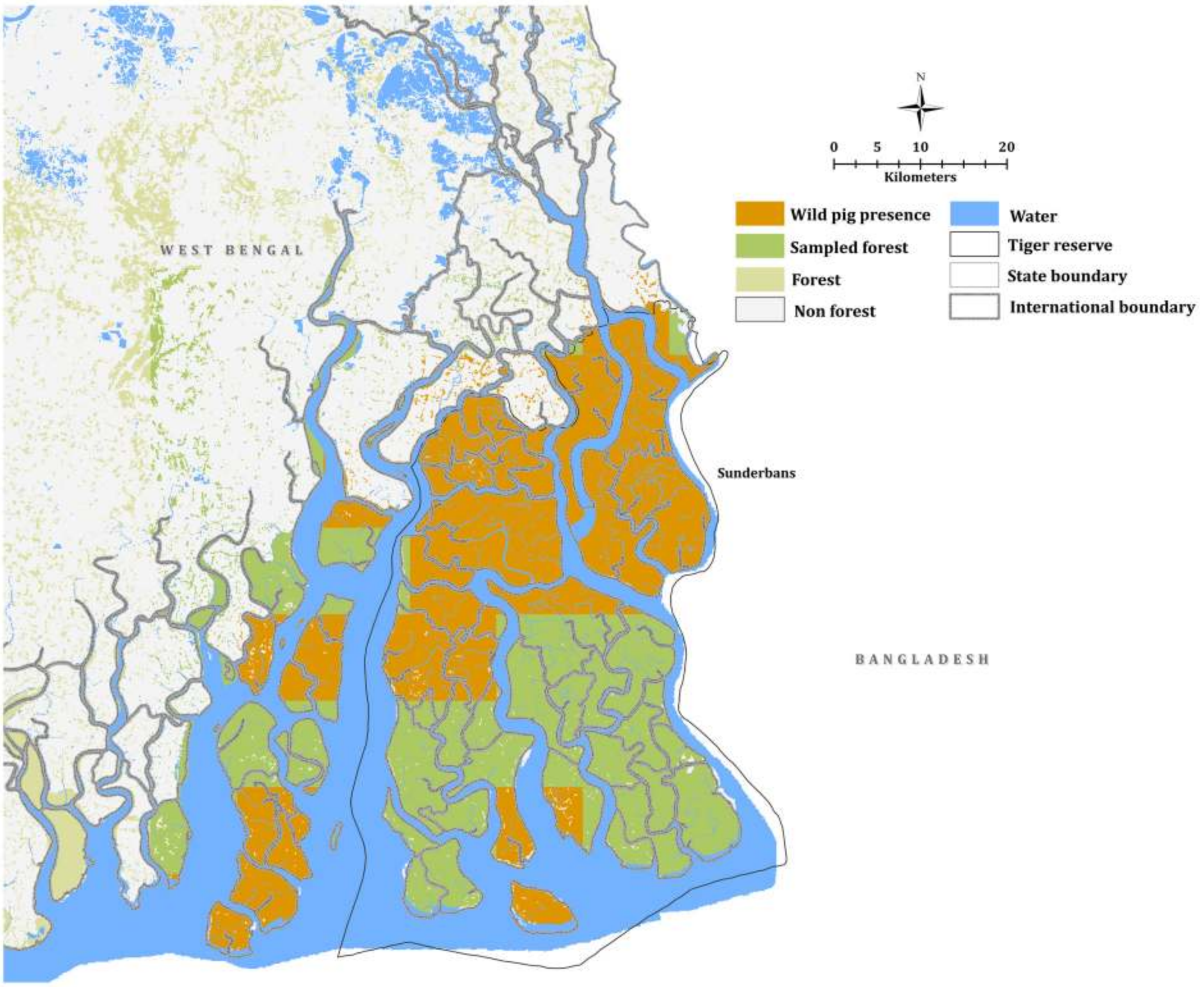


Wild pig: *Sus scrofa* *(Wildlife Protection Act, Amended, 2022: Schedule II, IUCN: Least Concern)*

Wild pig is recorded mostly from Sajnekhali and Basirhat ranges of the tiger reserve. National Park East and West ranges have comparatively low occupancy of wild pig. Wild pig occupancy in Sundarbans was approximately 1049 km^2 (Fig II.5.6). Detection of wild pig was also low in earlier cycles (Jhala *et al.* 2020).

Figure II.5.6

Wild pig distribution in Sundarbans, 2022



Section III

Plant invasions and restoration priorities in India

Ninad Avinash Mungi, Rajat Rastogi, Qamar Qureshi and Yadvendradev V. Jhala,

Section III

Plant invasions and restoration priorities in India

While invasive species are ubiquitously threatening our biosphere, our knowledge of their extent and mechanisms of spread is often deficient, undermining timely management interventions (Latombe *et al.* 2017). Unmanaged invasions can often escalate biodiversity loss, functional erosion of ecosystems, collapse of ecosystem services, and spells of global pandemics (Pyek *et al.* 2020). Recognition of these far-reaching consequences for ecological sustainability has led to the development of trans-national policies to arrest ongoing biological invasions and promote restoration of native ecosystems (IPBES, 2016). These global commitments are epitomized by the United Nations' declaration of the ongoing decade for ecosystem restoration. Yet, policies, management, and research on biological invasions are presently impeded by a lack of reliable information on the distribution of invasive species and their key drivers (McGeoch *et al.* 2016; Early *et al.* 2016). Generating this vital information periodically enables nations to mitigate the negative impact of biological invasions and achieve evidence-based restorations, as committed at the Convention on Biological Diversity (CBD). Nonetheless, it can be prohibitively costly to independently monitor invasions at a national scale, and hence, strategies to integrate invasion monitoring within larger biodiversity assessments must be conceived. In India, invasive plant monitoring has been conducted for the last two decades by integrating it with the umbrella project on tigers.

The survival of tigers depends on high densities of herbivores, which requires large wilderness areas with abundant nutritious forage; protecting such areas from deleterious invasive plants is thus a conservation priority (Rastogi *et al.* 2023). Habitat to diverse megafauna, India's natural ecosystems substantially contribute to regulating planetary climatic and biogeochemical cycles (IPCC, 2014), and their loss or alteration impedes these functions, affecting the livelihoods of millions of dependent people (IPBES 2018, Bawa & Gadgil, 1997). Plant invasions can likely compromise these valuable functions (Mungi *et al.* 2020; Raghubanshi & Tripathi, 2009; Sankaran *et al.* 2017) (Fig. III.1). Invasive plants reduce important forest produce (e.g., medicinal plants, fruits, fodder grass, etc.), on which many indigenous communities depend for their livelihood, thereby jeopardizing the marginalized sections (Mathur *et al.* 2015). The loss due to biological invasions is estimated to cost the Indian economy up to USD 182.6 billion (Bang *et al.* 2022).

A marked lacuna in national-level knowledge about plant invasions has impeded knowledge-driven management investments to reduce invasions and their impacts on ecosystems and society (Mathur *et al.* 2015). This has inadvertently resulted in unplanned actions where personal judgments are used to select invaded areas and remove invasive plants without recognizing their ecological or landscape-scale consequences. Often, such areas get reinvaded, generating management pessimism and inaction about invasive species control and restoration (Kannan, Shackleton, & Shaanker, 2013). Evaluating invasion status at landscape scale can not only provide a comprehensive assessment of ecosystems but can also help prioritize management and restoration investments (Banerjee *et al.* 2021). Past studies have used the presence of a few common invasive plants sampled from small areas to extrapolate large-scale distribution (Goncalves *et al.* 2014). However, as invasive species respond varyingly to their drivers across different biogeographies (Mungi *et al.* 2018a), irrespective of the rigorous statistical algorithms used for such projections, the scope of extrapolating species-environment relations to a large, heterogeneous country like India is inherently limited. To date, due to the unavailability of large-scale sampling, there have been few alternatives to fragmented and inadequate information on invasive species (Prajapati *et al.* 2022). The prerequisite for overcoming these limitations is long-term, large-scale sampling of invasive plants across socio-ecological regimes. Conducting large-scale monitoring for biological invasions would be resource-demanding and therefore untenable unless linked to an assessment with added conservation value.

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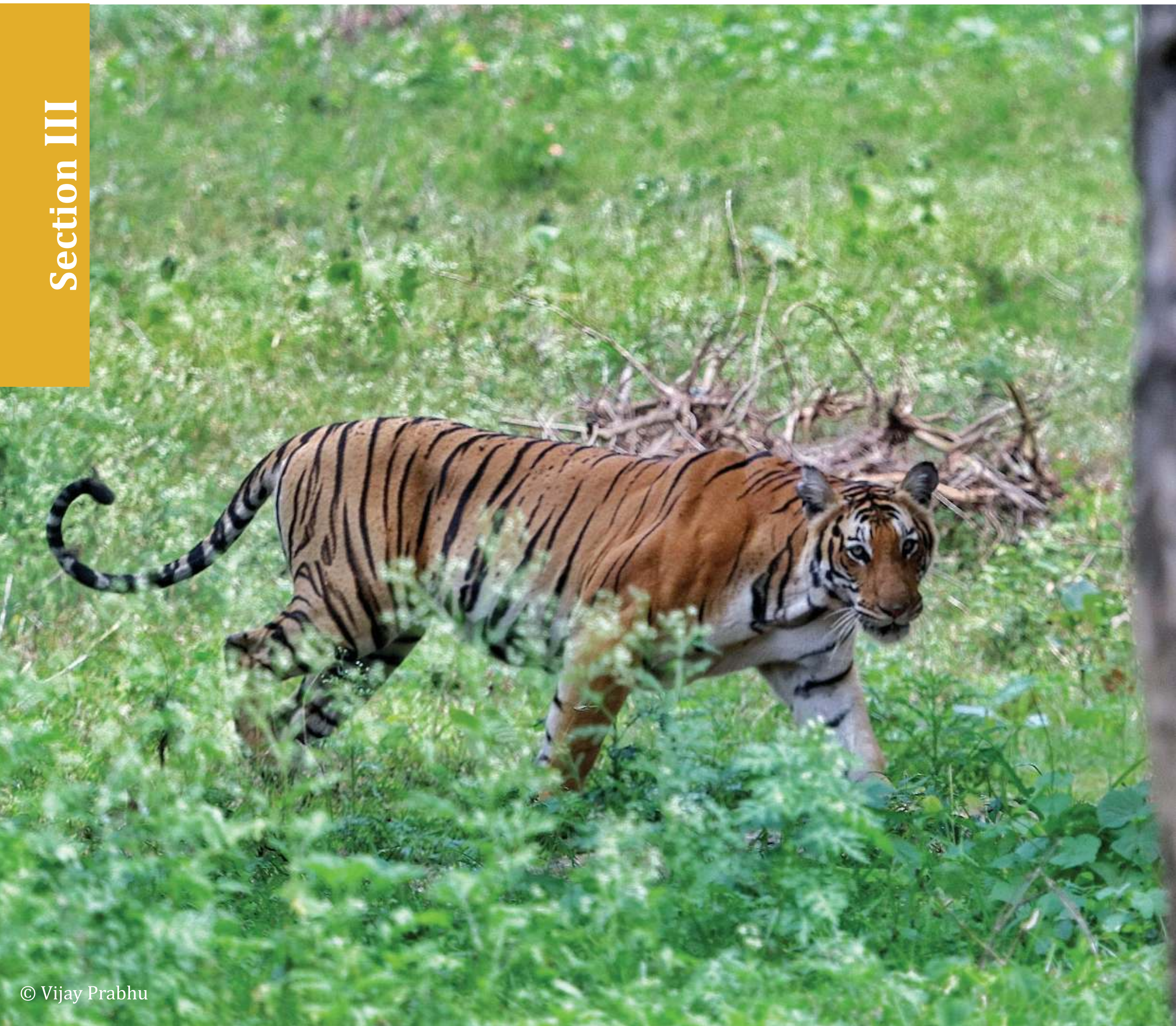
India has used the tiger not only as an umbrella for conserving biodiversity but also for long-term monitoring of various facets of ecosystems at a national scale (Jhala *et al.* 2020). This monitoring includes collecting information on invasive plants by systematically sampling natural areas at a 25 km^2 scale with multiple plots across 20 Indian states (Mungi *et al.* 2019). This has been conducted quadrennially since 2006, repeating in 2010, 2014, 2018, and 2022, thus monitoring these landscapes for 16 years now. We used this big data to model the occurrence of all high-concern invasive plants in India, their invasion rate, identify the socio-ecological drivers of their invasions, and provide management priorities based on different ground assumptions. The 11 high-concern invasive plant species were identified for priority management using objective criteria on their impacts on biotic and abiotic components, ecosystem services, and human wellbeing (Mathur *et al.* 2015; Mungi *et al.* 2019). Our study provides the first set of high-resolution models of invasive plants, crucial for developing a national strategy for managing plant invasions. We identify major drivers of plant invasion and use this information to prioritize areas for managing invasive plants to maximize returns in terms of biodiversity conservation.



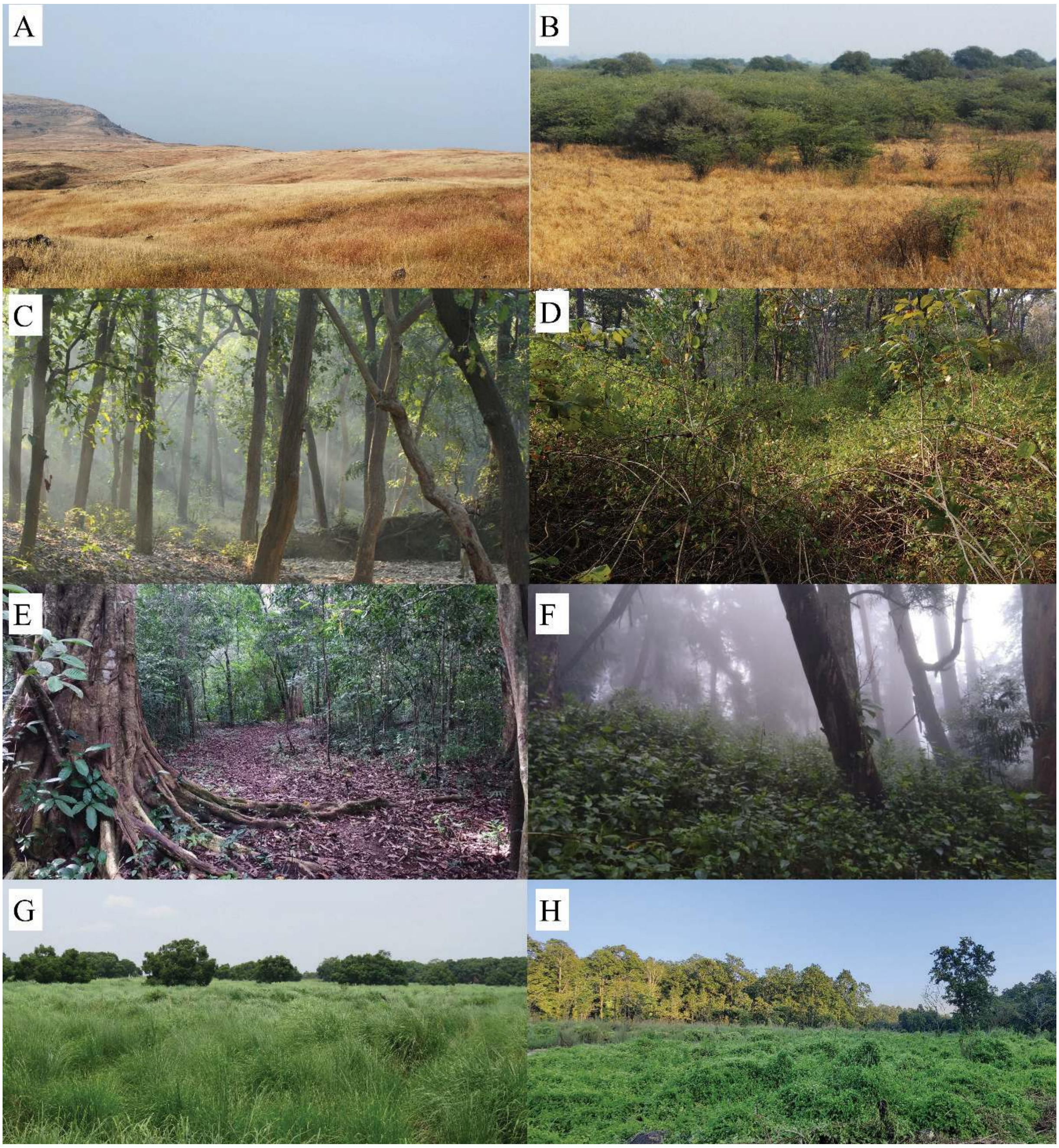


Figure III.1

Comparison between relatively uninvaded and invaded ecosystems highlighting the compositional and structural alterations in different ecoregions in India (A: uninvaded grassland, B: grassland invaded by *Prosopis juliflora*, C: uninvaded deciduous forest, D: deciduous forest invaded by *Lantana camara*, E: uninvaded evergreen forest, F: evergreen forest invaded by *Ageratina adenophora*, G: uninvaded moist grassland, H: moist grassland invaded by *Mikania micrantha*).

Methodology

Data collection:

Natural areas were systematically sampled across the tiger range, including protected and multi-used areas. These areas can be broadly classified into savannas, dry deciduous forests, moist deciduous forests, semi-evergreen forests, evergreen forests, and moist grasslands (Fig. III.2) (Champion & Seth, 1968). Natural areas were divided into a grid of 25 km^2 (Fig. III.2). Within each grid cell, one to three 2 km line transects were marked depending on the dominant vegetation types (Champion & Seth, 1968). On every such transect, inventory plots were sampled at every 400 m interval to record high-concern invasive plants. Tree species were counted on a 30 m diameter plot; shrub species cover was enumerated on a 10 m diameter plot; and herbaceous vegetation ground cover was recorded on a 2 m diameter plot (Fig. III.2). Shrub and herb cover were recorded on a percent scale using visual estimation of the ground cover (Jhala *et al.* 2017). Sampling was conducted during the post-monsoon months in India to maximize plant species encounters. At every sampling location, geographic coordinates, dates, data, and photographs were recorded. Since 2018, data has been recorded using a customized mobile app, MSTrIPES (Jhala *et al.* 2019), with embedded plant names to geotag every record. Sampling, on average, effectively covered 31% of savannas, 51% of dry deciduous forests, 40% of moist deciduous forests, 29% of semi-evergreen forests, 44% of evergreen forests, and 33% of moist grassland savannas. We developed a 5 km scale grid in ArcGIS (ver. 10.5.1) and spatially averaged the invasion cover of these 11 high-concern invasive plants recorded within all plots in the grid. The summary of plots and areas sampled across the years is provided in Table III.1. We added secondary datasets from different projects and publications of the authors, totalling a sampling of 358,551 km^2 (Fig. III.2A).

Table III.1

Summary of sampled plots and effectively sampled natural areas across years.

Year	2006	2010	2014	2018	2022
Sampled plots	124,104	132,150	157,121	158,979	153,844
Sampled forested area (km^2)	263,002	266,810	278,675	279,770	276,956

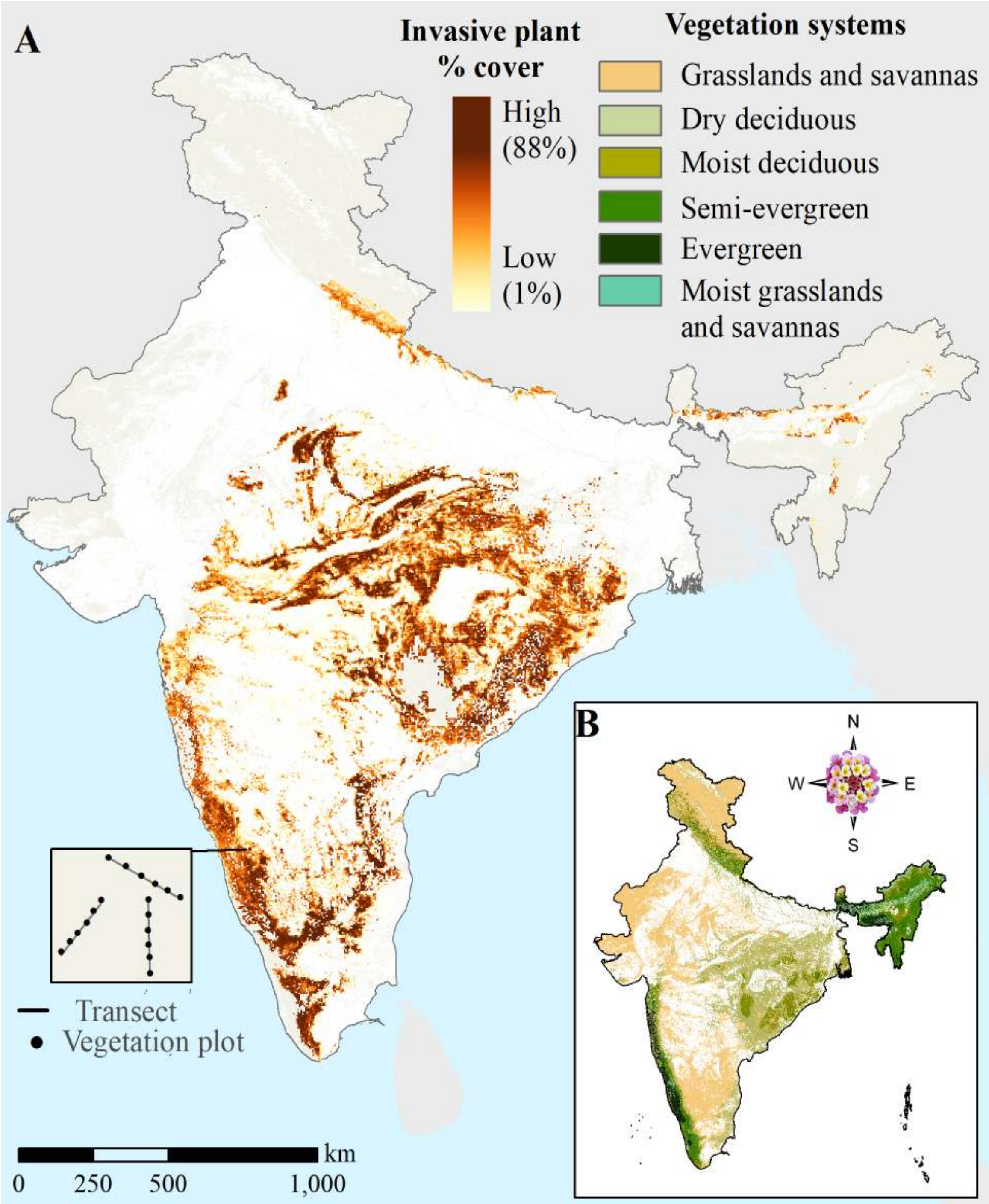


Figure III.2

Sampling coverage in India in 2018 and 2022 (A), where in every sampled grid (25 km^2), high-concern invasive plants were recorded using multiple plots. Every sampled grid is colored in a white to dark purple gradient representing increasing average invasion cover. This sampling covers diverse natural systems in India (B).

Environmental variables and exploratory analysis:

To address the effect of diverse socio-ecological settings that determine the occurrence of invasive plants across different forest systems in India, we used 24 environmental variables that would likely explain the varying occurrence of invasive plants based on ecological rationale (details in Table III.14). These predictors were derived from remote sensing products and global data compilations (e.g., climate data, livestock census) and represented ecological characteristics, climate, ecosystem attributes, disturbances, and human impacts. The variables were averaged on the grid scale. We conducted a Pearson's correlation test and included only those variables in a model that were insignificantly correlated. In cases where two variables were correlated, we selected the one within the pair that was ecologically more relevant. Species invasion cover was statistically compared with socio-environmental variables to explore ecological patterns. Instead of relying on parsimonious and simplistic models, we preferred developing ecologically informed models by using established ecological relationships (Table III.14).

Section III

Invasive plant distribution:

To estimate the distribution of invasive plants across natural systems, we used Maximum Entropy (MaxEnt) (Phillips *et al.*, 2006), one of the most widely used algorithms for distribution modeling. MaxEnt calibrates environmental variables from species presence locations and compares them with a set of random sample locations from the study area (the presence-background model). It uses this calibrated species-environment relationship to model potential suitability for the species. The most unconstrained model developed is considered the MaxEnt model. Being a presence-background model, the extent of the background environment substantially influences the model, which necessitates appropriate ecological criteria to define the background (Elith *et al.* 2011). Since we only consider natural areas, the model extent and background were restricted to natural areas of ecoregions occupied by species (Fig. III.2). Furthermore, background point density was conditioned on the sampling density (Phillips *et al.* 2009). For this, we sampled plot density within every 25 km^2 grid to generate a 2D kernel density surface. The number of background points was selected in proportion to this density surface and added along with species absence data recorded during sampling to obtain 10,000 background points per species. To address the inherent autocorrelation in species presence, presence locations were spatially thinned at a 1 km scale. Even though sampling was systematically distributed using a grid, the intensity of sampling plots in a grid may vary. To account for this variability, we used bias correction by including a sampling density map. MaxEnt uses this bias file to derive information on the representation of different covariates variability through sampling. For assessing the model outcomes, we divided the presence and pseudo-absence data for each species into training (80%) and testing (20%) sets for MaxEnt modeling and independent accuracy assessment, respectively. This was done using k-fold (k = 5) partitioning, where we used each k-partitioned set, for every species, as input data for MaxEnt.

We used the partitioned presence locations for each of the 11 species and developed the distribution model using varying combinations of linear, quadratic, hinge, and product features and 100 bootstrap simulations. The combination that yielded the highest True Skill Statistics

(TSS), an indicator of model performance (Allouche *et al.*, 2006), was considered the best model. To assess the TSS, we used the 20% test data retained initially and the absence data recorded during the ground sampling. This TSS also provides a primary indication for model accuracy. We performed Jackknifing simulations to estimate the contribution of different drivers to species suitability. The average Area Under the Receiver operating characteristic Curve (AUC) of the MaxEnt model was considered an additional criterion to assess the ability of MaxEnt to model invasive plant distribution. We used the logistic output of MaxEnt as it indexed relative species abundance (Phillips *et al.*, 2017). For every species, the results of all the k-partitioned models were averaged. MaxEnt produces probable suitability for every pixel that varies from 0 to 1. In the present study, all pixels greater than a threshold that yield the highest TSS were considered suitable.

Invasion rate and trajectory:

To understand the rate of invasion (i.e., increase in invasive plant cover) and its environmental drivers, we used those 25 km^2 grids that were consistently sampled since 2006. These grids covered around 250,000 km^2 of natural areas. We used these grids to form a multi-season occupancy matrix, where grids represented sampling units and plots represented sampling replicates. We modeled probabilities for yearly occupancy, colonization, and detections (there were insignificant extinction records for any species). We used the aforementioned environmental covariates for initial occupancy and colonization to make ecologically meaningful models for every species. Occupancy models using Maximum Likelihood were used in PRESENCE Ver. 13.46 (MacKenzie, 2006). A model with the lowest AICs was selected as the best explanatory model. The conditional occupancy estimates were used to derive modeled occupancy for every species for every year, and a linear model was fit to estimate the annual change in occupancy, i.e., the invasion trajectory. Similarly, a linear model was fitted to yearly occupancies for every grid cell to map spatial variability in invasion rate. We used the most significant covariates that explained invasion multi-season occupancies to highlight the relationship with invasion rates across all the species. These maps and relationships can assist in identifying vulnerable areas and drivers that result in increasing invasions.

Management prioritization:

We mapped plant invasion hotspots at a 25 km^2 scale using three variables: 1) average MaxEnt derived suitability of invasive plants 2) The number of invasive plants in a grid as a richness index 3) impact index of each invasive plant. For impacts, we used the published impact scores of these species (Mungi *et al.*, 2019) to index the threat posed by each species to native biodiversity, biophysical features, ecosystem services, and socio-economic aspects of recipient areas. These scores were consolidated to derive a relative impact index. We multiplied the average suitability and impact index and used it along with the richness index to derive Shannon's diversity, a model for hotspots of plant invasion impacts.

To assign spatial priority for managing invasions across different ecosystems, we considered four assumptions: 1) large proportions of native biodiversity mostly occur in protected areas, particularly in the tropical systems; 2) resources for managing invasive plants in terms of finances, techniques, trained capacity, and continuity are limited; 3) present conservation investments are prioritized for protected areas as they have higher conservation values due to a higher abundance of endangered species (Ghosh-Harihar *et al.*, 2019). Management in multi-used areas would be driven by regional social drivers (Howard & Pecl, 2019), which needs further studies. Hence, for multi-used areas, we provide information on the least invaded areas to inform further prioritization studies using socio-ecological criteria, whereas for protected areas, we provide a prioritization scheme.

We considered least invaded native ecosystems to have the highest conservation priority, as impacts from invasive species would be minimal and the investments in terms of monitoring and removing invasive plants in their early stages would be minimal (Mathur *et al.* 2015). For prioritizing, we used software Zonation ver. 4.0 (Moilanen *et al*. 2014) that uses an iterative cell-removal algorithm, wherein it first retains all areas and then removes those areas that cause an insignificant loss in the overall intact value. We used two datasets for assigning priority: the average cover of invasive plants recorded during sampling and a modeled invasion impact hotspot. We identified the largest area with the least invasion, i.e., 'intact' areas, in every protected area using the plant invasion cover. While doing so, we limited the inclusion of grids into the intact category only if the invasion cover was <50%. The largest contiguous patch of such intact grids was considered to have rank 1 priority. Subsequently, we identify rank 2 priority grids in proximity to the largest intact patch, including other such patches, where invasive plant removal can substantially increase the overall intactness of the native ecosystem in the protected area. Zonation iterates sites surrounding an intact patch and provides further priority values following the principles of cellular automata. This was considering the experience of managing invasive plants in India, where managed areas are often reinvaded due to colonization of invasive plants from proximal sources, and phased enlargement of managed areas can reduce reinvasions and reinforce restoration (Ramaswami *et al.* 2014). The remaining pervasively invaded patches were assigned rank 3 priority, as they would require maximum investments and modification of natural conditions, with uncertain and complex outcomes. We iterated Zonation settings for Boundary Length Penalty and Warp Factor to derive optimal values using visual assessment for spatial reliability. The model will capacitate stakeholders to systematically restore systems through long-term planning.

Results

Invasive plant distribution:

In total, 53% plots recorded at least one high-concern invasive plant, effectively invading 254,880 km^2 (72%) sampled areas at varying densities (Fig. III.2A). Exploratory analyses revealed differential relationships between average invasion cover and environmental covariates (Fig. III.3), suggesting reliable evidence for inferring increase in invasion with temperature up to a threshold and decline thereafter; decline with increasing rainfall; increase with seasonal vegetation opening and human modification index.

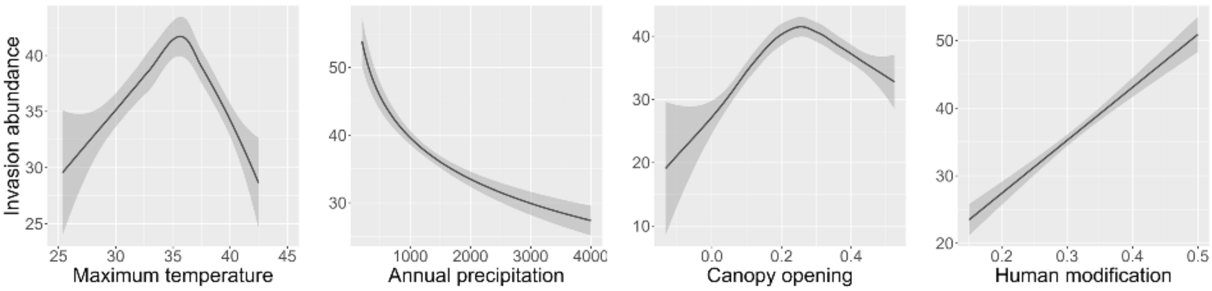


Figure III.3

Relationship between cover (%) of high-concern invasive plants and maximum temperature (^{0}C), annual precipitation (mm), seasonal change in vegetation cover - canopy opening (index), and human modification (index). Background color represents sample distribution.

A total of 750,905 km^2 of natural areas (65%) were found suitable for invasion by the high-concern invasive plants by MaxEnt models. MaxEnt model accuracies ranged between 0.2-0.69 TSS and 62–90% AUC across invasive plants. Savannas were the most invaded (87%) followed by moist grasslands and dry deciduous forests (72% each), while evergreen forests were relatively less invaded (42%) (Table III.2). The suitability of individual invasive plants and their drivers differed for every species (Fig. III.4). *Lantana camara* had the largest expanse (574,186 km^2, i.e., 50% of natural areas) and occurred across all natural systems, while *Mikania micrantha* had a relatively restricted expanse (148,286 km^2, i.e., 13% of natural areas), predominantly in moist grasslands and forests (Table III.2, Fig. III.4). Most species have an eco-climatic affinity. For example, 94% of *Prosopis juliflora* invasions coincided with dry grassland savannas and dry deciduous forests (Table III.2). Species like *Senna tora, Xanthium strumarium*, and *Mesosphaerum suaveolens* were predominant in dry savannas and deciduous forests, whereas *Mikania micrantha* and *Ageratina adenophora* were distributed in moist grasslands and evergreen forests. Amongst invasion drivers, climatic variables like thresholds of maximum temperature in the warmest month (contribution range: 36–59%) had the highest contribution, followed by a lower proportion of trees (5–13%), a higher human modification index (1–12%), a higher seasonal opening of canopy density (2–18%), proximity to water sources (1–18%), and thresholds of soil pH (1–19%). The directionality of effects was consistent for a few drivers (e.g., proximity to a fire or water source), while it differed for others. Details on the distribution, drivers, and maps of high-concern invasive plants are provided in the invasive species report.

Invasion rate and trajectory: Within the consistently sampled grid across the region, invasive plants were found to be consistently increasing (Fig. III.5). This rate of invasion trajectory and its magnitude varied across species, where *Chromolaena odorata* had the highest rate of invasion (around 2000 km^2/year), while *Parthenium hysterophorous* had the lowest invasion rate (the only negative rate, although insignificant). On average, invasive plants increased at an average rate of 729 km^2/year (SE 155). Among the areas with the highest invasion rates were the multi-use areas of the Central Highlands, Nilgiri Hills, Western Terai, and semi-arid savannas of Central India and the Deccan Peninsula. Notably, the transition zone between grassy open ecosystems and forest systems had the highest invasion rates.

While initial occupancy was significantly determined by niche availability for the species (climate and soil characteristics), subsequent colonization was driven by proximity to invaded areas, niche suitability, human modification index, increased site water balance, increased summer temperature, and increased agricultural areas (Fig. III.6). The most important driver was proximity to invaded areas, suggesting that once invasive species occur in an area, their further expansion is mostly unabated. The colonization was facilitated by human disturbance and changing climatic scenarios (increased water and temperature). The map of the rate of invasion for every species is provided in the species details section.

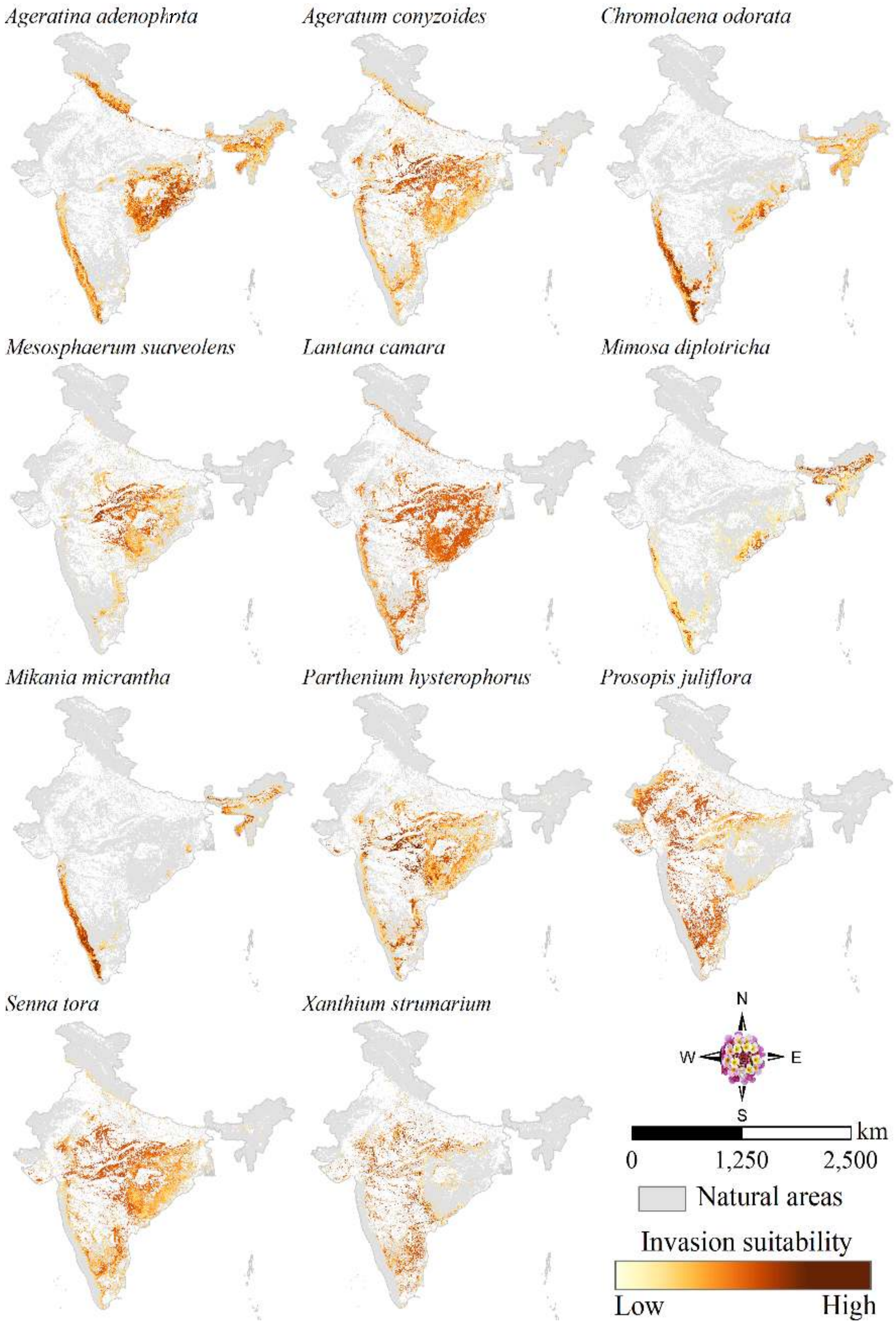


Figure III.4

Environmental suitability of high concern invasive plants in India at 1 km scale, modelled using large-scale intensive sampling.

Table III.2

Area (km^2) invaded by high concern invasive plants in India and suitable for invasions across different ecoregions (S: savannas, DDF: dry deciduous forests, MDF: moist deciduous forests, SEF: semi-evergreen forests, EF: evergreen forests, MG: moist grasslands, Total: total suitable area)

Species	Recorded invasion (% sampled area)	Suitable areas for invasion						
		S	DDF	MDF	SEF	EF	MG	Total area (%)
Ageratina adenophora	87,762 (25%)	2,664	23,144	139,801	87,838	22,830	20,881	297,158 (26%)
Ageratum conyzoides	58,036 (17%)	44,264	124,336	79,371	22,161	1,093	19,470	290,695 (25%)
Chromolaena odorata	43,287 (12%)	28,167	94,229	88,383	30,588	4,745	10,341	256,453 (22%)
Mesosphaerum suaveolens	48,110 (14%)	79,528	130,903	16,008	7,663	621	4,319	239,042 (21%)
Lantana camara	140,966 (40%)	157,534	216,422	100,074	67,561	12,938	19,657	574,186 (50%)
Mimosa diplotricha	23,870 (7%)	27,445	48,973	54,054	10,207	1,098	18,475	160,252 (14%)
Mikania micrantha	31,246 (9%)	3,516	5,839	46,547	55,343	16,061	21,980	148,286 (13%)
Parthenium hysterophorous	42,492 (12%)	70,563	92,908	60,317	33,091	285	17,353	274,517 (24%)
Prosopis juliflora	97,008 (28%)	190,433	196,975	23,860	449	0	1,022	412,739 (36%)
Senna tora	119,256 (33%)	200,892	240,489	99,300	7,637	1,311	10,677	560,306 (48%)
Xanthium strumarium	69,256 (20%)	174,580	46,865	11,793	227	0	662	234,127 (20%)
% area invaded	71%	87%	73%	51%	48%	42%	72%	66%

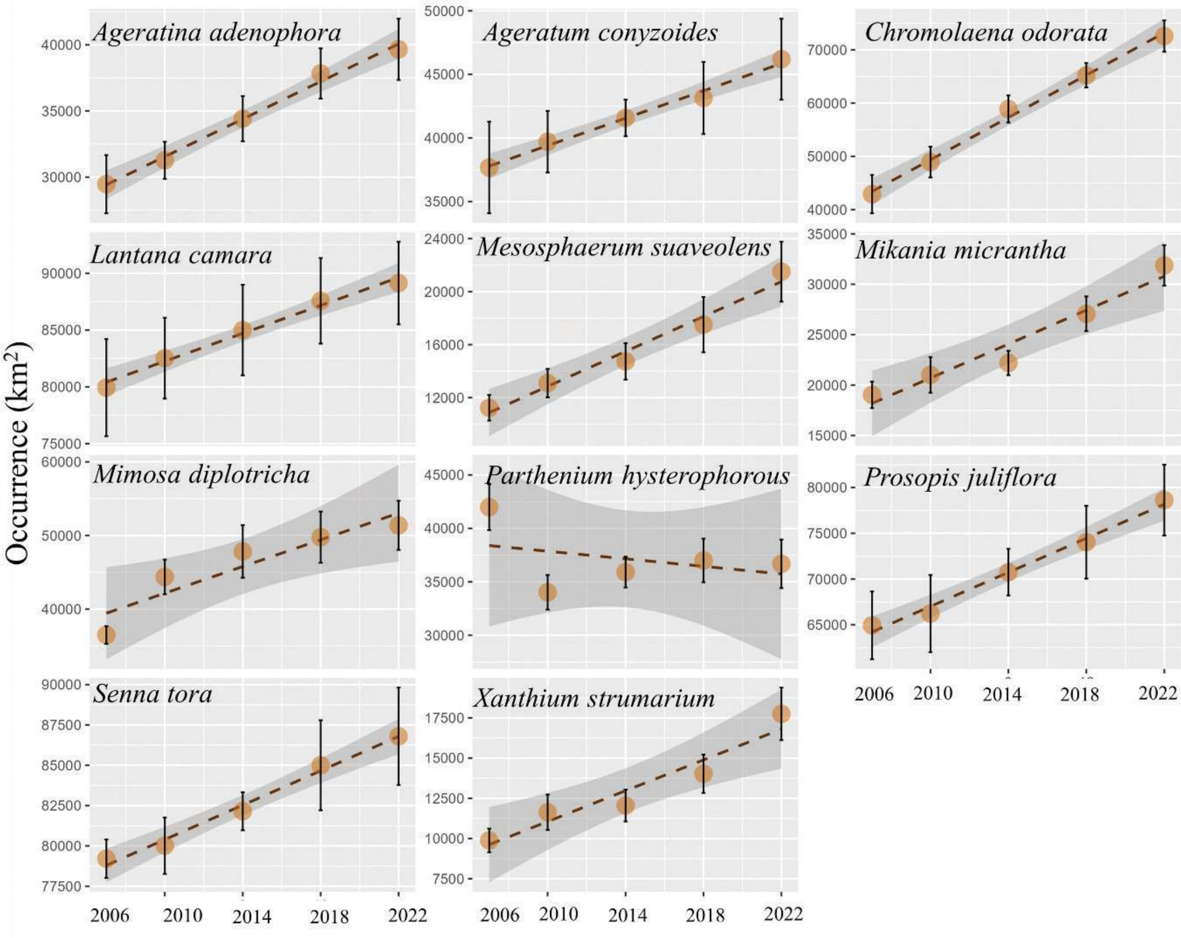


Figure III.5

Invasion trajectory (change in occurrence area) of high-concern invasive plants in India from 2006 to 2022 shows consistent increase in invaded areas by all species across the years.

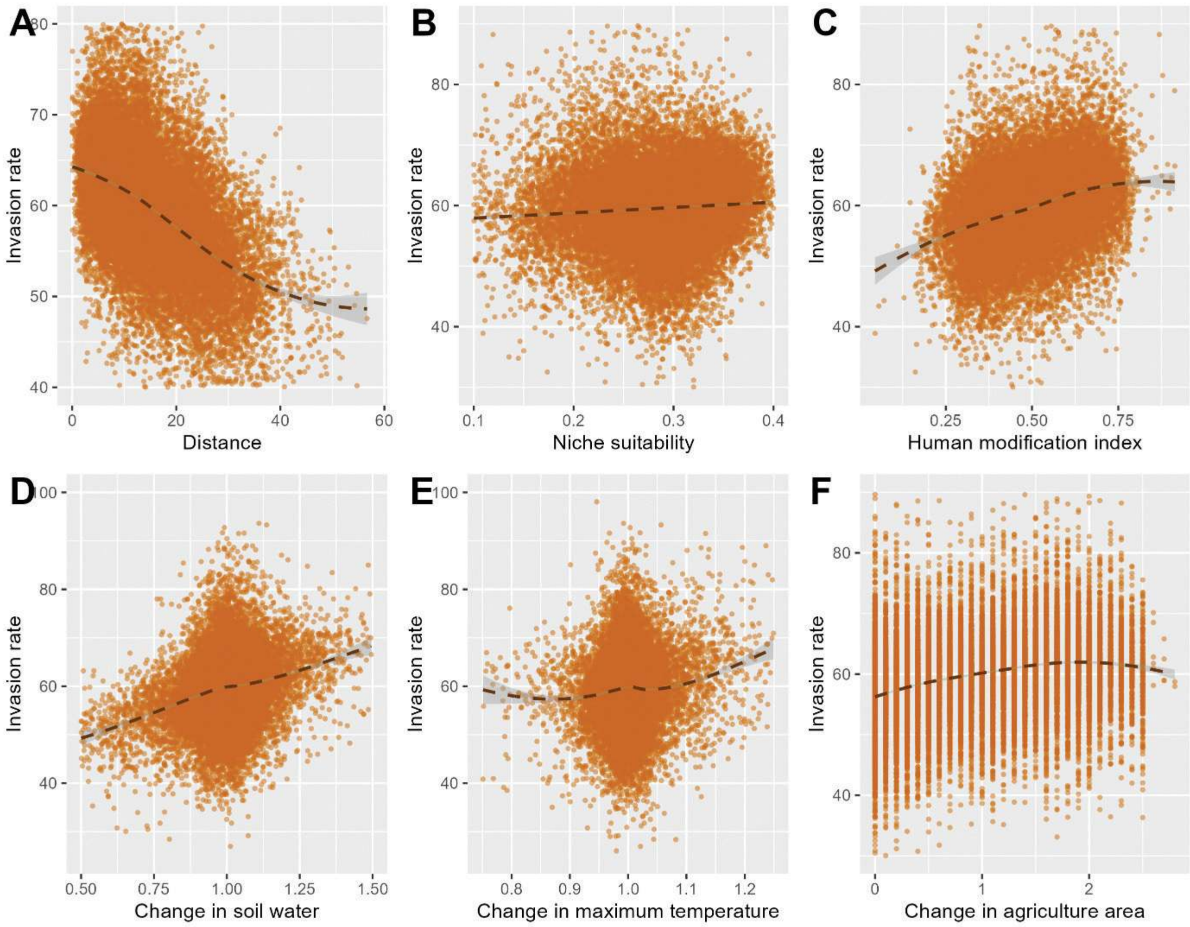


Figure III.6

Drivers of increasing invasions. Invasion rate i.e., change in area invaded by invasive plants increased with proximity to invaded sites (km) (A), niche suitability (B), human modification index (C), annual rate of change in site water balance (kg/m^2/year) (D), change in maximum temperature (^{0}C) (E), and annual rate of change in agriculture area (km^2) (F).

Management prioritization:

The invasion hotspot map depicts most natural systems as potentially invaded and impacted by high-concern invasive plants at varying magnitudes (Fig. III.7). Nilgiri Biosphere Reserve was one of the largest invasion impact hotspots by area, predominantly invaded by *Lantana camara*, *Prosopis juliflora,* and *Chromolaena odorata*. The Southern Eastern Ghats were among the most densely invaded landscapes, predominately by *Prosopis juliflora* and *Lantana camara*. Fragmented forests of the Central Indian highlands were also largely and densely invaded forest systems, typically around ecoclines of dry and moist systems. Savannas were largely invaded by woody plants, particularly surrounding protected areas (Fig. III.7).

The least suitable native systems for invasions were distributed at climatic limits like the desert in western India, the wet evergreen forest of northeastern India and the Western Ghats. The least human-modified areas in Central India were relatively less invaded (Fig. III.7). In total, 262,189 km^2 of multi-used areas were found to be relatively least invaded, which can be further prioritized for restoration of natural systems (Fig. III.7). Within protected areas, 25,220 km^2 of least invaded natural systems (2% of natural areas) were identified as rank 1 priorities, followed by 26,349 km^2 of invaded areas (2.5% of natural areas) as rank 2 priorities (Fig. III.7). The remaining 70,963 km^2 of protected areas were largely invaded and identified as rank 3 priorities (6.5% of natural areas). These priority areas in total constitute only 16% (122,532 km^2) of the invaded expanse and represent the minimum areas that can be restored at first. The largest priority sites were the tiger reserve core and national parks. Priority grids and invasion suitability are provided in MSTrIPES Desktop for management use.

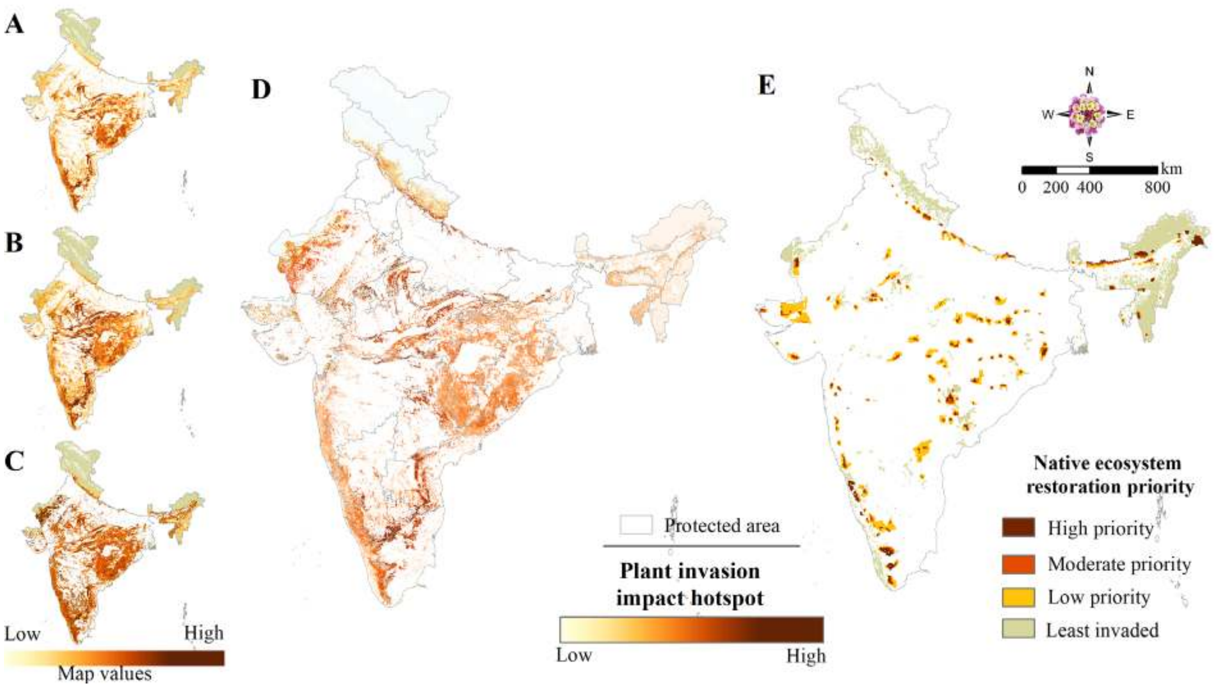


Figure III.7

A) Distribution of high concern invasive plants, modelled using MaxEnt. B) Invasion richness. C) impact index of invasive plants. D) Plant invasion hotspots across India derived using A, B and C. E) Least invaded and priority areas identified using Zonation for invasive plant management and restoration.

Distribution and drivers of high-concern invasive plants

Ageratina adenophora

Figure III.8

A typical understory invasion of *Ageratina adenophora* in moist forests

An herbaceous plant with a slender stem, often recorded in the moist forests of the lower and mid Himalaya (e.g., Rajaji, Corbett), Terai (e.g., Dudhwa, Valmiki), central moist deciduous forest (e.g., Similipal, Satkosia), Northeastern hills (e.g., Manas, Pakke), and Western Ghats (e.g., Periyar, Parambikulam) (Fig. III.8). Within these forests, it was observed around water channels, the edges of the woodlands, high abundance along the roadside, grazing pastures, and burnt forests.

Ageratina adenophora was recorded in 87,762 km^2 of natural areas and was observed spreading at a rate of around 700 km^2/year. Spatially independent species presence at 7914 sites was used to model its potential distribution. The best MaxEnt model had reliable accuracy (TSS: 0.67; AUC: 0.7 ± 0.001) and projected invasion suitability in 373,158 km^2 of natural areas (Fig. III.10). The bootstrapped contribution of all predictors is provided in Table III.S3. Species distribution increased with annual rainfall and human modification of an area (Fig. III.9). It was distributed in relatively colder areas (summer temperatures of 20° C to 40° C), which were burned or along water sources. It preferred soils from less acidic to neutral pH (5 to 7) and decreased with high alkaline soils. Its distribution increased in forests with seasonal canopy openings but occurred less in completely open areas (Fig. III.9).

Table III.3

Covariates of the *Ageratina adenophora* distribution and their percent contribution to the suitability model. Values in parenthesis are standard deviation.

Covariates	Percent contribution (%)
Annual precipitation	50.01 (±1.48)
Seasonal canopy openness	17.35 (±1.46)
Human modification index	12.2 (±0.99)
Maximum temperature of warmest month	7.03 (±0.91)
Distance from fire	4.24 (±0.62)
Distance from water	3.55 (±0.35)
Soil pH	2.78 (±0.54)
Long-term vegetation browning	1.49 (±0.24)
Soil organic carbon	1.38 (±0.31)

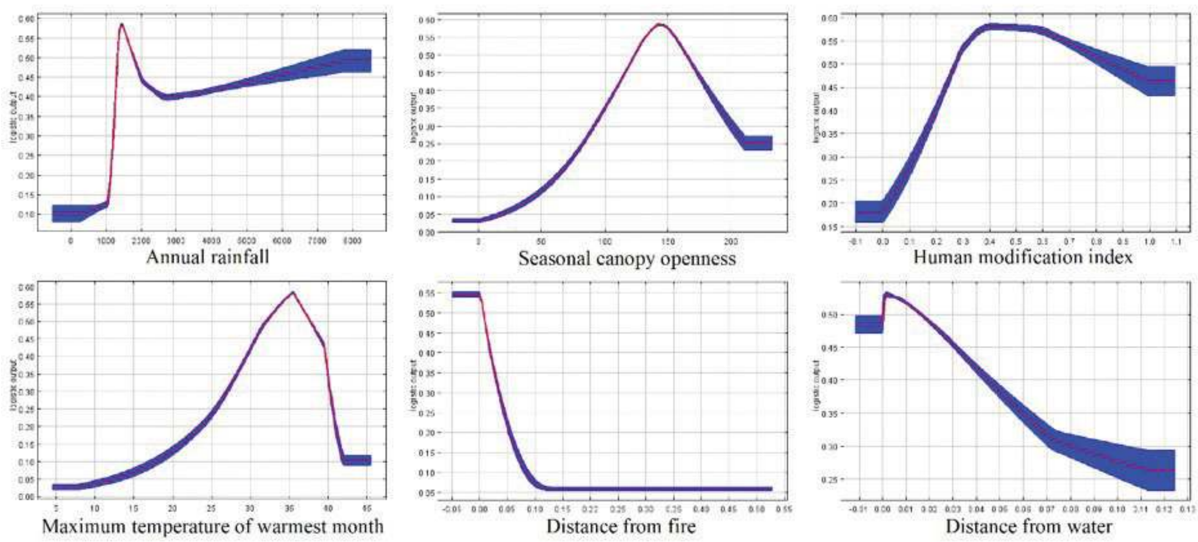


Figure III.9

Relationship between *Ageratina adenophora* and environmental covariates that jointly explained >80% of its distribution. X axes are the range of covariates, and Y axes are the logistic probabilities of the suitability model.

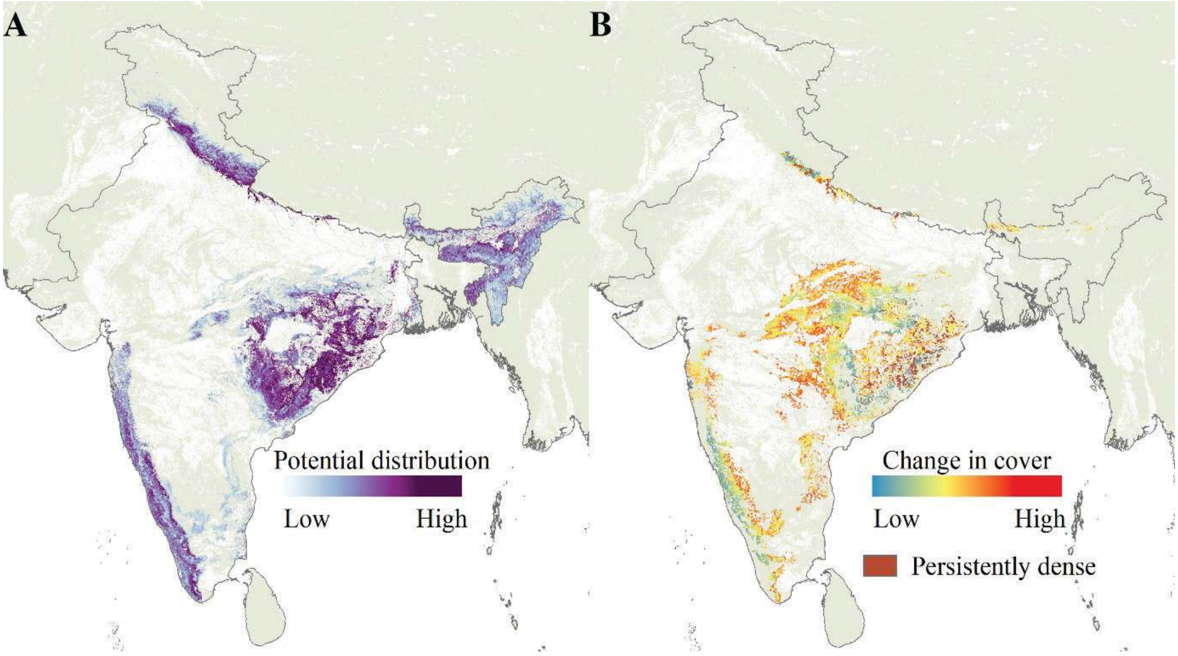


Figure III.10

Potential distribution (A) and rate of invasion (B) of *Ageratina adenophora* in India.

Management implications:

Ageratina adenophora occurred in priority management areas in Corbett, Valmiki, Anamalai, and other Tiger Reserves with high cover of moist deciduous, semi-evergreen, and evergreen forests. It should be systematically managed with priority at these sites (Fig. III.7). Its invasion in a few other protected areas is potentially in the initial stage and should be a high priority for removal before it establishes itself in a larger area. Example: Satpuda, Kanha, Navegaon-Nagzira, Dampa, Namdapha, Nameri, etc.

Ageratum conyzoides

Figure III.11

A typical invasion of *Ageratum conyzoides* along human settlements

An erect herb observed in the grasslands, ridges, floodplains, and open forests of the lower Himalaya (e.g., Rajaji, Corbett), Terai (e.g., Dudhwa, Pilibhit), central moist forest (e.g., Kanha, Satpura), Northeastern hills (e.g., Manas, Kaziranga), and Western Ghats (e.g., Mudumalai, Bandipur). Within these forests, this species occurred abundantly in those open habitats that had higher moisture and were frequently burned, grazed, or modified by humans.

Spatially independent presence of *Ageratum conyzoides* from 8664 sites was used to model its potential distribution. It was recorded in 58,036 km^2 of natural areas and was observed invading at a rate of 530 km^2/year. The best MaxEnt model had reliable accuracy (TSS: 0.6; AUC: 0.71 ± 0.001) and projected invasion suitability for 260,695 km^2 of natural areas (Fig. III.13). The bootstrapped contribution of all predictors is provided in Table III.4. Species distribution increased with the maximum temperature of the warmest month until 40° C and declined thereafter (Fig. III.12). Within these regions, it increased in areas where the minimum temperature of the soil remains cold to mildly warm (5°C to 20°C) in the coldest month. This likely indicates that an increased duration of frost in winter might restrict species invasion. However, its presence increased with areas being burned or with high human modifications. Within forested areas, its distribution increased with seasonal canopy openings, indicating its preference for open areas. It increased with increasing soil pH, with a preference for alkaline soils (Fig. III.12).

Table III.4

Covariates of the *Ageratum conyzoides* distribution and their percentage contribution to the suitability model. Values in parenthesis are standard deviation.

Covariates	Percent contribution (%)
Maximum temperature of warmest month	31.91 (±1.93)
Soil minimum temperature of coldest month	14.61 (±1.39)
Seasonal canopy openness	10.02 (±1.59)
Soil pH	8.95 (±2.3)
Distance from fire	6.67 (±1.6)
Proportion of tree cover	5.91 (±1.39)
Livestock density	4.91 (±0.49)
Human modification index	4.47 (±0.85)
Long-term vegetation browning	3.11 (±0.41)
Soil water content	1.14 (±0.27)
Soil organic carbon	0.54 (±0.14)

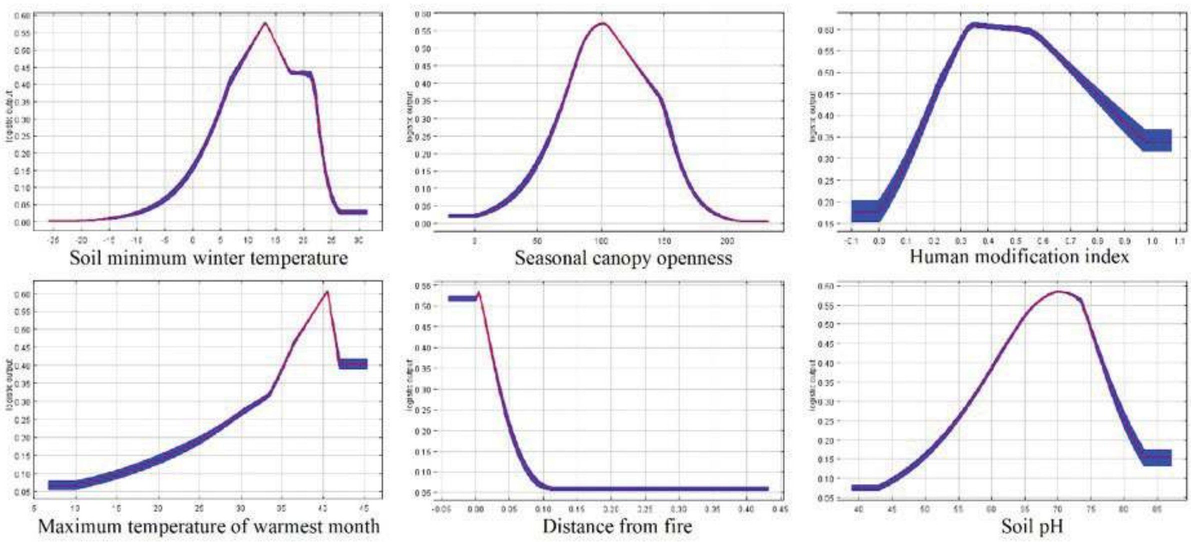


Figure III.12

Relationship between *Ageratum conyzoides* and environmental covariates that jointly explained >80% of its distribution. X axes are the range of covariates, and Y axes are the logistic probabilities of the suitability model.

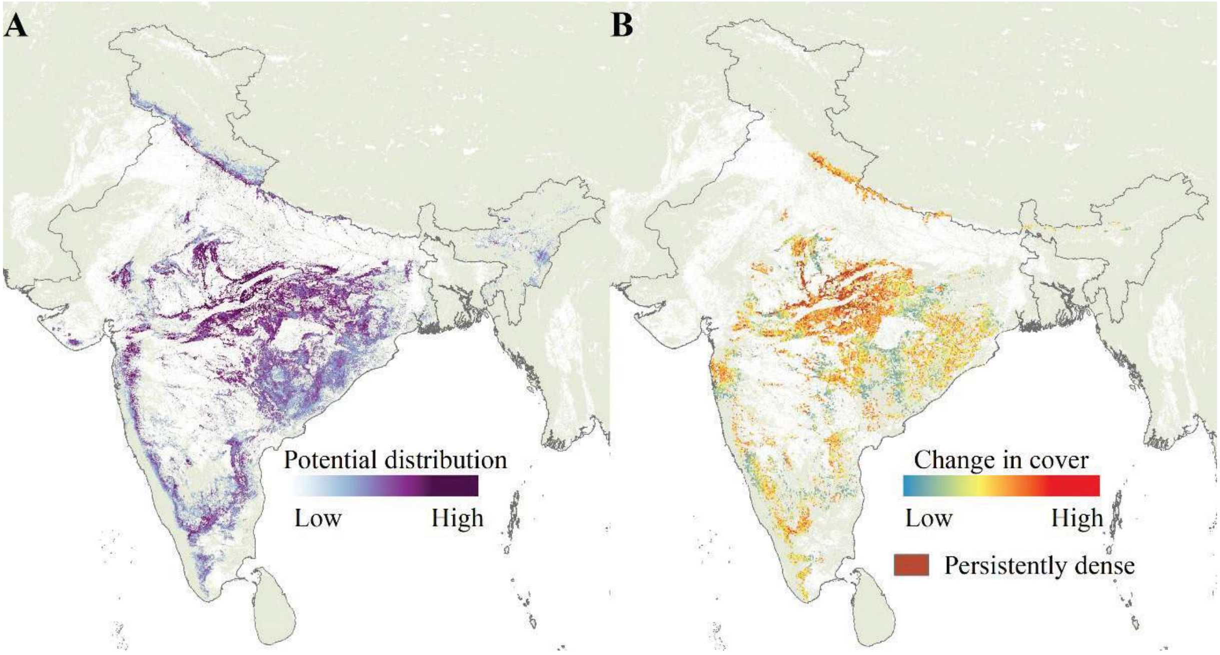


Figure III.13

Potential distribution (A) and rate of invasion (B) of *Ageratum conyzoides* in India.

Management implications:

Ageratum conyzoides occurred in priority management areas in Corbett, Dudhwa, Valmiki, Similipal, Palamau, Satpuda, Achanakamar, and other tiger reserves, as well as other protected areas like Gir, Kuno, Gandhi Sagar, and others with ecotones of dry deciduous and moist deciduous forests and moist open ecosystems. It should be systematically managed with priority at these sites (Fig. III.7). Its invasion in a few other protected areas is potentially in the initial stage and should be a high priority for removal before it establishes itself in a larger area. Example: Sahyadri, Bhadra, Dampa, Namdapha, Nameri, Anamalai, Periyar, etc.

Chromolaena odorata

Figure III.14

A typical plant of invasive *Chromolaena odorata*

This tall herb with broad leaves profusely invaded wet and deciduous forests in India, with high occurrence in the Northeastern hills (e.g., Pakke, Manas) and Western Ghats (e.g., Mudumalai, Bhadra), but also in moist parts of deciduous forests in central India (e.g., Satpuda, Satkosia). Within these forests, it occurred inside the woodlands as well as along the grasslands, with high abundance in open ecosystems, human settlements, roads, and burnt areas. Its distribution matched the ecotone of open ecosystems and deciduous forests in peninsular and Northeast India (Fig. III.16).

Spatially independent presence of *Chromolaena odorata* from 3321 sites was used to model its potential distribution. It was recorded in 43,287 km^2 of natural areas and was observed spreading at a rate of around 2000 km^2/year, becoming the largest spreading invasion in the last 16 years. The best MaxEnt model had reliable accuracy (TSS: 0.68; AUC: 0.79 ± 0.002) and projected invasion suitability in 248,453 km^2 of natural areas (Fig. III.16). The bootstrapped contribution of all predictors is provided in Table III.5. Species preferred areas with mild to warm summer temperatures (16°C to 40°C) (Fig. III.15). It increased in areas where the minimum temperature of the soil remains warm in the winter (10°C to 25°C), i.e., areas with minimal winter frost. Within forested areas, its distribution increased with seasonal canopy openings and long-term vegetation browning, indicating its preference for seasonally open forests that are degrading. *Chromolaena odorata* increased along the water source and with high human modifications. It preferred acidic soils (Fig. III.15).

Table III.5

Covariates of the *Chromolaena odorata* distribution and their percent contribution to the suitability model. Values in parenthesis are standard deviation.

Covariates	Percent contribution (%)
Maximum temperature of warmest month	53.2 (±1.35)
Soil minimum temperature of coldest month	26.22 (±1.34)
Human modification index	9.08 (±1.1)
Seasonal canopy openness	4.15 (±0.8)
Annual precipitation	3.33 (±0.44)
Soil pH	1.8 (±0.85)
Distance from water	1.49 (±0.35)
Distance from fire	0.67 (±0.21)
Long-term vegetation browning	0.08 (±0.08)
Soil organic carbon	0.05 (±0.06)

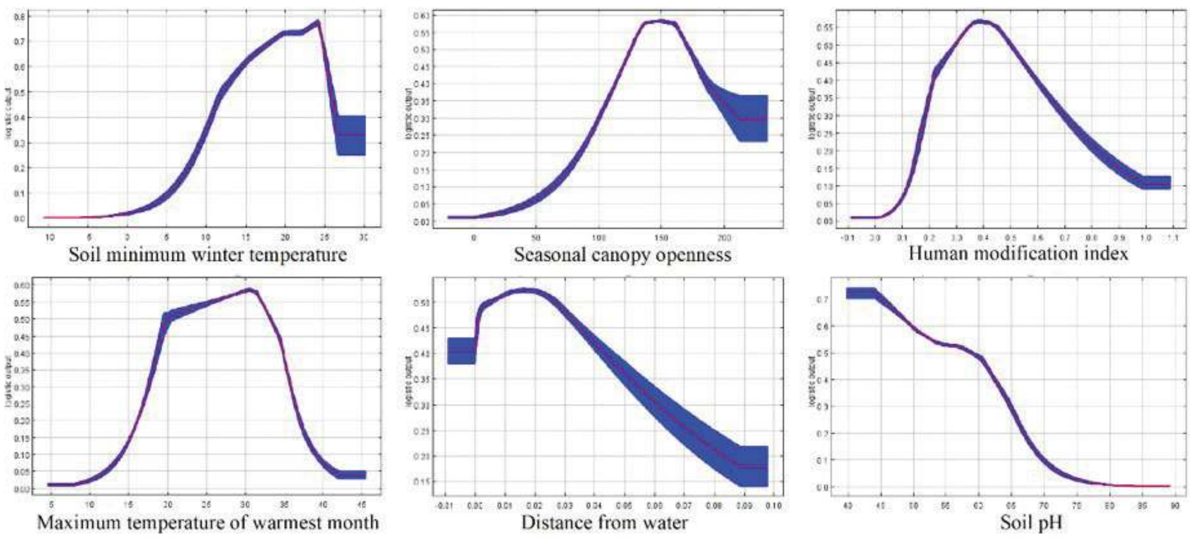


Figure III.15

Relationship between *Chromolaena odorata* and environmental covariates that jointly explained >80% of its distribution. X axes are the range of covariates, and Y axes are the logistic probabilities of the suitability model.

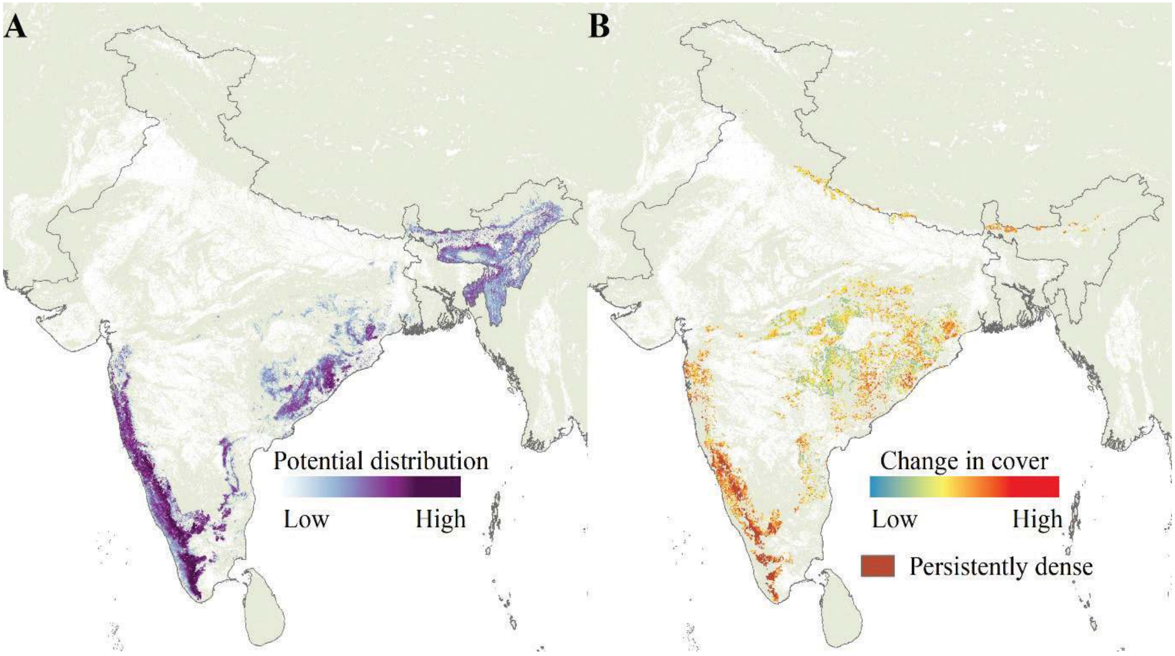


Figure III.16

Potential distribution (A) and rate of invasion (B) of *Chromolaena odorata* in India.

Management implications:

Chromolaena odorata occurred in priority management areas in Valmiki, Manas, Kaziranga, Similipal, Anamalai, Mudumalai, Nagarhole, Bhadra, Anshi Dandeli, Sahyadri, and other protected areas with a mosaic of open ecosystems and deciduous forests. It should be systematically managed with priority at these sites (Fig. III.7). Findings from experiments in Manas Tiger Reserve (Sinha *et al.*, 2022) could be utilized for planning its control across its invasion range. Its invasion in a few other protected areas is potentially in the initial stage and should be a high priority for removal before it establishes itself in a larger area. Example: Dudhwa, Corbett, Dampa, Namdapha, Nameri, Kanha, Satpuda, Melghat, Navegaon Nagzira, Kudremukh, Indravati, etc.

Mesosphaerum suaveolens

Figure III.19

A typical plant of *Mesosphaerum suaveolens*

This herb was recorded mostly in the deciduous forests of Central India (e.g., Melghat, Tadoba), drier parts of the Eastern Ghats (e.g., Amrabad), and in drier parts of Karnataka (e.g., Bandipur) and Tamil Nadu (e.g., Sathyamangalam). *Mesosphaerum suaveolens* was abundantly present on forest edges, roadside, nearby human habitation, water bodies, and rugged terrains. Secondary information indicate its invasion in dry areas of Punjab, Himachal Pradesh, Haryana, Gujarat, and West Bengal.

Spatially independent presence of *Mesosphaerum suaveolens* from 8861 sites was used to model its potential distribution. It was recorded in 48,110 km^2 of natural areas and was observed spreading at an average rate of around 650 km^2/year. The best MaxEnt model had reliable accuracy (TSS: 0.52; AUC: 0.74 ± 0.001) and projected invasion suitability in 235,042 km^2 of natural areas (Fig. III.19). The bootstrapped contribution of all predictors is provided in Table III.6. Species preferred areas with moderate aridity and warmer soil temperatures in the summer (35°C to 48°C) (Fig. III.18). Within this dry region, it increased with rainfall in the driest month, seasonal canopy openings, and long-term vegetation browning that indicate open forest degradation. *Mesosphaerum suaveolens* prefers neutral soil pH (5.5 to 8) (Fig. III.18). Its invasion was particularly high in and around teak (*Tectona grandis*) plantations in the Central Indian region and in areas that were used for livestock grazing.

Table III.6

Covariates of the *Mesosphaerum suaveolens* distribution and their percent contribution to the suitability model. Values in parenthesis are standard deviation.

Covariates	Percent contribution (%)
Soil maximum temperature of warmest month	41.1 (±1.21)
Precipitation of driest month	14.66 (±0.57)
Soil pH	11.33 (±1.19)
Seasonal canopy openness	10.79 (±0.65)
Aridity-humidity potential	9.16 (±0.85)
Human modification index	5.91 (±0.64)
Long-term vegetation browning	3.91 (±0.41)
Livestock density	1.61 (±0.29)
Distance from fire	0.93 (±0.69)
Soil water content	0.64 (±0.16)

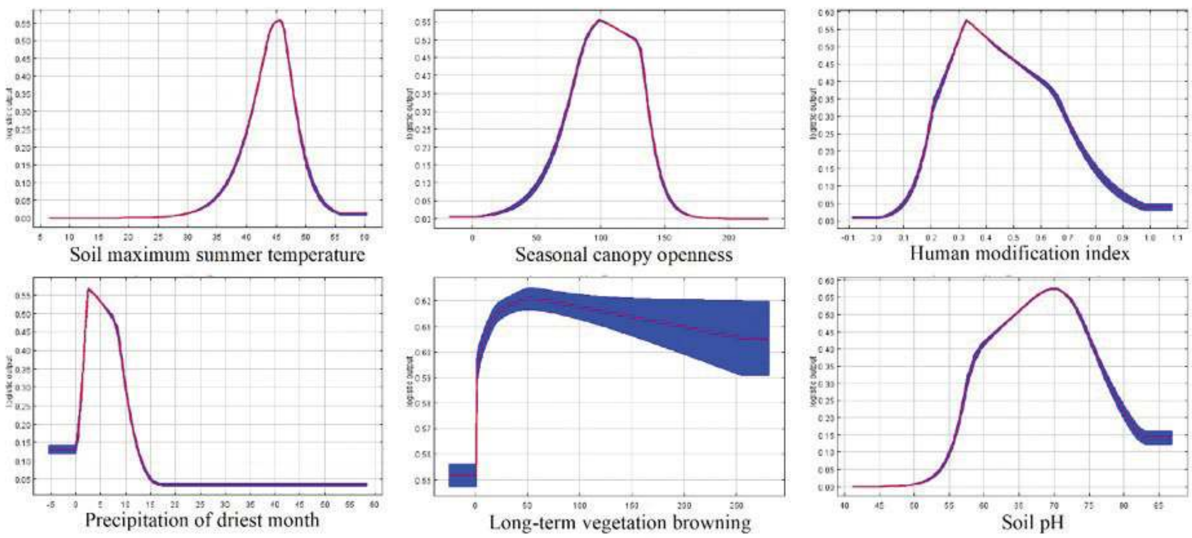


Figure III.18

Relationship between *Mesosphaerum suaveolens* and environmental covariates that jointly explained >80% of its distribution. X axes are the range of covariates, and Y axes are the logistic probabilities of the suitability model.

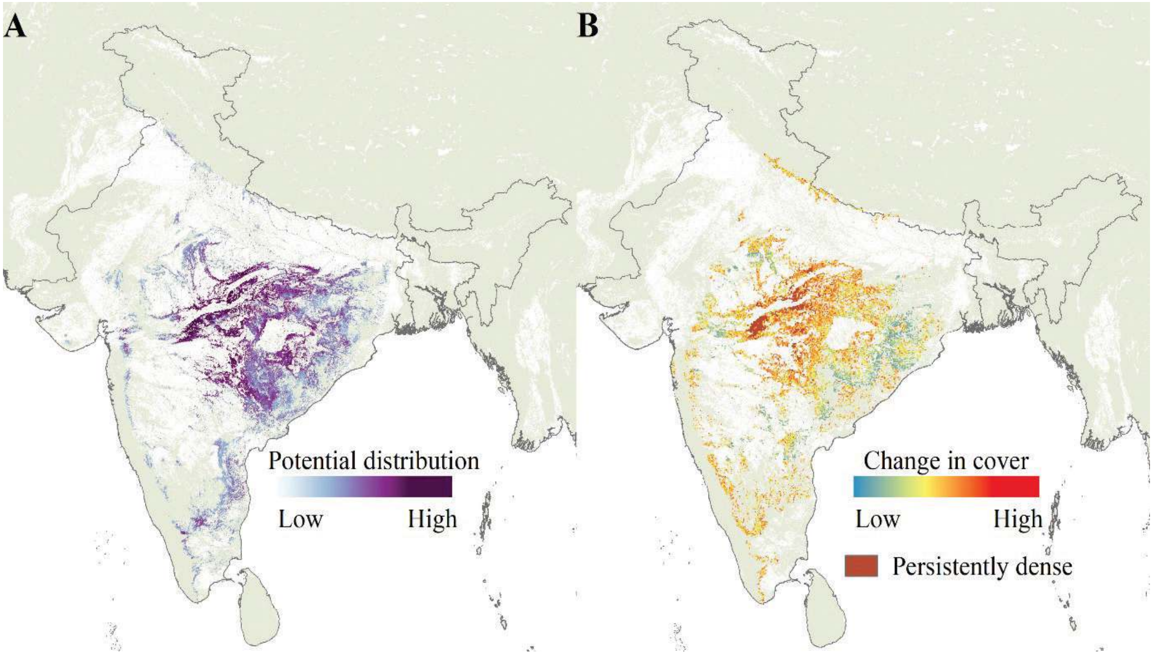


Figure III.19

Potential distribution (A) and rate of invasion (B) of *Mesosphaerum suaveolens* in India.

Management implications:

Mesosphaerum suaveolens occurred in priority management areas in Tadoba, Pench, Melghat, Bandhavgarh, Panna, Sanjay, Kaimur, Barnavapara, Amrabad, Sathyamangalam, and other protected areas with a mosaic of dry savannas and deciduous forests. It should be systematically managed with priority at these sites (Fig. III.7). Its invasion in a few other protected areas is potentially in the initial stage and should be a high priority for removal before it establishes itself in a larger area. Example: Gir, Rajaji, Kanha, Gandhi Sagar, Sahyadri, Indravati, Bhadra, Kalakad Mundanthurai, etc.

Lantana camara

Figure III.20

A typical plant of invasive *Lantana camara*

This woody shrub was sighted in all forest systems, excluding a few wet evergreen forests in the Northeastern hills and Western Ghats and dry grasslands in Western India (Fig. III.22). The highest invasions were recorded in the Central Indian highlands, seasonally dry forests of the Western Ghats and lower Eastern Ghats, open forest systems of the Shivalik Hills, and fragmented areas of moist and wet forests. Within its range, high densities of native trees, low human pressure, and the avoidance of fire were associated with its absence. Its spread was highest in Indian forests as compared to other high-concern invasive plants.

Spatially independent presence of *Lantana camara* from 18337 sites was used to model its potential distribution. It was recorded in 140,966 km^2 of natural areas and was observed spreading at an average rate of around 610 km^2/year. The best MaxEnt model had reliable accuracy (TSS: 0.36; AUC: 0.62 ± 0.001) and projected invasion suitability in 491,886 km^2 of natural areas (Fig. III.22). The bootstrapped contribution of all predictors is provided in Table III.7. Species prefer warm and humid areas with warmer summer soil temperatures (28° C to 50° C) (Fig. III.21). Within this broad region, it increased with seasonal canopy openings, proximity to fire, proximity to water sources, and human modifications of the area. *Lantana camara* preferred a wide range of soil pH (4.5 to 8.5) and increased with shrub cover and tree cover; however, it declined with very high tree cover (Fig. III.21).

Table III.7

Covariates of the *Lantana camara* distribution and their percent contribution to the suitability model. Values in parenthesis are standard deviation.

Covariates	Percent contribution (%)
Soil maximum temperature of warmest month	67.59 (±0.61)
Proportion of tree cover	7.18 (±0.64)
Precipitation of driest month	5.91 (±0.41)
Human modification index	4.55 (±0.37)
Distance from fire	4.38 (±0.48)
Aridity-humidity potential	2.61 (±0.38)
Proportion of shrub cover	2.39 (±0.22)
Seasonal canopy openness	2.36 (±0.23)
Soil water content	2.31 (±0.24)
Soil pH	0.76 (±0.18)

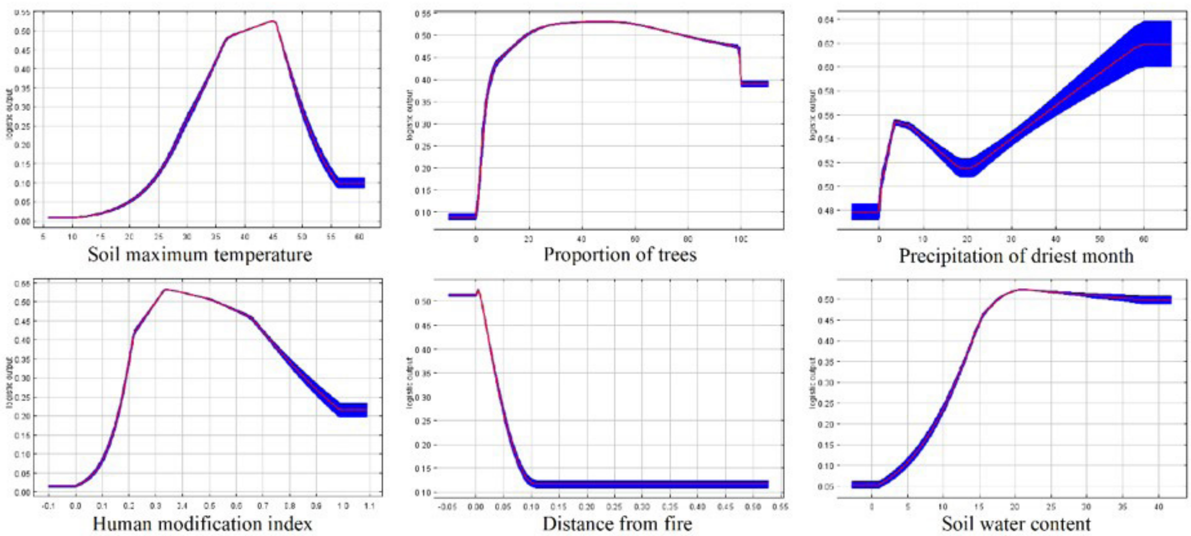


Figure III.21

Relationship between *Lantana camara* and environmental covariates that jointly explained >80% of its distribution. X axes are the range of covariates, and Y axes are the logistic probabilities of the suitability model.

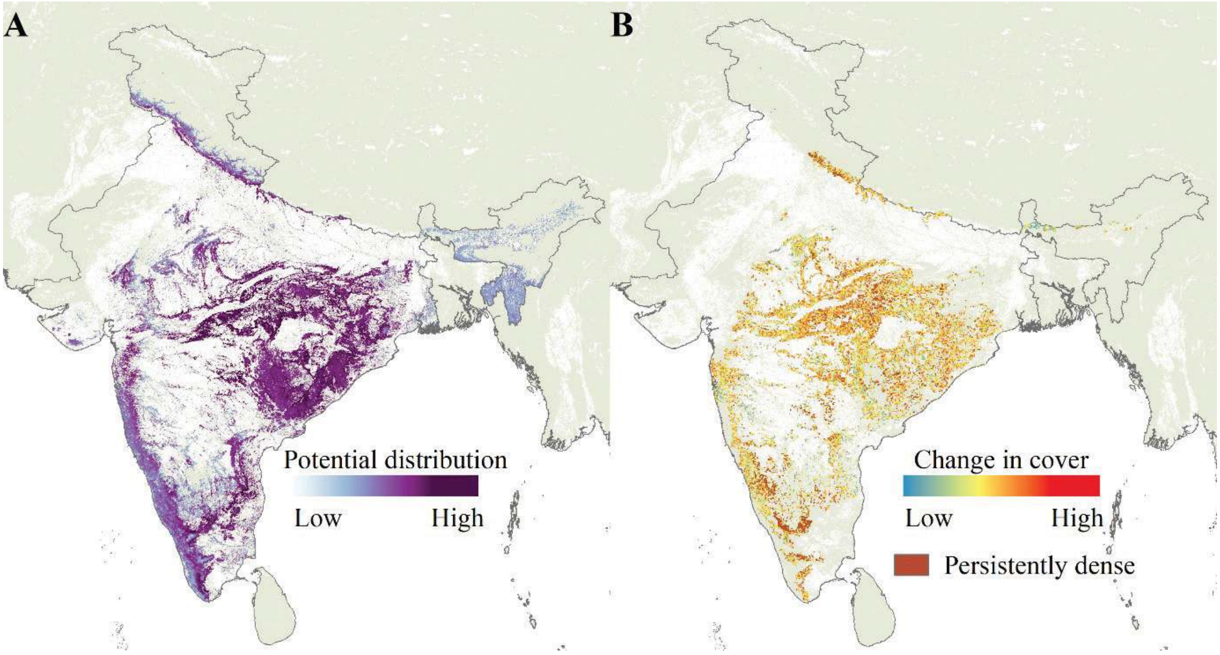


Figure III.22

Potential distribution (A) and rate of invasion (B) of *Lantana camara* in India.

Management implications:

Lantana camara occurred in priority management areas in all protected areas with deciduous forests. It should be systematically managed within the shown priority sites (Fig. III.7). Regional management experiments could be useful in upscaling control mechanisms (Babu *et al.* 2009). However, *Lantana camara* is known to adapt to changing ecological settings (Mungi *et al.* 2020), and hence independent management experiments are required for different ecosystems to identify the efficacy of varying interventions. Its invasion into a few protected areas is potentially in its initial stage and should be a high priority for removal before it establishes itself in a larger area. Example: Mukundara, Ranthambhore, Sahyadri, Kudremukh, Anshi Dandeli, Mukhurti, Similipal, Valmiki, Manas, Kaziranga, etc.

Mimosa diplotricha

Figure III.23

A typical invasion by invasive *Mimosa diplotricha*

This plant invaded the floodplains of the Brahmaputra River and the moist forest surrounding it (e.g., Kaziranga, Manas). Its presence was also recorded in the moist forests of Odisha (e.g., Similipal, Satkosia), Jharkhand (e.g., Palamau), Chhattisgarh (e.g., Barnavapara, Udanti Sitanadi), and the Western Ghats (e.g., Nagarahole, Sahyadri). Its presence coincided with grasslands, waterlogged areas, frequently burned and human-modified habitats, as well as forest along linear infrastructure.

Spatially independent presence of *Mimosa diplotricha* from 959 sites was used to model its potential distribution. It was recorded in 23,870 km^2 of natural areas and was observed spreading at an average rate of around 900 km^2/year. The best MaxEnt model had reliable accuracy (TSS: 0.69; AUC: 0.89 ± 0.004) and projected invasion suitability in 163,252 km^2 of natural areas (Fig.III.25). The bootstrapped contribution of all predictors is provided in Table III.S10. Species preferred specific areas with moderate potential evapotranspiration where the minimum winter temperature of the soil remains mildly warm (12°C to 25°C) (Fig. III.24). Within this region, it increased with seasonal canopy openings, proximity to fire, proximity to water sources, and human modifications of the area. *Mimosa diplotricha* prefers acidic to neutral soil pH (4.5 to 8.5) (Fig. III.24).

Table III.8

Covariates of the *Mimosa diplotricha* distribution and their percent contribution to the suitability model. Values in parenthesis are standard deviation.

Covariates	Percent contribution (%)
Potential evapotranspiration	29.26 (±4.39)
Soil minimum temperature of coldest month	26.81 (±1.43)
Maximum temperature of warmest month	25.74 (±4.63)
Seasonal canopy openness	5.76 (±1.03)
Distance from water	4.72 (±0.98)
Human modification index	4.68 (±1.11)
Soil pH	2.47 (±0.68)
Distance from fire	0.4 (±0.21)
Soil organic carbon	0.21 (±0.17)

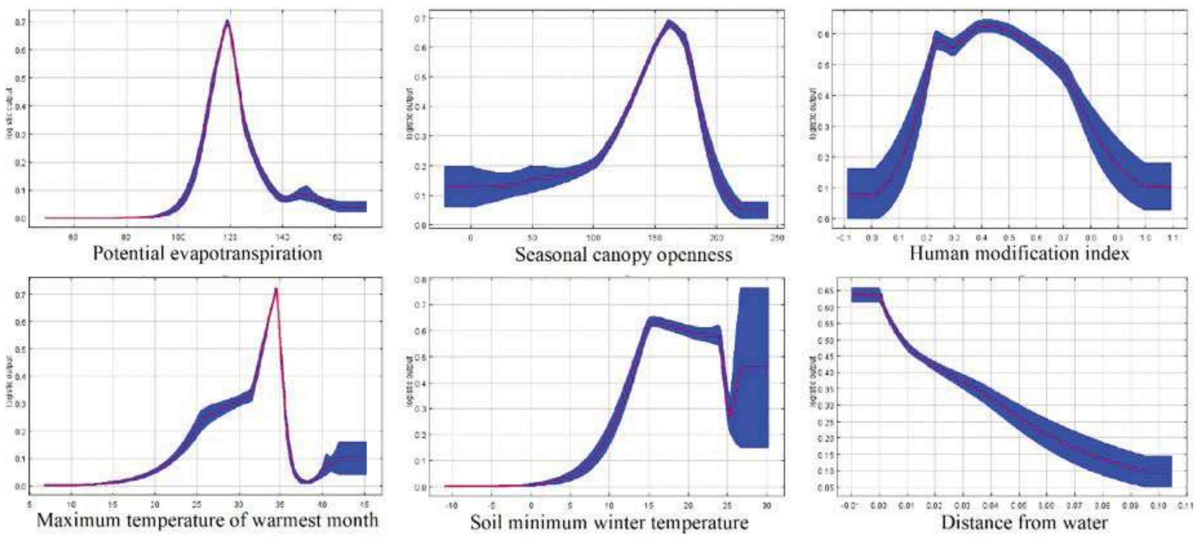


Figure III.24

Relationship between *Mimosa diplotricha* and environmental covariates that jointly explained >80% of its distribution. X axes are the range of covariates, and Y axes are the logistic probabilities of the suitability model.

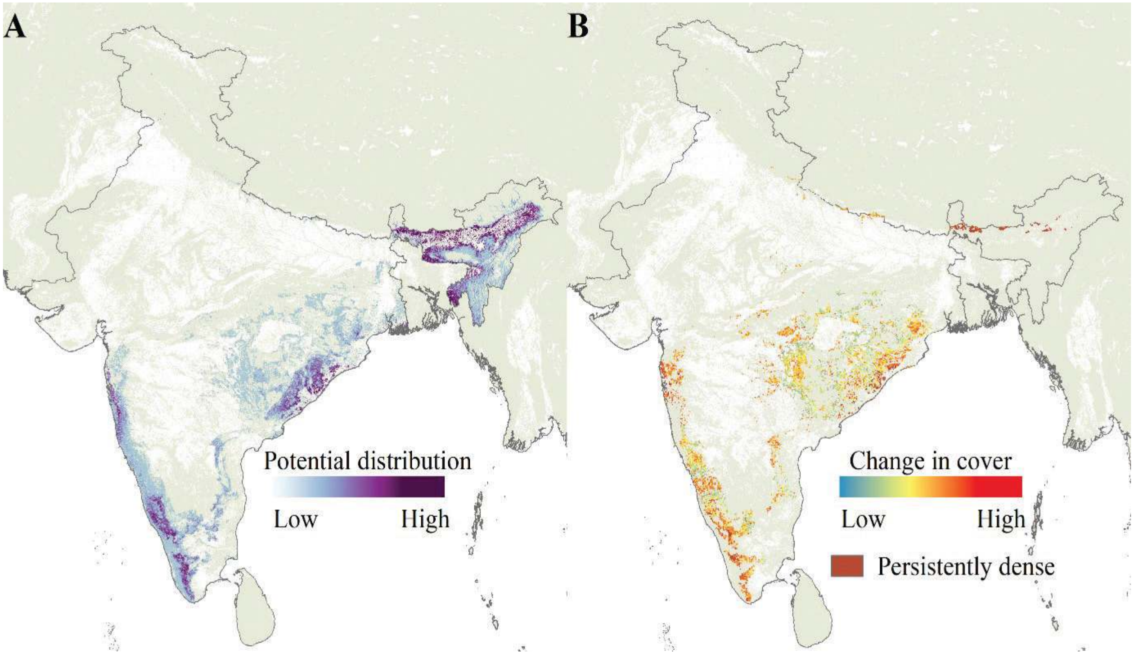


Figure III.25

Potential distribution (A) and rate of invasion (B) of *Mimosa diplotricha* in India.

Management implications:

Mimosa diplotricha occurred in priority management areas in protected areas with deciduous forests, like Manas, Kaziranga, Similipal, Sahyadri, Waynad, Parambikulam, Periyar, Kalakad Mundanthurai, etc. It should be systematically managed within these priority sites (Fig. III.7). *Mimosa diplotricha* invasion in a few protected areas is potentially in its initial stage and should be a high priority for removal before it establishes itself in a larger area. Example: Anshi Dandeli, Bhadra, Anamalai, Indravati, Nagarjuna Sagar Srisailam, Nameri, Pakke, Dampa, etc.

Mikania micrantha

Figure III.26

A dense invasion of grassland by invasive *Mikania micrantha* climber

This herbaceous climber species was sighted in the moist grasslands and forests of Northeast India (e.g., Manas, Nameri), the Western Ghats (e.g., Periyar, Waynad), and the moist forests of Central India. Within these systems, it abundantly occurs in grasslands, along water channels, in rugged areas, and in proximity to human land use. Within these regions, its abundance was recorded to be higher in proximity to orchards, tree plantations, and agriculture.

The spatially independent presence of *Mikania micrantha* at 1784 sites was used to model its potential distribution. It was recorded in 31,246 km^2 of natural areas and was observed spreading at an average rate of around 840 km^2/year. The best MaxEnt model had reliable accuracy (TSS: 0.66; AUC: 0.87 ± 0.002) and projected invasion suitability in 149,286 km^2 of natural areas (Fig. III.28). The bootstrapped contribution of all predictors is provided in Table III.9. Species preferred specific areas with high annual rainfall (1800–8000 mm) and moderate summer temperatures (12°C to 25°C) (Fig. III.27). It increased with the warmer winter temperature of the soil (13° C to 30° C), indicating an avoidance of frost. Within this region, it increased with seasonal canopy openings, proximity to fire, human modifications of the area, and long-term vegetation browning, i.e., forest degradation. Mikania micrantha also increased in drier areas of wet forests and preferred acidic to neutral soil pH (4 to 7) (Fig. III.27).

Table III.9

Covariates of the *Mikania micrantha* distribution and their percent contribution to the suitability model. Values in parenthesis are standard deviation.

Covariates	Percent contribution (%)
Annual precipitation	47.77 (±2.5)
Maximum temperature of warmest month	22.11 (±2.09)
Soil minimum temperature of coldest month	11.67 (±1.3)
Human modification index	9.83 (±1.19)
Proportion of tree cover	5.07 (±0.88)
Soil pH	1.23 (±0.62)
Seasonal canopy openness	1.21 (±0.35)
Long-term vegetation browning	0.54 (±0.18)
Distance from fire	0.4 (±0.32)
Distance from water	0.18 (±0.1)
Soil organic carbon	0.04 (±0.04)

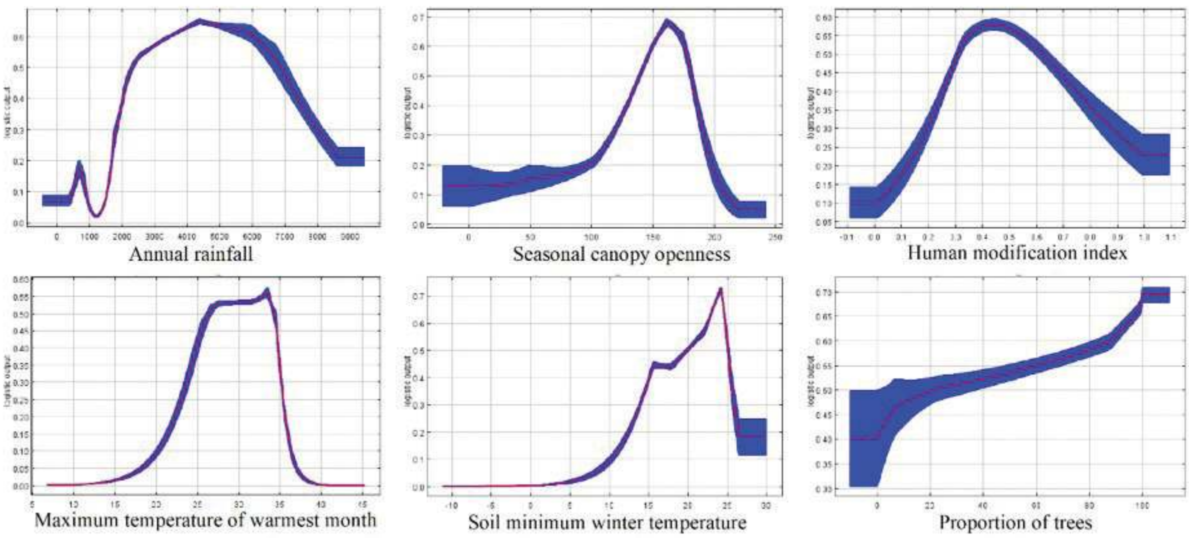


Figure III.27

Relationship between *Mikania micrantha* and environmental covariates that jointly explained >80% of its distribution. X axes are the range of covariates, and Y axes are the logistic probabilities of the suitability model.

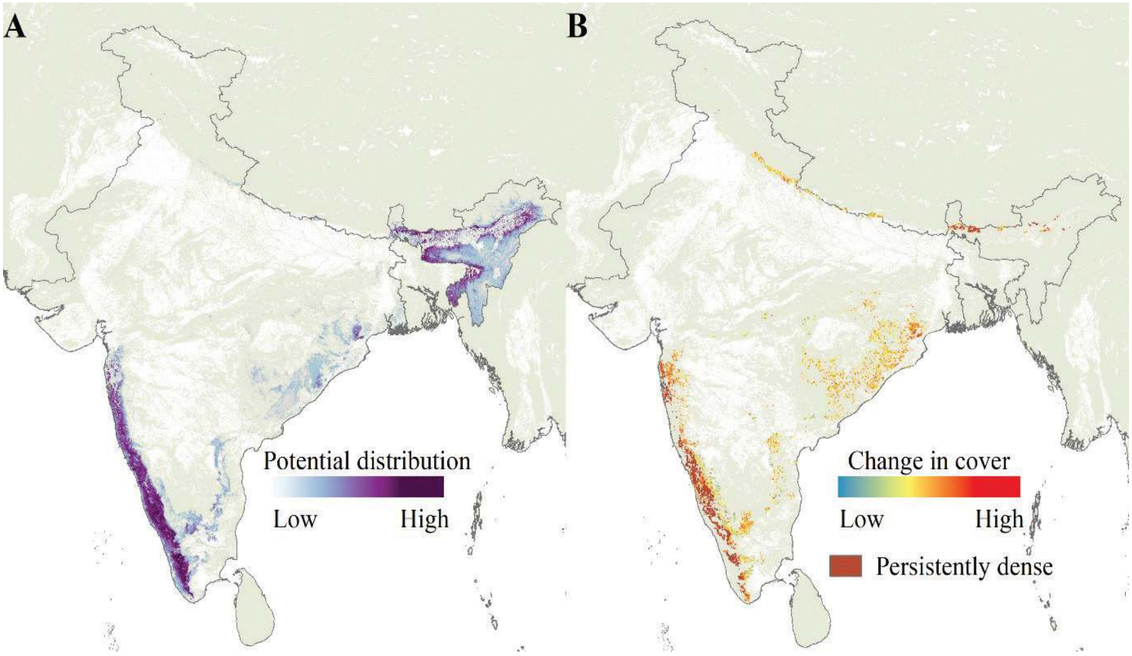


Figure III.28

Potential distribution (A) and rate of invasion (B) of *Mikania micrantha* in India.

Management implications:

Mikania micrantha occurred in priority management areas in protected areas with moist deciduous forests, like Manas, Kaziranga, Waynad, Parambikulam, Periyar, Bhadra, etc. It should be systematically managed within these priority sites (Fig. III.7). Experience with controlling this species invasions from parts of India and elsewhere can be helpful in directing future management (Sankaran *et al.* 2017). *Mikania micrantha* invasion in a few protected areas is potentially in its initial stage and should be a high priority for removal before it establishes itself in a larger area. Example: Anamalai, Indravati, Nagarjuna Sagar Srisailam, Kanha, Similipal, Nameri, Pakke, Valmiki, etc.

Parthenium hysterophorus

Figure III.29

A typical invasion of forested areas around roads by *Parthenium hysterophorus*

This species occurs in savannas and deciduous forest systems across India (e.g., Bandipur, Amrabad, Navegaon-Nagzira). Although it was not abundantly recorded across these forests, it occurred in managed grasslands, tourism roads, and relocated human settlements in the forested areas. Its absence was likely due to the multiple control mechanisms adopted to control this invasion since the 1990s. Its abundance was high along the agricultural fields, grasslands, grazing pastures, savannahs, and forest edges.

Spatially independent presence of *Parthenium hysterophorus* from 2611 sites was used to model its potential distribution. It was recorded in 42,492 km2 of natural areas. This was the only invasion that, although statistically insignificant, was observed to decline at a rate of around 170 km^2/year. However, its expanse since 2010 is seen to have increased. The best MaxEnt model had reliable accuracy (TSS: 0.19; AUC: 0.79 ± 0.003) but had poor specificity, and thus absence sites were likely shown to be suitable for invasion. The projected invasion suitability threatened 374,517 km^2 of natural areas (Fig. III.31). The bootstrapped contribution of all predictors is provided in Table III.10. Species preferred arid to moderately humid areas where the soil temperature in the winter remained warm (8°C to 25°C), indicating an avoidance of frost. Within this region, it increased with seasonal canopy openings, proximity to water, and human modifications of the area. *Parthenium hysterophorus* increased with grass cover and decreased with dense trees. It preferred moderately acidic to neutral soil pH (5–8) (Fig. III.30).

Table III.10

Covariates of the *Parthenium hysterophorus* distribution and their percent contribution to the suitability model. Values in parenthesis are standard deviation.

Covariates	Percent contribution (%)
Soil minimum temperature of coldest month	32.79 (±1.43)
Aridity-humidity potential	25.67 (±2.12)
Proportion of tree cover	12.91 (±1.3)
Seasonal canopy openness	12.88 (±1.43)
Human modification index	8.26 (±1.17)
Soil pH	4.46 (±0.99)
Soil water content	1.63 (±0.55)
Proportion of grass cover	0.81 (±0.21)
Distance from water	0.62 (±0.25)

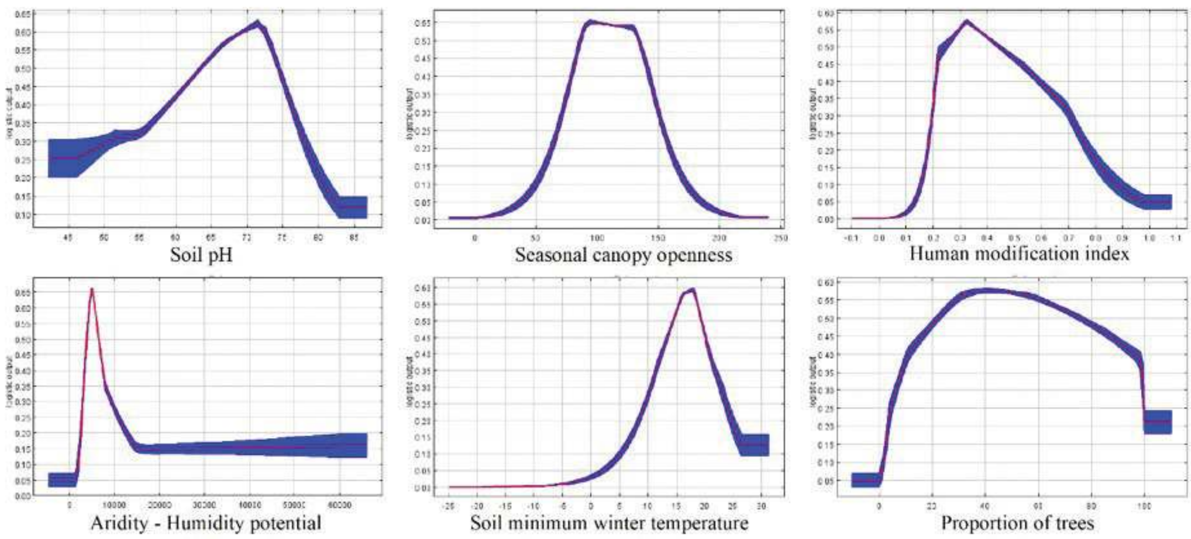


Figure III.30

Relationship between *Parthenium hysterophorus* and environmental covariates that jointly explained >80% of its distribution. X axes are the range of covariates, and Y axes are the logistic probabilities of the suitability model.

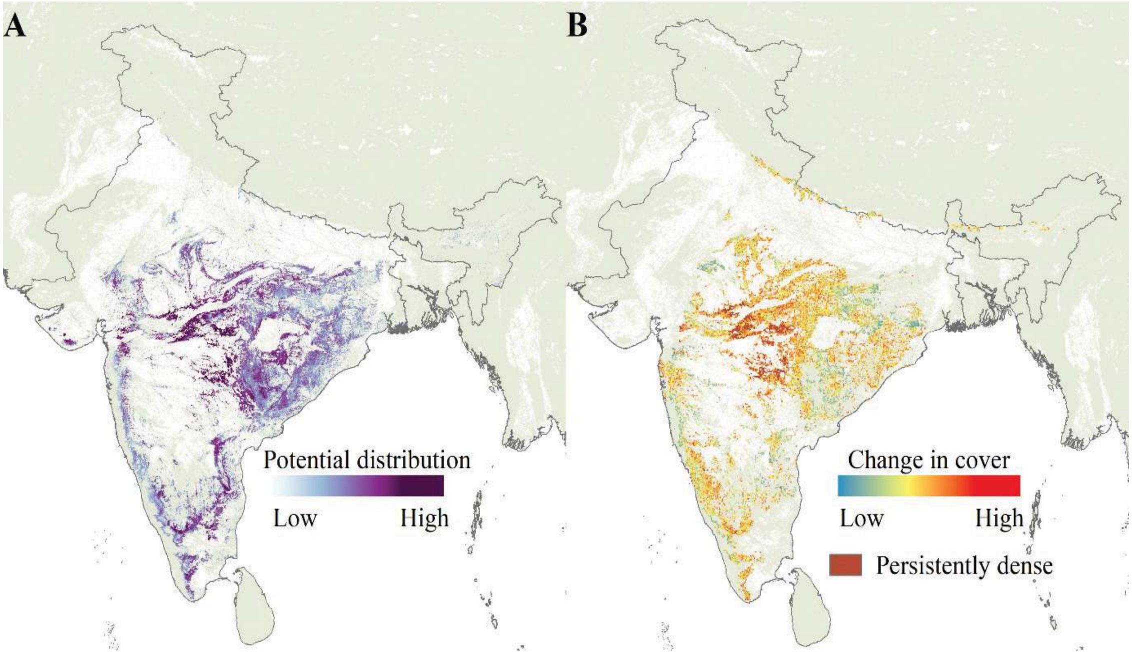


Figure III.31

Potential distribution (A) and rate of invasion (B) of *Parthenium hysterophorus* in India.

Management implications:

Parthenium hysterophorus occurred in priority management areas in protected areas with open ecosystems and dry deciduous forests, like Melghat, Pench, Kuno, Sariska, Sathyamangalam, Nagarjuna Sagar Srisailam, etc. It should be systematically managed within these priority sites (Fig. III.7). *Parthenium hysterophorus* invasion in a few protected areas is limited and should be a high priority for removal before it establishes itself in a larger area. Example: Rajaji, Corbett, Palamau, Indravati, Kanha, Satpuda, Similipal, Anamalai, Bhadra, etc.

Prosopis juliflora

Figure III.32
A dense invasion in dry savannas by woody shrub *Prosopis juliflora*

This woody shrub was spread across the drier parts of India. Its presence was abundantly found in the savannas and dry deciduous forests in the semi-arid parts of India, including Rajasthan (e.g., Ranthambhore, Sariska), Gujarat (e.g., Gir), Central Maharashtra (e.g., Bor, Tipeshwar), Karnataka (e.g., Bandipur, Biligiri Ranganathaswamy Temple), Tamil Nadu (e.g., Sathyamangalam), and Telangana its prevalence could be due to plantation drives by various agencies in the last 50 years, where this plant was deliberately introduced to green the drier parts of India. It has intensively spread across open ecosystems and likely exerted irreversible changes.

Spatially independent presence of *Prosopis juliflora* from 7321 sites was used to model its potential distribution. It was recorded in 97,008 km^2 of natural areas and was observed spreading at an average rate of around 920 km^2/year. The best MaxEnt model had reliable accuracy (TSS: 0.57; AUC: 0.71 ± 0.001) and projected invasion suitability in 352,290 km^2 of natural areas (Fig. III.34). The bootstrapped contribution of all predictors is provided in Table III.11. Species preferred areas with less annual rainfall (100–1800 mm) and warm summer temperatures (28°C to 50°C) (Fig. 33). It increased with grass cover and was high around water sources and human modification of areas. It was less invaded in immediate proximity to the fire but increased further from it. *Prosopis juliflora* preferred neutral to alkaline soil pH (6 to 8.5) (Fig. III.33).

Table III.11

Covariates of the *Prosopis juliflora* distribution and their percent contribution to the suitability model. Values in parenthesis are standard deviation.

Covariates	Percent contribution (%)
Annual precipitation	61.73 (±1.92)
Grassland cover	16.2 (±1.64)
Soil pH	9.63 (±1.98)
Maximum temperature of warmest month	5.23 (±0.47)
Human modification index	3.11 (±0.74)
Distance from water	1.81 (±0.35)
Soil minimum temperature of coldest month	1.08 (±0.15)
Soil water content	0.57 (±0.19)
Distance from fire	0.55 (±0.26)
Soil organic carbon	0.14 (±0.08)

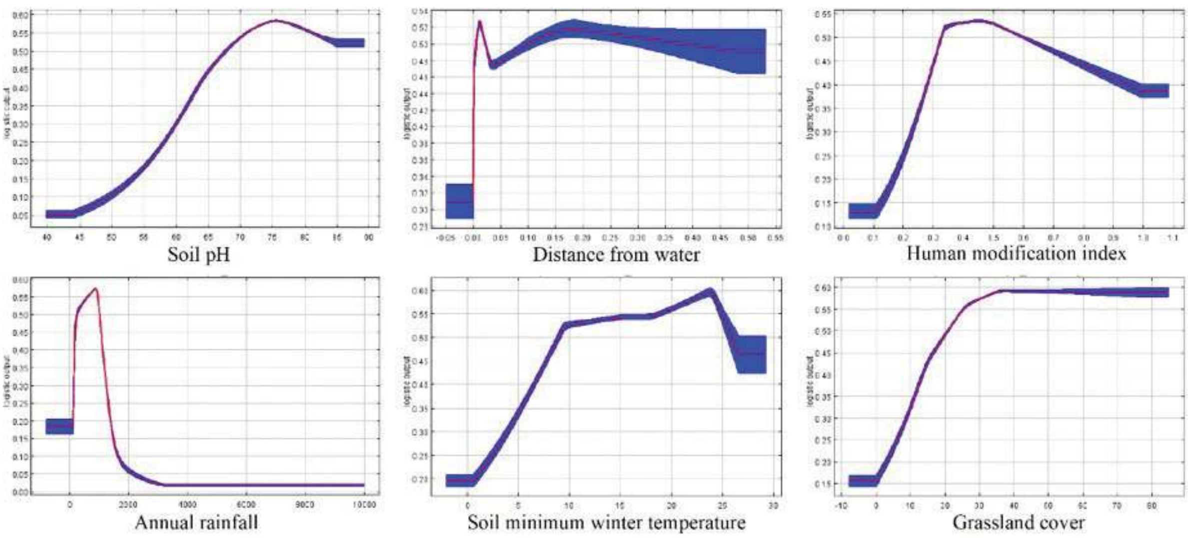


Figure III.33

Relationship between *Prosopis juliflora* and environmental covariates that jointly explained >80% of its distribution. X axes are the range of covariates, and Y axes are the logistic probabilities of the suitability model.

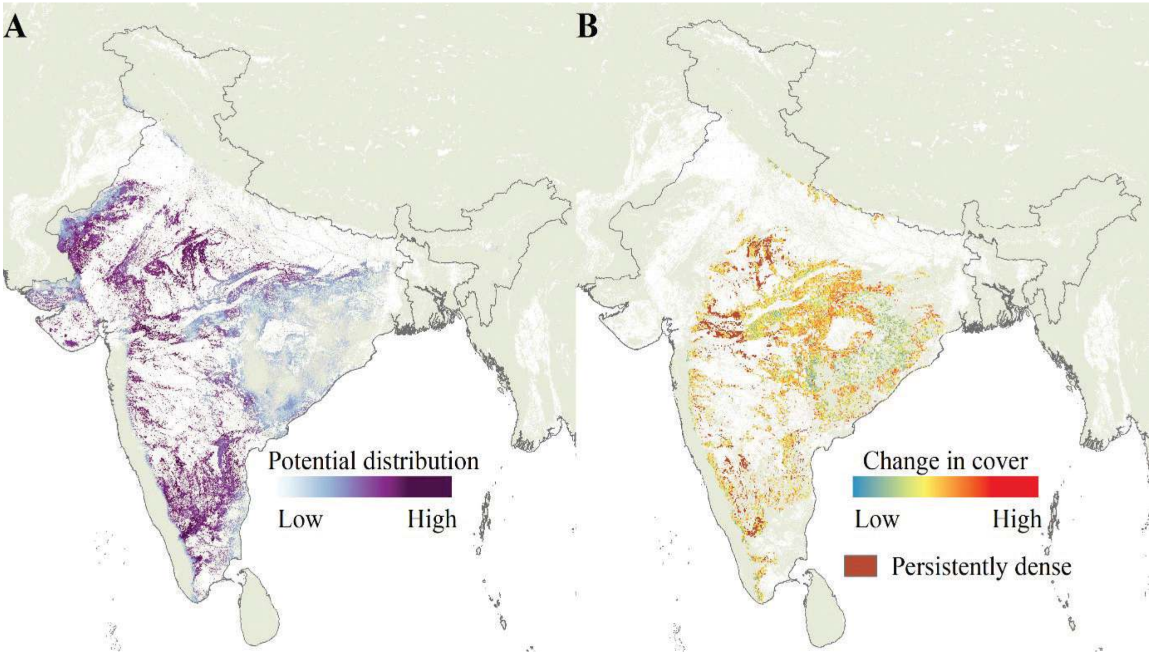


Figure III.34

Potential distribution (A) and rate of invasion (B) of *Prosopis juliflora* in India.

Management implications:

Prosopis juliflora occurred in priority management areas in all protected areas with open ecosystems and dry forests, like Desert National Park, Indian Wild Ass Sanctuary, Gir, Ranthambhore, Sariska, Kuno, Panna, Melghat, Sathyamangalam, Nagarjuna Sagar Srisailam, etc. It should be systematically managed within these priority sites (Fig. III.7). Experimental studies from dry savannas accentuate the necessity of site-specific management experimentation as the ecological and social implications of management actions may vary (Nerlekar *et al.* 2022). *Prosopis juliflora* invasion in a few protected areas is potentially in initial stage and should be at high priority for removal, before it establishes in a larger area. Example: Rajaji, Sanjay, Kanha, Indravati, Similipal, Anamalai, Bhadra, etc.

Senna tora

Figure III.35

A typical invasion of dry grasslands by *Senna tora*

This was among the most widespread invasive plants in India. Its presence was found across all the forest systems and is known to be limited by extreme hot conditions in the Western deserts of India, prolonged frost in the Himalaya, saline water in the mangroves, and waterlogged areas. Its distribution was driven by moderate aridity with high rainfall in dry seasons, less canopy density, proximity to water, high seasonal canopy opening, human modification index, proximity to fire, and a lower proportion of trees.

Spatially independent presence of *Senna tora* from 19834 sites was used to model its potential distribution. It was recorded from 119,256 km^2 natural areas and was observed spreading at an average rate of around 530 km^2/year. The best MaxEnt model had reliable accuracy (TSS: 0.35; AUC: 0.63 ± 0.001) and projected invasion suitability in 394,406 km^2 of natural areas (Fig. III.37). The bootstrapped contribution of all predictors is provided in Table III.12. Species preferred arid to moderately humid areas with warm summer temperatures (25°C to 45°C) (Fig. III.36). It increased with grass cover and was lowest in dense tree cover. Within the dry region, it increased in proximity to water, soil carbon, and seasonal canopy opening in forests. Species increased with livestock density and human modification of areas. *Senna tora* preferred moderate acidic to neutral soil pH (5 to 8) (Fig. III.36).

Table III.12

Covariates of the *Senna tora* distribution and their percent contribution to the suitability model. Values in parenthesis are standard deviation.

Covariates	Percent contribution (%)
Aridity-humidity potential	40.07 (±2.23)
Soil pH	18.93 (±1.1)
Maximum temperature of warmest month	11.88 (±1.19)
Seasonal canopy openness	10.23 (±1.27)
Soil organic carbon	5.51 (±1.86)
Proportion of tree cover	4.44 (±0.86)
Livestock density	2.91 (±0.28)
Soil minimum temperature of coldest month	2.66 (±0.68)
Human modification index	2.44 (±0.37)
Distance from water	0.79 (±0.13)
Proportion of grass cover	0.19 (±0.09)

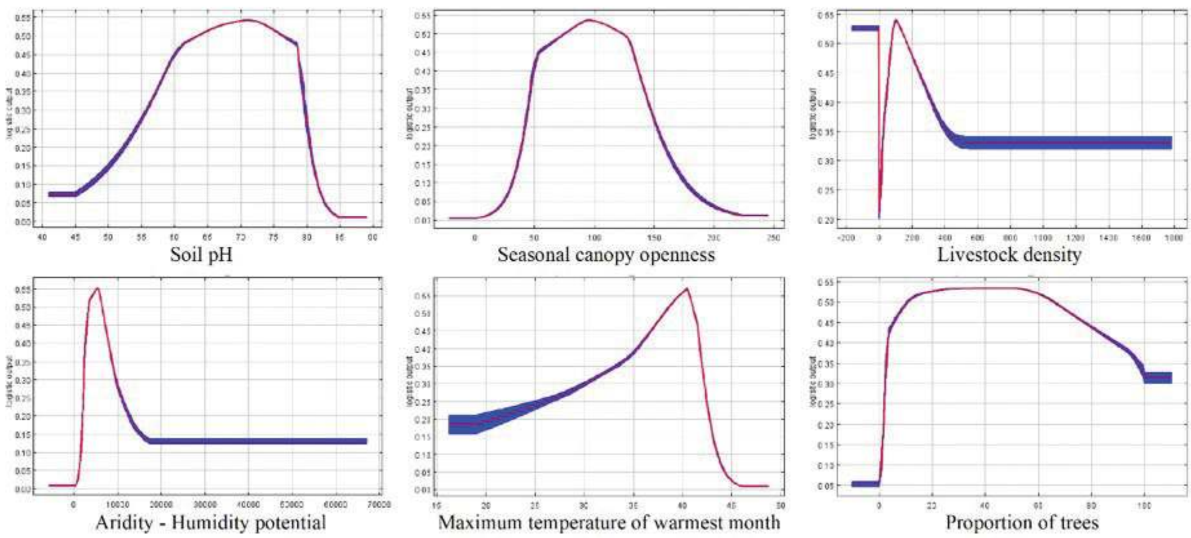


Figure III.36

Relationship between *Senna tora* and environmental covariates that jointly explained >80% of its distribution. X axes are the range of covariates, and Y axes are the logistic probabilities of the suitability model.

Section III

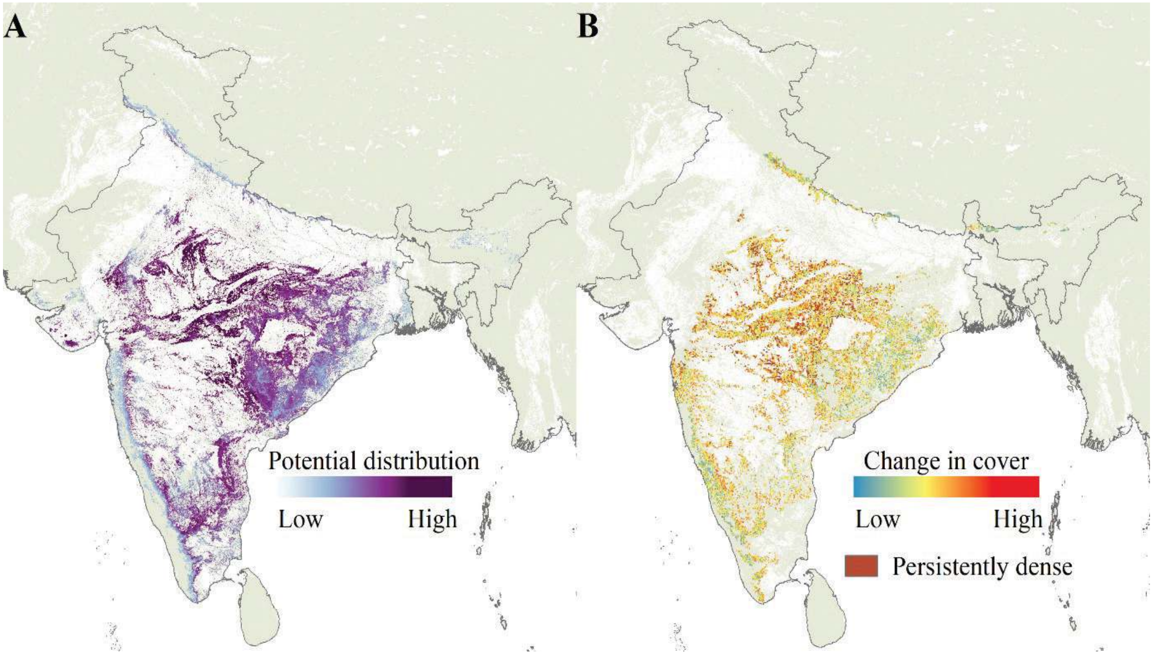


Figure III.37

Potential distribution (A) and rate of invasion (B) of *Senna tora* in India.

Management implications:

Senna tora occurred in priority management areas in all protected areas with open ecosystems and dry forests, like Gir, Sariska, Kuno, Panna, Melghat, Pench, Tadoba, Bandhavgarh, Sathyamangalam, Nagarjun Sagar Srisailam, etc. It should be systematically managed within these priority sites (Fig. III.7). *Senna tora* invasion in a few protected areas is potentially in initial stage and should be at high priority for removal, before it establishes in a larger area. Example: Mukurthi, Anshi Dandeli, Indravati, Similipal, Valmiki, Manas, Kaziranga, etc.

III.11 *Xanthium strumarium*

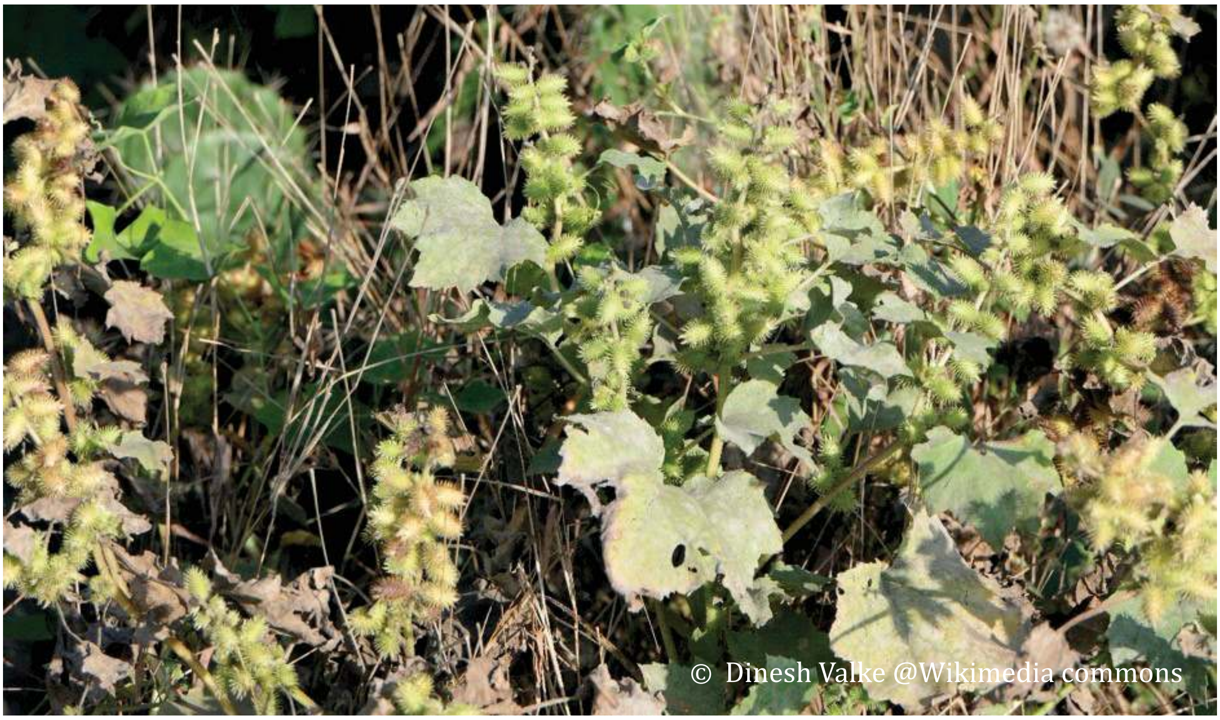


Figure III.38

A typical invasion of riverine grasslands by *Xanthium strumarium*

This broad-leaf herb was mostly recorded in the central dry deciduous forests (e.g. Melghat, Tadoba, Pench) and savannas (e.g. Ranthambhore, Kuno). Its presence in these dry parts was mostly around the water bodies, roads and livestock trails.

Spatially independent presence of *Xanthium strumarium* from 2566 sites was used to model its potential distribution. It was recorded from 69,256 km^2 natural areas and was observed spreading at an average rate of around 470 km^2/year. The best MaxEnt model had reliable accuracy (TSS: 0.44; AUC: 0.82 ± 0.002) and projected invasion suitability in 254,127 km^2 of natural areas (Fig. III.40). The bootstrapped contribution of all predictors is provided in Table III.13. Species preferred arid to moderately humid areas and increased with the temperature of the summer (30°C to 45°C) (Fig. III.39). It increased with grass cover but declined with higher grass densities. Within the dry region, it was specifically high in proximity to water, soil water content, and seasonal canopy opening in forests. Species increased with livestock density and human modification of areas. *Xanthium strumarium* preferred moderate acidic to moderate alkaline soil pH (5.7 to 8.5) (Fig. III.39).

Table III.13

Covariates of the *Xanthium strumarium* distribution and their percent contribution to the suitability model. Values in parenthesis are standard deviation.

Covariates	Percent contribution (%)
Aridity-humidity potential	52.1 (±2.42)
Distance from water	17.34 (±1.12)
Maximum temperature of warmest month	11.56 (±2.13)
Soil pH	10.82 (±2.88)
Soil water content	2.33 (±0.41)
Soil minimum temperature of coldest month	1.8 (±0.52)
Livestock density	1.68 (±1.08)
Seasonal canopy openness	1.35 (±0.58)
Human modification index	0.88 (±0.2)
Proportion of grass cover	0.15 (±0.1)
Soil organic carbon	0.04 (±0.03)

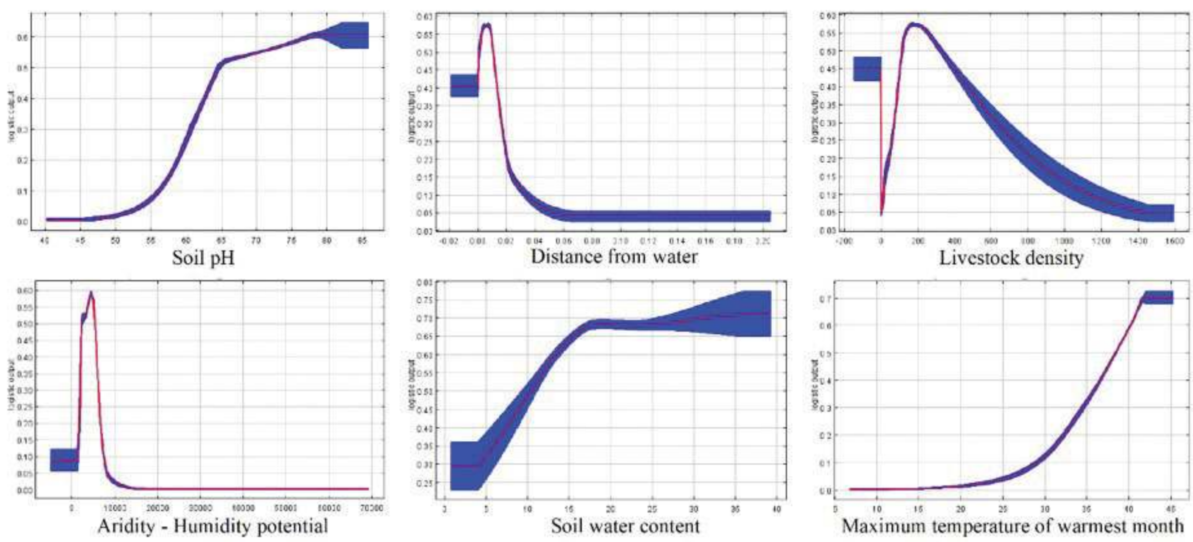


Figure III.39

Relationship between *Xanthium strumarium* and environmental covariates that jointly explained >80% of its distribution. X axes are the range of covariates, and Y axes are the logistic probabilities of the suitability model.

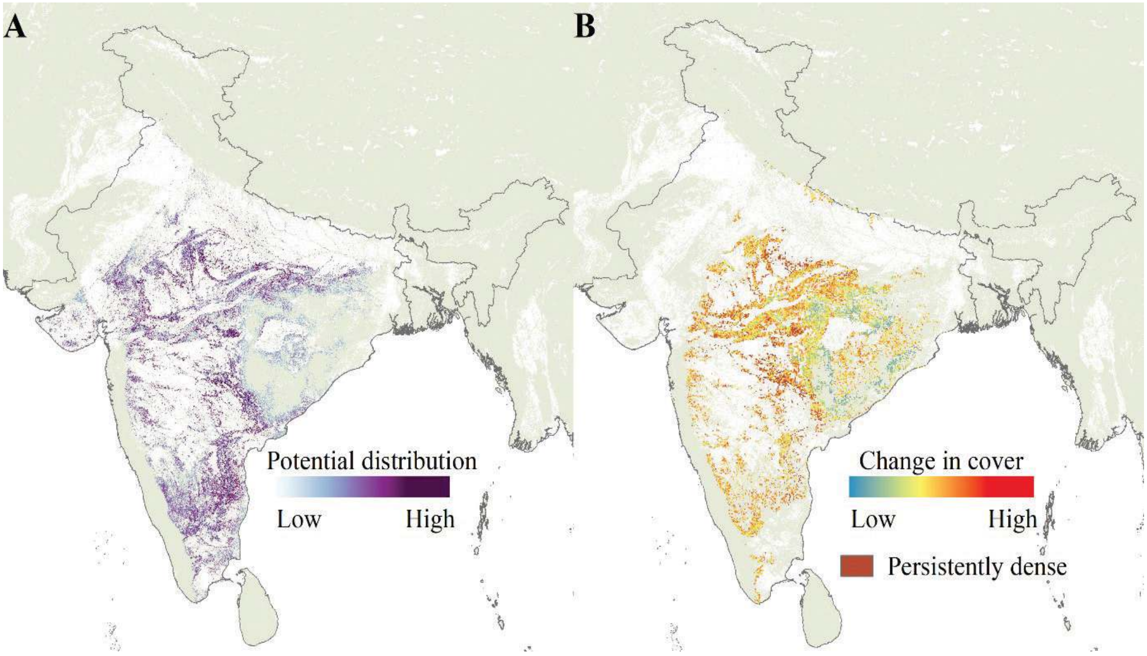


Figure III.40

Potential distribution (A) and rate of invasion (B) of *Xanthium strumarium* in India.

Management implications:

Xanthium strumarium occurred in priority management areas in all protected areas with open ecosystems and dry forests, like Sariska, Kuno, Panna, Kaimur, Melghat, Pench, Tadoba, Bandhavgarh, Sathyamangalam, Nagarjuna Sagar Srisailam, etc. It should be systematically managed within these priority sites (Fig. III.7). *Xanthium strumarium* invasion in few protected areas is potentially in initial stage and should be at high priority for removal, before it establishes in a larger area. Example: Rajaji, Ranthambhore, Indian Wild Ass Sanctuary, Indravati, Bhadra, Sahyadri, Kalakad Mundanthurai, etc.

Conservation implications:

Our study provides the first account of the distribution status of high-concern invasive plants at a national scale in India. There has been a long-standing lacuna on the status of high concern invasive plants, management priority areas institutionalized monitoring of invasions and their management. Present results derived from a national monitoring institutionalized with Project Tiger, can provide the necessary information. High-concern plant invasions were recorded in 22% natural areas and modelled to threaten 65% natural areas, using statistically robust models (Table III.2). All invasive plants were observed spreading across their suitable areas in India, at an average rate of 729 km^2/year. With the present expanse, most terrestrial ecosystems in India emerge as mixed-species communities of native and non-native plants. Invasive plants were present across the climatic and ecological spectrum in India, with species specific preference towards certain environments. These distributions highlighted macroecological affiliations of invasions, where the overall cover of invasive plants peaked at mid-temperatures and declined towards both ends; as well as declined with higher annual rainfall (Fig. III.3). Invasive plant cover displayed an intermediate rise with vegetation cover openings and a ubiquitous increase with human modification of area (Fig. III.3). Notably, a dense woody invasion was observed in the ecotone of open grassy ecosystems and forest ecosystems in India.

Human modification of natural areas (e.g., linear infrastructure, agriculture, extractive use in terms of tree felling, livestock grazing, mining, etc.) emerged as the most significant driver of invasions (Fig.s III.3, III.6). India's forests are surrounded by one of the densest human populations, livestock populations, and linear infrastructures in the world (Nayak *et al.* 2020), which not only extract plant biomass or fragment these ecosystems but also act as conduits for the spread of invasive species (Chaudhary *et al.* 2021; Mungi *et al.* 2021). Once a species establishes itself in an area, its further spread depends on its local dispersion, which seems to be happening unabated across the region (Fig. III.6). Thus, the present expanse of invasion across India could be traced to the legacy of human modification of natural areas and subsequent spread. The influence of other environmental drivers could be broadly segregated into dry and wet systems. Proximity to water was found to facilitate invasive plants in dry systems (savannas, dry deciduous forests, etc.), whereas proximity to fire facilitated invasive plants in wet systems (semi-evergreen and evergreen forests). Recent climatic variability across peninsular India indicates increasing precipitation in drier regions (Jin & Wang, 2017). We observe increasing site water balance in drier regions in India to correlate with increased cover of woody invasive plants like *Lantana camara and Prosopis juliflora* in the last 16 years (Fig. III.6). These climatic changes in interactions with land use changes like agricultural area expansion change the local hydrological regimes and can result in rapid changes in plant assemblages, which seems to facilitate invasive plants. India's drier areas are also increasingly irrigated, whereas fire in wet forests has reportedly increased (Kodandapani *et al.* 2004). With an increasing population and demand for food, energy, and infrastructure, these socio-ecological drivers of invasive species will only increase. Considering the prevalence of invasive species and scenarios with escalating drivers, active invasion management becomes a critical conservation priority.

The last remaining relatively uninvaded areas (35% of total natural areas) are largely contiguous systems with the least human modifications owing to extreme climate (e.g., Thar desert) or terrain (e.g., Northeastern hills) (Fig. III.7). Another study using the same data showed that wet ecosystems protected against invasive plants (Mungi *et al.*, 2021). However, alteration in their structure or composition by anthropogenic means obliterates this biotic resistance. As many uninvaded systems are outside legally protected areas, they are increasingly fragmented by developmental activities like irrigation, linear infrastructure, mining, dams, and socio-ecologically unsustainable plantations. If the last remaining native ecosystems of India are to be safeguarded, their protection from anthropogenic modifications, which are the major drivers of invasions, is vital.

Our results demonstrate the compositional alteration of grassy systems by woody plants like *Prosopis juliflora* and *Lantana camara*. Such invasions can propel ecosystems irreversibly to alternate states, with potential and severe socio-ecological ramifications (Nackley *et al.*, 2017). In India, a large proportion of grassy open ecosystems are outside protected areas and are treated as 'wastelands', either exposing them to rapid human modifications or woody plantations (Madhusudan & Vanak, 2022; Ratnam *et al.*, 2016). Woody invasions can only exacerbate the tragedy of these open ecosystems by compositionally, structurally, and functionally distorting them. These ecosystems are important for large herbivores (e.g., *Bos gaurus, Rusa unicolor, Axis axis, Antilope cervicapra*), on which a myriad of large carnivores depend (e.g., *Panthera tigris, Panthera leo, Canis lupus pallipes*) (Jhala *et al.*, 2021). Dense invasions in these habitats reduce forage plants on which herbivores depend, thereby endangering the faunal trophic system (Rastogi *et al.*, 2023). Considering the priority of megafauna conservation in India, it becomes imperative to mitigate the impacts of plant invasions, with priority given to protected areas that have higher faunal densities.

Management implications:

Considering conservative estimate for managing all high-concern invasive plants in an area, the least cost of management with the present expanse of invasions would exceed 13.5 billion USD (1.1 trillion INR) (USD value for November 2022). This estimate represents only one-time management costs, which are seen as ineffective as often managed areas get subsequently reinvaded (Bhagwat *et al.*, 2012). As eradicating large-scale pervasive invasions seems ineffective due to costly and ineffective strategies, it is essential that management be targeted (but not limited) to areas with guaranteed outcomes (e.g., reducing the impacts of invasions). Our study identified priority areas where timely management of invasive species is possible in terms of economics and can help restore native biodiversity. A large proportion of priority areas for restoring native systems are in the core regions of tiger reserves and national parks (Fig. III.7).

In rank 1 priority sites, management can eradicate invasive plants and monitor them to control future introductions. In rank 2 priority sites, subsequent eradication of invasive plants should be conducted to enlarge the native patch and reduce the source of future invasions. In rank 3 priority areas, management can reduce the density of plant invasions and mitigate impacts on native biodiversity and functions. These protected priority areas represent 11% of the existing natural areas in India. The remaining 23% of priority sites are outside designated protected areas. It is critical to recognize their ecological value before subjecting them to modifications, which can obliterate their inherent biodiversity and promote invasions. These areas might be prioritized for future extensions of protected areas, although merely declaring an area protected does not guarantee resistance to invasions but may be helpful in reducing human modifications that ubiquitously promote invasions. Our prioritization identified areas to begin systematic restoration at the national level using scientific evidence, but not be limited to it. Stakeholders can refine suggested priority sites based on biodiversity information, local conservation objectives, and social requirements.

As management experimentation and research on controlling invasions from mixed-species ecosystems are still at a nascent stage, we see lessons from global research that can guide the development of an approach based on invasion processes and the availability of management options (Fig. III.8). Adopting a unifying framework on the invasion-management spectrum (Blackburn *et al.* 2011), we highlight how stages of invasion can assist optimal management decisions. During the initial stage, when the expanse of invasion is limited, eradication could be attempted with a vision to revive pre-invasion biodiversity. However, with increasing expanse and time, the cost of eradication can be massive, and management may focus on the containment of species to reduce their documented negative impact on native biodiversity. With further spread, the interaction between native and non-native species could result in mixed-species communities (but see invasional meltdown (Simberloff & Von Holle, 1999)), which necessitates adaptive management to mitigate the negative impacts of invasions and steward biodiversity and services in the unfolding system. These three management approaches are not definitive but adaptive and contextual and must be developed using robust scientific evidence in the milieu of social values through a bottom-up approach. These approaches can also be aligned with the Resist-Direct-Accept (or Adapt) typology (Schuurman *et al.* 2022) and with the alternate stable states of ecosystems (Scheffer & Carpenter, 2003). At the initial phase of invasion, management can resist and prevent invasions and retain the baseline state of the ecosystem; in the case of existing large expanses of invasions, management can actively direct the co-occurrence of uninvaded areas along with mixed-species areas; whereas in the case of pervasive invasions, management can adapt to steward biodiversity and services to achieve a mixed-species ecosystem by mitigating the impacts of invasive species (Fig. III.41). It is important to understand the stages of invasion and its relationship with native biodiversity to inform adaptive management, which necessitates long-term monitoring and scientific experimentation. In this context, area does not imply the entire ecosystem or landscape but patches of management-appropriate scale within it. For example, in drier parts of the Western Ghats, Lantana camara has been established for more than 100 years and has influenced ecological interactions, necessitating adaptive management, but its invasion in parts of wet evergreen forests in the Western Ghats may be in its initial stage, where eradication can be achieved.

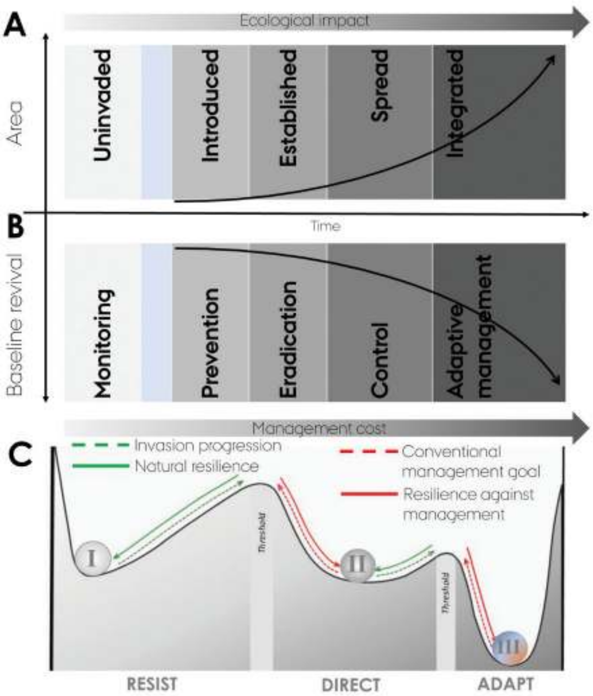


Figure III.41

Typology of invasion – management spectrum. Adopting the framework of invasion – management continuum (Blackburn *et al.*, 2011), we show different stages in the invasion process and management interventions relevant to it. A non-native species expands in area along with time, eventually integrating pervasively into the system. (A) The management cost and ecological impacts of non-native species increase with this quantum and the potential of reviving baseline system becomes more uncertain. (B)It could be compared with the alternate stable state scenario, (C) where prior to non-native species introduction, a baseline state (I) comprising native species existed. With introduction of non-native species that spread pervasively, causing higher interactions between native and non-native species forming an alternate invaded state (II). When the progressing invasions have its fingerprints on most ecological interactions in a system, a novel mixed-species state might emerge (III). These three states could be compared with the Resist-Direct-Adapt management typology and aligns with restoration priority zones identified by the present study. The progression from state I to III is triggered by spread of non-native species, where control mechanisms could resist shift in a state up to a threshold. The revival progression towards previous state is rare, and revival failure is common, as it is challenging to shift to a previous state when interactions and environments are simultaneously and rapidly changing. Hence, threshold of alternate states of a system must be monitored to adapt management interventions and develop conservation goals that could accommodate novel changes.

Nature-based Solutions (NbS) for biological invasions:

As management priority areas are identified, it becomes pivotal to devise methods for the removal of invasive plants and the restoration of ecosystems. Despite severe invasions and a long history of controlling invasive plants, scientific experiments on restoration have been neglected (Bhagwat *et al.*, 2012). Few studies (Babu *et al.*, 2009; Nerlekar *et al.*, 2022; Sinha *et al.*, 2022) demonstrate the efficacy of mechanical removal of invasive plants, as it is the most commonly used technique. But a large-scale implementation of mechanical removal using chronic human interventions in the last remaining wilderness areas can reduce biodiversity value (Kopf *et al.*, 2017), while being costly and uncertain in restoring biodiversity. It is important that the removal of invasive plants be treated not as an end objective but as a step in the long process of restoring biodiversity and human wellbeing. It is also important to reconsider that, in the absence of native plants, several native fauna and people depend on the large patches of invasive plants for their sustenance. Management of invasive plants amidst such novel mixed-species communities needs scientific experiments and evidence-based applications, which necessitate investments in restoration experiments. At present, invasive species management in India is restricted to a few stakeholders with limited resources, even though a diverse range of stakeholders are directly affected by invasions. It is increasingly recognized that government agencies are necessary but not sufficient for effective invasive species control (Miyanaga & Nakai, 2021). Including diverse stakeholders can increase resources for management, outreach, and restoration and deliver inclusive benefits in multiuse areas.

The intended large-scale management interventions to remove invasive plants from ecosystems are usually met with heavy usage of machinery and/or chemicals (e.g., using bulldozers to remove invasive plants from open ecosystems) and regular eradication drives. Though such interventions might achieve contextual and local success, their large-scale blanket application would be economically daunting and may escalate social conflicts and ecological ramifications (Fleischman *et al.*, 2020; Zavaleta *et al.*, 2001). Mere removal of invasive species does not always guarantee revival of the lost biodiversity or ecosystem services, particularly when the climate and other environmental variables are rapidly changing, hindering the revival of the baseline ecosystem (Crowley *et al.*, 2017; Lampert *et al.*, 2014). More nuanced alternatives are required that are essentially bottom-up in approach, where socio-ecological settings surrounding an ecosystem are considered when developing solutions and subsequently upscaled by adaptively integrating them at various scales and contexts (Eggermont *et al.*, 2015). These are the NbS's flagship concepts, pivotally guiding governments, institutions, businesses, and citizens to develop innovative ways to protect, sustainably manage, and restore ecosystems to elevate biodiversity and human well-being (Cohen-Shacham *et al.*, 2019). NbS are motivated by the idea of initially intervening in an ecosystem to eventually facilitate autonomy within the system (i.e., a resilient socio-ecological system) (Seddon *et al.*, 2021).

To provide sustainable and attainable goals in the face of the seemingly unsurmountable spread of invasions, we evaluated relatively less invaded areas across ecosystems to find NbS based on the inherent characteristics of least invaded areas. A general pattern of ecosystem-specific ecological mechanisms emerged that can be leveraged to manage invasions and restore native biodiversity. In high-productive ecosystems (e.g., semi-evergreen and evergreen forests), native species richness that is protected from human modifications offers biotic resistance against invasive species (Mungi *et al.*, 2021); and in moderately productive ecosystems (e.g., floodplain ecosystems and moist savannas), restoring optimal densities of megaherbivores reduces the dominance of invasions (Mungi *et al.*, 2023). Thus, protection of forest structure and diversity, megaherbivore restoration, and other ecologically vital factors can be potential NbS to reduce and/or mitigate the dominance of plant invasions. However, the effectiveness of these mechanisms diminished in the presence of human modifications that fragment wet forests, reduce the abundance of megaherbivores, or deprived native plant diversity. These ecological mechanisms that could be used as NbS for biological invasions were notably observed in the core regions of tiger reserves, where, owing to limited human modification since the last few decades, natural functions are largely intact. Thus, protection of ecosystems for tigers augments reinforcement of NbS within systems, making it resistant and resilient to the impact of biological invasions.

Way forward:

While a large part of India holds mixed-species communities, it supports the last thriving biodiversity in the region. Many alien species (particularly benign aliens with positive or neutral effects) are interacting in novel ways with native species and are being used by people for livelihood. Such a socio-ecological interface only adds to the contextuality of the management approach and conservation goals. As species are being introduced at an unceasing rate, the quantum of future invasions would only add to the present levels (Mormul *et al.*, 2022). Their cascading consequences for biodiversity and ecological interactions would trigger rapid changes within ecosystems and their states (Svenning & Sandel, 2013). The scale and pace of current management approaches may require substantial changes to manage the complexities brought on by seemingly unsurmountable invasions. It necessitates transformative changes in conservation science, beginning with reforming ideas on non-native species and ecosystem management.

Conventional binaries in conservation science have largely hindered progress in the management of mixed-species ecosystems (Lemoine & Svenning, 2022). Binaries such as native vs. non-native, eradicate vs. accept, positive impacts vs. negative impacts, invasive vs. naturalize, manage vs. not manage, are largely considered unfit to approach ecosystem management. It undermines both nature's complexities and human resolve to understand and conserve them. Transcending these binaries, it is urgent and vital to rethink approaches for stewarding biodiversity and nature's contribution to people through novel mixed-species systems (Mungi & Qureshi, 2018). It is important to acknowledge that species cannot be defined by mere political borders (Davis *et al.*, 2011); the addition of new species cannot always be detrimental (Sax *et al.*, 2022); a species cannot always be "declared" as invasive or naturalized across a political unit (Lemoine & Svenning, 2022); ecosystem restoration does not imply futile efforts to push back ecosystems in time (Higgs *et al.*, 2014); and changes in species composition and interactions are not very uncommon across ecosystems (Hobbs *et al.*, 2018). As conservation becomes more interventionist, contextuality becomes key (Corlett, 2016). A conventional approach, such as in India, where the efficacy of a management intervention in one area triggers its blanket application over arguably diverse systems, is seemingly inadequate. Blanket application of a strategy developed to manage invasive species without considering ecological contextuality and conservation value can have negative socio-ecological ramifications that must be prevented (Kopf *et al.*, 2017). Thus, science and management pertaining to novel mixed-species ecosystems need transformative reforms and adaptive conservation goals.

The unsurmountable scale of the invasion might seem overwhelming to management. Nevertheless, global examples highlight the efficacy of long-term systematic management in controlling pervasive invasions and restoring native biodiversity (European Union Regulation 2016/1141). The first step to solving a problem is to recognize it. Ecological restoration requires policies that could transfer the information that our study provides into conservation actions, considering social ethos and environmental ambitions, with measurable indicators of success. Present policies and practices pertaining to invasive species management are too unclear to act objectively (Kannan, Shackleton, & Shaanker, 2013). Hence, adaptive policies and scientific guidelines can enhance management outcomes. India is a signatory to the CBD, which mandates priority management of invasions and the delivery of equitable benefits to the native ecosystem and society. While India recognizes threats to its biodiversity and periodically monitors natural areas, other regions of conservation importance, particularly in the Global South and tiger-ranging countries, lack such assessments. Our study shows the efficacy of integrating invasive species assessment into national-scale biodiversity projects to monitor the pulse of changing ecosystems. Other countries could greatly benefit from adapting similar monitoring for biodiversity stewardship in our rapidly changing world.

Table III.14

Details about the explanatory variables used for modelling suitability of invasive plants in India, ecological relevance of variables for their *a priori* selection and the source of data.

Sl	Variable	Relevance	Source and resolution
Soil resource variables			
1	Soil water content	Water has a contextual effect, where in drier regions, its overabundance can facilitate the spread of invasive plants, while is wet areas, its absence can facilitate invasions (Nath *et al.*, 2019).	(Gupta *et al.*, 2022) 250 m
2	Soil organic carbon content	We used soil organic carbon content as an index of soil fertility, as it is known to determine the occurrence and growth of invasive plants (Das *et al.*, 2019)	(Hengl & Wheeler, 2018) 250 m
3	Soil pH	Soil pH controls the germination and growth of many plants, by modulating the microbial activities in the soil (Kimmel *et al.*, 2020).	(Hengl *et al.*, 2017) 250 m
4	Soil maximum temperature of warmest month	Soil warming modulate the role of soil biota in regulating minerals and growth of plants (Heinze *et al.*, 2016)	(Lembrechts *et al.*, 2022) 1 km
5	Soil minimum temperature of coldest month	Minimum temperature of soil modulates the occurrence and frequency of frost, which in turn regulates the germination and growth of many plants (Joshi *et al.*, 2020)	(Lembrechts *et al.*, 2022) 1 km
Climatic variables			
6	Maximum temperature of warmest month	Higher summer temperature and low rainfall determines the xeric floral diversity and invasions in it (Kannan, Shackleton, & Uma Shaanker, 2013; Panda *et al.*, 2018)	(Fick & Hijmans, 2017) 1 km
7	Mean temperature of coldest quarter	Lower winter temperature are known to cause frost that delimits germination of many plants, both native and invasive (Adhikari *et al.*, 2015; Mungi *et al.*, 2018b)	(Fick & Hijmans, 2017) 1 km
8	Annual precipitation	Annual rainfall determines productivity and floral diversity across the tropics and the distribution of invasive plants in it (Mungi *et al.*, 2021)	(Fick & Hijmans, 2017) 1 km

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Sl	Variable	Relevance	Source and resolution
9	Precipitation of driest quarter	Persistent rainfall in drier season can enhance prolonged productivity in drier forest systems. This can facilitate invasive plants, as native plants are adapted to periodic drier spells and prolonged water availability can impact their regeneration (Chaudhary *et al.*, 2021; Mondal *et al.*, 2022; Mungi *et al.*, 2020).	(Fick & Hijmans, 2017) 1 km
10	Aridity	Aridity determines the productivity and richness of the native as well as invasive plants (Zomer *et al.*, 2014)	(Trabucco & Zomer, 2019) 1 km
11	Evapotranspiration	Evapotranspiration is the proportion of rainfall in forests to the rate of transpiration due to temperature, thereby indexing the effective water available for plant growth (Zomer *et al.*, 2014)	(Trabucco & Zomer, 2019) 1 km
		Ecosystem variables	
12	Ecosystem types	Species assemblage and ecophysiology varies across different ecosystem types, which can change the relationship of species with its environment (Mungi *et al.*, 2021). We used following types: dry grasslands, savannas, dry deciduous forests, moist deciduous forests, semi-evergreen forests, evergreen forests and moist grasslands.	(Buchhorn *et al.*, 2020; FSI, 2009) 30 m
13	Tree proportions	Dense canopy reduces the light availability to understory, thereby reducing the growth of many understory plants (including invasive plants) (Sharma & Raghubanshi, 2009)	(Buchhorn *et al.*, 2020) 30 m
14	Shrub proportions	Higher shrub cover can exert competition for invasive species spread by utilizing the soil, water and sunlight resources (Sharma & Raghubanshi, 2010)	(Buchhorn *et al.*, 2020) 30 m
15	Grass proportions	Higher grass cover an exert competition for invasive species spread by inducing competition during germination of invasive plants (Joshi *et al.*, 2020)	(Buchhorn *et al.*, 2020) 30 m

Sl	Variable	Relevance	Source and resolution
16	Seasonal canopy opening	The seasonal change in the forest productivity i.e. deciduousness creates temporal openings that can influence the invasion and its spread (Rastogi, 2017). We derived this index by calculating the difference in post-monsoon (average of October, November and December) and pre-monsoon (average of March, April and May) Normalized Differential Vegetation Index obtained from Landsat 8	(Huete *et al.*, 2002) 30 m
		Disturbance	
17	Fire	In wet forests, extensive fire causes loss of native plants and provides a window for establishment of invasive species, which act as a source of propagule (Mungi *et al.*, 2021). In dry forests, fire can control invasive plants (Ratnam *et al.*, 2011).	(Giglio *et al.*, 2003; Schroeder *et al.*, 2014) 90 m
18	Water sources	Water sources act as dispersers for many invasive plants and can also influence native plants through periodic flooding and influencing productivity (Nath *et al.*, 2019)	(Feng *et al.*, 2016) 30 m
		Human impacts	
19	Human modification index	We used this index that is derived from human impacts like built-up areas, human density, agriculture, livestock density, linear infrastructure, mines, oil wells, powerlines, night-light, protected areas, forest areas, etc. Areas with higher modifications have higher propagule pressure of invasive plants as humans are primary agent for introducing these species, as well as these impacts are known to degrade native forest systems thereby reducing the competition for invasive plants (Mungi *et al.*, 2020)	(Kennedy *et al.*, 2019) 1 km

Sl	Variable	Relevance	Source and resolution
20	Livestock density	Over-grazed areas provide unutilized resources that can facilitate establishment of invasive species that act as a source of propagules (Mungi *et al.*, 2020). Livestock are also known to act as seed dispersers for many invasive plants.	(Gilbert *et al.*, 2018) 30 m
21	Long-term vegetation browning	Long term browning of vegetation is known to represent structural degradation of forested areas. Forest degradation can facilitate plant invasions (Mungi *et al.*, 2020)	https://developers.google.com /earth-engine tutorials/community/time-series-modeling 250 m
22	Annual site water balance	Many dry systems in India are experiencing increasing rainfall. The irrigation systems are also increasing the surface water. This can interactively change the hydrological regime of systems and invasive plants could exploit these novel changes.	(Karger *et al.*, 2017) 1 km
23	Annual mean temperature of summer	Higher summer temperature and low rainfall determines the xeric floral diversity and associated invasions (Kannan, Shackleton, & Uma Shaanker, 2013; Panda *et al.*, 2018)	(Karger *et al.*, 2017) 1 km
24	Agriculture area	Agriculture is conduit for many alien introductions. Moreover, it represents loss of natural systems, potential change in hydrology and soil characters. These factors can provide temporal opportunities for introduction of invasive species.	(Karra *et al.*, 2021) 1 km

Section IV

Habitat connectivity across tiger bearing landscapes

Swati Saini, Qamar Qureshi, Yadvendradev V. Jhala, Ujjwal Kumar, Shikha Bisht, Ayan Sadhu, Deb Ranjan Laha, Vishnupriya Kolipakam

Section IV

HABITAT CONNECTIVITY ACROSS TIGER BEARING LANDSCAPES

India is home to a significant proportion of the global tiger population, with 77% residing in and around its 53 tiger reserves and other Protected Areas. The remaining tigers inhabit various forest patches in Territorial Forest Divisions within multi-use landscapes. However, many of these populations are small, making their long-term survival dependent on connectivity with other habitat patches for gene flow and individual exchange between populations (Qureshi *et al.,* 2014; Jhala *et al.,* 2015). To ensure the sustained existence of wildlife, it is vital to maintain large metapopulations through a safe corridor structure (Hanski 1994, 1998, & Jhala *et al.* 2020, 2022). The need of the hour is to consolidate the corridor connectivity for most of the conservation-dependent species as well as ensure ecological resilience to keep the system functioning as well as aid in mitigating climate impacts.

The defining attribute of a conservation core and source area lies in its exceptional biodiversity, which makes it a crucial reservoir of diverse and conservation-dependent species. In contrast, an ecological corridor is valued for its strategic location, which facilitates connectivity between these core areas. Ecological networks, comprised of a well-planned arrangement of core areas and ecological corridors, serve as vital tools for bolstering biological diversity and preserving essential ecosystem processes (Keeley *et al.,* 2021; Jhala *et al.*, 2020).

Compared to isolated individual core areas, such integrated ecological networks provide substantial benefits. They enhance gene flow and promote population connectivity, facilitating the exchange of genetic material between various populations (Kolipakam *et al.,* 2019). Additionally, these networks play a pivotal role in maintaining critical ecosystem functions, such as nutrient cycling, pollination, seed dispersal, and climate resilience, which are fundamental for ecosystem resilience and productivity (Levins 1969; Kim and With 2002; Krosby *et al.* 2010; Hilty *et al.* 2019; Keeley *et al.* 2021).

Moreover, ecological networks contribute significantly to species' long-term survival, particularly under the pressures of a changing climate. By offering pathways for migration and adaptation, they allow species to shift their ranges and colonize new suitable habitats, thus increasing their chances of persistence and survival in the face of environmental disturbances (Keeley *et al.,* 2021). These corridors between habitat patches facilitate species movements and contribute to the re-colonization of remnant patches, enhancing the viability of populations in the landscape (Noss 1987, Fahrig & Merriam 1985, Forman 1983, Qureshi *et al.* 2014, and Jhala *et al.* 2015, 2020). Stable metapopulation dynamics are more resilient to extinction and capable of withstanding stochastic events affecting local population dynamics, such as demographic and environmental fluctuations. However, the rapid development and associated spatial changes have led to habitat fragmentation and degradation, adversely affecting wildlife populations and their survival. Geographically distant habitat patches restrict animal movements, making them susceptible to inbreeding depression and demographic, environmental, or genetic stochasticity, ultimately posing a risk of population extinction (Burkey 1995).

The success of landscape connectivity in biodiversity management and the survival of fragmented populations depend on the effectiveness of these linkages and corridors and their conservation in the future. A well-connected landscape can serve as a successful conservation tool, providing benefits to animals without hindering their developmental requirements (Beier & Noss 1998). Increasing dispersal probabilities enhances the chances of re-colonization, with individuals from a well-populated patch potentially restoring a population in another patch (Brown & Kodric-Brown 1977; Hess & Fischer 2001; Qureshi *et al.* 2014; Menon *et. al.* 2017).

Currently, habitat connectivity for wild species is often tenuous, narrow, and under severe pressure due to linear infrastructure development, agriculture expansion, mining activities, deforestation, and other factors. This deterioration of habitat quality affects animal distribution and abundance significantly. In 2010, countrywide corridors were mapped using circuit theory and least-cost path algorithms with tiger suitability maps at a scale of 100 km^2. However, the current All India Tiger Estimation has produced refined maps with a finer resolution of 25 km^2, incorporating extensive field surveys and data availability. Additionally, a re-assessment of corridors was conducted in 2022, considering the dynamic nature of animals and rapidly developing landscapes, using the latest field information and remotely sensed data.

This connectivity model is based on the habitat suitability of umbrella species like tigers and evaluates the distribution of megaherbivores like elephants and gaur within these connectivities, which are dependent on seasonal local movement for food and water. By designing corridors based on the preferences of these large-ranging species, we can ensure the protection of routes and passages for other species as well. The long-term conservation of connectivity can safeguard a range of critically important habitats and offer various benefits to the ecosystem.

Methodology:

Field data: The field data was collected through the carnivore sign surveys and transect walks in each beat (Forms 1 and 2 of Phase I; see Section I.2 for details). This information was collated at a 25 km^2 grid size as a record of the histories of detection and non-detection during the field surveys.

Remotely Sensed data: Additional information on habitat features, quality, and characteristics was obtained from remotely sensed information available on open source platforms (Table I.2.1). The primary data collected was on elevation, intensity of night time visible lights, forest cover, and the presence of roads; these variables were also used to derive the secondary information on habitat quality. Information on 38 covariates was used (Table I.2.1), explaining habitat quality, human disturbance, and prey abundance in the landscape. There were 25 variables on Prey abundance and human disturbance collected during transect sampling. The rest of the 13 variables are secondary variables derived from remotely sensed data in GIS. Collinearity in the data was addressed through Principal Component Analysis performed in SPSS (SPSS Inc., released 2007).

The landscape connectivity for tigers was modelled using occupancy analysis using program PRESENCE (Bailey *et al.,* 2007). The habitat suitability layer was derived at a fine scale of 25 km^2 for each landscape, incorporating various landscape features, human disturbance indicators (distance from roads, road density, and human habitation), elevation, topography, and other ecologically relevant spatial attributes. The occupancy models utilized animal presence/absence surveys and covariates to calculate grid-based probabilities of tiger occupancy, providing valuable insight into habitat suitability.

To develop the occupancy models, ecologically relevant covariates for tigers were standardized using Principal Component Analysis (PCA). Around 38 covariates were selected based on the behavioural and ecological requirements of tigers in each landscape, offering information on habitat quality, prey abundance, and human disturbance.

Subsequently, the habitat suitability layer derived from the occupancy models served as the basis for constructing the conductance map of the landscape using the program CIRCUITSCAPE (McRae, Shah, and Mohapatra, 2009). CIRCUITSCAPE utilizes circuit theory to assess landscape connectivity, correlating landscape structure weighted with "conductances and resistances" with the habitat suitability of tigers. The conductance map quantifies the preference of land cover features by animals for movement. Forested areas were weighted with the occupancy probability values obtained from the occupancy models, while non-forested areas were assigned a low conductance value to account for possible dispersal through agricultural areas. Urban areas, as indicated by night time lights, were assigned a conductance value of 0, considering that animals tend to avoid moving through such regions. River channels or streams, which provide dispersal routes for animals, were assigned a low conductance value to account for their importance in landscape connectivity.

By integrating occupancy modelling and circuit theory, this study provides valuable insights into the habitat suitability and landscape connectivity of tigers, which can aid in conservation planning and management strategies. The details of linkages will be provided in corridor report.

Landscape Occupancy:

The naïve occupancy estimated for Shivalik Hills and Gangetic Plains was 55%, in Central India and Eastern Ghats landscape - 12.3%, and in Western Ghats landscape, it was 26.4%. For North Eastern landscape, tiger suitability was modelled using MAXENT (Philips 2005, Philips *et.al.* 2017) as sampled space was restricted to Tiger Reserves only.

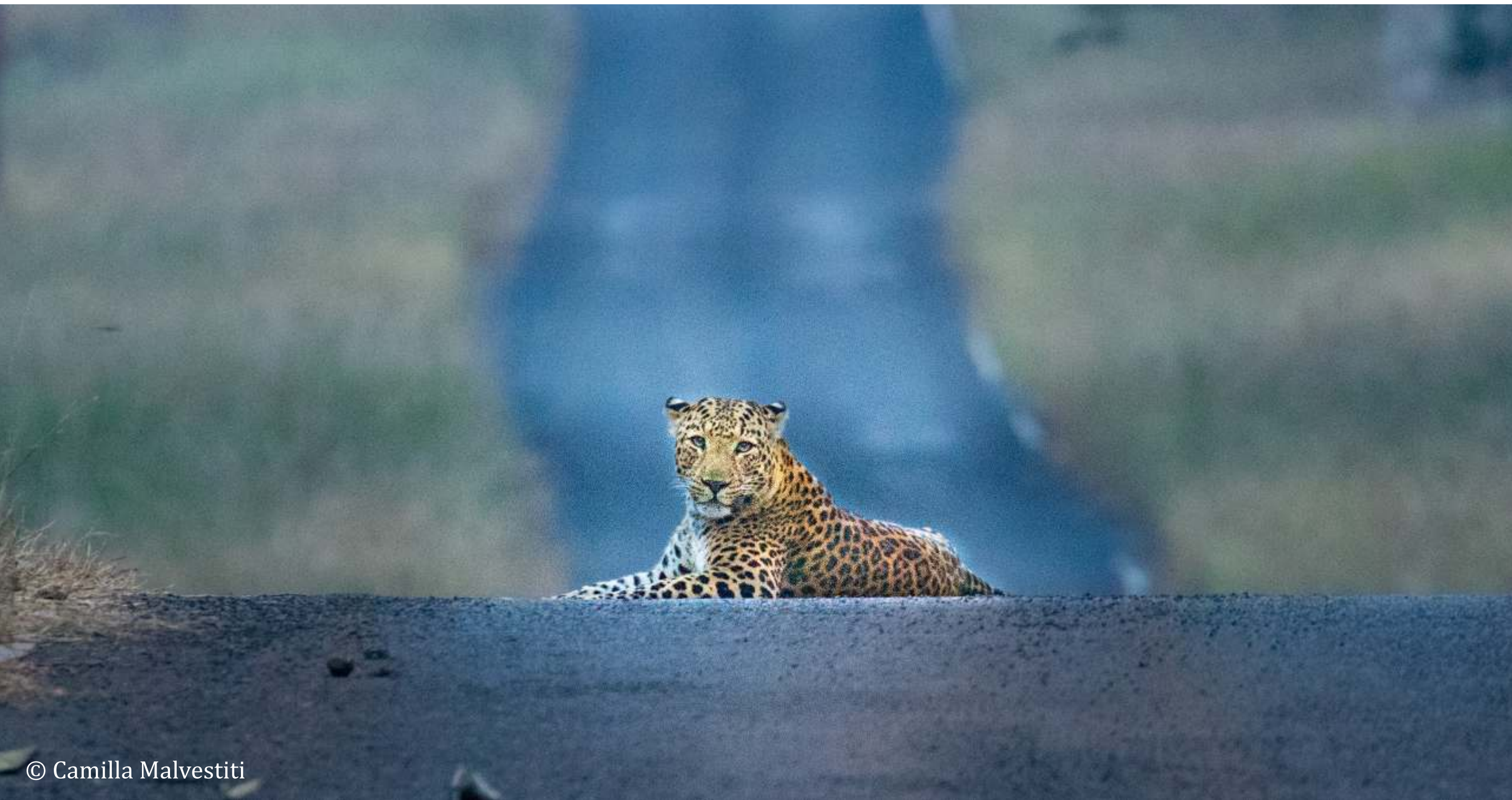
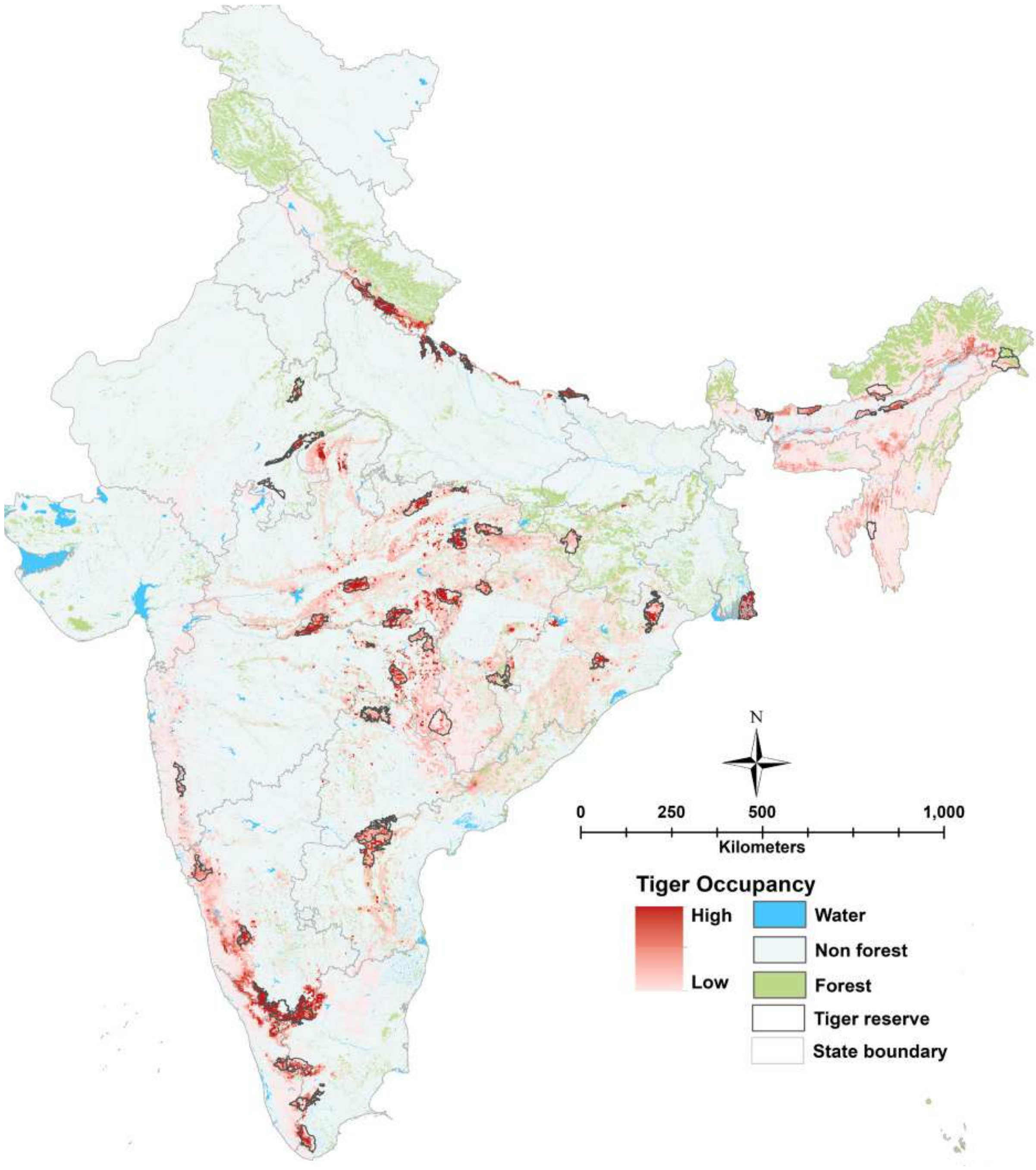

© Camilla Malvestiti

Figure IV.1

Modelled tiger occupancy depicts occupied and potential tiger habitat,2022.

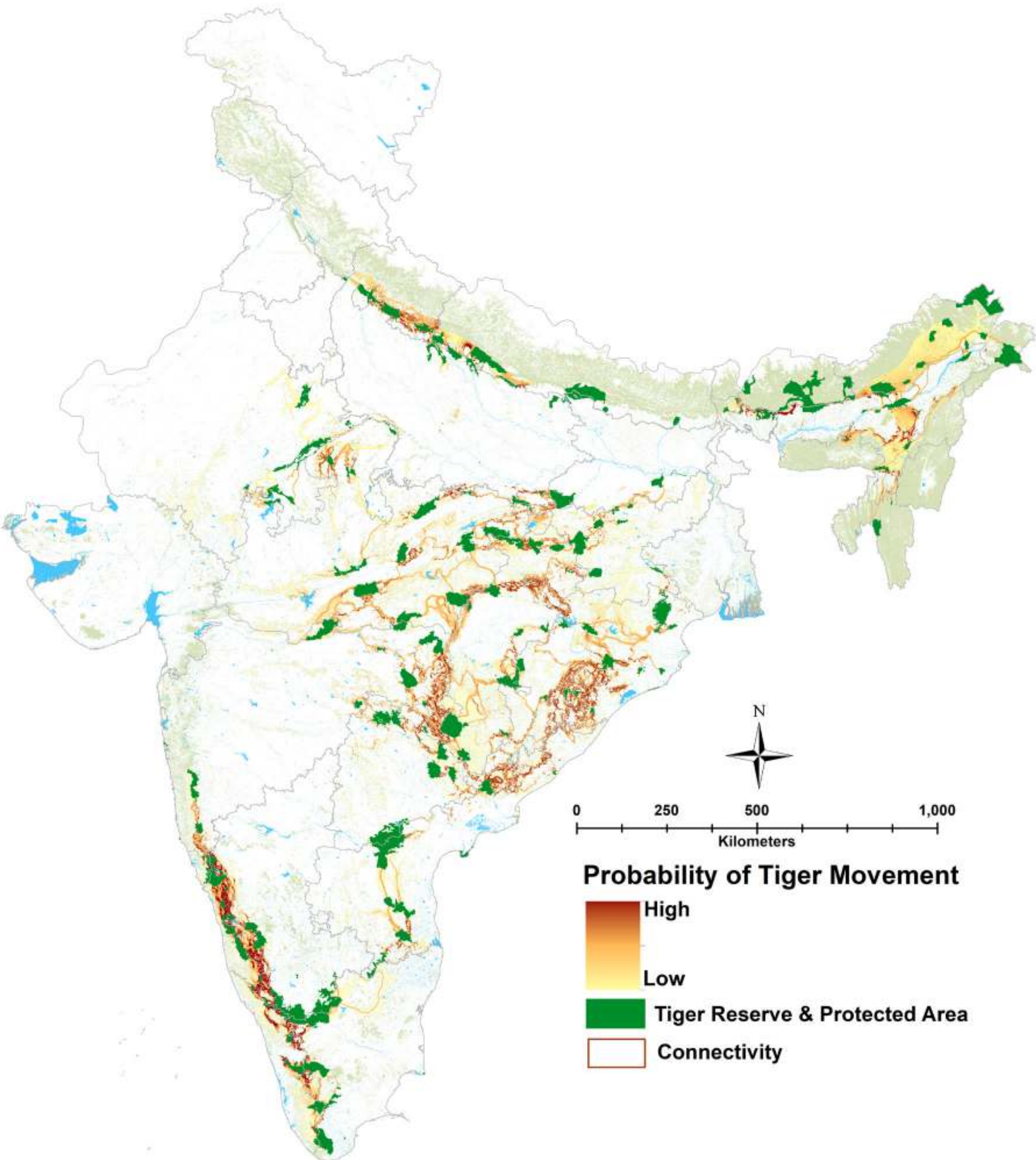


Corridors

The current landscape connectivity between potential tiger source populations and other suitable habitats is illustrated in a modified version from Qureshi *et al.* (2014) (Fig. IV.2). High values indicate robust connectivity, while low values represent impedance in the landscape matrix. The corridors identified will serve the needs of 80% of elephants, gaur, and other large or medium-sized carnivores and herbivores in a landscape. The requirements may differ, and details of species behaviour and obstacle negotiation abilities will determine the details needed to ensure safe passage of the species of concern.

Figure IV.2

Landscape Connectivity for Tiger Dispersal Using Habitat Suitability Model, 2022.



CORRIDORS OF THE SHIVALIK HILLS AND GANGETIC PLAINS LANDSCAPE

The Shivalik landscape exhibits substantial connectivity through forested patches in Uttarakhand. However, connectivity is severely compromised in many places making it difficult for tigers and elephants to move, like East and West Rajaji. Several developmental projects caused impediments in movement. Many of the impediments were resolved by providing movements pathways by making flyovers.

Despite consistent occupancy, there are concerns about crucial connectivity in the landscape being under threat. Resorts, townships, and private farms along National Highway 121, as well as the township of Ramnagar along the banks of the Kosi River, limit the eastern connectivity of Corbett Tiger Reserve. These developments have created hard boundaries that hinder animal movement. Only two corridors remain in this eastern part that connect Corbett forests with Ramnagar Forest Division, but they face challenges like abandoned developmental projects and encroachment.

It is crucial to assess projects in these important corridors for tigers and elephants more critically. Measures should be taken to foster these remaining linkages with restorative inputs, mitigating infrastructural development and controlling encroachment. Sensitizing resorts and private landowners to remove impermeable fences at critical points is essential to allow wildlife passage through their property. The loss of connectivity between Corbett and Ramnagar forest division has been observed, and tiger movement has shifted towards Amangarh and Terai West before reaching Ramnagar forest division, leading to negative interactions in heavily populated areas with forest patches.

Forest connectivity from Haldwani division to Shuklaphanta National Park in Nepal is affected by urban sprawl, boulder mining, human activities, and major roads like National Highway 87 and the railway line to Kathgodam. Restoring connectivity in the Gola corridor is crucial for elephant movement to reduce conflicts. The Jamrani multi-purpose dam need to provide appropriate mitigation measures to ensure movement of wildlife specifically elephants and tigers.

Uttar Pradesh has precarious connectivity with Uttarakhand, but it is crucial and needs to be strengthened. Most of Uttar Pradesh has only the possibility of dispersal through the forests of Nepal. The Indo-Nepal border road needs mitigation measures to provide passage to tigers, elephants, rhinos, and a range of other species. The connectivity of the Valmiki Tiger Reserve in Bihar with Chitwan needs transboundary cooperation and strengthening in both countries. Implementing mitigation measures along the borders could promote safe animal movement in this landscape. The alignment of major roads planned along the India-Nepal border should avoid traversing Protected Areas and corridors and ensure proper animal passageways through mitigation to maintain the movement of wildlife, including tigers and elephants. The presence of tiger cubs and juveniles in Sohagibarwa Wildlife Sanctuary indicates the positive colonization of this area by tigers, which is promising. It is important to ensure connectivity between Valmiki and Sohagibarwa, which is highly disturbed at present.

CORRIDORS OF CENTRAL INDIA AND THE EASTERN GHATS LANDSCAPE

The Central India and Eastern Ghats landscape face the challenge of fragmented habitats, making connectivity with source populations crucial. In Central India, habitat patches are connected through fragile, narrow forest corridors surrounded by a human-dominated matrix with significant developmental pressure. Moreover, this region is a mining hub, with many mining locations either in or near the corridors. Adopting eco-friendly mining methods is essential to mitigate habitat damage. Linear development, such as highways, poses further pressure on this landscape. Proper mitigation measures are necessary to manage these challenges effectively. The success of underpasses along NH7/44 highway sets an example that can be replicated in other ecologically sensitive and movement-critical areas.

Among the significant corridors, the Kanha-Pench Corridor is essential, connecting the source populations of tigers in Kanha and Pench Tiger Reserves through Madhya Pradesh's forests. This corridor facilitates the movement of tigers, dholes, leopards, and gaurs. The Kanha-Achanakmar Corridor ensures eastward connectivity between the Kanha-Pench-Achanakmar landscape, but it faces threats from resource extraction and road development, crucial for the recovery of Achanakmar Tiger Reserve.

The Kanha-Navegaon-Tadoba-Indravati Corridor links Kanha Tiger Reserve to tiger populations in Maharashtra and Chhattisgarh. However, fragmented patches, poaching, linear infrastructures, and mining pose significant threats to this linkage. The Satpura-Pench Corridor connecting Satpura and Pench Tiger Reserves faces pressure from agriculture and human settlements, necessitating urgent mitigation measures.

The Satpura-Melghat Corridor, linking Satpura in Madhya Pradesh to Melghat in Maharashtra, is vital for tiger populations, but national highways and human habitation create bottlenecks requiring mitigation. The Bandhavgarh-Sanjay-Guru Ghasidas-Palamau Corridor is crucial for the recovery of low-density tiger reserves.

Other corridors, like Panna-Ranipur-Kaimur, Kanha-Bandhavgarh, Kanha-Satpuda, Bandhavgarh-Noradehi-Satpuda, Noradehi-Ratapani-Kheoni, Melghat-Bor-Tadoba, Tipeshwar-Kawal, Madhav-Kuno-Ranthambore, and Panna-Madhav-Kuno-Ranthambore, play essential roles in connecting tiger habitats but require restoration efforts and careful management to ensure smooth movement permeability.

The Indravati-Udanti Sitanadi Corridor connects Indravati to Udanti-Sitanadi Tiger Reserve through contiguous forests. Similarly, the Udanti-Sitanadi-Sonabeda-Barnawapara-Gomardha-Hirakund-Bamra-Satkosia Corridor connects multiple tiger habitats but faces challenges due to fragmented forests.

The Pamed-Papikonda-Kanger Ghati-Satkosia Corridor links Pamed to Satkosia Tiger Reserve but faces fragmentation issues. The Similipal-Satkosia Corridor between Similipal and Satkosia requires significant restoration efforts. The Similipal-Dalma Corridor connecting Similipal to

Dalma Wildlife Sanctuary is vital for Elephants. The Palamu-Lawalong-Hazaribagh-Gautam Budhha-Bhimbandh Corridor connects Palamau to Bhimbandh Wildlife Sanctuary.

The Nagarjunasagar Srisailam-Shri Venkateshwara-Kaudinya Corridor passes through several protected areas, but highways pose threats. Lastly, the Sahyadri-Kali Corridor linking Sahyadri to Goa and Karnataka connects tiger populations in the region.

CORRIDORS OF THE WESTERN GHATS LANDSCAPE

The Western Ghats wildlife corridors are essential for connecting fragmented habitats and enabling the movement of diverse species in this biodiverse region. However, these corridors face numerous challenges like deforestation, habitat fragmentation, and human activities, which threaten wildlife and hinder their dispersal. Conservation efforts focus on identifying and preserving these vital corridors through collaborative efforts involving governments, conservation organizations, and local communities. By protecting and restoring these connections, the Western Ghats' ecological balance can be maintained, safeguarding endangered species and preserving the region's biodiversity.

The landscape of the Western Ghats is primarily connected through forested areas, interspersed with human settlements, plantations, and agriculture. While the forests are contiguous, developmental projects, plantations, and agriculture are causing significant habitat fragmentation, potentially affecting gene flow in the region. Hence, it's crucial to legitimize and protect connectivity between tiger populations to maintain gene flow.

In the northern Western Ghats, the landscape harbours a low-density tiger population, but it is well connected through various forest divisions and tiger reserves. However, developmental projects like the railway line widening threaten connectivity between these areas. The Bhadra-Kudremukha landscape spans a vast area, including source populations and adjoining protected areas. Although connectivity exists, the increasing number of linear infrastructures and development projects weakens it. The Nagarahole-Bandipur-Sathyamangalam-BRT-Mudumalai-Wayanad population is the most significant tiger population in the Western Ghats, well connected, but human settlements pose a threat.

In the Wayanad landscape, connectivity to Silent Valley NP is threatened by NH67 and vehicular traffic. The Parambikulam-Anamalai complex is a crucial source population well connected through forested areas, but linear infrastructures like NH 208 pose a threat. Periyar and KMTR landscapes harbor tiger populations with essential connectivity between them, ensuring gene flow and future expansion. Preserving and restoring these wildlife corridors in the Western Ghats are vital for the continued survival and thriving of the region's diverse wildlife.

CORRIDORS OF NORTH EAST HILLS AND BRAHMAPUTRA FLOOD PLAINS

The North East Hills and Brahmaputra Flood Plains landscape is facing a persistent challenge of low tiger abundance. However, tiger reserves such as Kaziranga, Manas, and Orang are proving to be crucial source populations for tigers in this region. Interestingly, these reserves are not only supporting tigers but also harbor healthy populations of other conservation-important species like Asiatic elephants and one-horned rhinoceroses, adding to the ecological significance of these areas.

Despite the low number of tigers, the landscape boasts vast contiguous forested tracks, acting as vital corridors for the movement of tigers and other wildlife species. This connectivity is crucial for maintaining genetic diversity and ecological balance among tiger populations in the region. To better understand the landscape, it can be divided into three major parts: the North Bengal Dooars, the Brahmaputra Flood Plains, and the North East Hills.

The North Bengal Dooars region faces high human pressure as protected areas are situated amidst various human land use areas. However, Mahananda Wildlife Sanctuary and Neora Valley National Park, as part of the Greater Khangchendzonga landscape, are connected to the Pangolakha Wildlife Sanctuary in Sikkim and Jigme Khesar Nature Reserve in Bhutan through forested patches. Towards the east, Mahananda Wildlife Sanctuary's wildlife population connects to Apalchand Reserve Forest of Baikunthapur Forest Division through river islands or "Chaurs" of the Teesta River. Further connectivity from Apalchand to Gorumara is fragmented and connected through the Chel River, numerous tea gardens, and human habitations. Jaldapara National Park and Buxa Tiger Reserve maintain connectivity through the Torsa River's islands and forested patches of Chilapata Reserve Forest and Nimtijhora Tea Estate. In the north, Buxa Tiger Reserve is connected to Royal Manas National Park in Bhutan through Phibsoo Wildlife Sanctuary. This entire Buxa- Royal Manas- Manas block serves as a single population unit, necessitating trans-boundary cooperation and knowledge sharing to sustain genetic connectivity and ecological viability of wildlife species. However, large-scale encroachment and logging in Kokrajhar district have severely affected the movement of wildlife species in the northern Bengal Dooars. Linear infrastructures, mines, and human land use areas, like the railway track between Siliguri and Alipurduar junction and NH 31, also act as major barriers to wildlife movement. Implementing appropriate mitigation measures, such as controlling vehicular traffic speed at bottleneck points, becomes essential to ensure the viability of corridors in this block.

Kaziranga Tiger Reserve stands as the largest tiger population in the Brahmaputra flood plains and acts as the primary source for the entire landscape. Towards the west, Kaziranga's wildlife population connects to Orang Tiger Reserve through Burachapori and Laokhowa Wildlife Sanctuary and numerous river islands of the Brahmaputra. In the north, the population is connected to Nameri and Pakke tiger reserves through the river islands or "Chaporis" of Kameng or Jia Bhoroli and Dikrong rivers. The river islands of the Subansiri river also serve as potential ecological conduits for wildlife species, connecting Kaziranga to Tale Valley Wildlife Sanctuaries in Arunachal Pradesh. However, the highly productive nature of these river islands makes them vulnerable to encroachment and human-induced land use changes, weakening the linkages between metapopulation blocks. This hampers the movement of wildlife species and gene flow between flood plains and hill populations of tigers. Towards the south, the tiger population of Kaziranga connects to Intanki National Park of Nagaland through East Karbi-Anglong, Nambor, and Bherajan Borajan Podumoni wildlife sanctuaries and Dhansiri Reserve Forest, and to Nonghkhyllem Wildlife Sanctuary in Meghalaya through Amcahang and Pobitora Wildlife Sanctuary in Assam. However, the presence of tigers has not been recorded in the Karbi Anglong Intanki block during consecutive two cycles of the All India Tiger Estimation. The forested tracks through Karbi-Anglong forest have potential for the movement of wildlife species such as elephants and gaurs, along with tigers, provided that protection levels are maintained through appropriate law enforcement monitoring and community participation. Major hindrances, like NH 715 (earlier NH 37) and numerous built-up areas along the highway and the southern border of Kaziranga, have left only a few designated habitats or wildlife corridors for the movement of wildlife species between Kaziranga and the Karbi-Anglong landscape. It is crucial to ensure movement of animals through this connectivity to provide safe passage during periodic floods. Intanki National Park further connects to Barail Wildlife Sanctuary in Assam, Pualreng Wildlife Sanctuary, and Dampa Tiger Reserve in Mizoram. However, the connectivity between Barail and Pualreng is weak and fragmented. Protected areas on the northern bank of the Brahmaputra along the foothills of the eastern Himalayas have good connectivity through forested patches, with Manas Tiger Reserve playing a significant role as the source population in this block. Towards the east, Manas is connected to Bornadi Wildlife Sanctuary through Jomotsangkha Wildlife Sanctuary in Bhutan. The population further connects to Nameri and Pakke tiger reserves through Sonai Rupai and Eagle Nest wildlife sanctuaries. However, the increasing biotic pressure in Sonai Rupai Wildlife Sanctuary could hinder further movement of tigers and other wildlife species to Nameri. Implementing managerial measures to reduce biotic pressure and supplement prey in Sonai Rupai could help maintain the genetic connectivity and population viability between Manas, Nameri, and Pakke tiger reserves.

The tiger populations in Pakke and Nameri Tiger Reserves are linked to the expansive forested complex of Arunachal Pradesh, with potential extensions to Myanmar. Towards the east, the tiger population forms a continuous habitat with numerous reserve forests and wildlife sanctuaries along the borders of Assam and Arunachal Pradesh. Pakke Tiger Reserve is connected to Tale Valley Wildlife Sanctuary through Itanagar Wildlife Sanctuary, and further to D'Ering Wildlife Sanctuary. However, the connectivity between Tale Wildlife Sanctuary, Yordi-Rabe Supe Wildlife Sanctuary, and Mouling National Park is weak and fragmented due to the development of linear infrastructure. In the southern direction, D'Ering Wildlife Sanctuary maintains a strong connection with Dibru Saikhowa National Park in Assam, although effective law enforcement monitoring is required to reduce biotic and grazing pressure. These floodplains provide an excellent habitat and refuge for numerous endangered wildlife species.

Moving further east, the connectivity between Dibru Saikhowa National Park and D'Ering Wildlife Sanctuary extends to Mehao Wildlife Sanctuary in Lower Dibang Valley district through rivers and forested patches. However, the development of highways between Pasighat and Roing poses a significant constraint for wildlife species in this landscape matrix. The Dibang River and its tributaries hold the potential to serve as a corridor between Mehao and the Dibang Wildlife Sanctuary. Nevertheless, the development of border roads poses a major threat, necessitating detailed sampling to assess the viability of connectivity.

In the south-west direction, the connectivity extends to the Kamlang-Namdapha block. This block features contiguous forested connections across the international border of India and Myanmar, with links to Htamanthi Wildlife Sanctuary in Myanmar. However, the abundance of tigers and major prey species is considerably low in this block. Further south, the Kamlang-Namdapha block connects to Intanki National Park of Nagaland and Barail Wildlife Sanctuary of Assam through forested patches in Tirap, Arunachal Pradesh, and districts of Nagaland including Mon, Mokokchung, Wokha, Dimapur, and Peren. Towards the west, Intanki is connected to Nongkhyllem Wildlife Sanctuary and further to Balpakram National Park in Meghalaya through a weakly fragmented landscape matrix. To enhance gene flow between wildlife populations, connectivity within the protected area network of Mizoram should be strengthened. On the other hand, Dampa Tiger Reserve receives weak connections from Intanki National Park and Barail Wildlife Sanctuary. In the southern direction, it could potentially be further linked to forested patches of Myanmar and the Chitagong hill tracts of Bangladesh through wildlife sanctuaries like Thorangtlang, Tawi, Nengpui, Khawnglung, Phawngpui Blue Mountain, and Murlen national parks.

However, the corridor connectivity in the north-east hills landscape matrix faces various threats, including the development of numerous linear infrastructures, hydroelectric projects, and the depletion of prey species from the forested patches. Addressing these challenges is essential to ensure the long-term survival and well-being of the diverse wildlife populations in this ecologically critical landscape.

CORRIDORS OF SUNDARBANS

In the Sundarbans, the tiger population is surrounded by human habitation on the west and the Bay of Bengal on the south. The Matla River on the west and the Harinbhanga River on the east serve as interdivisional corridors and conduits to Bangladesh, respectively. This landscape features two significant inland waterways, Kolkata-Silghat and Kolkata-Karimganj. These inland waterways can pose a problem for tiger movements between islands especially if there is heavy ship traffic. These inland waterways can pose a problem for tiger movements between islands especially if there is heavy ship traffic (Naha *et al.* in 2016).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Sites

Section V.1

Shivalik Hills and Gangetic Plains Landscape

This landscape comprises of shivaliks- bhabar and terai forest tracts of Uttarakhand, Uttar Pradesh and Bihar. Camera trapping was carried out in 26 protected areas in this landscape in All India Tiger Estimation exercise 2022.

UTTARAKHAND

ALMORA FOREST DIVISION

Biodiversity of Almora Forest Division plays a vital role in contributing to the region's overall natural heritage. The division is known for its sacred groves, which are pockets of ancient forests protected by local communities for religious and cultural reasons. Almora Forest Division is north of Corbett Tiger Reserve and is important for high altitude tiger conservation in the state. Total of 12 tiger images were obtained from which 1 tiger individual was identified (Table V.1.1). Due to insufficient photo-captures and recaptures, density of tigers for this site was not estimated.

Figure V.1.1

Camera trap layout and tiger presence in Almora Forest Division, 2022

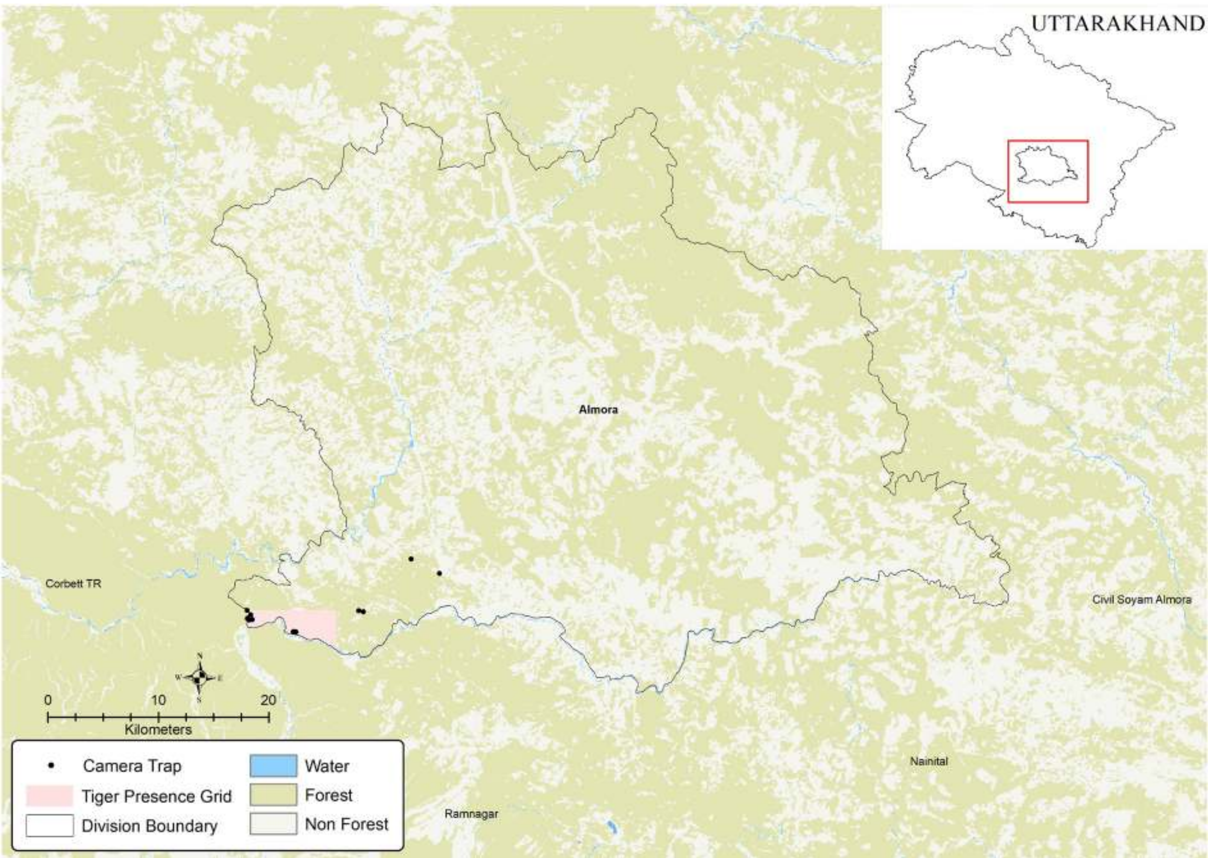

Table V.1. 1

Sampling details and number of tiger photo-captured in Almora Forest Division, 2022.

Parameters	Estimate
Camera points	13
Trap nights (effort)	258
Number of tiger photos	12
Unique tigers captured	1

CHAMPAWAT FOREST DIVISION

Champawat forest division is in the Kumaon forest circle and has important cultural significance in terms of sacred groves and rich biodiversity. It is also infamous for its man-eating tigress as documented in “Maneaters of Kumaon” by Jim Corbett.

Eleven tigers were identified from 83 tiger images (Table V.1.2). Due to insufficient photo-captures, poor recaptures and trapping design density of tigers for this site was not estimated.

Figure V.1.2

Camera trap layout and tiger presence in Champawat Forest Division, 2022

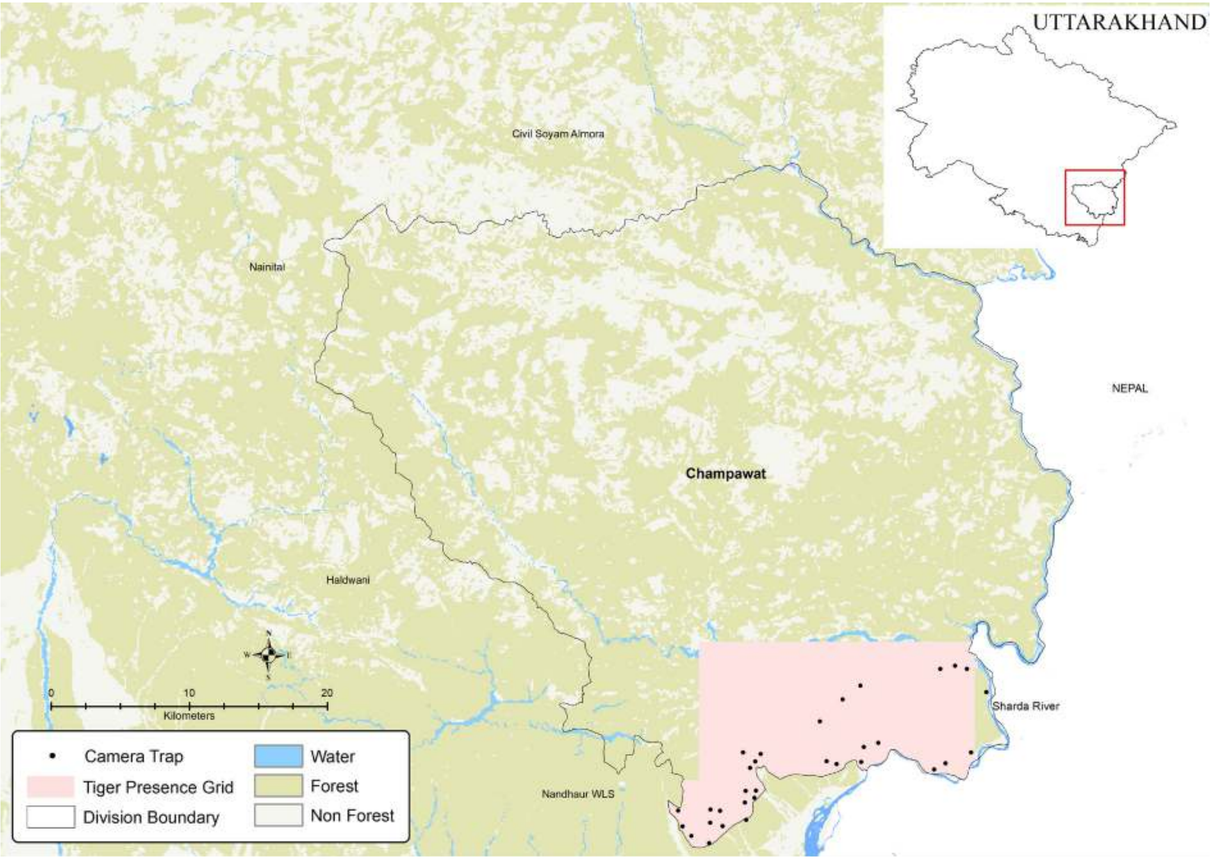

Table V.1. 2

Sampling details and number of tiger photo-captured in Champawat Forest Division, 2022.

Parameters	Estimate
Camera points	32
Trap nights (effort)	1388
Number of tiger photos	83
Unique tigers captured	11

CORBETT TIGER RESERVE

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$05'E to $79^0$05'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 (Barthari 1999). 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.

Total of 260 tigers were identified from 9961 tiger images. Tiger density was estimated at 14.65 (SE 0.92) tiger per 100 km^2 (Table V.1.3). The detection corrected tiger sex ratio was nearly 2 females per male (Table V.1.3). A total of 49 young tigers were photo-captured during camera trapping session.

Figure V.1.3

Camera trap layout and spatial density of tigers in Corbett Tiger Reserve, 2022

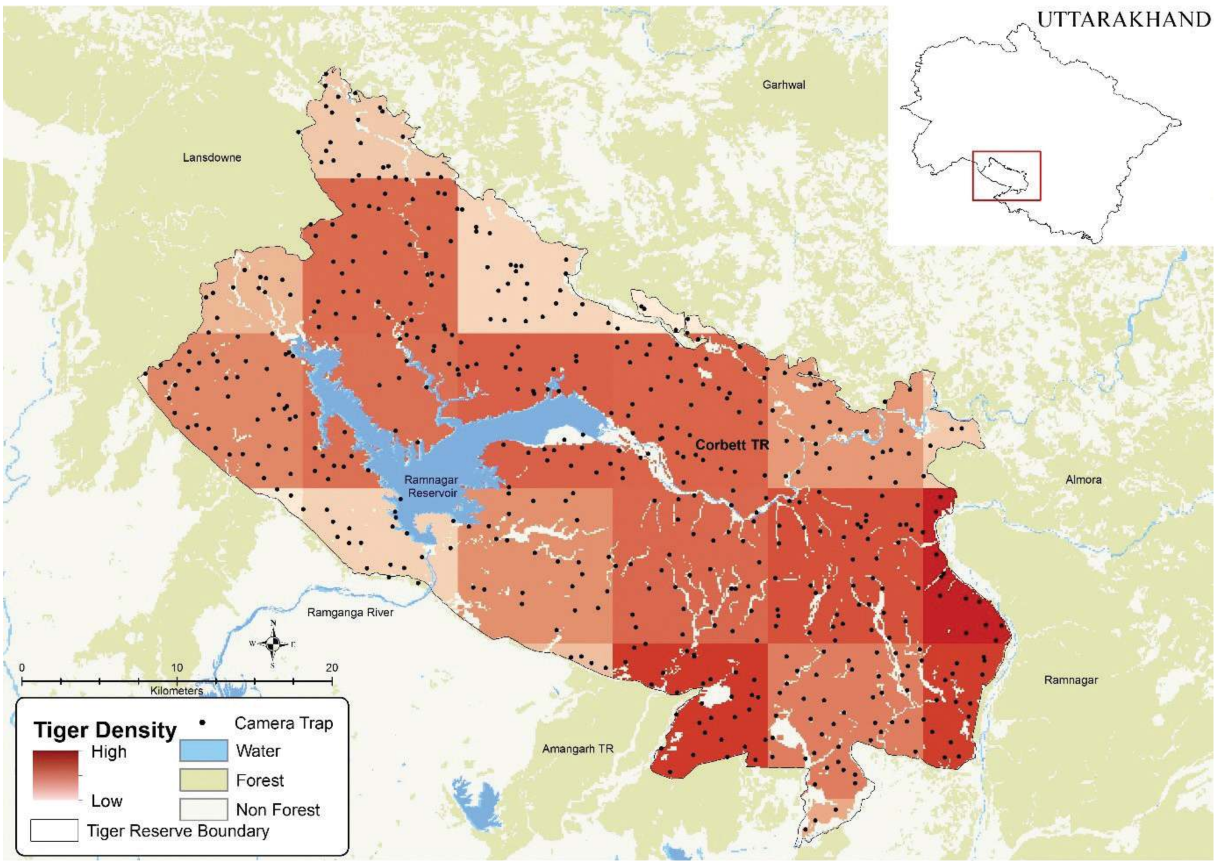

Table V.1. 3

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Corbett Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	2182
Camera points	514
Trap nights (effort)	36845
Unique tigers captured	260
Model	Pmix(sex) g0(.)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	14.65(0.92)
σ Female (SE) (km)	1.53(0.010)
σ Male (SE) (km)	1.93(0.01)
g0 Female (SE)	0.09(0.001)
g0 Male (SE)	0.09(0.001)
Pmix Female (SE)	0.63(0.05)
Pmix Male (SE)	0.37(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: estimate of proportion of male /female (detection corrected sex ratio)

The tiger population in the reserve has remained constant. It is one of the highest density tiger population in the world which is a source of tigers in the larger landscape. This has led to negative interaction of tigers with humans in and around the tiger reserve. To gain insights in how a territorial large mammal operates at such high density and provide an early warning system to alert nearby villages of tiger movement, radio collaring of tigers should be carried out in the tiger reserve.

DEHRADUN FOREST DIVISION

Dehradun Forest Division of Shivalik Circle is situated between 30^0- 2' to 30^0- 26' North Latitude and 77^0- 52' to 78^0- 19' East in the Dehradun, Vikasnagar and Rishikesh Tehsil of Dehradun district. Forest conservation started in these areas in 1861. After the constitution of Rajaji National Park, reorganization of both Dehradun East & West Forest Divisions was done.

The forests of the division are bounded in the North by Mussoorie Forest Division, in the South by Rajaji National Park, in the West by Shivalik and Soil Conservation Division, Kalsi and in the East by the river Ganga. The forests of the division are interspersed by numerous fields, farms, villages and townships. After the creation of the new state; number of industrial areas has also come up in this region. The northern belt is a complicated mass, being interspersed with and intersected by a large number of 'chaks' and villages resulting in a number of isolated sometimes narrow finger like formations.

The Dehradun Forest Division was camera trapped for the first time, resulting in the 43 tiger images from which 3 distinct tiger individuals were identified (Table V.1.4). However, due to inadequate photo-captures and recaptures, tiger density estimation for this site was not possible.

Figure V.1.4

Camera trap layout and tiger presence in Dehradun Forest Division, 2022

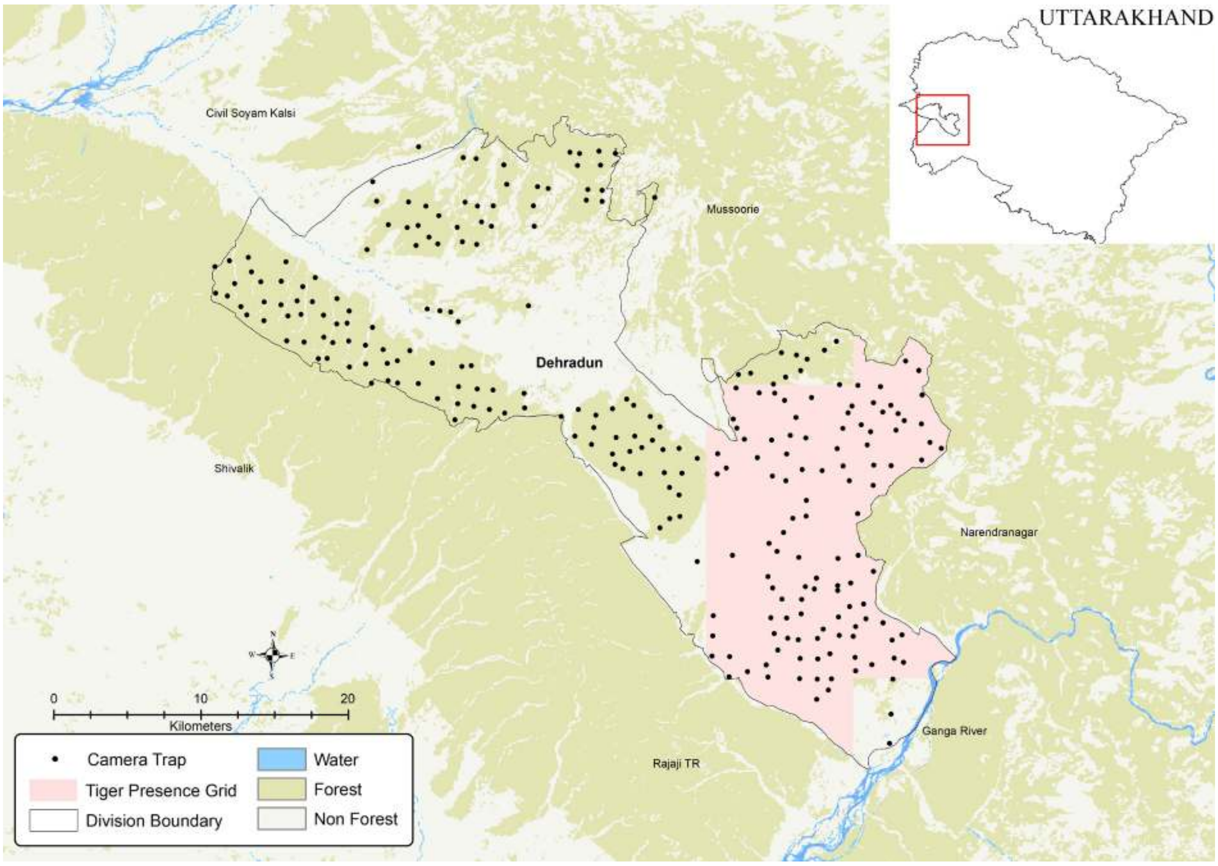

Table V.1. 4

Sampling details and number of tiger photo-captured in Dehradun Forest Division, 2022.

Parameters	Estimate
Camera points	262
Trap nights (effort)	13702
Number of tiger photos	43
Unique tigers captured	3

HALDWANI FOREST DIVISION

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.

Total of 1066 tiger images were obtained from which 36 tiger individuals were identified and tiger density was estimated at 4.68 (SE 0.79) tiger per 100 km^2 (Table V.1.5). The detection corrected tiger sex ratio was 3 females per male (Table V.1.5). A total of 5 young tigers were photo-captured.

Figure V.1.5

Camera trap layout and spatial density of tigers in Haldwani Forest Division, 2022

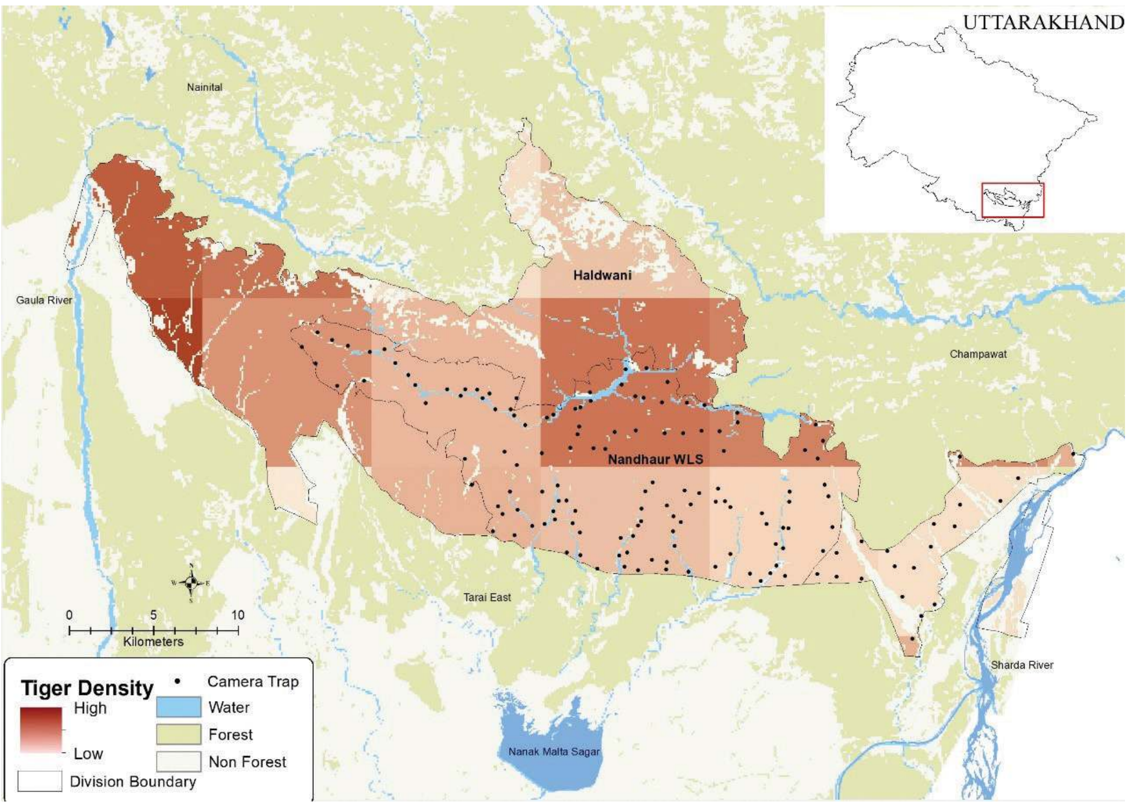

Table V.1. 5

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Haldwani Forest Division, 2022.

Variables	Estimate
Model space (km^2)	1138
Camera points	149
Trap nights (effort)	5881
Unique tigers captured	36
Model	Pmix(sex) g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	4.68(0.79)
σ Female (SE) (km)	1.58(0.038)
σ Male (SE) (km)	3.07(0.11)
g0 Female (SE)	0.15(0.01)
g0 Male (SE)	0.09(0.01)
Pmix Female (SE)	0.76(0.07)
Pmix Male (SE)	0.24(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: estimate of proportion of male /female (detection corrected sex ratio)

Haldwani is an important tiger population that connects Shivalik plains to high altitude tiger population of Champawat and Nainital. With increasing pressure from the expanding township of Haldwani and multipurpose projects coming in the area, this tiger population needs to be secured and appropriate mitigation measures adhered to.

KALSI SOIL CONSERVATION FOREST DIVISION

Kalsi Soil Conservation Forest Division comprises of three ranges, viz., Choharpur, Langha and Timli Range. This Division comes under Shivalik Circle. The three territorial ranges lying between 30^0 – 19` to $30^0$ – 32` North Latitude and 77^0 – 34` to $78^0$ – 0` East Longitude falling in the Vikasnagar Tehsil of Dehradun district. Northern boundary is adjacent to Mussoorie Forest Division and covers Sub Temperate to Temperate forest of outer Himalaya. The southern boundary connected to Shivalik Forest Division. Similarly, eastern boundary lies adjacent to Jhajra and Malhan Ranges of Dehradun Division. The western part of these areas lies adjacent to River Range of Chakrata Forest Division and Yamuna river. In between Timli and Choharpur ranges there are fertile cultivation lands.

The Lesser Himalayan part of these ranges has steep slope, upper reaches are covered with grasses and shrubs. Middle and lower foot hills are covered with sub-tropical and tropical vegetation mainly is also covered with good vegetation, predominantly sal, southern part of the valley is the Northern aspect of Shivaliks mountain range. The upper ridges are covered with miscellaneous dominated by sal and miscellaneous species. Valley proper is also covered with good vegetation, predominantly sal, southern part of the valley is the Northern aspect of Shivalik mountain range. The upper ridges are covered with miscellaneous species whose density is scanty and lower flatter areas have good vegetation cover, mostly dominated by sal and its associates

The Kalsi Forest Division was camera trapped for the first time, and no tiger images were captured at this site despite a trapping effort spanning 7159 days (Table V.1.6).

Figure V.1.6

Camera trap layout in Kalsi Forest Division, 2022

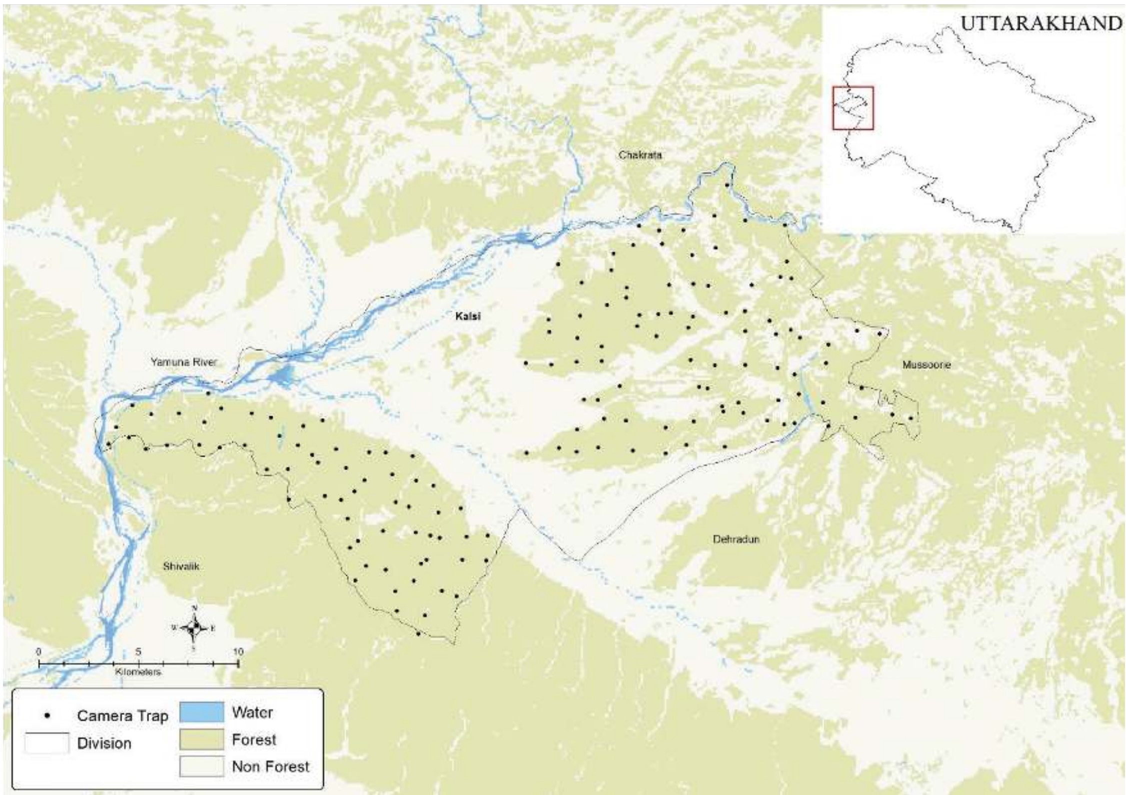

Table V.1. 6

Sampling details and number of tiger photo-captured in Kalsi Forest Division, 2022

Parameters	Estimate
Camera points	154
Trap nights (effort)	7159
Number of tiger photos	0

LANSDOWNE FOREST DIVISION

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.

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 home to a thriving population of tigers.

Total of 29 tigers were identified from 356 tiger images and tiger density was estimated to be 3.22(SE 0.61) tiger per 100 km^2 (Table V.1.7). The detection corrected sex ratio was nearly1 female per male (Table V.1.7). A total of 1 young tigers were photo-captured.

Figure V.1.7

Camera trap layout and spatial density of tigers in Lansdowne Forest Division, 2022

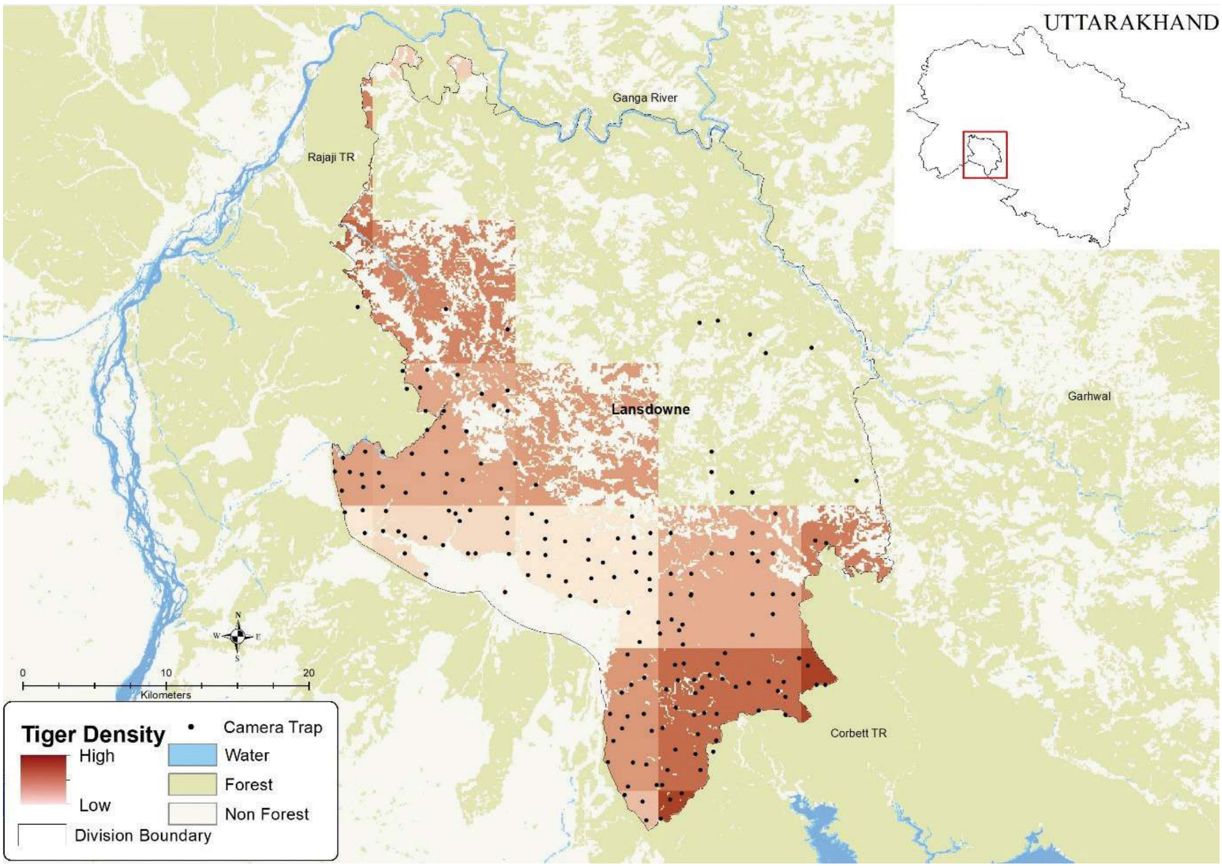

Table V.1. 7

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Lansdowne Forest Division, 2022.

Variables	Estimate
Model space (km2)	1654
Camera points	181
Trap nights (effort)	6371
Unique tigers captured	29
Model	Pmix(sex) g0(.)σ(.)
$\hat{D}$ SECR (per 100 km^2)	3.22(0.61)
σ Female (SE) (km)	1.73(0.07)
σ Male (SE) (km)	1.73(0.07)
g0 Female (SE)	0.06(0.01)
g0 Male (SE)	0.06(0.01)
Pmix Female (SE)	0.53(0.11)
Pmix Male (SE)	0.47(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: estimate of proportion of male /female (detection corrected sex ratio)

Lansdowne is an important stepping stone for tigers to move between Corbett and Rajaji Tiger Reserve and an important corridor for elephant movement as well. Tiger population here has been constant over the year but this division has been under increasing pressure due to linear infrastructure development. Agencies need to invest in green infrastructure to maintain this crucial connectivity in this landscape.

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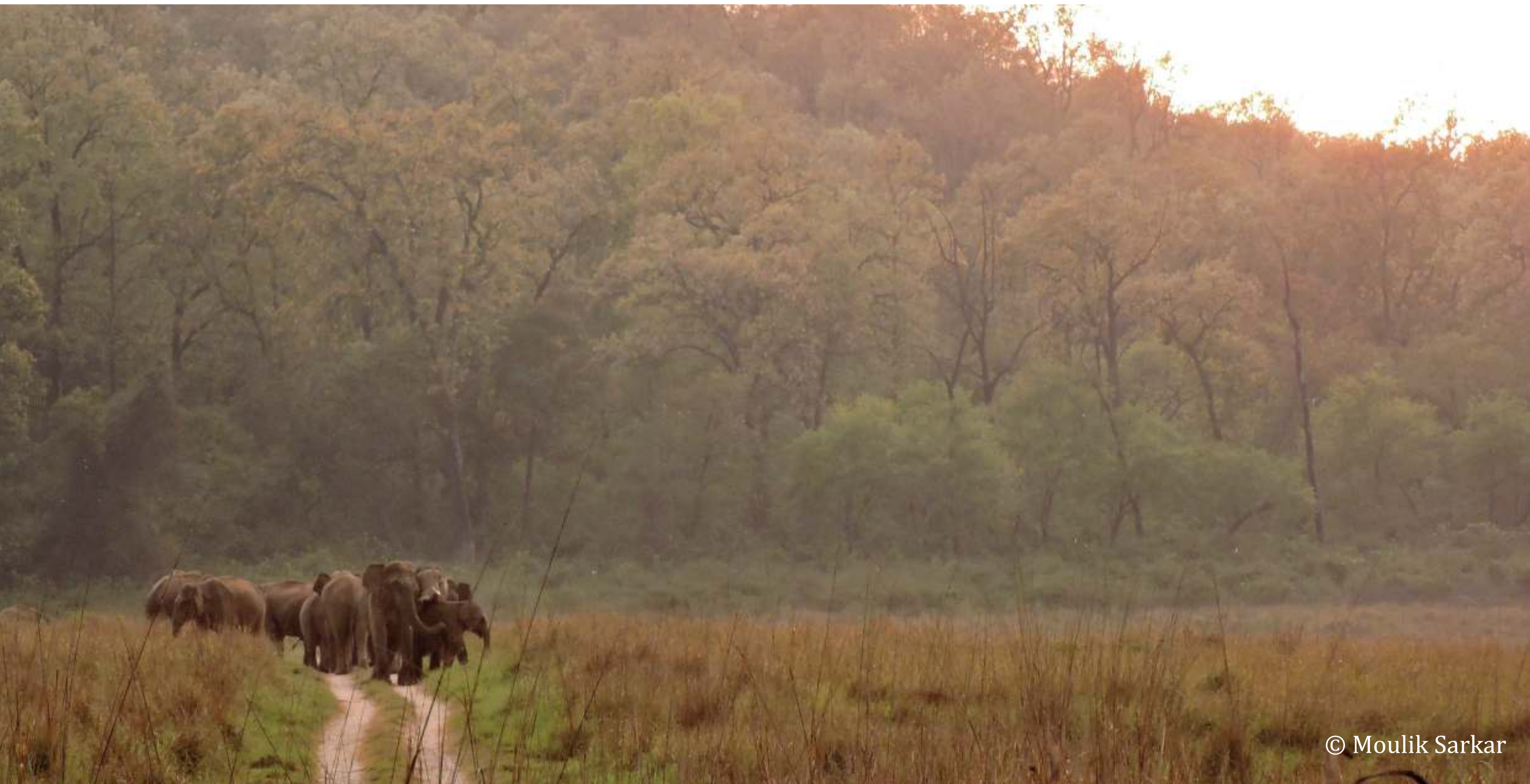

NAINITAL FOREST DIVISION

Nainital region is 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. The division forms a part of tiger landscape of Uttarakhand which is important for long term conservation. Several incidents of killing of humans by tigers is recorded in this division in the year 2022-23. Expanding human and tiger population in surrounding landscape as well as lack of awareness is a major challenge to find long lasting solutions. Total of 2 tiger images were obtained from which 1 tiger individuals was identified (Table V.1.8).

Figure V.1.8

Camera trap layout and tiger presence in Nainital Forest Division, 2022

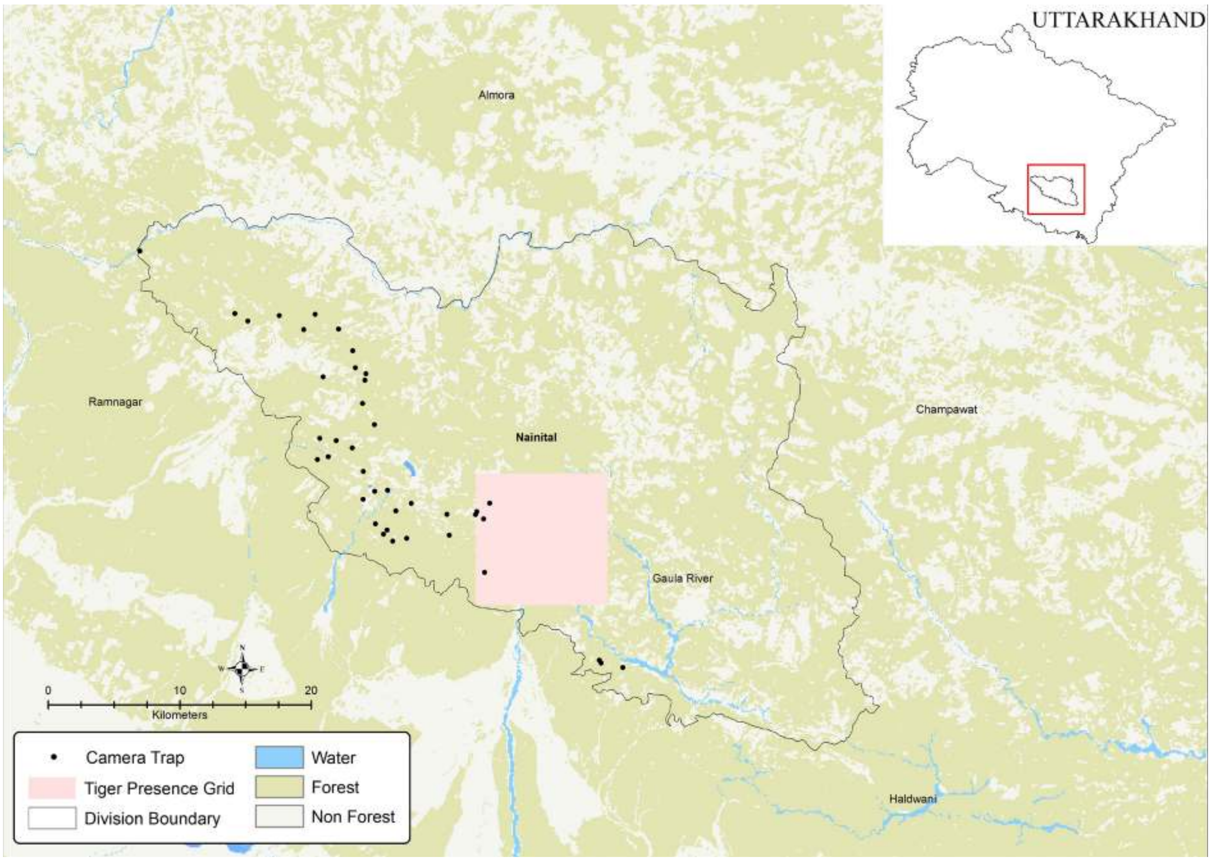

Table V.1. 8

Sampling details and number of tiger photo-captured in Nainital Forest Division, 2022.

Parameters	Estimate
Camera points	40
Trap nights (effort)	1577
Number of tiger photos	2
Unique tigers captured	1

NARENDRANAGAR FOREST DIVISION

This forest division was camera trapped for the first time during the current All India Tiger estimation exercise, no tiger images were photo-captured (Table V.1.9).

Figure V.1.9

Camera trap layout in Narendranagar Forest Division, 2022

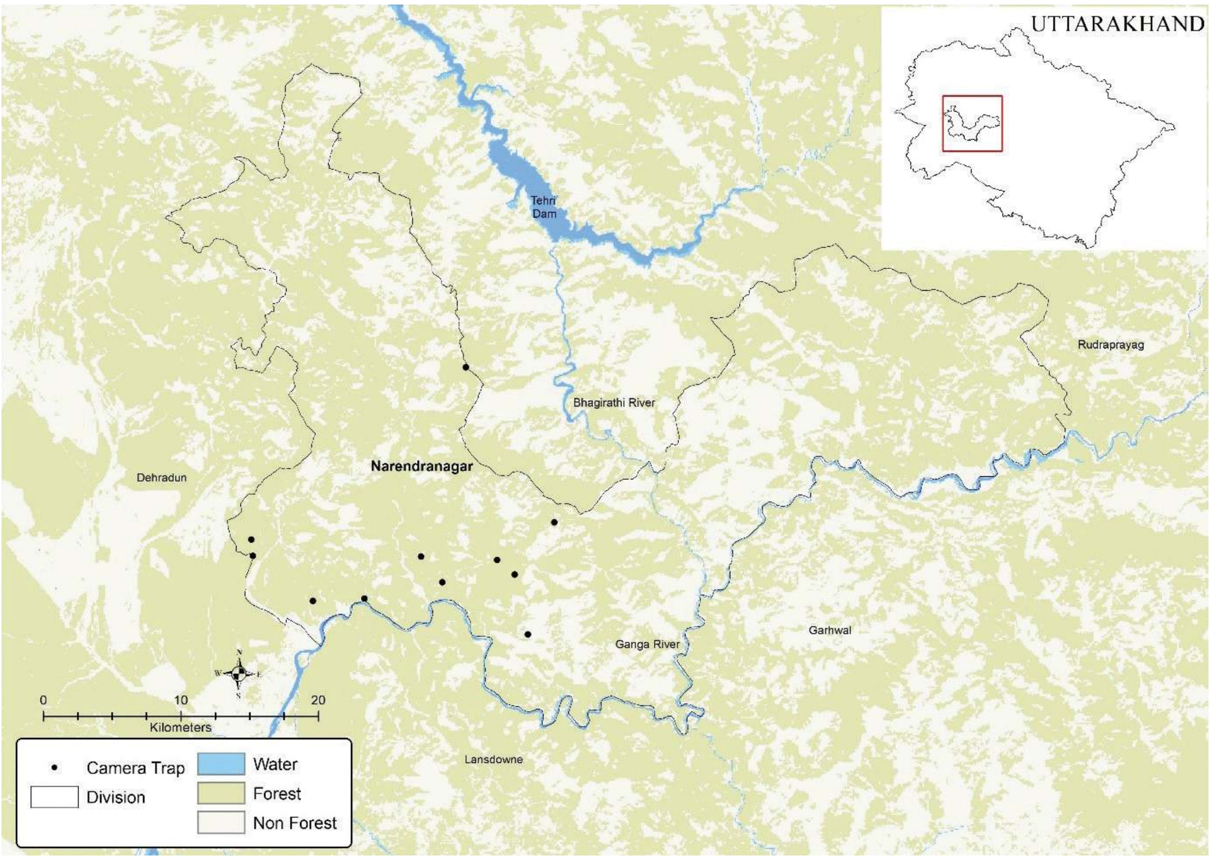

Table V.1. 9

Sampling details and number of tiger photo-captured in Narendranagar Forest Division, 2022.

Parameters	Estimate
Camera points	11
Trap nights (effort)	445

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RAJAJI TIGER RESERVE

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.

Total of 1106 tiger images were obtained from which 54 tiger individuals were identified. A total of 1091 images yielded 51 tiger individuals in the eastern part of the tiger reserve where tiger density was estimated at 8.15 (SE 1.25) tiger per 100 km^2 (Table V.1.10). In the western part of the tiger reserve 3 tigers were re-introduced, that were photo-captured. The detection corrected sex ratio in Eastern Rajaji was 2 females per male (Table V.1.10). A total of 5 young tigers were photo-captured.

Figure V.1.10

Camera trap layout and spatial density of tigers in Rajaji Tiger Reserve, 2022

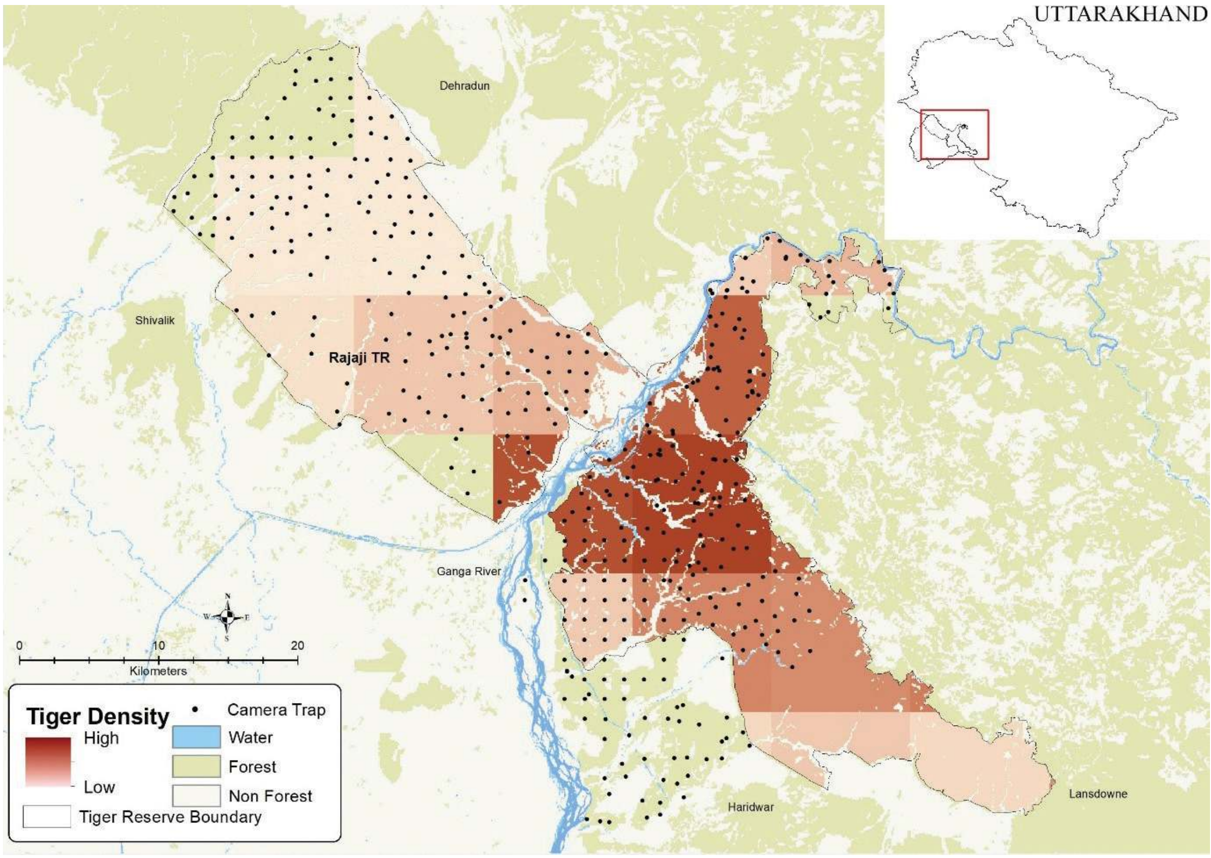

Table V.1. 10

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Rajaji Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	780
Camera points	246
Trap nights (effort)	17188
Unique tigers captured	51
Model	Pmix(sex) g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	8.15(1.25)
σ Female (SE) (km)	1.3(0.4)
σ Male (SE) (km)	2.7(0.1)
g0 Female (SE)	0.06(0.01)
g0 Male (SE)	0.03(0.002)
Pmix Female (SE)	0.65(0.07)
Pmix Male (SE)	0.35(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: estimate of proportion of male /female (detection corrected sex ratio)

In 2020 three tigers from Corbett Tiger Reserve and nearby areas were reintroduced in the western side of the tiger reserve. It is a step forward towards re-establishing this tiger population through active management. Tiger from the eastern part of tiger reserve have also been found to move to Himachal Pradesh sparking hope for re-colonization in western limit of the Shivaliks landscape which used to have tigers till 2004 (Johnsingh et al 2004).

RAMNAGAR FOREST DIVISION

Ramnagar Forest Division is located between rivers Kosi and Gola, and administratively it comes under the district of Nainital of Uttarakhand State. 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. Ramnagar Forest Division stands as a vital component of the larger Corbett landscape, contributing to the conservation of wildlife, promotion of sustainable tourism, and preservation of the region's natural heritage.

Total of 863 tiger images were obtained from which 67 tiger individuals were identified and tiger density was estimated at 11.48(SE 1.43) tiger per 100 km^2 (Table V.1.11). The detection corrected tiger sex ratio was two females per male (Table V.1.11). A total of 8 young tigers were photo-captured.

Figure V.1.11

Camera trap layout and spatial density of tigers in Ramnagar Forest Division, 2022

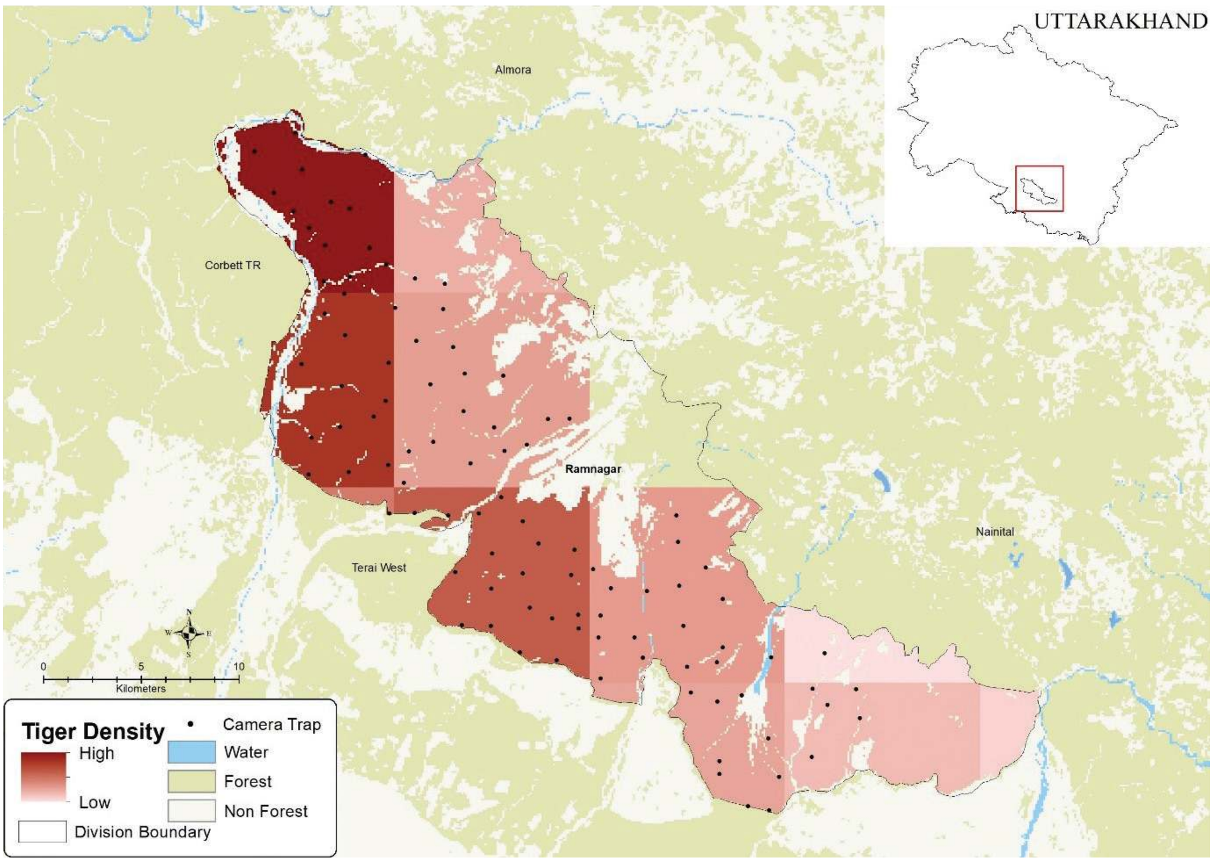

Table V.1.11

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Ramnagar Forest Division, 2022.

Variables	Estimate
Model space (km^2)	1146
Camera points	100
Trap nights (effort)	3318
Unique tigers captured	67
Model	Pmix(sex) g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	11.48(1.43)
σ Female (SE) (km)	1.12(0.037)
σ Male (SE) (km)	1.77(0.063)
g0 Female (SE)	0.17(0.01)
g0 Male (SE)	0.13(0.01)
Pmix Female (SE)	0.62(0.06)
Pmix Male (SE)	0.38(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: estimate of proportion of male /female (detection corrected sex ratio)

Ramangar Forest Division harbours second highest tiger population in the Uttarakhand. The tiger population has doubled here and it is a very important area for maintaining connectivity in this landscape and serves as a sink for tigers from Corbett Tiger Reserve. Tigers have been in conflict with humans in this forest division due to straying incidences. The Forest Division needs to radio collar tigers and have a warning system in place to actively manage the population.

TERAI CENTRAL FOREST DIVISION

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. It 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.

Due to poor trapping total of 34 tiger images were obtained from which 8 tiger individuals were identified (Table V.1.12). Due to insufficient photo-captures and recaptures density of tigers for this site was not estimated.

Figure V.1.12

Camera trap layout and tiger presence in Terai Central Forest Division, 2022

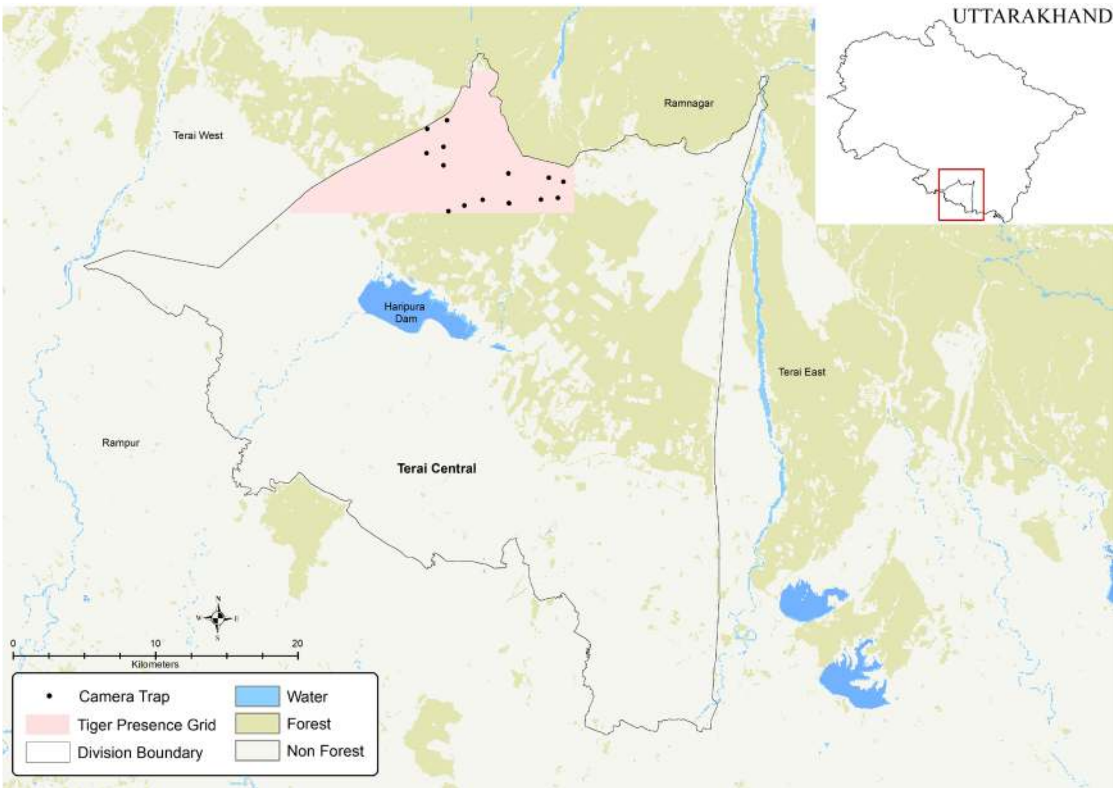

Table V.1. 12

Sampling details and number of tiger photo-captured in Terai Central Forest Division, 2022.

Parameters	Estimate
Camera points	15
Trap nights (effort)	320
Number of tiger photos	34
Unique tigers captured	8

TERAI EAST FOREST DIVISION

Terai East comes under the Udhamsingh nagar district of Uttarakhand State. The forested area of three ranges of Terai East forest division 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.

Terai east forest division faces severe encroachment which is exemplified by Khatima range, the forests of this 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. The Terai East Forest Division is the important link for population dispersal between Uttarakhand, Uttar Pradesh and Nepal. The population of tigers from 2006 to 2022 has been substantially increased.

Total of 53 tigers were identified from 877 tiger images obtained and tiger density was estimated at 2.69 (SE 0.79) tiger per 100 km^2 (Table V.1.13). The detection corrected tiger sex ratio was two females per male (Table V.1.13). A total of 2 young tigers were photo-captured.

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Figure V.1.13

Camera trap layout and spatial density of tigers in Terai Forest Forest Division, 2022

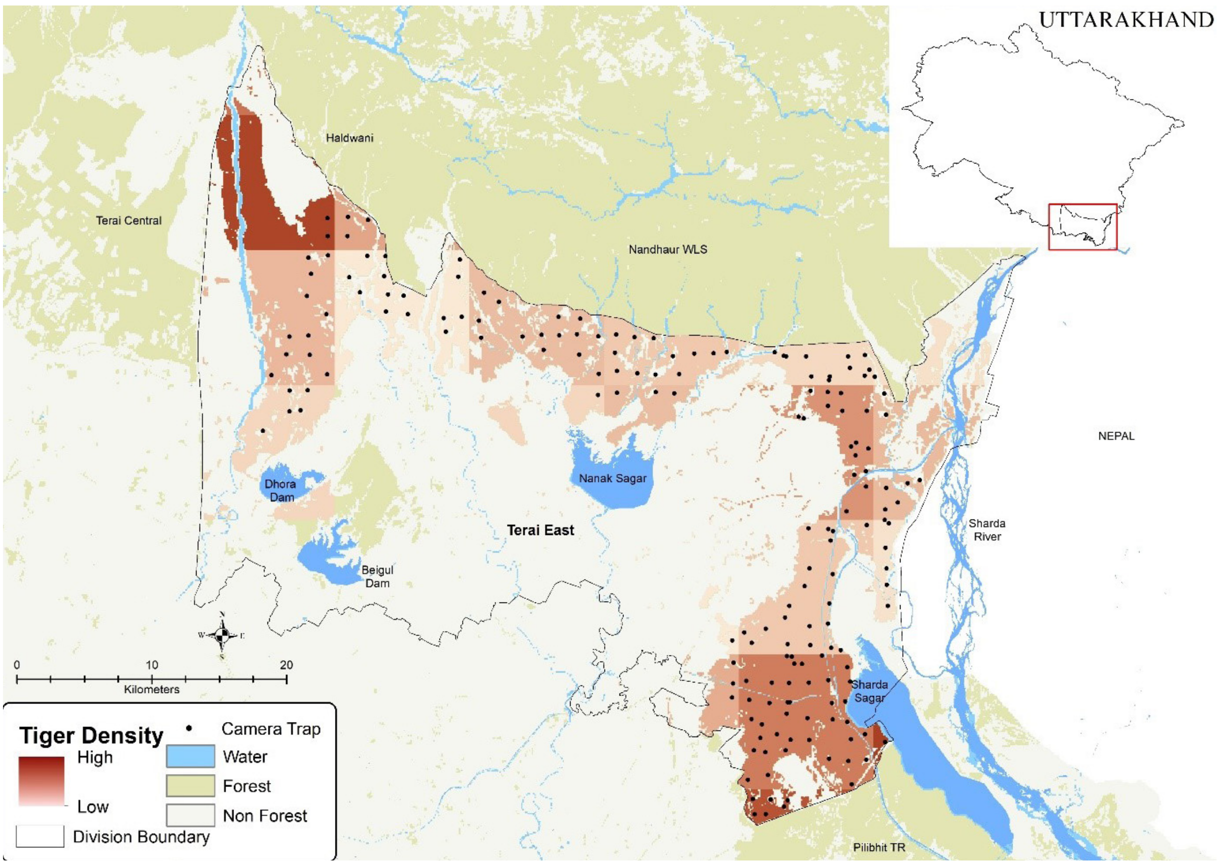


Table V.1. 13

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Terai East Forest Division, 2022.

Variables	Estimate
Model space (km^2)	2983
Camera points	177
Trap nights (effort)	8427
Unique tigers captured	53
Model	Pmix(sex) g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	2.69(0.38)
σ Female (SE) (km)	4.28(0.19)
σ Male (SE) (km)	12.34(0.50)
g0 Female (SE)	0.04(0.003)
g0 Male (SE)	0.02(0.003)
Pmix Female (SE)	0.67(0.06)
Pmix Male (SE)	0.33(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: estimate of proportion of male /female (detection corrected sex ratio)

Terai East Forest Division is the connecting link between the western and eastern terai. Tigers move towards Pilibhit Tiger Reserve and Kishenpur Wildlife Sanctuary through this area. This area is also an important trans boundary animal corridor between connecting Shuklaphanta National Park in Nepal with Pilibhit Tiger Reserve in India.

Such forest should have annual assessment of tiger, co-predator and prey since they provide important link and facilitate tiger movement between various patches and also connect major source populations like Corbett and Pilibhit Tiger Reserve.

TERAI WEST FOREST DIVISION

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 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. 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.

Total of 589 tiger images were obtained from which 52 tiger individuals were identified and tiger density was estimated at 15 (SE 2.4) tiger per 100 km^2 (Table V.1.14). The detection corrected tiger sex ratio was three females per male (Table V.1.14). A total of 1 young tigers was photo-captured.

Figure V.1.14

Camera trap layout and spatial density of tigers in in Terai West Forest Division, 2022

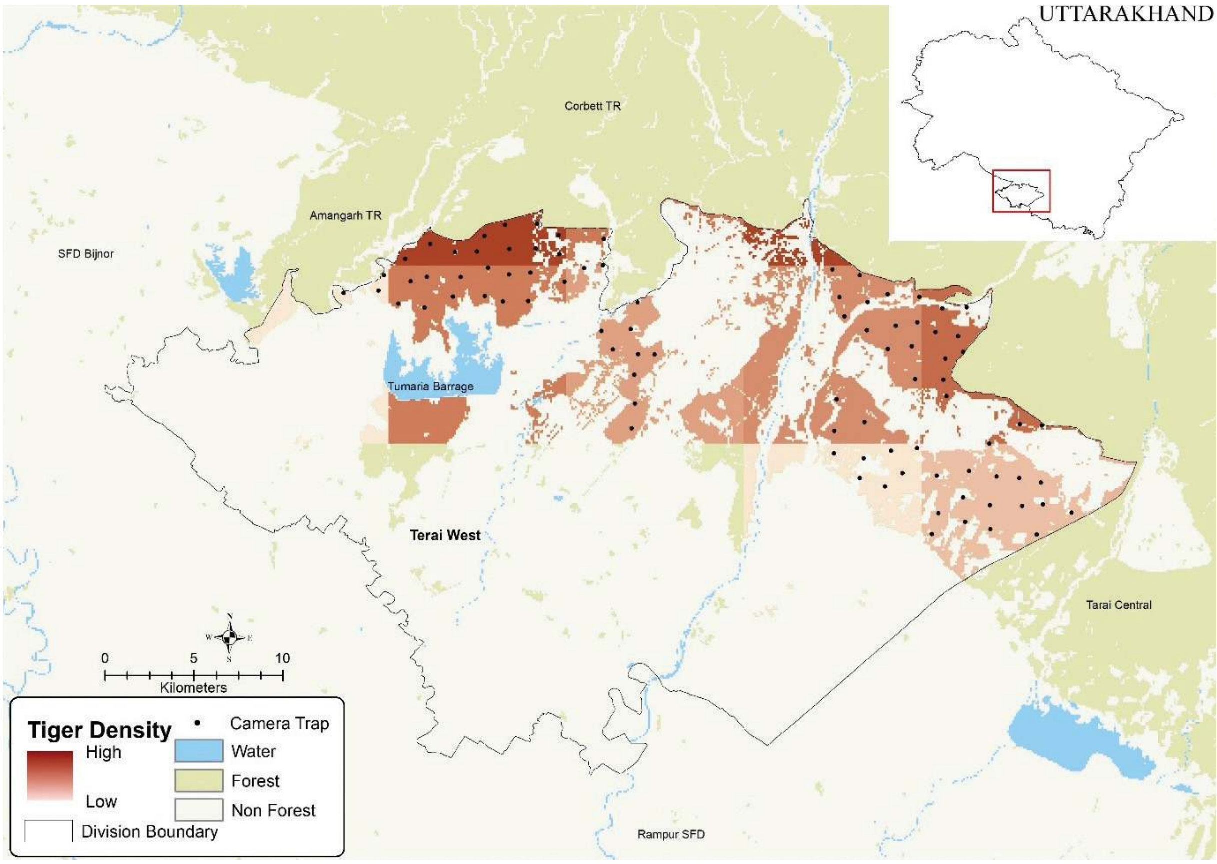


Table V.1. 14

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Terai West Forest Division, 2022.

Variables	Estimate
Model space (sq)	630
Camera points	88
Trap nights (effort)	2956
Unique tigers captured	52
Model	Pmix(sex), g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	15 (2.4)
σ Female (SE) (km)	0.95(0.03)
σ Male (SE) (km)	2.6(0.12)
g0 Female (SE)	0.2(0.02)
g0 Male (SE)	0.07(0.01)
Pmix Female (SE)	0.75(0.06)
Pmix Male (SE)	0.25(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: estimate of proportion of male /female (detection corrected sex ratio)

The tiger population has shown an increase in this forest division which is surrounded by human habitation. Tigers from Corbett Tiger Reserve use this area to move towards Ramnagar and Haldwani Forest Division. The Terai West Forest Division serves as a crucial link between various protected areas, facilitating wildlife movement and genetic exchange. It plays a significant role in maintaining the ecological connectivity and integrity of the Terai landscape. As it is an important tiger population it needs to be monitored on an annual basis on the lines of Phase IV protocols followed by the tiger reserves.

UTTAR PRADESH

AMANGARH TIGER RESERVE

Amangarh is situated in Bijnore district of Uttar Pradesh and is situated on the southern boundary of Corbett Tiger Reserve. It 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.

We obtained 388 tiger images from which 20 tiger individuals were identified and tiger density was estimated at 9.34(SE 1.96) tiger per 100 km^2 (Table V.1.15). Since all the tigers were assigned gender during identification, we used raw count to estimate the sex ratio was 1 female per male.

Figure V.1.15

Camera trap layout and spatial density of tigers in Amangarh, 2022

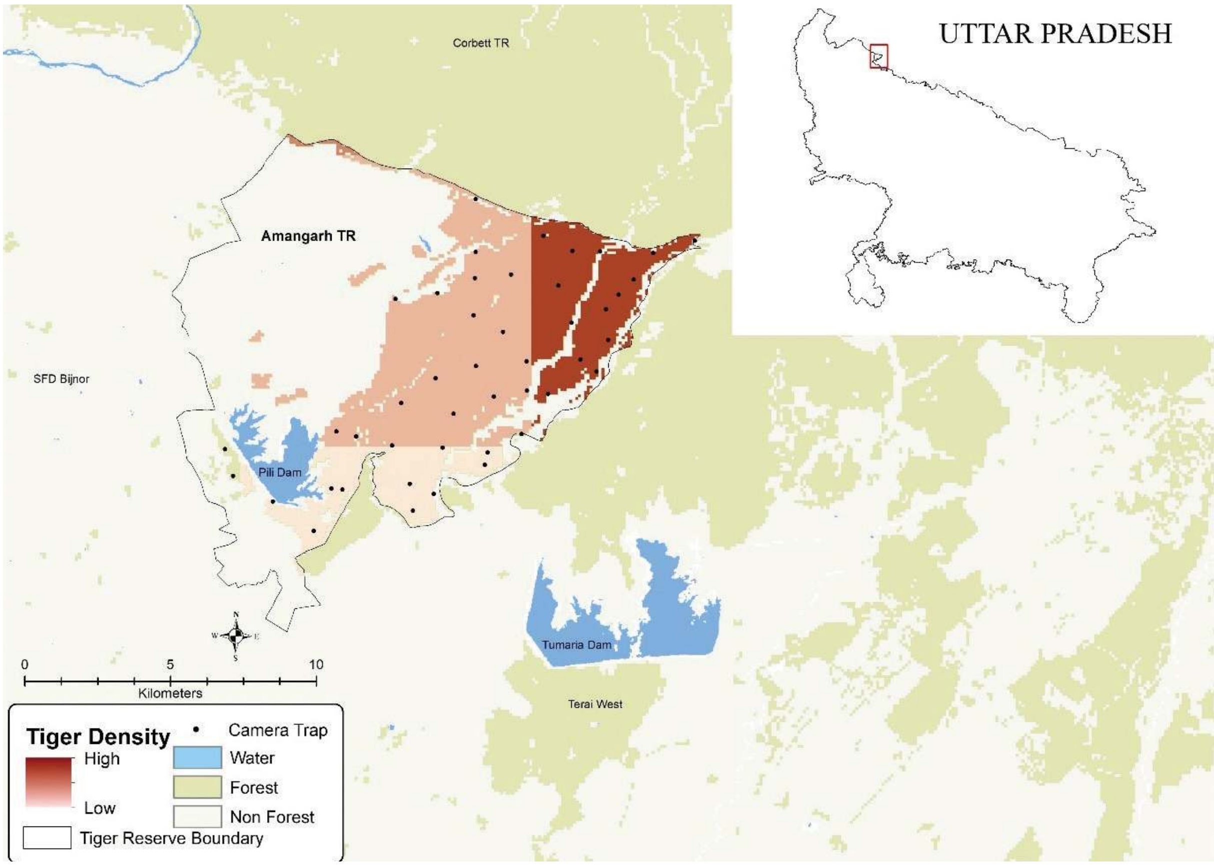


Table V.1. 15

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Amangarh, 2022.

Variables	Estimate
Model space (km^2)	808
Camera points	45
Trap nights (effort)	1678
Unique tigers captured	20
Model	g0(.)σ(.)
$\hat{D}$ SECR (per 100 km^2)	9.34(1.96)
σ (SE) (km)	1.81(0.10)
g0 (SE)	0.05(0.01)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Amangarh is an important buffer for Corbett Tiger Reserve. This area has a very porous boundary and hence protection in this area needs to be enhanced to safeguard long term persistence of tiger usage in the larger landscape. Annual monitoring of this population is important to keep pulse of tiger movement in this area.

DUDHWA TIGER RESERVE

Dudhwa tiger reserve comprises of:

1. Dudhwa National Park has an area of 680 km^2 and is 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.
2. Kishanpur Wildlife Sanctuary 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

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. 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.

This park is the only representative area of terai in Uttar Pradesh and is important for protecting floodplain fauna and flora. Camera trapping in this area resulted in 4778 tiger images of which 135 tiger individuals were identified and tiger density was estimated at 6.10 (SE 1.64) tiger per 100 km^2 (Table V.1.16). The detection corrected tiger sex ratio was one female per male (Table 16). A total of 24 young tigers were photo-captured.

Figure V.1.16

Camera trap layout and spatial density of tigers in 1) Dudhwa National Park 2) Kishenpur Wildlife Sanctuary 3) Katarniaghat Wildlife Sanctuary, 2022

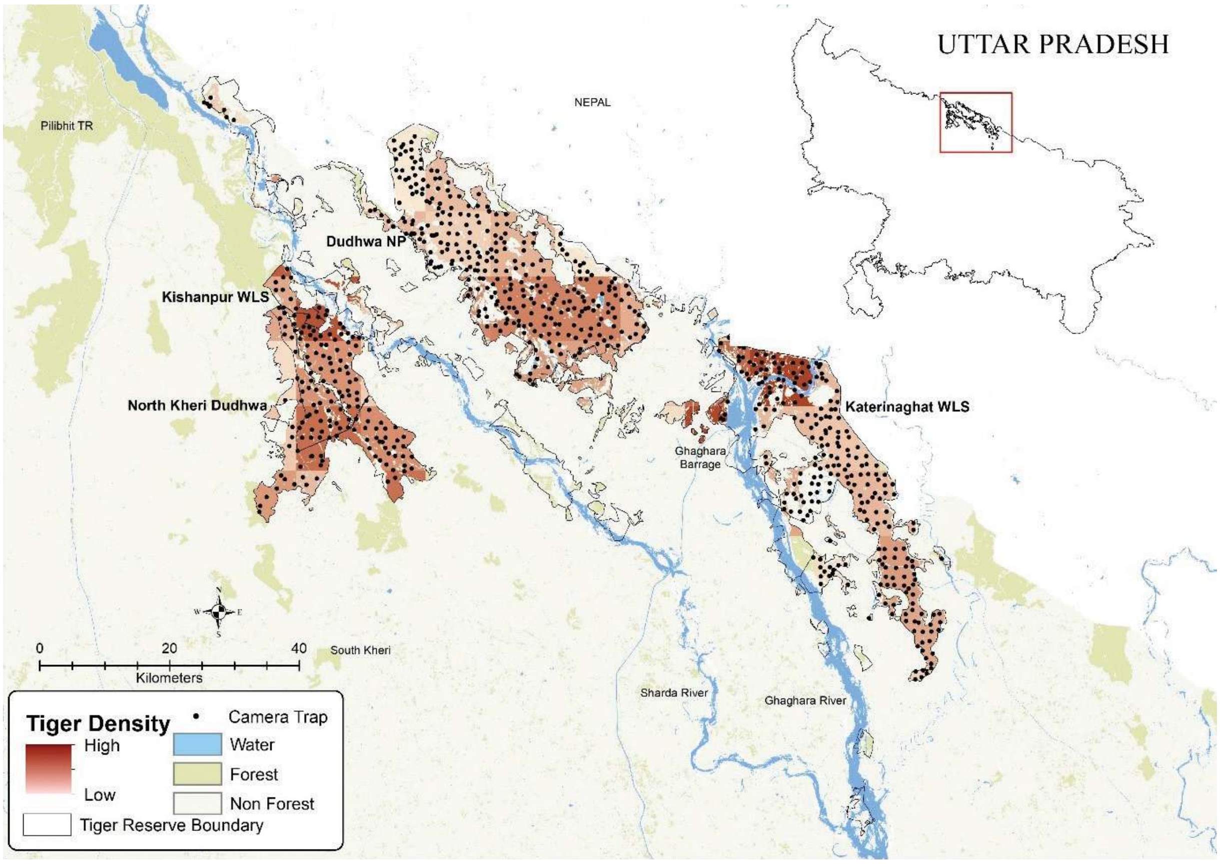


Table V.1. 16

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Dudhwa National Park, Kishenpur Wildlife Sanctuary and Katarniaghat Wildlife Sanctuary, 2022.

Parameter	Dudhwa National Park	Kishenpur Wildlife Sanctuary	Katarniaghat Wildlife Sanctuary
Model space (km^2)	819.25	913	737
Camera points	296	98	251
Trap nights (effort)	12907	8722	10752
Unique tigers captured	35	41	59
Model	Pmix(sex) g0(sex)σ(sex)	Pmix(sex) g0(sex)σ(sex)	Pmix(sex) g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	4.53(0.77)	6.10(0.96)	7.69(1.04)
σ Female (SE) (km)	2.36(0.062)	2.09(0.044)	3.94(0.12)
σ Male (SE) (km)	4.88(0.14)	2.68(0.057)	6.30(0.253)
g0 Female (SE)	0.08(0.004)	0.13(0.01)	0.03(0.001)
g0 Male (SE)	0.031(0.002)	0.10(0.01)	0.02(0.001)
Pmix Female (SE)	0.50(0.09)	0.56(0.08)	0.59(0.07)
Pmix Male (SE)	0.50(0.09)	0.44(0.08)	0.41(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: estimate of proportion of male /female (detection corrected sex ratio)

Tiger population has increased in the tiger reserve. The park has no buffer and influence of people and wildlife need to be actively managed. Developmental activities like border road need to be done only if appropriate mitigation measures are put in place (WII report 2022). It is crucial to manage mosaic burning to ensure long term survival of tall wet grassland fauna of this landscape. One horned rhino was introduced in Dudhwa National Park in 1984 and since then from 5 individuals the population has increased to 40 individuals. It is important to introduce rhinos from West Bengal or Assam into this population to increase its genetic diversity. Barasingha population is important and is stable, efforts are needed to ensure its survival. Bengal florican population is on decline and needs scientific assessment to provide ground level actions to arrest this trend.

PILIBHIT TIGER RESERVE

Pilibhit Tiger Reserve 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 Wildlife Sanctuary in the south-east. This reserve also provides connectivity to ShuklaPhanta 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.

Pilibhit forests and grasslands were important for conservation of tiger, elephant, barasingha, one horned rhino and Bengal florican.

Camera trapping exercise yielded total of 2114 tiger images having 63 tiger individuals and tiger density was estimated at 5.84 (SE 0.75) tiger per 100 km^2 (Table V.1.17). The detection corrected tiger sex ratio was two females per male (Table V.1.17). A total of 8 young tigers were photo-captured.

Figure V.1.17

Camera trap layout and spatial density of tigers in Pilibhit Tiger Reserve, 2022

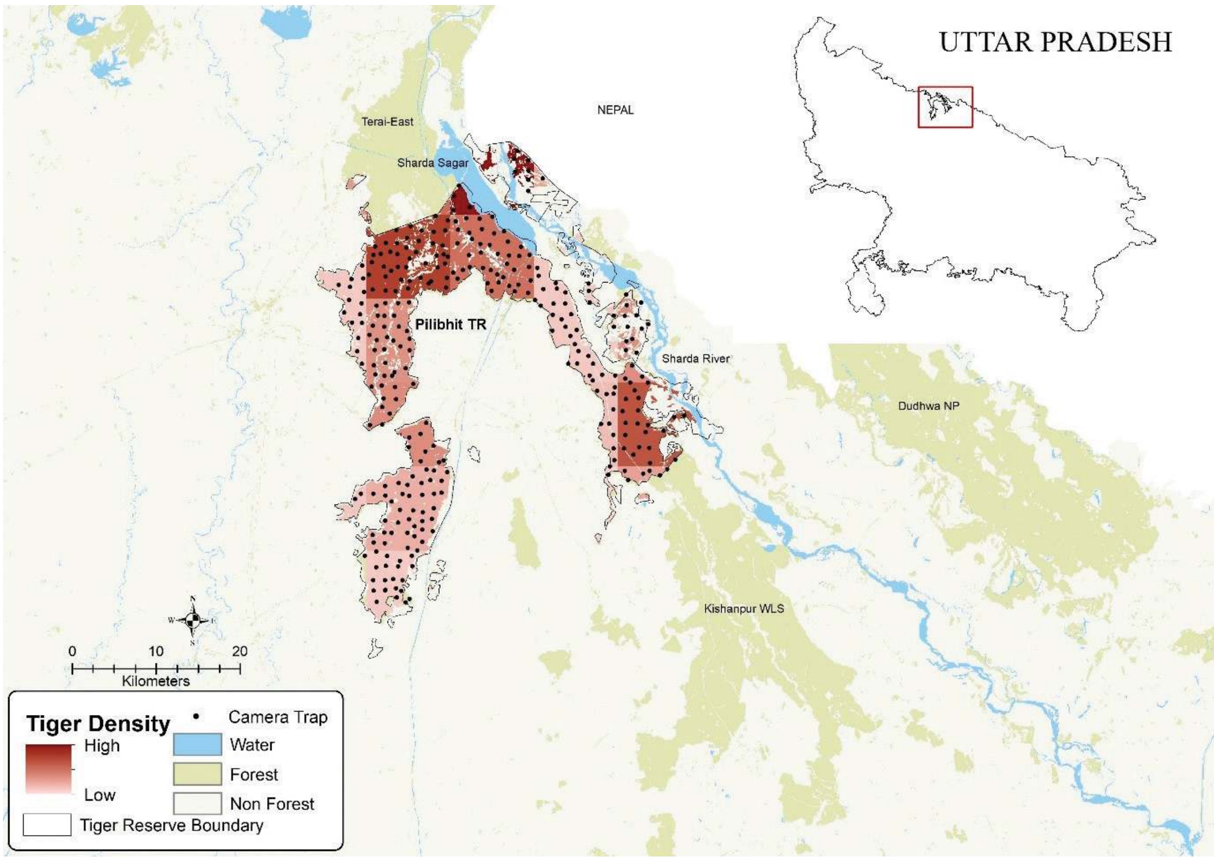


Table V.1. 17

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Pilibhit Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	1191
Camera points	308
Trap nights (effort)	15537
Unique tigers captured	63
Model	Pmix(sex) g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	5.84(0.75)
σ Female (SE) (km)	2.51(0.048)
σ Male (SE) (km)	4.55(0.114)
g0 Female (SE)	0.072(0.003)
g0 Male (SE)	0.033(0.0017)
Pmix Female (SE)	0.62(0.06)
Pmix Male (SE)	0.38(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: estimate of proportion of male /female (detection corrected sex ratio)

With the increase in tiger numbers in the tiger reserve the instances of tiger straying in nearby areas has also increased. This has led to increased negative interaction with humans around tiger reserve. The reserve is surrounded by dense human population and where majority of population grows sugarcane which harbors wild pig and hog deer. this leads to high conflict with tiger since these two species are tiger prey. Lagga-Bagga area in this landscape is crucial link between India and Nepal (Shukla-Phanta National Park) and no development should be allowed in this patch. This patch is also rich in grassland fauna. Active management through moving excess tigers to suitable habitat like Suhelwa, Ranipur Tiger Reserve and even Nepal as well as warning system for people and awareness program need to be put in place to address conflict.

RANIPUR TIGER RESERVE

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.

Total of 45 tiger images were obtained from which 4 tiger individuals were identified (Table V.1.18). Due to insufficient photo-captures density of tigers for this site was not estimated.

Figure V.1.18

Camera trap layout and tiger presence in Ranipur Tiger Reserve, 2022

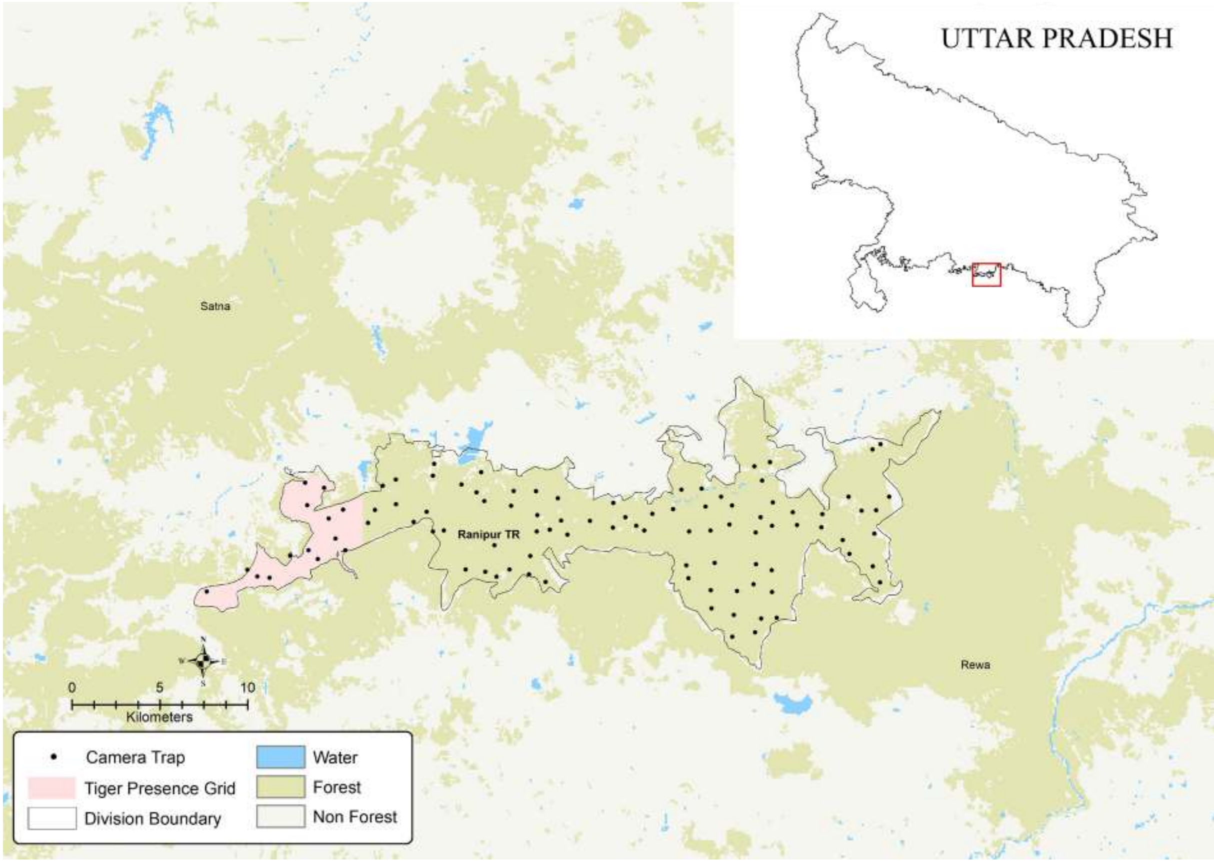


Table V.1. 18

Sampling details and number of tiger photo-captured in Ranipur Tiger Reserve, 2022.

Parameters	Estimate
Camera points	99
Trap nights (effort)	4092
Number of tiger photos	45
Unique tigers captured	4

Ranipur has been declared as Tiger Reserve. It is connected with Panna Tiger Reserve and had 3 tigers common with Satna. Minimum number of tigers have increased by one tiger since 2018.

SOHAGIBARWA WILDLIFE SANCTUARY

Sohagibarwa Wildlife Sanctuary lies in Maharajganj and Kushinagar districts of Uttar Pradesh. It is at the border of Uttar Pradesh and Bihar and also shares the international Indo-Nepal border in the North. It 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. Wetlands at Sohagibarwa Wildlife Sanctuary are a major habitat type. They include rivers, streams, wetlands and marshy areas. The sanctuary has a number of perennial water sources *viz*, the Gandak, Pyas and Rohin rivers.

Total of 4 tiger images were obtained from which 1 tiger individuals was identified (Table V.1.19). Due to insufficient photo-captures density of tigers for this site was not estimated.

Figure V.1.19

Camera trap layout and tiger presence in Sohagibarwa Wildlife Sanctuary, 2022

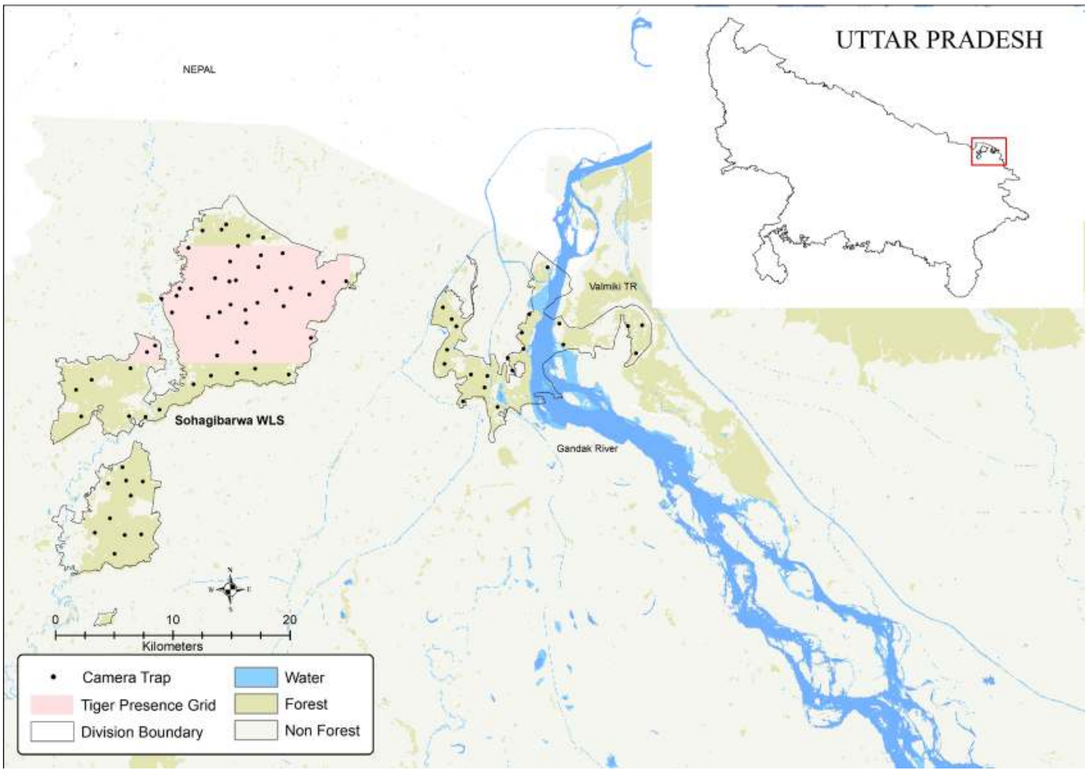


Table V.1. 19

Sampling details and number of tiger photo-captured in Sohagibarwa Wildlife Sanctuary, 2022.

Parameters	Estimate
Camera points	80
Trap nights (effort)	2413
Number of tiger photos	4
Unique tigers captured	1

In 2018 five tiger individuals were photo-captured here, this decline in minimum tigers requires urgent attention before the government brings the sanctuary under the ambit of Tiger Reserve. The tiger photo-captured here was a juvenile from Valmiki TR that established in Sohagibarwa.

SOUTH KHERI FOREST DIVISION

The erstwhile South Kheri Division included Forests of Dudhwa and Kishenpur and was famous for hunting and commercial exploitation of timber specifically Sal. The earliest shikar records are from 1815 (Williamson). The division have now in small patches of forests and grassland as the main forested habitat has become tiger reserve.

South Kheri forest division is the southern most part of the Kishenpur Wildlife Sanctuary 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.

Total of 110 tiger images were obtained from which 10 tiger individuals were identified (Table V.1.20). Due to insufficient photo-captures and recaptures density of tigers for this site was not estimated. Sex ratio from the images was one female per male.

Figure V.1.20

Camera trap layout and tiger presence in South Kheri Forest Division, 2022

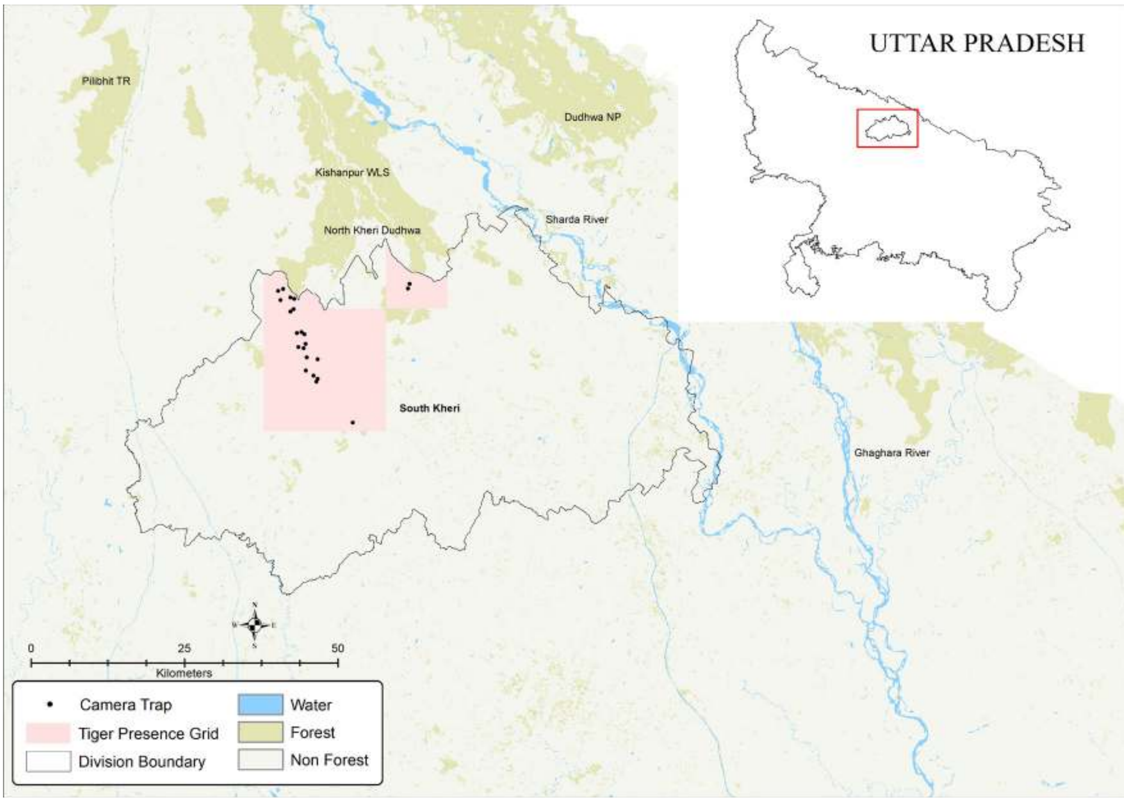


Table V.1. 20

Sampling details and number of tiger photo-captured in South Kheri Forest Division, 2022.

Parameters	Estimate
Camera points	22
Trap nights (effort)	966
Number of tiger photos	110
Unique tigers captured	10

SUHELWA WILDLIFE SANCTUARY

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 & 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.

Suhelwa Sanctuary is largely long narrow patch of bhabar, which have Shivalik range on the northern border in Nepal. This sanctuary is highly disturbed and needs immediate attention in terms of protection. Tiger was first time recorded in 2020 area since 2006 (Qureshi et al 2022).

Total of 39 tiger images were obtained from which 3 tiger individuals were identified (Table V.1.21).

Figure V.1.21

Camera trap layout and tiger presence in Suhelwa Wildlife Sanctuary, 2022

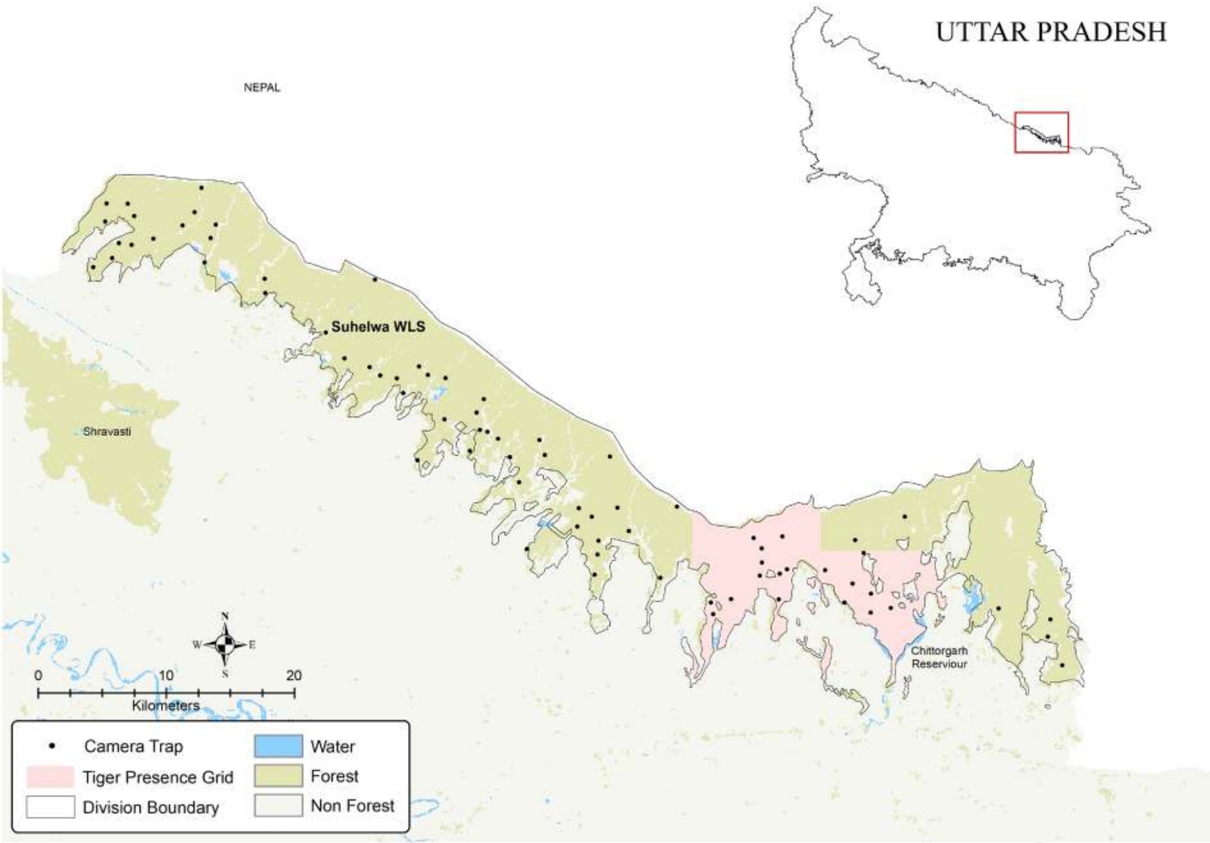


Table V.1. 21

Sampling details and number of tiger photo-captured in Suhelwa Wildlife Sanctuary, 2022.

Parameters	Estimate
Camera points	75
Trap nights (effort)	2400
Number of tiger photos	39
Unique tigers captured	3

Government of Uttar Pradesh is currently deliberating on bringing Suhelwa Wildlife Sanctuary under the ambit of Tiger Reserve. This will not only promote tiger conservation efforts in the state but also enable conserving some crucial tracts of forests connecting Indian and Nepal part of Terai. However, prior to declaration of Suhelwa WLS as a tiger reserve, following considerations need to be carefully factored in for successful implementation of the project:

1. Forests needs to be protected from human disturbances to create inviolate space for tigers. To plan tiger reintroduction, an understanding on biological carrying capacity of Suhelwa for tigers is a prerequisite.
2. Given the linear and isolated shape the sanctuary and adjoining human-dominated landscape, there is an urgent need to assess the potential for creating an inviolate core and multi-use buffer area for tiger conservation. However, this needs suitability mapping of tiger habitats, mapping of vegetation cover, water sources, and other essential resources using remote sensing GIS (RS-GIS). Along with that, ground surveys are needed to assess the quality of habitat as well as to evaluate the impacts of the anthropogenic activities.
3. Tiger is a conservation dependent species. Successful conservation of tigers needs a proactive and efficient management system in place. Therefore, capacity building of the frontline staff by conducting rigorous field training is crucial. In light of this, implementation of MSTrIPES is the need of the hour to facilitate information-driven park management.
4. To assess the impact of tiger reintroduction and declaration of the Tiger Reserve on the local community, socio-economic surveys should be conducted beforehand to avoid future retaliation by the local villagers. Without the supports of the local people, the success of tiger recovery is often questionable.
5. A landscape-level plan, aiming at the long-term conservation goals for the Suhelwa WLS needs to be prepared which should include – i) tiger monitoring plan, ii) prey augmentation plan, iii) corridor management plan, iv) conflict management plan, v) fire management plan, vi) watershed management plan.

BIHAR

VALMIKI TIGER RESERVE

Valmiki Tiger Reserve is located at 27° 19′N, 84° 9′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.

Camera trapping exercise provided total of 1368 tiger images we from which 54 tiger individuals were identified and tiger density was estimated at 4.32 (SE 0.06) tiger per 100 km^2 (Table V.1.22). The detection corrected tiger sex ratio was one female per male (Table V.1.22). A total of 7 young tigers were photo-captured.

Figure V.1.22

Camera trap layout and spatial density of tigers in Valmiki Tiger Reserve, 2022

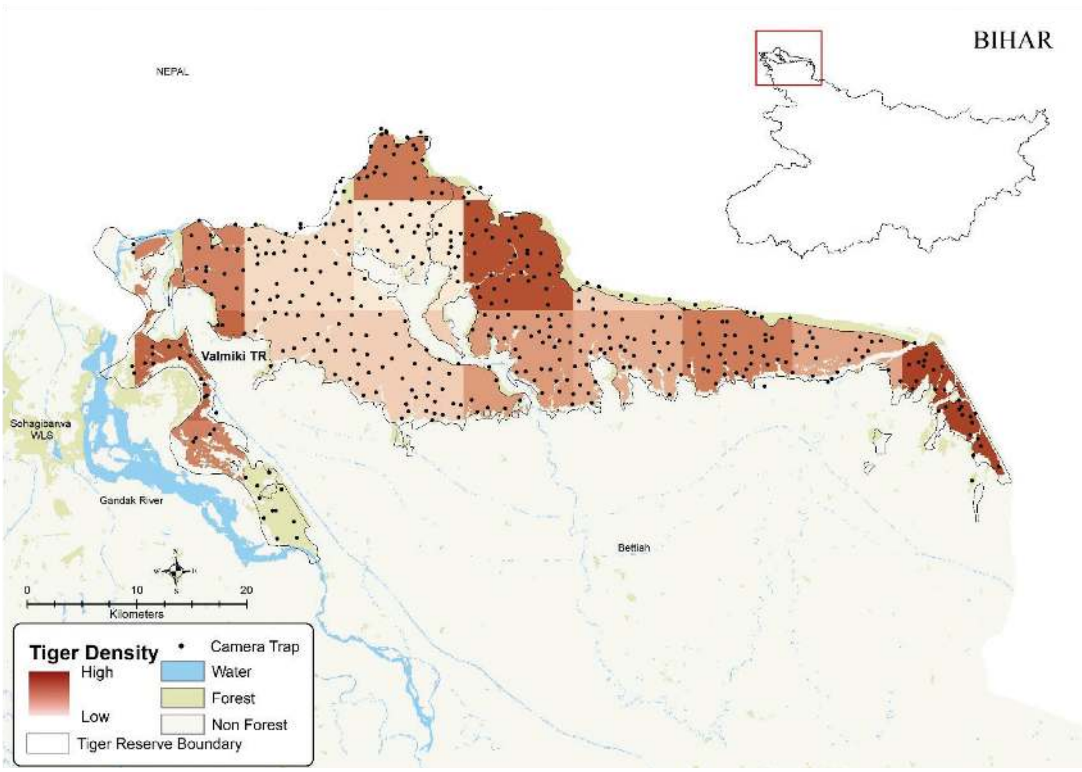


Table V.1. 22

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Valmiki Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	1368
Camera points	429
Trap nights (effort)	14707
Unique tigers captured	54
Model	Pmix(sex) g0(sex)σ(sex)
D̂ SECR (per 100 km^2)	4.32(0.06)
σ Female (SE) (km)	2.23(0.059)
σ Male (SE) (km)	4.27(0.118)
g0 Female (SE)	0.06 (0.004)
g0 Male (SE)	0.03(0.004)
Pmix Female (SE)	0.43(0.07)
Pmix Male (SE)	0.57(0.07)

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: estimate of proportion of male /female (detection corrected sex ratio)

Valmiki tiger reserve has seen increase in tiger numbers since the 2006 tiger monitoring exercise. Valmiki is also an important trans boundary linkage with Chitwan National Park in Nepal. This is amongst the handful of protected area representing floodplain habitat and fauna in India. The wet grasslands are under tremendous human pressure, specifically Mohana range. Rhino reintroduction plan is prepared and process is underway to reintroduce rhino in this area. Being a high density tiger population it is prone to conflict with humans in the area, recently several cases of human kill and injuries due to tiger has been recorded. These conflicts need to be actively managed before it leads to any serious repercussions.

Section V.2

Central India & Eastern Ghats Landscape

The landscape of Central India and the Eastern Ghats encompasses the semi-arid zone of Rajasthan and the Central Indian Plateau, which includes Maharashtra, Madhya Pradesh, Chhattisgarh, Jharkhand, and Odisha. Additionally, it comprises parts of the Eastern Ghats, specifically Telangana, Andhra Pradesh, and Odisha. In total, 65 sites were camera-trapped during the All India Tiger Estimation-2022 cycle.

ANDHRA PRADESH

NAGARJUNASAGAR SRISAILAM TIGER RESERVE

Nagarjunsagar Srisailam Tiger Reserve is situated in the Nallamala Hills Ranges (an offshoot of the southern Eastern Ghats) in the state of Andhra Pradesh. 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 area of the reserve, including the core and buffer, is 3296.31 km^2, and it is India's largest Tiger Reserve. The river Krishna traverses through this critical tiger habitat for a linear distance of 130 km and separate it with Amrabad tiger reserve of Telangana state.

Camera trapping was carried out in the entire tiger reserve landscape that also include nearby protected areas like Sri Lankamalleshwaram, Sri Penusila Narsimha, and Shri Venkateswara wildlife sanctuaries. An effort of 36600 trap nights were invested, and 2443 photos of tigers were obtained, from which 57 unique tigers (>1 year old) were identified. The tiger density was estimated at 0.77 (SE 0.10) tigers per 100 km^2 (Table V.2.1). The detection-corrected sex ratio is female-biased by 2.8 females per male. (Table V.2.1).

Figure V.2.1

Camera trap layout and spatial tiger density in Nagarjunsagar Srisailam Tiger Reserve, 2022

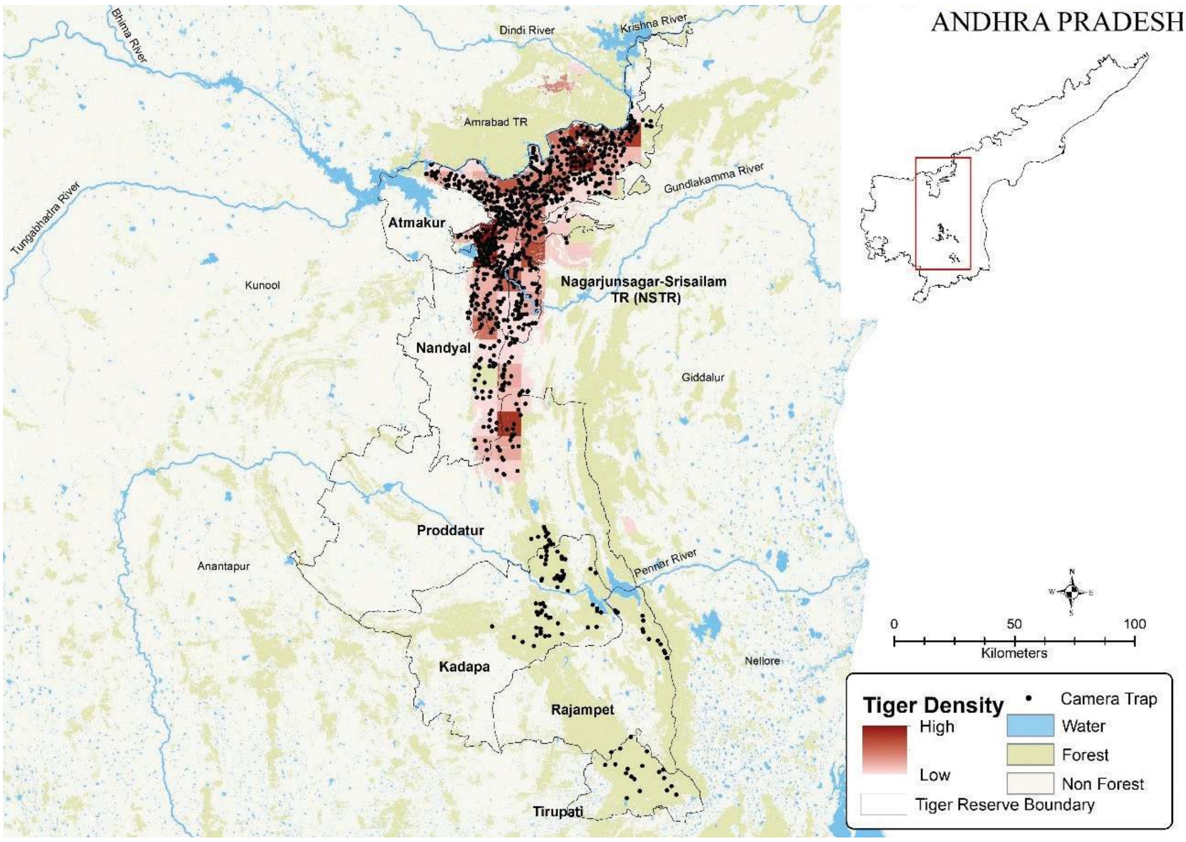


Table V.2.1

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Nagarjunsagar Srisailam Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	9456
Camera points	886
Trap nights (effort)	36600
Unique tigers captured	57
Model	Pmix(sex)g_0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	0.77 (0.10)
σ Female (SE) (km)	2.89 (0.08)
σ Male (SE) (km)	5.18 (0.18)
g0 Female (SE)	0.03 (0.00)
g0 Male (SE)	0.02 (0.00)
Pmix Female (SE)	0.74 (0.06)
Pmix Male (SE)	0.26 (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: estimate of proportion of male /female (detection corrected sex ratio)

A substantial increase in the tiger population has been seen in the Nagarjunasagar -Srisailam Tiger Reserve since the last countrywide tiger estimation of 2018. Nagarjunasagar -Srisailam Tiger reserve (NSTR) is contiguous with the Amrabad tiger reserve of Telangana state forms the largest tiger population in the Eastern Ghat landscape. NSTR is connected to through Sri Lankamalleswaram, Sri Penusila wildlife sanctuaries which further connected with Sri Venkateswara National Park. No tigers were reported from the Sri Lankamalleswaram, Sri Penusila wildlife sanctuaries and Sri Venkateswara National Park.

Section V.2

PAPIKONDA NATIONAL PARK

Papikonda National Park is situated in the Papi Hills of the Alluri, Sitharama Raju, and Eluru districts of Andhra Pradesh. The park has an area of 1012.85 km^2 and spreads across the East and West Godavari districts of Andhra Pradesh and Khamman district in Telangana. The predominant and most extensive forest type found in the park is Southern Tropical Dry Deciduous type. The Polavaram irrigation project, once completed, will submerge parts of the national park.

An effort of 3792 trap-nights were invested and resulted into photo-captures of 1 adult tiger individual for the first time **(Table V.2.2)**.

Figure V.2.2

Camera trap layout and tiger presence in Papikonda National Park, 2022.

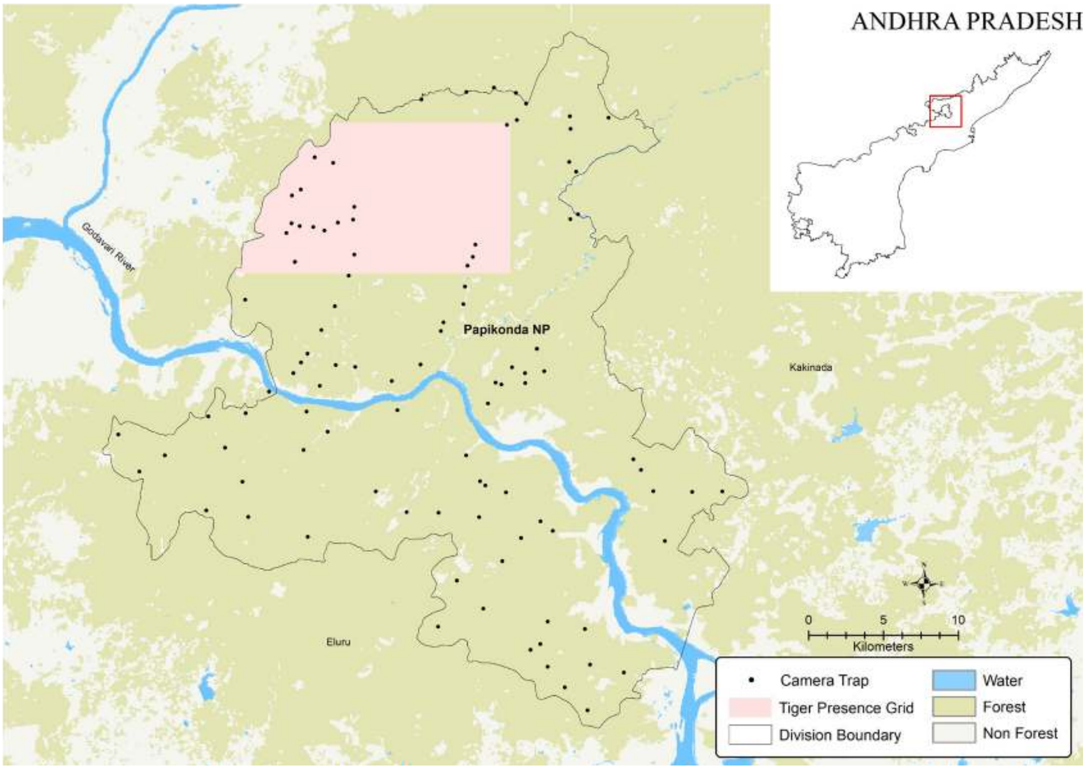


Table V.2.2

Sampling details of camera trapping exercise in Papikonda National Park, 2022.

Sampling Details	Counts
Camera points	103
Trap nights (effort)	3792
Number of tiger photos	6
Unique tigers captured	1

Papikonda National Park is connected with the Indravati Tiger Reserve and the nearby Kawal Tiger Landscape. An effective protection and prey recovery within this landscape can allow tiger recovery.

CHHATTISGARH

ACHANAKMAR TIGER RESERVE

Achanakmar Tiger Reserve is situated in the eastern part of the Maikal hills of the Satpura ranges spread across Mungeli and Bilaspur districts of Chhattisgarh. It is spread across a 914 km^2 area consisting of a 626.2 km^2 core and a 287.8 km^2 buffer. It was established in 1975. According to Champion and Seth (1968), its vegetation is classified as tropical moist and dry deciduous forest.

Achanakmar is connected to Kanha Tiger Reserve via Phen Wildlife Sanctuary through an extensive but fragmented forest patch in Kawardha and Bilaspur forest divisions of Chattishgarh, as well as Dindori and East Mandla forest divisions of Madhya Pradesh. Bandhavgarh and Sanjay Tiger Reserves are present on the northern side of Achanakmar Tiger Reserve, and the corridor between them is heavily fragmented by linear infrastructural structures like SH9, SH22, and NH43, human settlements, and agricultural land.

An effort of 8606 trap nights were invested, and a total of 93 detections of tigers were obtained, from which five unique tigers were identified. The detections of the tigers were insufficient for abundance estimation. Sampling details are given in Table V.2.3.

Figure V.2.3

Camera trap layout and tiger presence in Achanakmar Tiger Reserve, 2022.

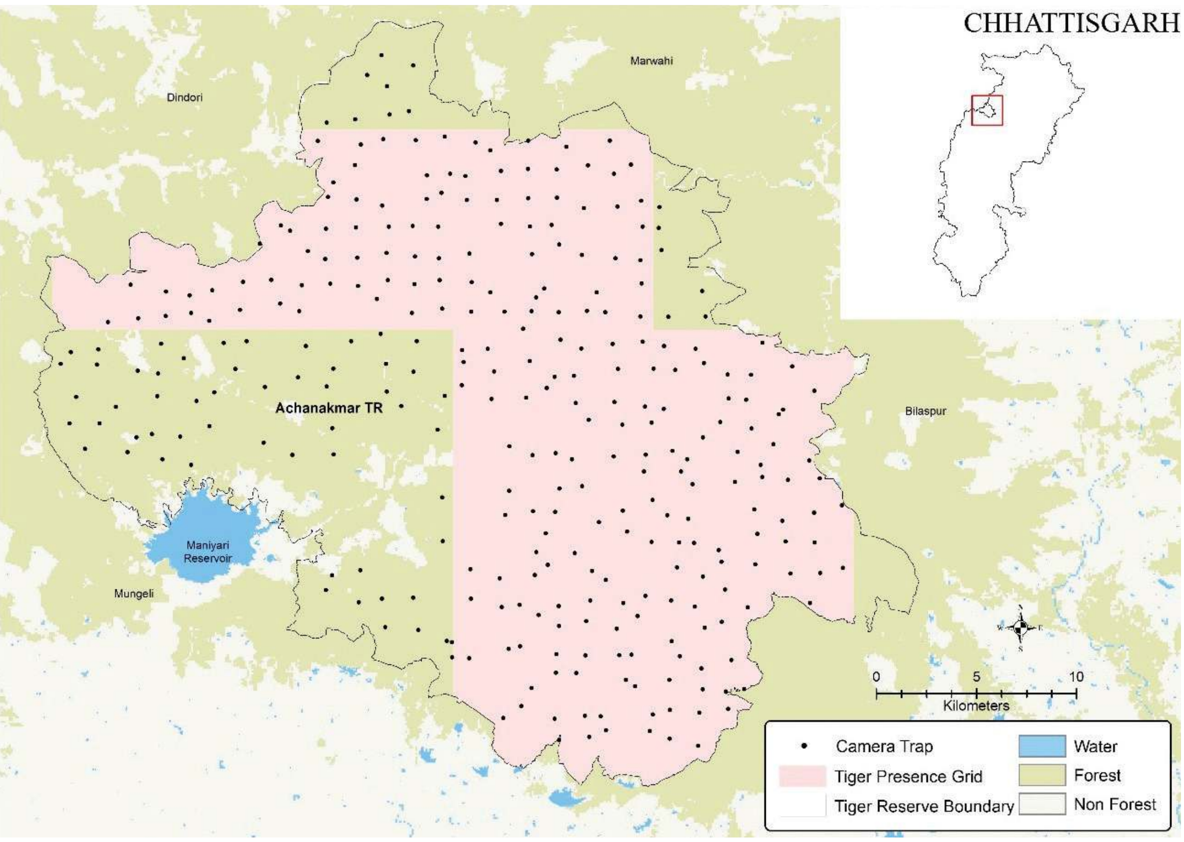
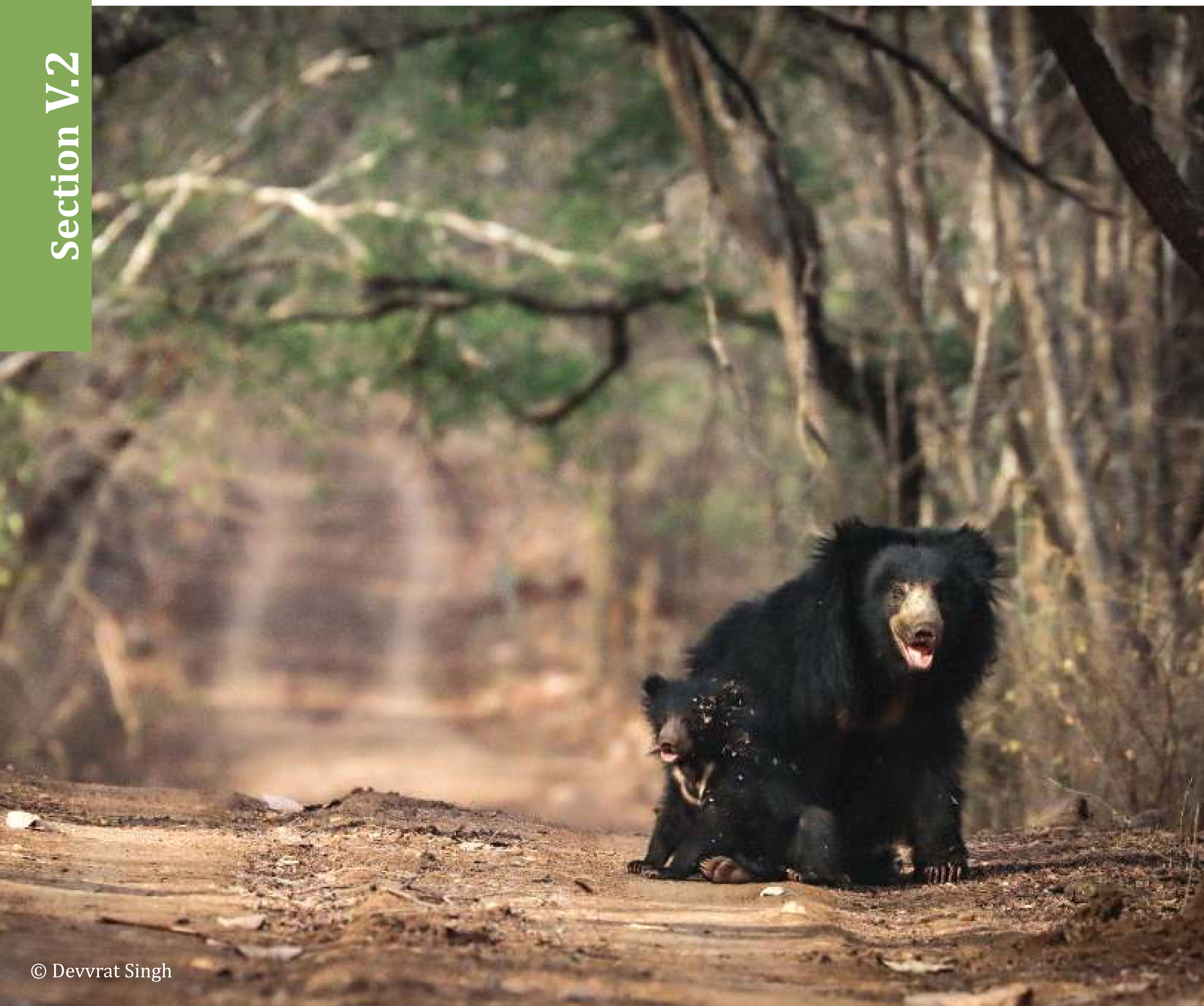


Table V.2. 3

Sampling details of camera trapping exercise in Achanakmar Tiger Reserve, 2022.

Sampling Details	Counts
Camera points	317
Trap nights (effort)	8606
Number of tiger photos	93
Unique tigers captured	5

The Kanha-Achanakmar and Bandhavgarh-Sanjay-Achanakmar corridors needs to be protected to allow the dispersal of the tiger population in the landscape and maintain gene flow between the populations. There has been continuous decline in tiger population observed in Achanakmar TR over the years. The major cause of this decline is likely to be poaching of tigers and their prey. The prey population is poor, and the park needs urgent protection measures, prey augmentation, and tiger translocation to establish tigers in this reserve.



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UDANTI SITANADI TIGER RESERVE

Udanti-Sitanadi Tiger Reserve (USTR) is situated in Gariaband and Dhamtari districts of Chhattisgarh. It is spread across an 1842.54 km^2 area consisting of an 851.09 km^2 core and a 991.45 km^2 buffer. It includes Udanti Wildlife Sanctuaries and Sitanadi Wildlife Sanctuaries, which have derived their names from the rivers Udanti and Sitanadi flowing through the sanctuaries. Both sanctuaries are well connected with a 30 km forest stretch spread across Udanti Forest Division, Ranipur Forest Division, and Dhamtari Forest Division in Dhamtari District, which allows wild animals to move between them. According to Champion and Seth (1968), its vegetation is classified as tropical peninsular sal forest and southern tropical dry deciduous mixed forest.

The Udanti-Sitanadi tiger reserve has hunting pressure from local communities as well as external hunters (Basak *et al.* 2020). It is connected to the Indravati Tiger Reserve through the Kanker and North Kondagaon forest divisions. The forest patches connecting the two are fragmented due to linear infrastructure forming a bottleneck.

An effort of 3783 trap nights was invested, were invested, but not a single photograph of a tiger was obtained during sampling. (Table V.2.4).

Figure V.2.4

Camera trap layout and tiger presence in Udanti-Sitanadi Tiger Reserve, 2022

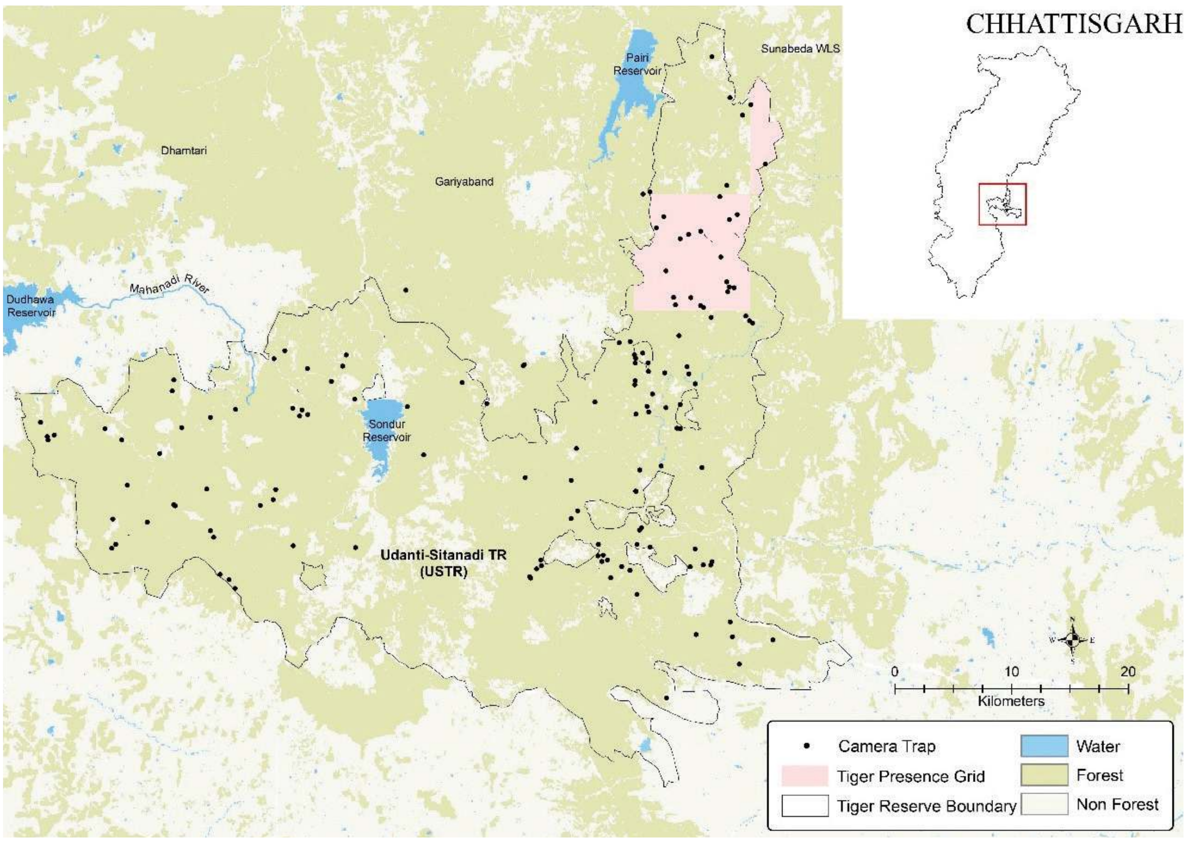

Table V.2. 4

Sampling details of camera trapping exercise in Udanti-Sitanadi Tiger Reserve, 2022.

Sampling Details	Counts
Camera points	143
Trap nights (effort)	3783
Number of tiger photos	0

One tiger record has been confirmed from scat based genetic sample. In 2018, one tigress has been recorded in camera trap and 2 tiger in 2014 through genetic samples. Udanti-Sitanadi has low prey abundance due to high biotic pressure; ungulate population recovery programme is urgently required (Basak *et al.* 2020). The Udanti-Sitanadi-Indravati corridor needs habitat restoration and protection to facilitate the tiger movement. Currently this region of the landscape lacks a source population and tigers are unlikely to recover on their own, active management is required in the form of prey augmentation followed by tiger supplementation provided biotic pressure is brought under control.

JHARKHAND

PALAMAU TIGER RESERVE

Palamau Tiger Reserve, one of the initial nine tiger reserves established in India, is situated on the western side of the Latehar district, atop the Chhotanagpur plateau in Jharkhand. It is bounded by the Netarhat Forest to the south, the Auranga River to the north, the Latehar Forest Division to the east, and the Garhwa Forest Division and Sarguja District Forest of Chhattisgarh to the west. The reserve covers a total area of 1129.93 km^2, with a core area of 414.08 km^2 and a buffer area of 715.85 km^2. Among the core areas, 226.32 km^2 are occupied by the Betla National Park. It is connected to Sanjay-Bandhavgarh tiger reserves through the forest corridor, passing through Balrampur and Surajpur forest divisions, Semarsot and Timorpingla wildlife sanctuaries, and Guru Ghasidas National Park of Chhattisgarh. Palamau Tiger Reserve will benefit from its connectivity with Bandhavgarh Tiger Reserve if habitat recovery and protection in the connected forest divisions and sanctuaries is strengthened.

An effort of 17765 trap nights were invested, but not a single photograph of a tiger was obtained during sampling. Sampling details are given in Table V.2.5.

Figure V.2.5

Camera trap layout and tiger presence in Palamau Tiger Reserve, 2022

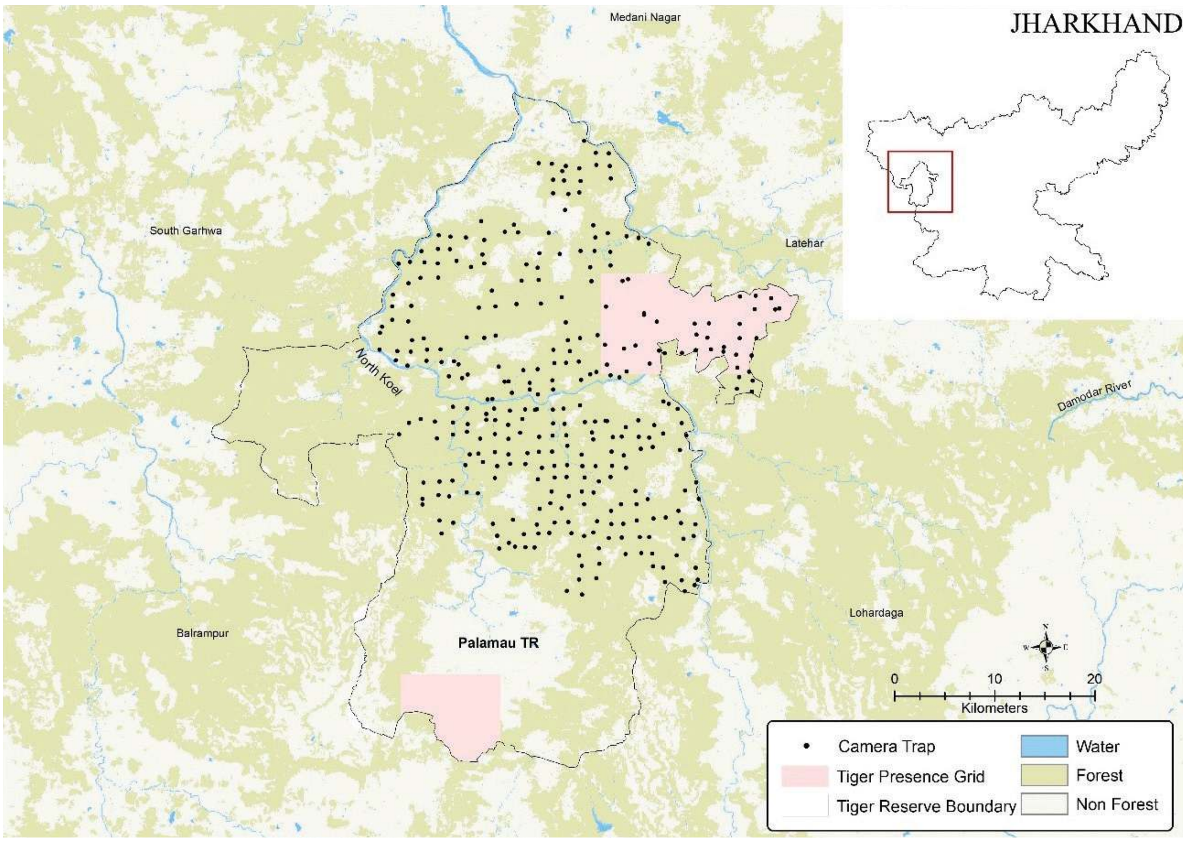

Table V.2.5

Sampling details of camera trapping exercise in Palamau Tiger Reserve, 2022.

Sampling Details	Counts
Camera points	323
Trap nights (effort)	17765
Number of tiger photos	0

In Palamau Tiger Reserve, genetic analysis of three potential tiger scats revealed that they belonged to the same individual tiger, indicating the presence of only one tiger in the reserve. This critically low tiger population in Palamau is functionally extinct and at high risk of total anhelation. The reserve faces significant anthropogenic disturbances such as livestock grazing, non-timber forest product collection, and the movement of security forces and left wing extremists. These disturbances make it challenging to identify undisturbed areas necessary for the breeding nucleus of tigers within tiger reserve. Human settlements within the core area of the reserve further hinder wildlife restoration efforts. To address these issues, voluntary and incentivized resettlement of villages and their livestock from the core zone is crucial. The National Tiger Conservation Authority (NTCA) and state government guidelines should be followed for the relocation process. Creating a large inviolate core area, ideally spanning over 800 km^2 (although the current designated core area of 414 km^2 is insufficient), is essential. The agricultural lands left by resettled villages should be managed as grasslands.

The important objective should be to focus on capacity building for forest officers in habitat and species management across all verticals. Once these objectives are achieved, prey restoration can be considered. To supplement the tiger population in Palamau, tigers from Bandhavgarh Tiger Reserve in Madhya Pradesh, genetically closest to the Palamau population, should be considered. Declaring Guru Khasidas National Park in Chhattisgarh will help facilitate tiger movement from Bandhavgarh-Sanjay into Palamau TR in the long term. By implementing these measures, including resettlement, habitat consolidation, and prey and tiger supplementation, the Palamau Tiger Reserve can work towards restoring tigers and a functional ecosystem.

MADHYA PRADESH

BANDHAVGARH TIGER RESERVE

Bandhavgarh Tiger Reserve, situated in Madhya Pradesh, India, is situated on the northeastern border of the state, along the northern slopes of the eastern Satpura Mountain range. Initially declared a National Park in 1968, it has expanded over time to cover a total area of 1536.94 km^2, comprising the Bandhavgarh National Park and Panapata Wildlife Sanctuary as the core area (716.903 km^2). An additional buffer area of about 820.035 km^2 was designated to complement the reserve. The reserve derives its name from the Bandhavgarh fort, which holds historical significance. "Bandhavgarh" combines two Sanskrit words, "Bandhav" meaning brother and "Garh" meaning fort, as it is believed to have been given to Lakshmana, the brother of Lord Rama. Bandhavgarh Tiger Reserve has been recognized as having the largest tiger population in central India since 2018, indicating successful conservation efforts. In terms of wildlife conservation, Bandhavgarh has also played a crucial role in reintroducing the gaur, an important species that had become disappeared between 1995 and 1998. The camera trapping effort of 20138 trap nights, yielded 4300 tiger photos of 134 individual tigers (>1 year). The tiger density was estimated to be 7.5 (SE 0.65) tigers per 100 km^2 (Table V.2.6). Additionally, the detection-corrected tiger sex ratio in Bandhavgarh was found to be 1.76 females per male (Table V.2.6).

Figure V.2.6

Camera trap layout and spatial tiger density in Bandhavgarh Tiger Reserve, 2022

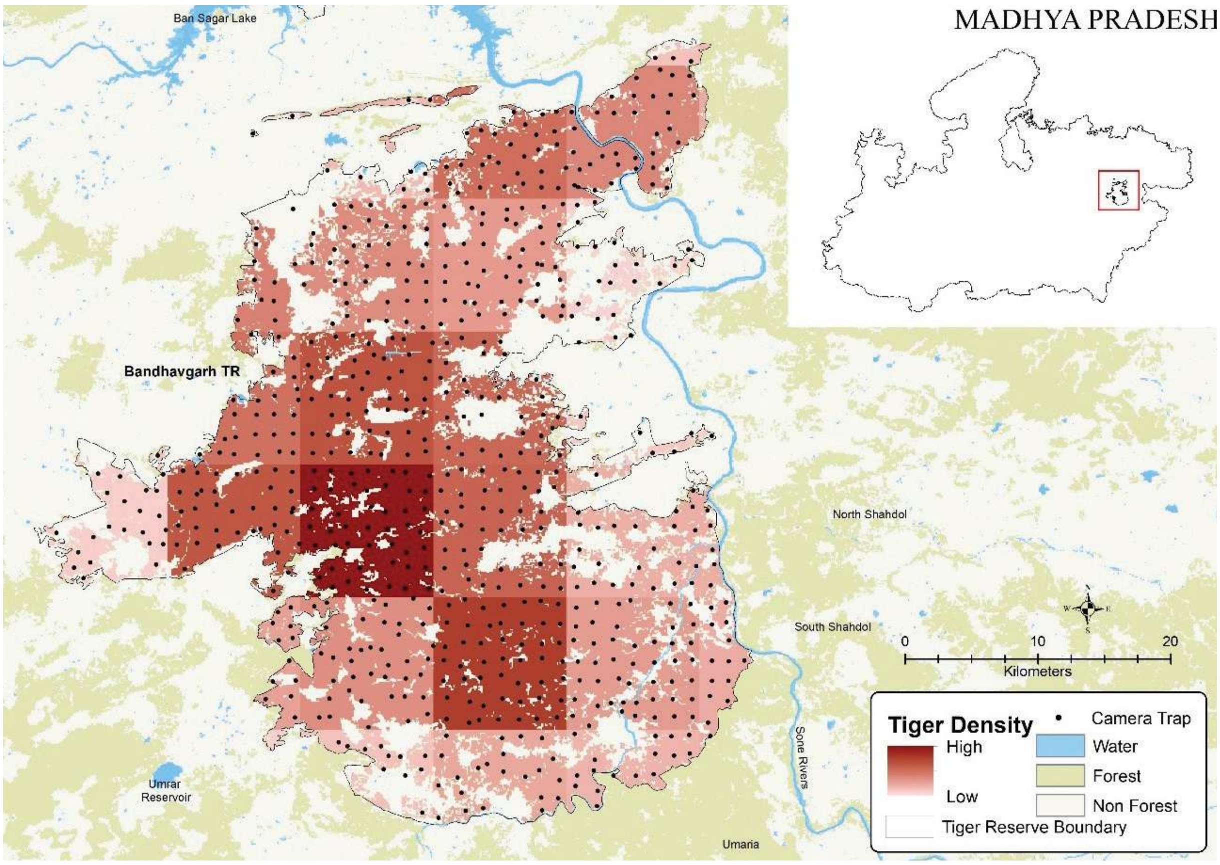

Table V.2.6

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Bandhavgarh Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	2181
Camera points	697
Trap nights (effort)	20138
Unique tigers captured	134
Model	Pmix(sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	7.5(0.65)
σ Female (SE) (km)	1.5(0.03)
σ Male (SE) (km)	2.5(0.05)
g0 Female (SE)	0.05(0.002)
g0 Male (SE)	0.02(0.001)
Pmix Female (SE)	0.65(0.04)
Pmix Male (SE)	0.34(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: estimate of proportion of male /female (detection corrected sex ratio)

The tiger population at Bandhavgarh has increased since the last cycle of the National Tiger Estimation Exercise in 2018. Moreover, the reserve has witnessed the migration of a herd of elephants from Chhattisgarh, which settled within its boundaries in November 2018. The forest corridor connectivity between Bandhavgarh Tiger Reserve and other protected areas like Sanjay-Dubri Tiger Reserve, Achanakmar Tiger Reserve, and Kanha Tiger Reserve is of vital importance. These corridors serve as pathways for the movement of tigers and other wildlife between these protected areas, allowing for genetic exchange and the maintenance of the meta-population and help in mitigating human-tiger conflict.

KANHA TIGER RESERVE

Kanha Tiger Reserve, situated in the Mandla and Balaghat districts of Madhya Pradesh, India, is situated within the Maikal hills of the Satpura range. The reserve boasts a diverse landscape comprising Dadars (flat hilltops), grassy areas, dense forests, and riverine forests. It is divided into three zones: the core zone, known as Kanha National Park, covering an area of 917.43 km^2; the buffer zone spanning 1134.39 km^2; and the microsatellite core, represented by Phen Wildlife Sanctuary, encompassing an area of 110.740 km^2. The reserve is characterized by the presence of two rivers Banjar and Halon, which contribute to its rich ecosystem. The vegetation in Kanha Tiger Reserve can be categorized into two types based on the classification by Champion and Seth (1968), moist sal forests (3C/C2), with subgroups of high level sal (3C/C2 ci) and low level sal (3C/C2 cii), and miscellaneous forests (3A/C2), including southern tropical moist deciduous forest, southern tropical dry mixed deciduous forest, and grassland.

By sampling 664 camera trap locations with an effort of 22168 trap nights, 4570 photos of tigers > 1 year were obtained. From these photos, 105 individual tigers were identified, and the tiger density was computed at 5.57 (SE 0.54) tigers per 100 km^2 (Table V.2.7). Additionally, the detection-corrected tiger sex ratio in Kanha Tiger Reserve was found to be 1.5 females per male (Table V.2.7).

Figure V.2.7

Camera trap layout and spatial tiger density in Kanha Tiger Reserve, 2022.

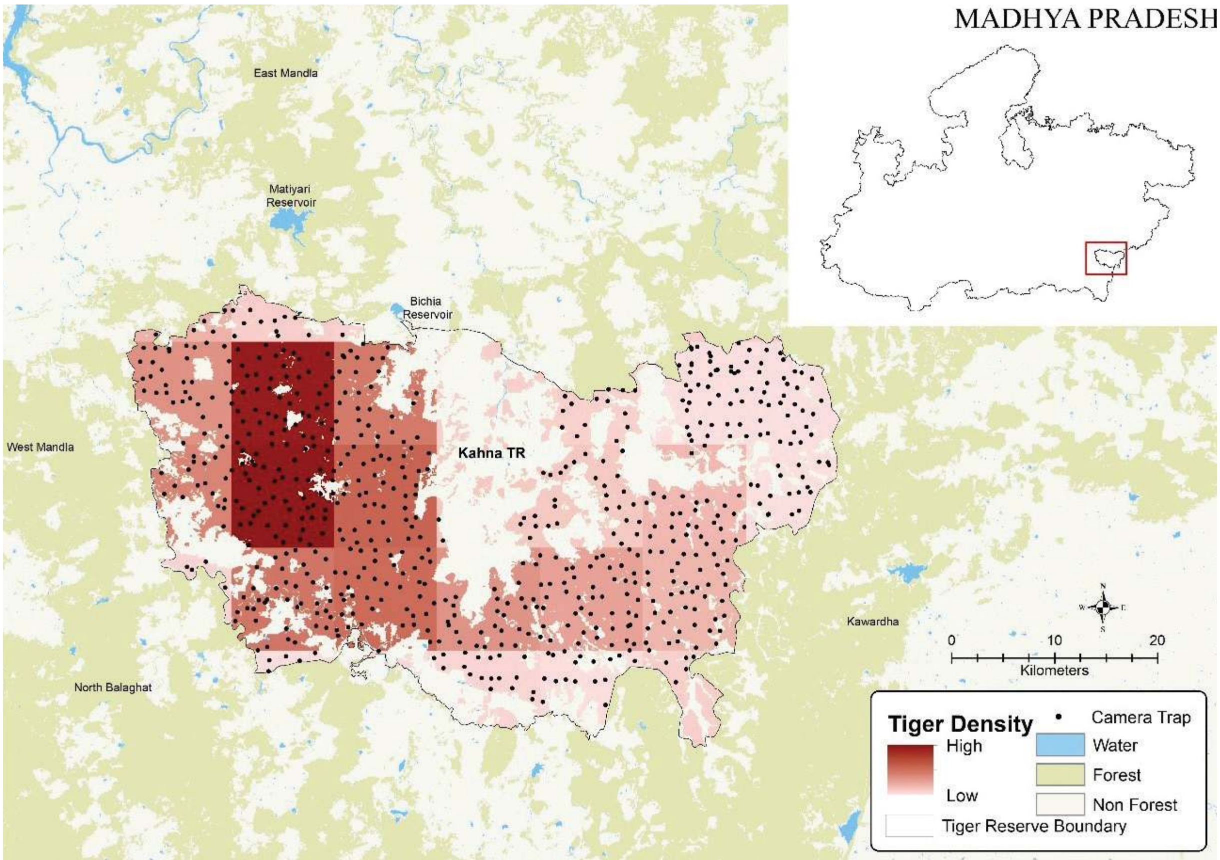

Table V.2. 7

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Kanha Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	2314
Camera points	664
Trap nights (effort)	22168
Unique tigers captured	105
Model	Pmix(sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	5.57 (0.54)
σ Female (SE) (km)	1.48(0.02)
σ Male (SE) (km)	2.51(0.04)
g0 Female (SE)	0.07(0.003)
g0 Male (SE)	0.04(0.002)
Pmix Female (SE)	0.60(0.04)
Pmix Male (SE)	0.40(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: estimate of proportion of male /female (detection corrected sex ratio)

The tiger population at Kanha has increased since the last cycle of the National Tiger Estimation Exercise in 2018. Kanha is one of the largest tiger populations in the Kanha-Pench complex. Tigers from Kanha are known to disperse to Satpura, Nawegaon Nagzira, Pench Achanakmar, and Bandhavgarh-Sanjay Tiger Reserves. Kanha tiger reserve was the largest population of Central India in earlier three cycle of national tiger estimation exercise 2006, 2010 & 2014. Major threats for this tiger reserve are recent advent of left wing extremism, which is know to cause severe declines in wildlife populations.

PANNA TIGER RESERVE

Panna Tiger Reserve is situated in Madhya Pradesh, India, within the Vindhya Mountain ranges. It is divided into three distinct regions: the upper Talgaon plateau, the middle Hinnauta Plateau, and the Ken river valley. These regions contribute to the reserve's biodiversity and provide various habitats for plants and animals. The reserve covers a core area of 542.66 km^2 and a buffer area of 1002.42 km^2. The vegetation in Panna Tiger Reserve includes different types of forests and dry bamboo brakes. After experiencing local extinction, tigers were successfully reintroduced to the reserve. Panna is not only renowned for its wildlife but also houses ancient rock paintings that depict human figures, animals, hunting scenes, and geometric patterns. Panna lost all its tigers due to poaching in 2008; since then, it has been on a path of recovery.

A camera trap sampling of 574 locations with a sampling effort of 25428 trap-nights resulted in the capture of 55 individual tigers (>1 year of age) from 2034 tiger photos. The estimated tiger density was 3.18 (SE 0.43) tigers per 100 km^2 (Table V.2.8). The detection-corrected tiger sex ratio in Panna Tiger Reserve was 1.58 females per male, indicating a female-biased sex ratio (Table V.2.8).

Figure V.2.8

Camera trap layout and spatial tiger density in Panna Tiger Reserve, 2022

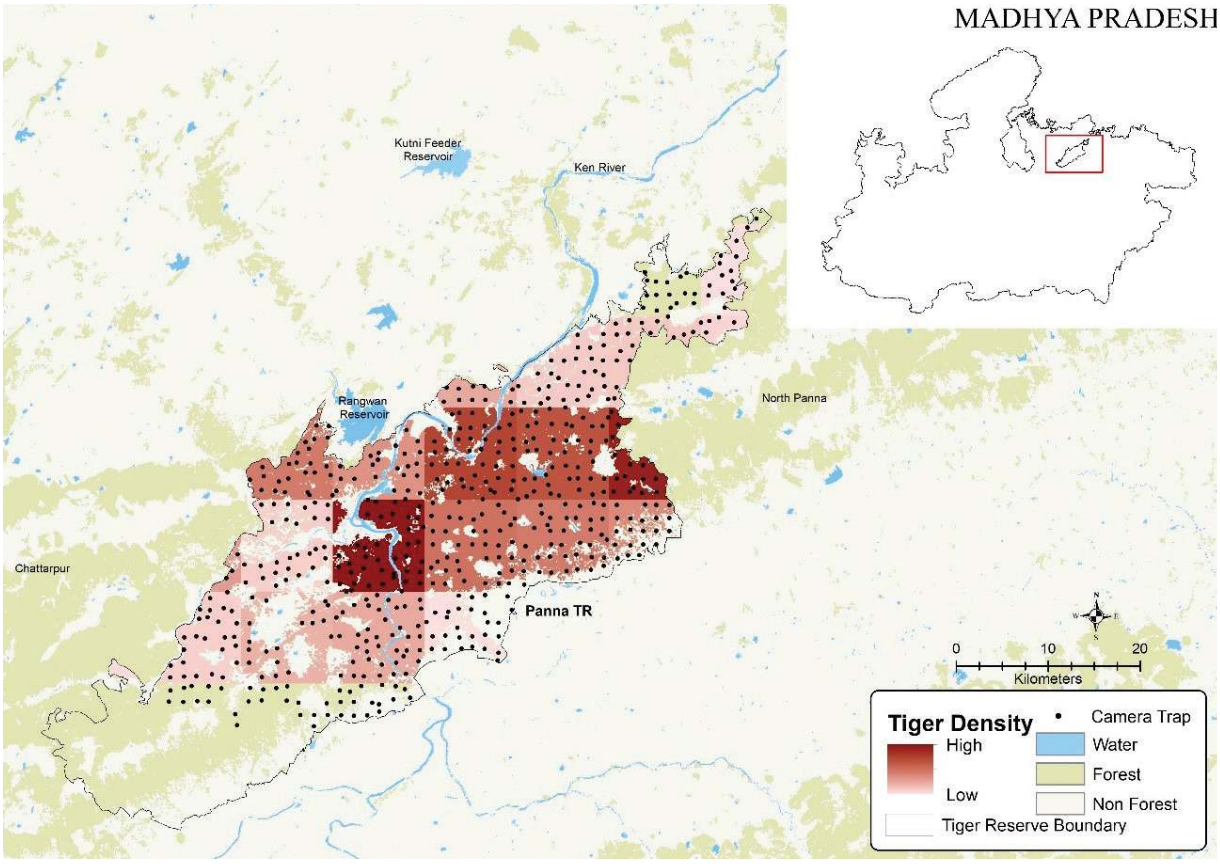

Table V.2.8

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Panna Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	2019
Camera points	574
Trap nights (effort)	25428
Unique tigers captured	55
Model	Pmix(sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	3.18 (0.43)
σ Female (SE) (km)	1.92 (0.086)
σ Male (SE) (km)	2.7(0.1)
g0 Female (SE)	0.035 (0.0024)
g0 Male (SE)	0.022(0.002)
Pmix Female (SE)	0.66(0.06)
Pmix Male (SE)	0.33(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: estimate of proportion of male /female (detection corrected sex ratio)

The tiger population in Panna has increased since the last cycle of the National Tiger Estimation Exercise in 2018. Panna Tiger Reserve, along with the surrounding territorial forest divisions of north Panna and south Panna, represents a significant and relatively intact wildlife habitat in the fragmented forested landscape of northern Madhya Pradesh. This connectivity continues until the Ranipur Tiger Reserve (recently declared) in Uttar Pradesh state. The connectivity between Panna Tiger Reserve and Ranipur Tiger Reserve is crucial for maintaining ecological corridors and allowing the movement of wildlife. This connectivity contributes to larger landscape-level conservation efforts. If connectivity is restored towards the west, then tigers from Panna can potentially disperse to Nauradehi WLS (South) and to Madhav NP (North).

PENCH TIGER RESERVE, MADHYA PRADESH

The Pench Tiger Reserve is situated on the southern slope of the Satpura-Maikal landscape and is associated with Rudyard Kipling's famous work, "The Jungle Book." The reserve is believed to have inspired Kipling's setting for the story and is often referred to as Mowgli Land." Its name is derived from the Pench River, which originates from the Mahadeo Hills and traverses the reserve in a north-south direction, covering a length of approximately 24 kilometers. The reserve is situated in Seoni and Chhindwara districts in southern Madhya Pradesh. The total area of the reserve is 1179.632 km^2, which comprises Pench Priyadarshini National Park (292.86 km^2) and Pench Mowgli Wildlife Sanctuary (118.47 km^2) as the core zones and an additional buffer zone with an area of 768.302 km^2.

An effort of 14657 trap nights was invested, and a total of 2647 tiger photos were obtained, from which 77 tiger individuals (>1 year of age) were identified, and tiger density was estimated at 5.50 (SE 0.6) tigers per 100 km^2 (Table V.2.9). The detection-corrected sex ratio in Pench MP was 3.05 females per male (Table V.2.9).

Figure V.2.9

Camera trap layout and spatial tiger density in Pench Tiger Reserve, Madhya Pradesh 2022

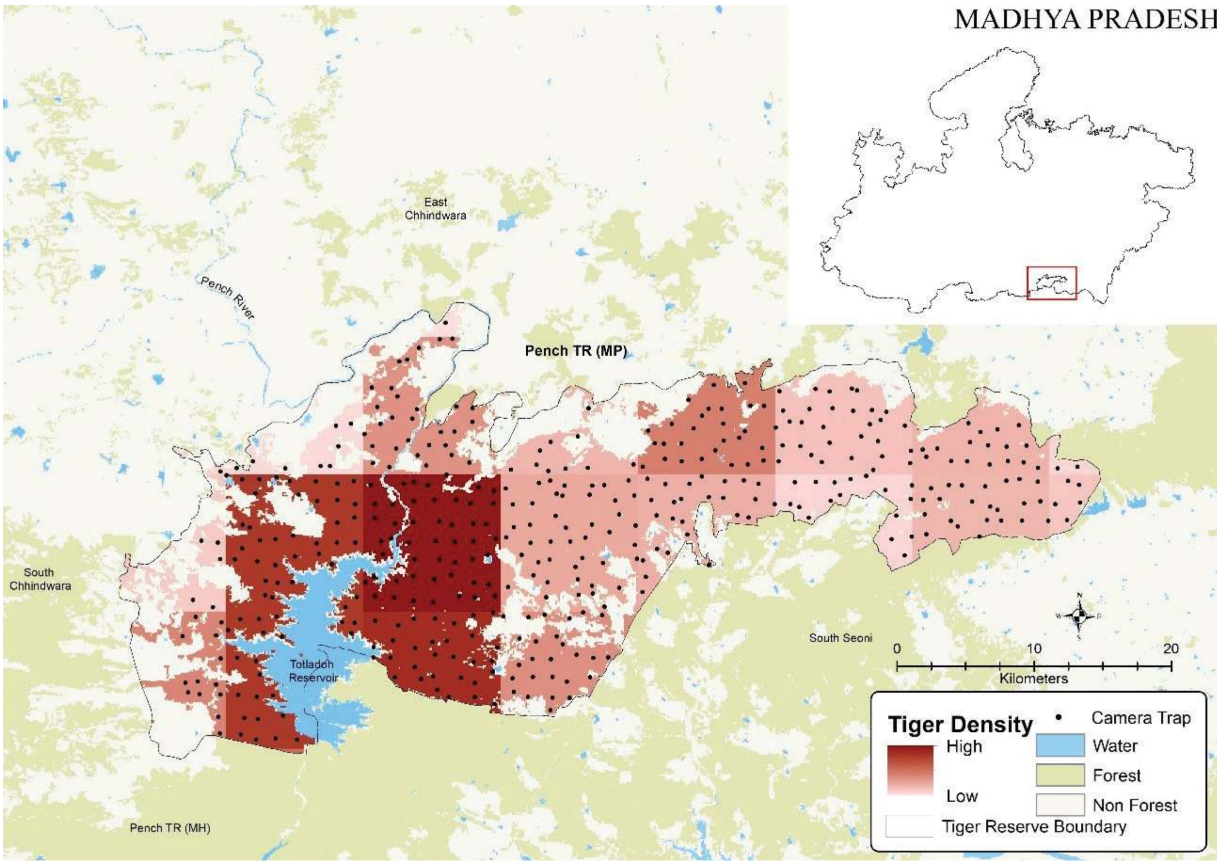

Table V.2.9

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Pench (Madhya Pradesh) Tiger Reserve, 2022

Variables	Estimate
Model space (km^2)	2100
Camera points	426
Trap nights (effort)	14657
Unique tigers captured	77
Model	Pmix(sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	5.50 (0.6)
σ Female (SE) (km)	1.9(0.05)
σ Male (SE) (km)	4.7(0.15)
g0 Female (SE)	0.03(0.002)
g0 Male (SE)	0.01(0.0008)
Pmix Female (SE)	0.59 (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: estimate of proportion of male /female (detection corrected sex ratio)

The tiger population at Pench has substantially increased since the last cycle of the National Tiger Estimation Exercise in 2018. The Pench Tiger Reserve of Madhya Pradesh shares a contiguous boundary with the Pench Tiger Reserve of Maharashtra, creating a transboundary conservation area that benefits wildlife conservation efforts. The Pench Tiger Reserve is connected to Kanha Tiger Reserve through the forests of Seoni, Balaghat, and Mandla divisions and to Satpura Tiger Reserve through Chhindwara forest division. The NH44 passes through Pench, SH26 & SH11 passes through Kanha-Pench corridor, SH249 cuts the Pench-NNTR corridor and NH26, NH69, SH19, & SH43 passes through Pench-Satpura corridor. Pench-NNTR corridor need special attention as there is lack of connected forest patch followed by Pench-Satpura, which has one bottleneck forest patch and one highly human dominated patch along the railway line connecting Chhindwara and Amla. These forested areas serve as crucial corridors for wildlife, allowing them to disperse and migrate between the tiger reserves.

SANJAY-DUBRI TIGER RESERVE

Sanjay-Dubri Tiger Reserve, situated in the north-eastern part of Madhya Pradesh's Siddhi district, shares its border with Guru Ghasidas National Park in Chhattisgarh. The Tiger Reserve has an area of 1674.511 km^2. This includes 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 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).

An effort of 17011 trap nights was invested, and a total of 874 tiger photos were obtained, from which 16 tiger individuals (>1 year of age) were identified, and the tiger density was estimated at 0.78 (SE 0.20) tiger per 100 km^2 (Table V.2.10). The detection-corrected sex ratio in Sanjay Tiger Reserve was 4 (Table V.2.10).

Figure V.2.10

Camera trap layout and spatial tiger density in Sanjay-Dubri Tiger Reserve, 2022

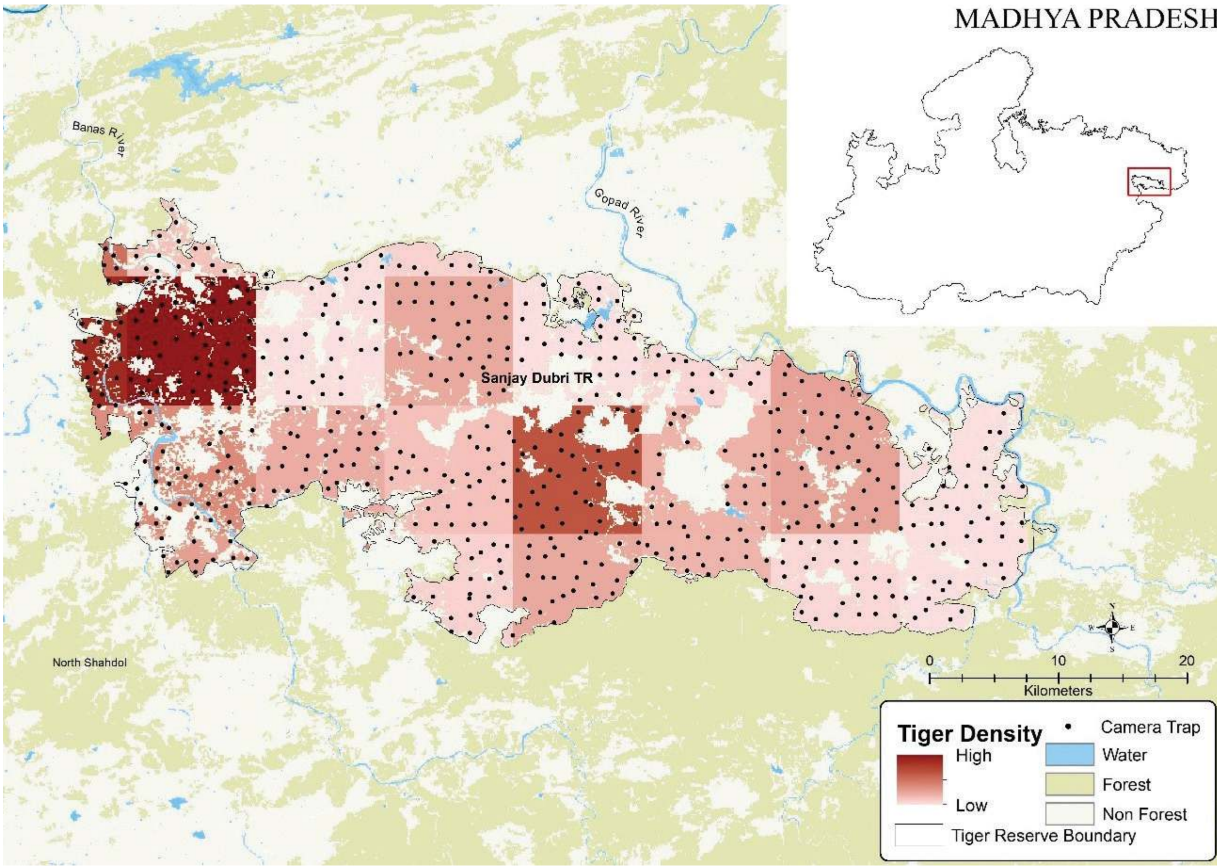

Table V.2.10

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Sanjay Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	2565
Camera points	573
Trap nights (effort)	17011
Unique tigers captured	16
Model	Pmix(sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	0.78(0.20)
σ Female (SE) (km)	2.44(0.1)
σ Male (SE) (km)	6.6(0.3)
g0 Female (SE)	0.04(0.004)
g0 Male (SE)	0.01(0.002)
Pmix Female (SE)	0.65(0.07)
Pmix Male (SE)	0.35(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: estimate of proportion of male /female (detection corrected sex ratio)

The tiger population has increased since the last national tiger estimation cycle in 2018. Incentivized voluntary village relocation from Sanjay will help in establishing an inviolate area, reducing biotic pressure, and subsequently facilitating prey recovery. Gaur was reintroduced this year from Kanha and Satpura Tiger Reserves. Sanjay Dubri Tiger Reserve is continuous with Guru Ghasidas National Park in Chhattisgarh, Palamau Tiger Reserve in Jharkhand, and Bandhavgarh Tiger Reserve in Madhya Pradesh through the forest of Shahdol Forest Division. Due to connectivity with neighbouring states, herds of wild elephants occasionally venture into the tiger reserve. Prey recovery measures such as the reintroduction of Gaur, and the supplementation of chital, from Bandhavgarh Tiger Reserve were done in Sanjay tiger reserve. These actions aimed to enhance the prey base and ensure a sustainable ecosystem for the tigers in Sanjay Tiger Reserve.

SATPURA TIGER RESERVE

Satpura Tiger Reserve is situated in the central Indian highlands within the Deccan peninsular biogeographic zone. It is situated in the Hoshangabad district of Madhya Pradesh, India. The reserve encompasses a total area of 2133.30 km^2, which includes Satpura National Park, Bori Wildlife Sanctuary, and Panchmarhi Wildlife Sanctuary as the core habitat, along with the peripheral area of 794.04 km^2 consisting of Hoshangabad Division, Rampur Bhatodi Project Division, and west Chhindwara Division as the buffer zone. The terrain of the national park is characterized by its ruggedness, featuring deep valleys, sandstone peaks, narrow gorges, rivulets, dense forests, and reservoirs. The combination of various climatic and soil factors at different altitudinal levels has resulted in a diverse and lush tropical flora within this protected area. The higher ranges of the Panchmarhi plateau are covered with sal *(Shorea robusta)* forests on Gondwana sandstone, while dense teak *(Tectona grandis)* forests dominate the lower hill ranges on basaltic traps. In recent years, the endangered central Indian hard ground swamp deer *(Cervus duvauceli branderi)* has been reintroduced to Satpura Tiger Reserve from Kanha Tiger Reserve to establish a new and separate population.

During the survey, a comprehensive effort of 26761 trap-nights were undertaken, leading to the collection of 2649 tiger photos. From these photos, 50 individual tigers (>1 year of age) were identified, resulting in an estimated tiger density of 2.01 (SE 0.28) tigers per 100 km^2 (Table V.2.11). The detection-corrected tiger sex ratio in Satpura Tiger Reserve was found to be 3.05 females per male (Table V.2.11).

Section V.2

Figure V.2.11

Camera trap layout and spatial tiger density in Satpura Tiger Reserve, 2022

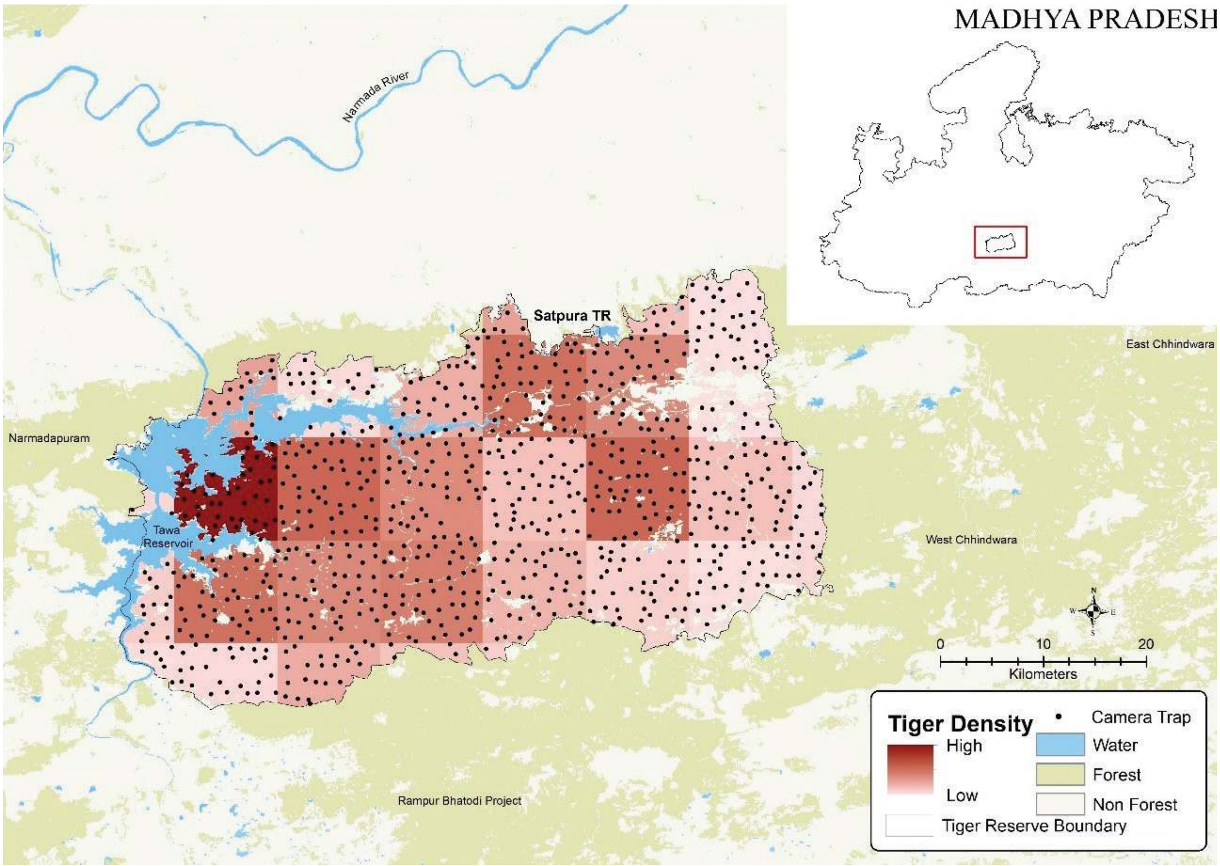

Table V.2.11

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Satpura Tiger Reserve, 2022

Variables	Estimate
Model space (km^2)	2955
Camera points	830
Trap nights (effort)	26761
Unique tigers captured	50
Model	Pmix(sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	2.01(0.28)
σ Female (SE) (km)	2.47(0.05)
σ Male (SE) (km)	4.09(0.11)
g0 Female (SE)	0.03(0.002)
g0 Male (SE)	0.01(0.00)
Pmix Female (SE)	0.57(0.06)
Pmix Male (SE)	0.42(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

The tiger population at Satpura has increased since the last cycle of the National Tiger Estimation Exercise in 2018. Incentivized voluntary village relocation has made Satpura the largest inviolate area for tigers in Madhya Pradesh. The Satpura tiger reserve has the potential to become one of the largest tiger populations in India if prey recovery in the tiger reserves is achieved. The connectivity of Satpura is with Melghat Tiger Reserve on the west, while on the east side it is connected to Pench Tiger Reserve through Chhindwara Forest Division in the south-east, which eventually connects to the Kanha Tiger Reserve in Madhya Pradesh. Active coal mines exist both to the east and to west of the corridor which need proper monitoring, and mitigation with restorative inputs.

BHOPAL-RATAPANI TIGER COMPLEX

This region includes following camera trapping sites and together the form largest tiger population in Malwa region.

A) BHOPAL FOREST DIVISION

Bhopal is situated on the Malwa plateau, just north of the upper limit of the Vindhyan mountain ranges in the central Indian landscape. The 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 total forested area of the division is about 366 km^2. The forest division has uneven terrain and 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 southern regions. The division covers parts of two river sub-basins: The Betwa river sub-basin and the lower Chambal basin. The Bhopal territorial division comprises two forest ranges, namely the Berasia forest range and the Samardha forest range.

An effort of 1044 trap nights were invested, and a total of 147 tiger photos were obtained, from which 7 tiger individuals were identified. As the sample size is small, density could not be estimated separately for this population block.

Bhopal Forest Division lies in the periphery of Bhopal City, is a good example of urban ecology. Tigers and other carnivores thrive in that area. Division is connected to Obedullaganj FD, Sehore FD and Raisen FD in Bhopal forest Circle. This corridor act as vital link of connectivity for Nauradehi Wildlife Sanctuary.

B) DEWAS FOREST DIVISION

Dewas Forest Division covers a forested area of 2000 km^2. The division is a part of the Vindhya range and is positioned between the Malwa plateau in the north and the Narmada River valley in the south. Kheoni Wildlife Sanctuary is a part of the Dewas Forest Division. The vegetation of the forest division is dominated by teak and mixed southern tropical dry deciduous forest.

Dewas is a continuous forest patch with Sehore Forest Division in the east, which connects the division with Ratapani Wildlife Sanctuary in Obedullaganj Forest Division. In the south, the division shares boundaries with Harda and Khandwa Forest Divisions.

An effort of 3309 trap nights were invested, and a total of 1390 tiger photos were obtained, from which 7 tiger individuals were identified. As the sample size is small, density could not be estimated.

C) SEHORE FOREST DIVISION

Sehore Forest Division covers an area of approximately 1520 km^2. The forest division connects Ratapani WLS and Dewas FD, forming a continuous forested area. The forest division is geographically spread over the Malwa plateau, lower Vindhya hills, Narmada plains, and the watershed of the Narmada and Parvati rivers. The terrain of the forest division is mostly undulating. The 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.

An effort of 1217 trap nights were invested, and a total of 252 tiger photos were obtained, from which 10 tiger individuals (>1 year of age) were identified, and the tiger density was estimated at 2.11 (SE 0.70) tigers per 100 km^2 (Table V.2.12). The detection-corrected tiger sex ratio in Sehore forest division was 1.(Table V.2.12).

Sehore Forest Divison lies in between Dewas Forest Division and Obedullaganj FD forming a continuous patch for the moment of wildlife. Three tiger individuals from Sehore FD are in common with Obedullaganj FD Tigers. This showcase the active corridor between the Forest Divisions.

D) RATAPANI WLS (OBEDULLAGANJ FOREST DIVISION)

Ratapani Wildlife Sanctuary is situated in Raisen and Sehore districts of Madhya Pradesh, under the administrative control of Obedullaganj Forest Division. The sanctuary runs parallel to the Narmada River on the northern side. The Kolar River forms the western boundary of the sanctuary. Ratapani WLS is spread across an area of 823.065 km^2, out of which 763.812 km^2 have 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 upgradation of Ratapani WLS to a tiger reserve. The area is classified under the semi-arid Gujarat Rajputana (4B) biogeographic province (Rodger *et al.* 2002).

An effort of 26500 trap nights were invested, and a total of 1843 tiger photos were obtained, from which 56 tiger individuals (>1 year of age) were identified, and tiger density was estimated at 2.30 (SE 0.31) tigers per 100 km^2 (Table V.2.12). The detection-corrected sex ratio in Ratapani WLS was 1.9 females per male (Table V.2.12).

Figure V.2.12

Camera trap layout and spatial tiger density in Bhopal-Ratapani complex, 2022.

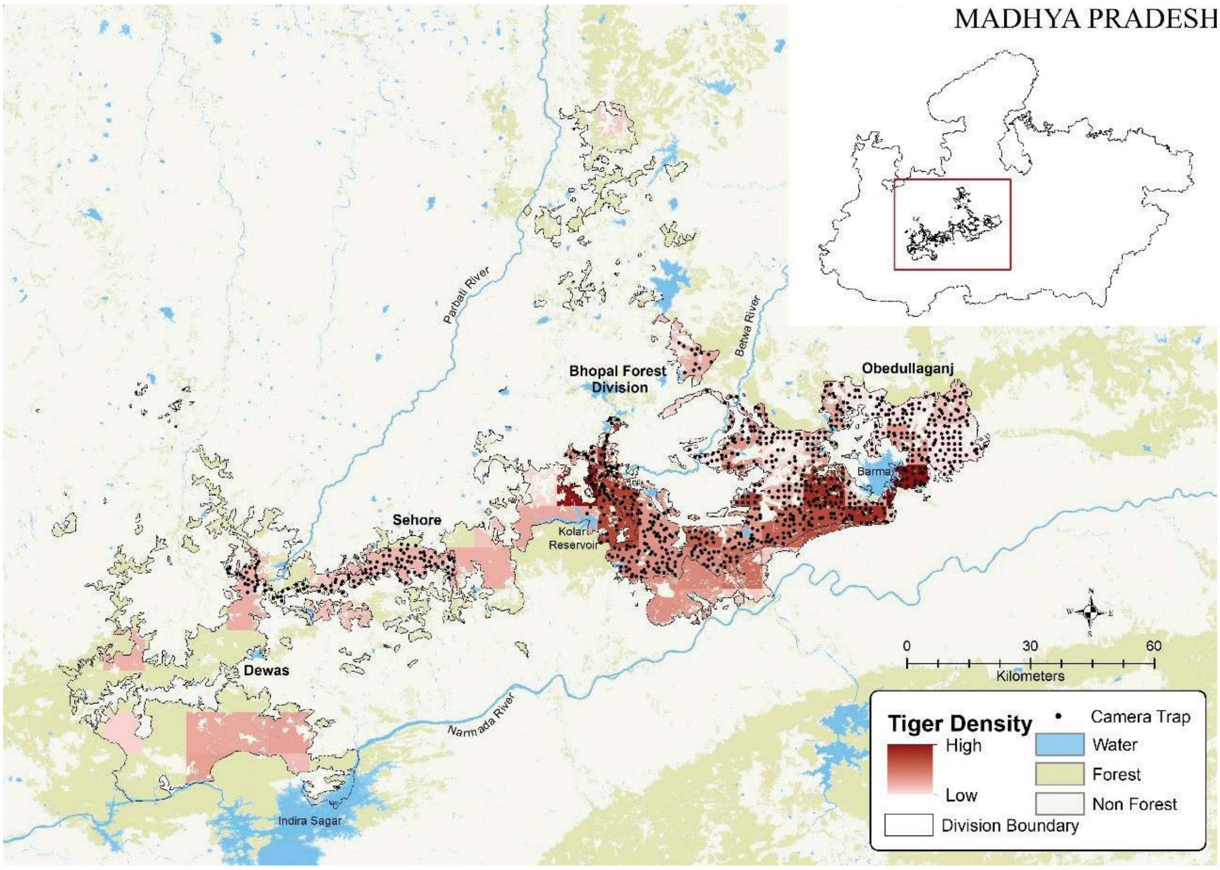

Table V.2.12

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Bhopal Forest Circle, 2022.

Variables	Estimate			
	Bhopal FD	Dewas FD	Sehore FD	Ratapani WLS (Obedullaganj)
Model space (km^2)	NA	NA	740	3060
Camera points	43	120	48	666
Trap nights (effort)	1044	3309	1217	26500
Unique tigers captured	07	07	10	56
Model	NA	NA	Pmix(sex)g0(sex) σ(sex)	Pmix(sex)g0(sex) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	NA	NA	2.11(SE 0.70)	2.30 (SE 0.31)
σ Female (SE) (km)	NA	NA	2.30(SE 0.27)	2.61 (SE 0.09)
σ Male (SE) (km)	NA	NA	3.81(SE 0.57)	4.56 (SE 0.16)
g0 Female (SE)	NA	NA	0.02(SE 0.01)	0.02 (SE 0.001)
g0 Male (SE)	NA	NA	0.02(SE 0.01)	0.04 (SE 0.002)
Pmix Female (SE)	NA	NA	0.52(0.17)	0.60 (0.06)
Pmix Male (SE)	NA	NA	0.47(0.17)	0.40 (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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Ratapani WLS connects Sehore Forest Division with Raisen and Bhopal Forest Divisions, forming a continuous patch of forested area. The connecting landscapes around the Ratapani Wildlife Sanctuary can act as spill over areas. This continuous patch forms an active corridor for the movement of wildlife across the landscape. Ratapani has largest tiger population. With inputs to increase the prey population Ratapani WLS has a capacity to harbour source tiger population for adjoining forest divisions. The government of India had given in principle approval for declaring it a Tiger reserve.

KANHA-PENCH CORRIDOR COMPLEX

This complex consists of following sites

A) MANDLA FOREST DIVISION

Mandla Forest Division is situated within the Mandla district of Madhya Pradesh, between Kanha Tiger Reserve and Balaghat Forest Division. It is divided into East and West Mandla Forest Divisions. Most of the forest is classified as reserved forest, while a small portion of the forest is categorized as protected forest and revenue forest. As per the forest classification (Champion and Seth, 1968), the major forest type of Mandla is 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).

Mandla Forest Division and Mohgaon Project were camera-trapped together in a single block for the All India Tiger Monitoring Exercise. Movements of tigers have been observed between Kanha Tiger Reserve, Mandla Forest Division, and Balaghat Forest Division. Hence, the protection of these corridors is crucial for facilitating the dispersal of tigers between the Kanha Tiger Reserve, Pench Tiger Reserve, and surrounding landscapes.

An effort of 4326 trap nights were invested, and a total of 152 tiger photos were obtained, from which 14 tiger individuals (>1 year of age) were identified, and the tiger density was estimated at 1.52 (SE 0.43) tigers per 100 km^2 (Table V.2.13). The detection corrected tiger ratio in Mandla FD was 2.8 female per male (Table V.2.13).

B) BALAGHAT FOREST DIVISION

The Balaghat Forest Division lies in the biodiverse Maikal hills of Balaghat district in Madhya Pradesh. It comprises 4823 km^2 of forested area. The sampling area includes the North and South Balaghat Territorial Divisions and the Lamta and Mohgaon project divisions. Combining all this forms an important tiger landscape.

Balaghat Forest Division is a significant area situated strategically in the corridor regions of central India. It serves as a connecting link between various source population sites for wildlife, particularly tigers. It connects high-density Kanha and Pench Tiger Reserves in Madhya Pradesh with protected areas of low tiger densities, such as Achanakmar Tiger Reserve in Chhattisgarh and Nawegaon-Nagzira Tiger Reserve in Maharashtra.

An effort of 18770 trap nights were invested, and a total of 736 tiger photos were obtained, from which 49 tiger individuals (>1 year of age) were identified, and the tiger density was estimated at 1.77 (SE 0.25) tigers per 100 km^2 (Table V.2.13). The detection-corrected tiger sex ratio in Balaghat Forest Division was 2 females per male. (Table V.2.13).

C) BARGHAT PROJECT DIVISION

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 the Barghat block of Barghat Project Division. Barghat Project Division covers a forested area of 503 km^2. The Barghat Project Division is spread out into patches. It is connected with the South Balaghat, South Seoni, and Mohgaon Projects in different patches. Thus, it forms the continuous corridor between Pench Tiger Reserve, MP, and South Balaghat Division.

The forests of Barghat Project Division are classified into two major forest types: southern tropical dry deciduous teak forest and southern dry mixed deciduous forest (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, *Dendrocalamaus strictus* and other commercially valuable trees are grown by the department.

An effort of 1110 trap nights were invested, and a total of 41 tiger photos were obtained, from which 8 tiger individuals were identified. However, the density could not be estimated due to the insufficient detections.

D) SOUTH-SEONI FOREST DIVISION

Nestled in the Southern Ranges of Satpura Hills, striking northeast to southwest, is the Forest of South Seoni Territorial Division. The Forest area of division is 1142 km^2. The forests of South Seoni Division fall into (i) South Indian tropical moist deciduous slightly moist teak forest, (ii) Southern tropical dry deciduous teak forest, and (iii) Southern dry mixed deciduous forest.

The demand for firewood, small timber, and fodder from the ever-increasing human and cattle populations has not only put pressure on the Forests but has also effectively reduced their productivity. Uncontrolled and excessive grazing has led to the destruction of the regeneration in these areas, coupled with the hardening of the forest floor, as a result of which there is swift run-off of rainwater leading to soil erosion.

The South Seoni Forest Division acts as a vital link for wildlife corridors and connectivity between Kanha and Pench forested areas. It provides an ecological pathway for the movement of animals, ensuring gene flow, maintaining genetic and demographic viability. Protecting and managing this division helps maintain landscape connectivity, support healthy populations, and overall ecosystem resilience.

An effort of 2410 trap nights were invested, and a total of 107 tiger photos were obtained, from which 12 tiger individuals (>1 year of age) were identified, and the tiger density was estimated at 0.81 (SE 0.27) tiger per 100 km^2 (Table V.2.13). The detection-corrected tiger sex ratio in South Seoni was 0.93 females per male (Table V.2.13).

Section V.2

Figure V.2.13

Camera trap layout and spatial tiger density in Kanha-Pench Corridor, 2022

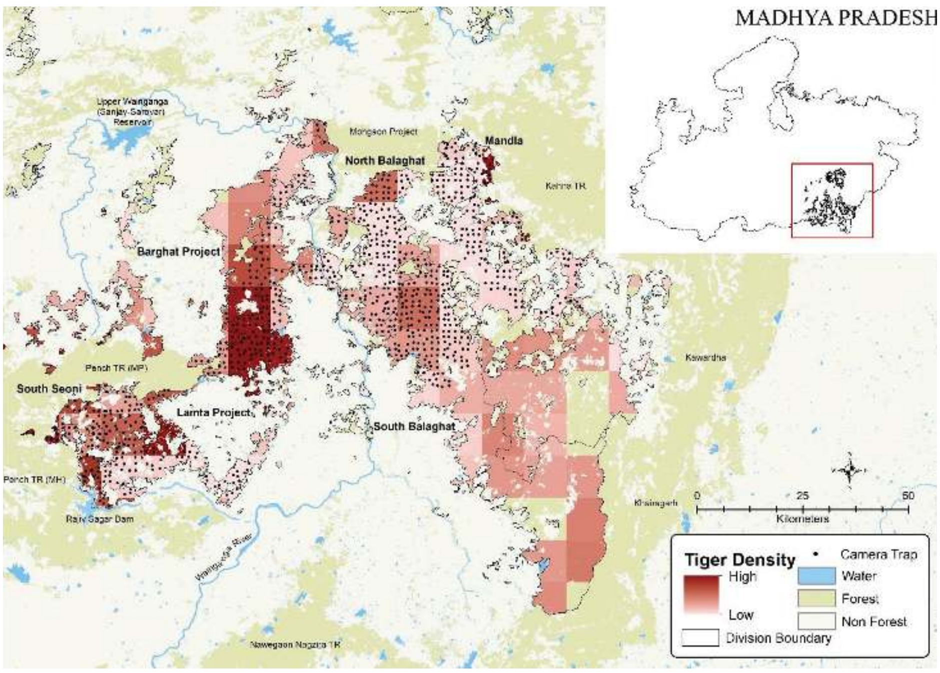

Table V.2.13

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Kanha-Pench Corridor, 2022.

Variables	Estimate				
	Mandla FD	Balaghat FD	Lamta Project	Barghat Project	South-Seoni FD
Model space (km^2)	1779.75	4542	2480.25	NA	2060.75
Camera points	107	495	221	69	96
Trap nights (effort)	4326	18770	9082	1110	2410
Unique tigers captured	14	49	14	08	12
Model	Pmix(sex) g0(sex)σ(sex)	Pmix(sex) g0(sex) σ(sex)	Pmix(sex) g0(sex) σ(sex)	NA	Pmix(sex) g0(.)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	1.52(0.43)	1.77(0.25)	1.04(0.28)	NA	0.81(0.27)
σ Female (SE) (km)	2.36(1.00)	2.4(0.12)	2.00(0.24)	NA	7.6(0.9)
σ Male (SE) (km)	6.67(1.00)	4.06(0.25)	5.84(0.69)	NA	7.5(0.9)
g0 Female (SE)	0.02(0.00)	0.02(0.002)	0.02(0.00)	NA	0.015(0.007)
g0 Male (SE)	0.007(0.00)	0.01(0.002)	0.01(0.00)	NA	0.016(0.007)
Pmix Female (SE)	0.58(0.13)	0.59(0.07)	0.65(0.12)	NA	0.37(0.17)
Pmix Male (SE)	0.41(0.13)	0.40(0.05)	0.34(0.12)	NA	0.62(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Total 97 tigers were captured in this complex. This complex plays an important role in connecting important populations of Central India. Specifically, it is continuous forest patch connecting 2 tiger reserves with 2 state highways SH26 & SH11 passing through Barghat-Balaghat and Mandla-Lamta respectively. The South-Seoni Forest Division connect Pench TR to NNTR but the area between South-Seoni is highly disturbed with linear infrastructure and human settlements. This corridor is crucial in long-term sustenance of Central Indian tiger population.

KUNO NATIONAL PARK

Kuno National Park is part of the Sheopur-Shivpuri forested landscape (6800 km^2) in the district of Sheopur in Madhya Pradesh. It lies in the north-West of Madhya Pradesh, close to the state border with Rajasthan, so the effects of Rajasthan vegetation can be experienced in the forest of Kuno. Spread over an area of 748 km^2. The area is classified under the semi-arid Gujarat Rajputana (4B) biogeographic province (Rodger *et al.* 2002). The site was considered for Cheetah reintroduction in 2010. In September 2022, eight cheetahs from Namibia and, in February 2023, 12 Cheetahs from South Africa were reintroduced 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. No tiger was photo-captured during the sampling period of this estimation, although signs were recorded. Recently, the forest staff and team working in the park have recorded the presence of a male tiger.

Figure V.2.14

Camera trap layout in Kuno National Park, 2022

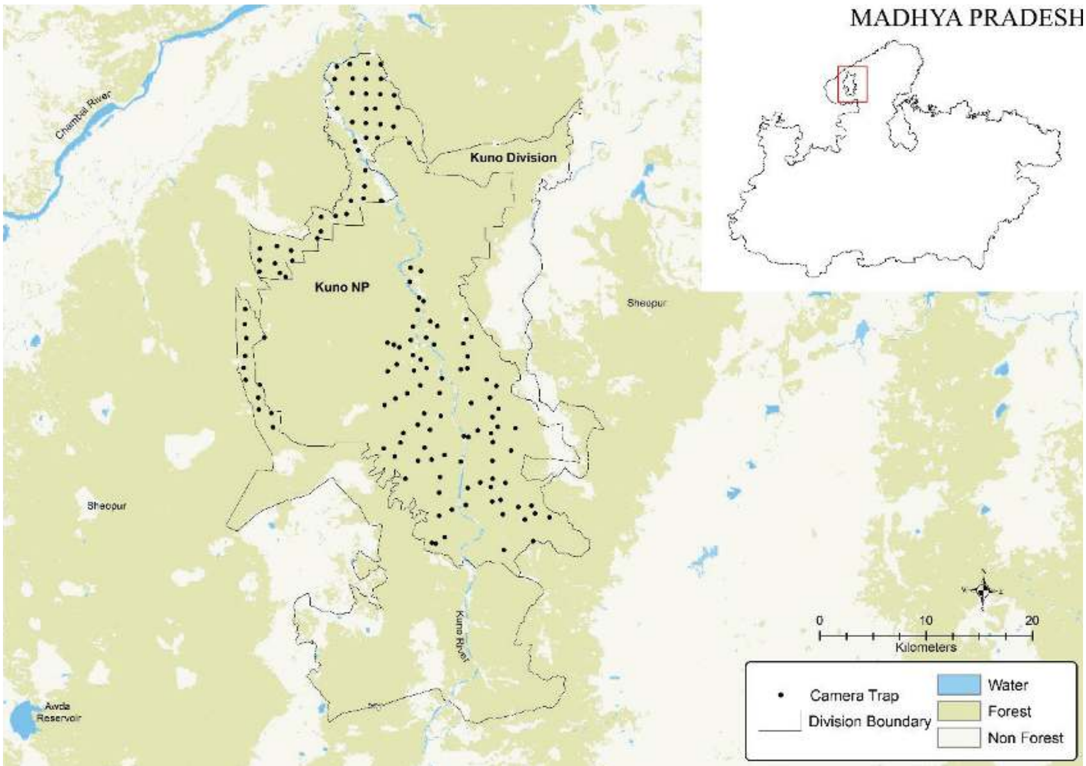

Table V.2. 14

Sampling details of camera trapping exercise in Kuno National Park, 2022

Variables	Counts
Camera points	146
Trap nights (effort)	4735
Number of tiger photos	0

NARMADAPURAM FOREST DIVISION

Narmadapuram Division, previously known as Hoshangabad Division, is situated in the central Narmada valley and the northern fringe of the Satpura plateau in India. It is surrounded by Raisen, Sehore, Harda, Narsinghpur, Betul, and Chhindwara districts. The division have 2422.65 km^2 of forests. The forests of Narmadapuram Division predominantly consist of Teak forests, classified as South Tropical Dry Deciduous Teak Forests. Additionally, there are mixed forests categorized as Southern Tropical Dry Deciduous Mixed Forests. These forests serve as a buffer zone for the Satpura Tiger Reserve and also act as a wildlife corridor connecting the Satpura and Melghat Tiger Reserves. However, the forests in Narmadapuram Division face various challenges. Forest fires, the collection of fuelwood, illegal tree felling, and encroachment activities exert significant pressure on the region's biodiversity and ecological balance. It is crucial to address these issues and ensure sustainable management and conservation of the forests.

During the survey, a total effort of 8510 trap nights was invested, resulting in the capture of 13 tiger photos. From these photos, 2 individual tigers (>1 year of age) were identified. However, due to the small sample size, it is not possible to estimate tiger density accurately.

Figure V.2.15

Camera trap layout and tiger presence in Narmadapuram Forest Division, 2022

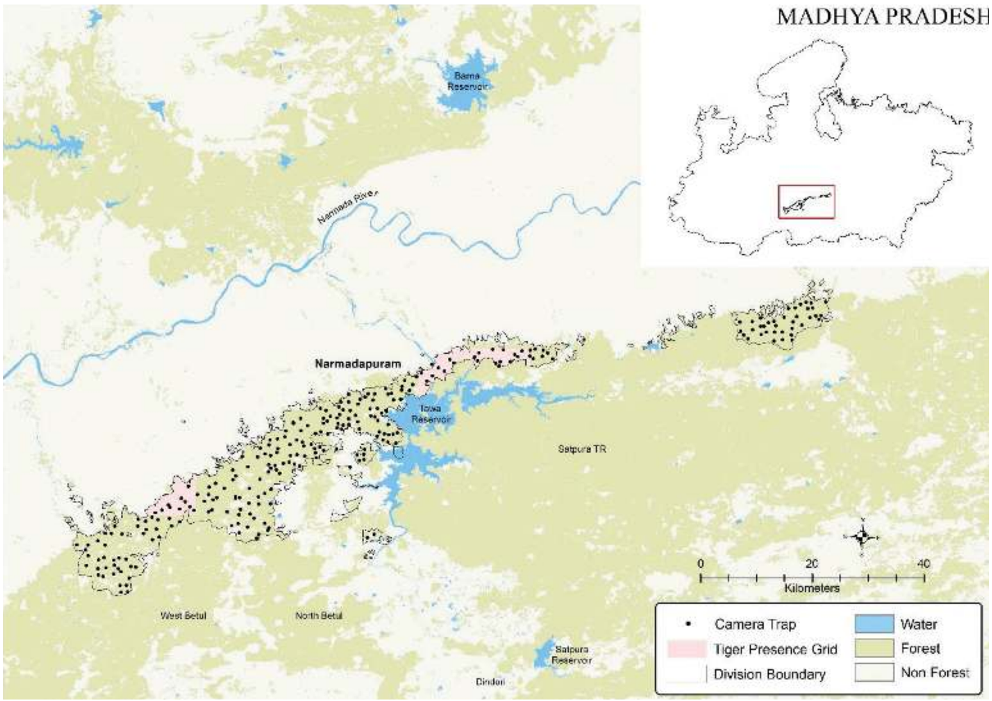

Table V.2.15

Sampling details of camera trapping exercise in Narmadapuram Forest Division, 2022.

Variables	Counts
Camera points	267
Trap nights (effort)	8510
Number of tiger photos	13
Unique tigers captured	2

NAURADEHI WILDLIFE SANCTUARY

Nauradehi Wildlife Sanctuary, the largest wildlife sanctuary in Madhya Pradesh, covers approximately 1197 km^2 across Sagar, Damoh, and Narsinghpur districts. A unique protected area that encompasses the Ganges and Narmada river basins. Falling under the Deccan Peninsula biogeographic region, the sanctuary is situated on a plateau within the upper Vindhyan range. Nauradehi serves as a crucial fragmented corridor connecting Panna Tiger Reserve and Bandhavgarh Tiger Reserve. It also has a connecting forest patch with Veerangana Durgawati Sanctuary in Damoh district, extending towards Bandhavgarh Tiger Reserve. Moreover, Nauradehi is identified as a potential site for the reintroduction of cheetahs.

In 2018, the sanctuary witnessed the reintroduction of one orphaned tiger from Kanha Tiger Reserve and one male tiger from Bandhavgarh Tiger Reserve. The tiger population has since grown to five individuals within the sanctuary.

During the survey, an effort of 3171 trap-nights was undertaken, resulting in the capture of 178 tiger photos. From these photos, 5 individual tigers were identified. However due to less detentions, it is not possible to estimate the tiger density accurately.

Figure V.2.16

Camera trap layout and tiger presence in Nauradehi Wildlife Sanctuary, 2022

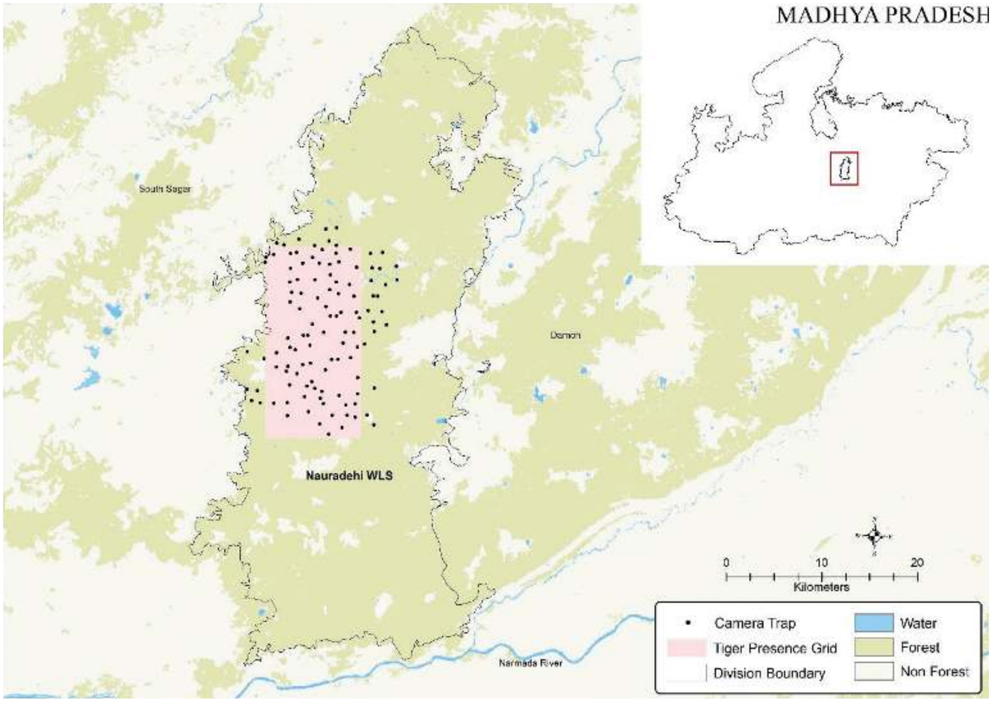

Table V.2.16

Sampling details of camera trapping exercise in Nauradehi Wildlife Sanctuary, 2022.

Variables	Counts
Camera points	114
Trap nights (effort)	3171
Number of tiger photos	178
Unique tigers captured	5

NORTH BETUL FOREST DIVISION

The North Betul Forest Division is situated north of the Betul revenue district in Madhya Pradesh, India. The division is predominantly hilly and is part of the Satpura mountain range, comprising the Satpura Range and the Satpura Plateau. Covering a total area of 1844 km^2, encompassing 1148 km^2 of forests. The forests in this division consist of South Indian Tropical Moist Deciduous Forest, Southern Tropical Dry Deciduous Forest, Riparian Fringing Forest, and Boswellia Forest. Each forest type supports a diverse range of flora and fauna. The North Betul Forest Division serves as a vital wildlife corridor connecting the Satpura and Melghat Tiger Reserves. This corridor provides a crucial habitat for wildlife species to move and disperse between the two reserves. It plays a significant role in conserving biodiversity and maintaining ecological balance in the region. During the survey, a comprehensive effort of 3170 trap nights were invested, resulting in the capture of 50 tiger photos. From these photos, 2 individual tigers were identified. However, due to the small sample size, it is not possible to estimate the tiger density accurately.

Figure V.2.17

Camera trap layout and tiger presence in North Betul Forest Division, 2022

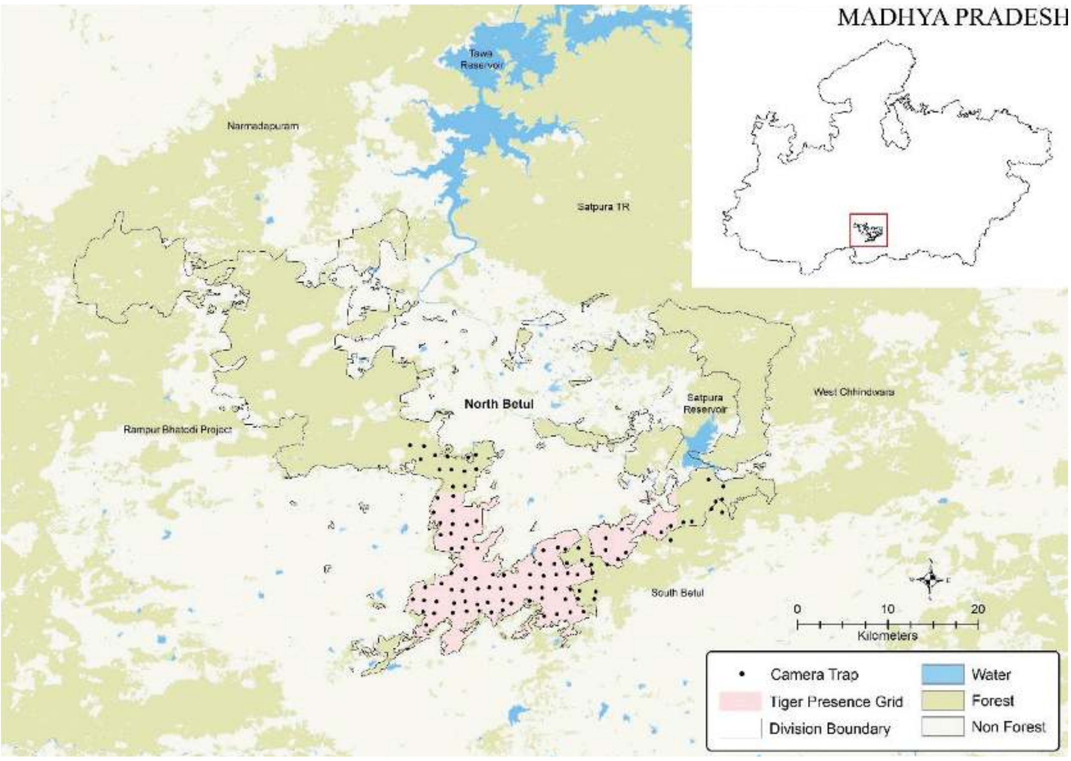

Table V.2.17

Sampling details of camera trapping exercise in North Betul Forest Division, 2022.

Variables	Counts
Camera points	107
Trap nights (effort)	3170
Number of tiger photos	50
Unique tigers captured	2

NORTH PANNA TERRITORIAL FOREST DIVISION

North Panna Territorial Forest Division is situated in the central portion of the plateau of Bundelkhand. 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 is classified into two major forest types viz. southern tropical dry deciduous teak forest and southern dry mixed deciduous forests (Champion and Seth 1968).

North Panna Territorial Forest Division shares its proximity with Panna Tiger Reserve. Hence acting as corridor between Panna TR and Satna Forest Division. Panna complex forms active corridor for the movement of wildlife across the two states i.e. Madhya Pradesh and Uttar Pradesh. The major part of district's population resides adjacent to this area thus increasing the biotic pressure inside the division.

During the survey, a comprehensive effort of 3631 trap-nights were invested and 113 tiger photographs were obtained. From these photos, 13 individual tigers (>1 year of age) were identified, resulting in an estimated tiger density of 2.10 (SE 0.60) tigers per 100 km^2 (Table V.2.18). The detection-corrected tiger sex ratio in North Panna Territorial Forest Division was found to be 1 female per male. (Table V.2.18).

Figure V.2.18

Camera trap layout and spatial tiger density in North Panna Forest Division, 2022

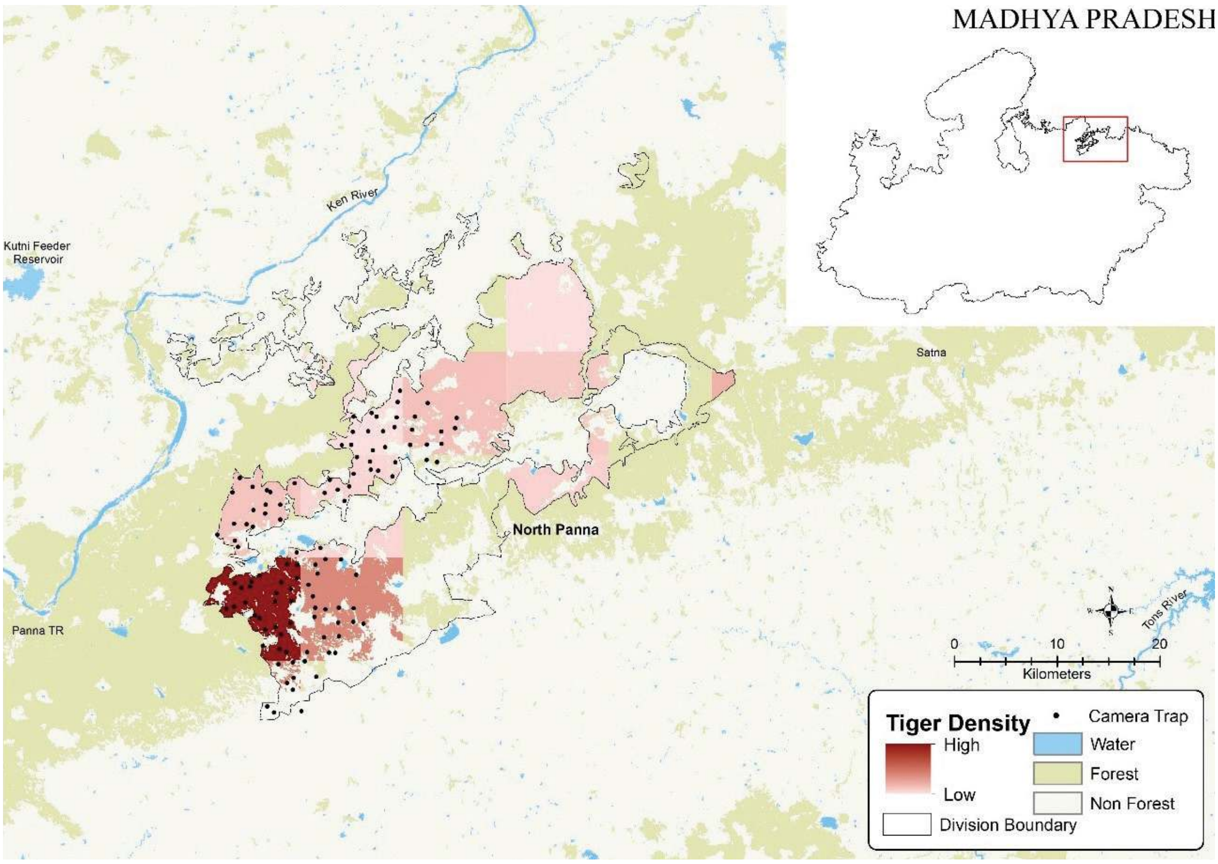

Table V.2.18

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for North Panna Forest Division, 2022.

Variables	Estimate
Model space (km^2)	826
Camera points	112
Trap nights (effort)	3631
Unique tigers captured	13
Model	Pmix(sex)g0(.)σ(.)
$\hat{D}$ SECR (per 100 km^2)	2.1 (0.60)
σ Female (SE) (km)	2.57 (0.19)
σ Male (SE) (km)	2.57 (0.19)
g0 Female (SE)	0.043 (0.007)
g0 Male (SE)	0.043 (0.007)
Pmix Female (SE)	0.57 (0.17)
Pmix Male (SE)	0.43(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

North Panna act as sink to Panna tiger reserve and is contiguous to the Panna Tiger Reserve. An increase from last cycle of countrywide tiger estimation is reported.

RAMPUR BHATODI PROJECT DIVISION

The Rampur Bhatodi Project Division is situated in Betul district and lies between the Satpura, Melghat, and Pench corridors. It is adjacent to the buffer zone of the Satpura Tiger Reserve. The division covers an area of 300 km^2 and is under the administrative control of the Madhya Pradesh Rajya Van Vikas Nigam Ltd. The forests within the Rampur Bhatodi Project Division are classified into two major types: southern tropical moist deciduous forests and southern dry mixed deciduous forests, as per the classification by Champion and Seth 1968. These forest types indicate the dominant vegetation and ecological characteristics found within the division. Rampur Bhatodi Project Division is a part of the Satpura-Melghat-Pench corridors.

An effort of 1046 trap nights were invested, and a total of 14 tiger photos were obtained, from which 3 tiger individuals were identified. As the sample size is small, density could not be estimated.

Figure V.2.19

Camera trap layout and tiger presence in Rampur Bhatodi Project Division, 2022

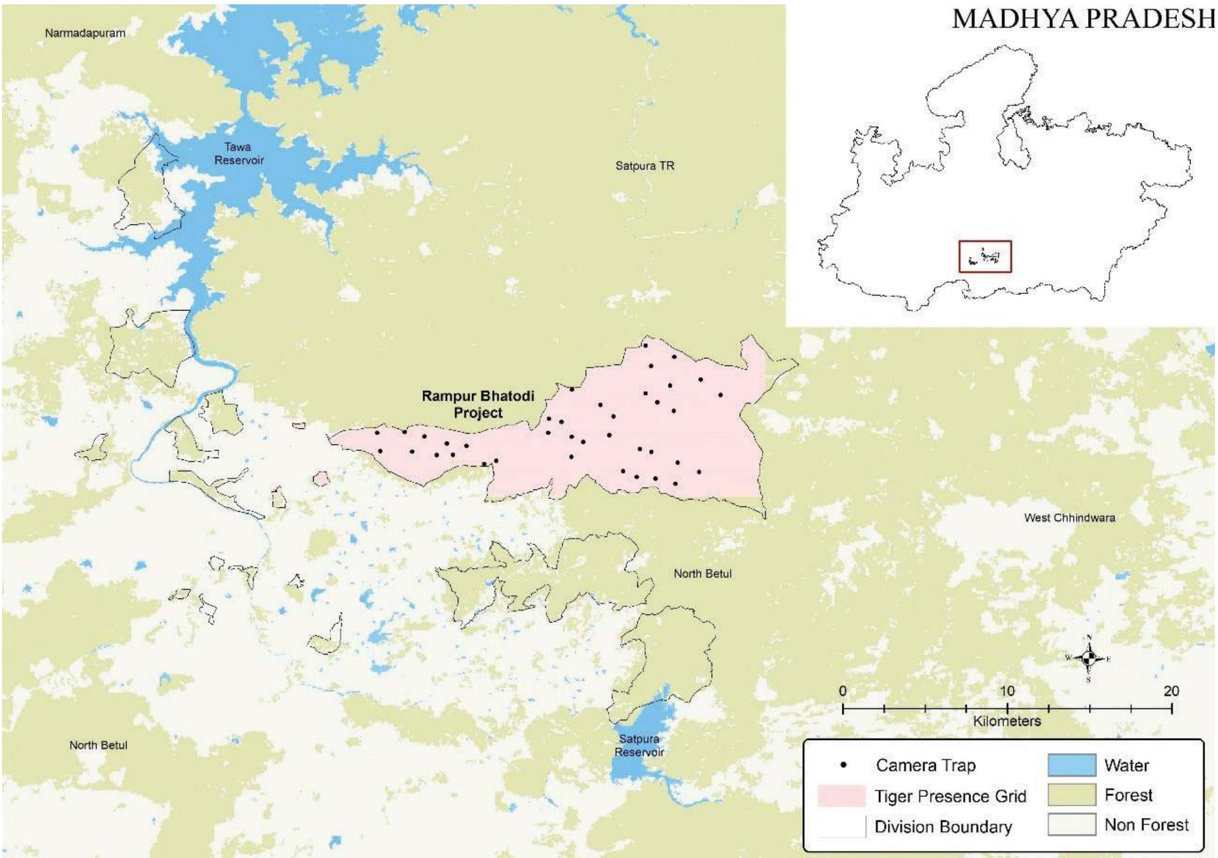

Table V.2. 19

Sampling details of camera trapping exercise in Rampur Bhatodi Project Division, 2022.

Variables	Counts
Camera points	39
Trap nights (effort)	1046
Number of tiger photos	14
Unique tigers captured	3

SATNA FOREST DIVISION

Satna division, situated within the Vindhyachal mountain range, is a significant region characterized by the upper Vindhyan geological formation. It shares borders with Panna district in the west, Banda district in Uttar Pradesh to the north, Rewa district to the east, Sidhi district to the southeast, Jabalpur district to the south, and Umaria and Shahdol districts to the southwest. The division encompasses a total forest area of 2267.02 km^2. The landscape of Satna division consists of a combination of plains and hills. The plains are primarily utilized for agricultural activities, while the hills are covered by forests. The forests in this division are primarily classified as mixed forests of the North Tropical Dry Deciduous type, with smaller sections comprising Teak and Sal forests.

Unfortunately, human activities have resulted in significant damage to the forests in this region. Illegal tree felling, encroachment on forestland, unsustainable collection of minor forest produce, excessive grazing, and illegal mining due to the presence of rich mineral resources contribute to forest degradation. To address these issues and restore forest cover, it is crucial to implement appropriate measures. Restorative activities in degraded forest areas can be an effective strategy to increase forest cover. By restoring ecological balance and enhancing biodiversity, these efforts will contribute to the preservation of the forests in the region. Furthermore, the protection of moderately dense forests is essential for improving the quality and productivity of existing forests. This can be achieved through sustainable forest management practices and robust enforcement of forest protection laws.

Satna Forest Division (FD) is a part of Panna landscape. Satna FD is connected to Panna TR via North Panna Territorial Division. Satna FD is also connected to Rani Tiger Reserve (recently declared) in the state of Uttar Pradesh. Recent tiger cycle data confirms this as all the 3 tiger individuals of Satna FD are common with Rani Tiger Reserve showing the movement of tigers across the landscape.

During the survey, an effort of 2810 trap nights was conducted, resulting in 112 tiger photographs. From these photos, 3 individual tigers were identified. However, due to the small sample size, it was not possible to estimate tiger density accurately.

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Figure V.2.20

Camera trap layout and tiger presence in Satna Forest Division, 2022

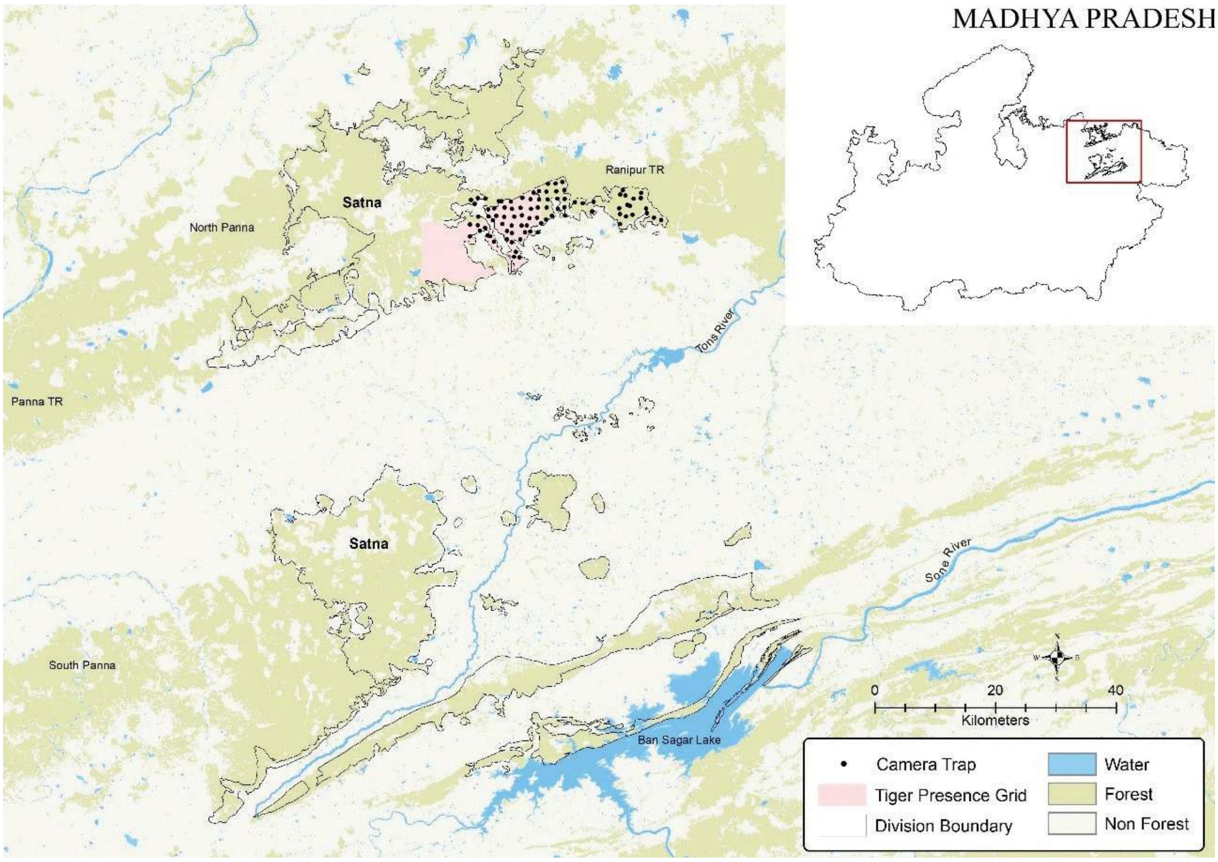

Table V.2.20

Sampling details of camera trapping exercise in Satna Forest Division, 2022.

Variables	Counts
Camera points	88
Trap nights (effort)	2810
Number of tiger photos	112
Unique tigers captured	3

SHAHDOL FOREST DIVISION

The forests of Shahdol are divided into the North Shahdol Forest Division and the South Shahdol Forest Division. Most of the forests are reserved forests, while a small portion of the forests are categorized as protected forests and unclassified forest land. The vegetation of the region is characterized by tropical moist deciduous Sal forests and northern dry mixed deciduous forests (Champion and Seth, 1968). Shahdol Forest Division works as a corridor between Bandhavgarh Tiger Reserve and Sanjay Tiger Reserve. Shahdol Forest Division acts as a sink population for the tigers moving out or dispersing from the nearby tiger reserves.

An effort of 2699 trap nights was invested, and a total of 229 tiger photos were obtained, from which 15 unique tigers (>1 year of age) were identified. The tiger density was estimated at 1.56 (SE 0.45) tigers per 100 km^2 (Table V.2.21). The detection-corrected tiger sex ratio in Shahdol FD was 5 females per male (Table V.2.21).

Figure V.2.21

Camera trap layout and spatial tiger density in Shahdol Forest Division, 2022

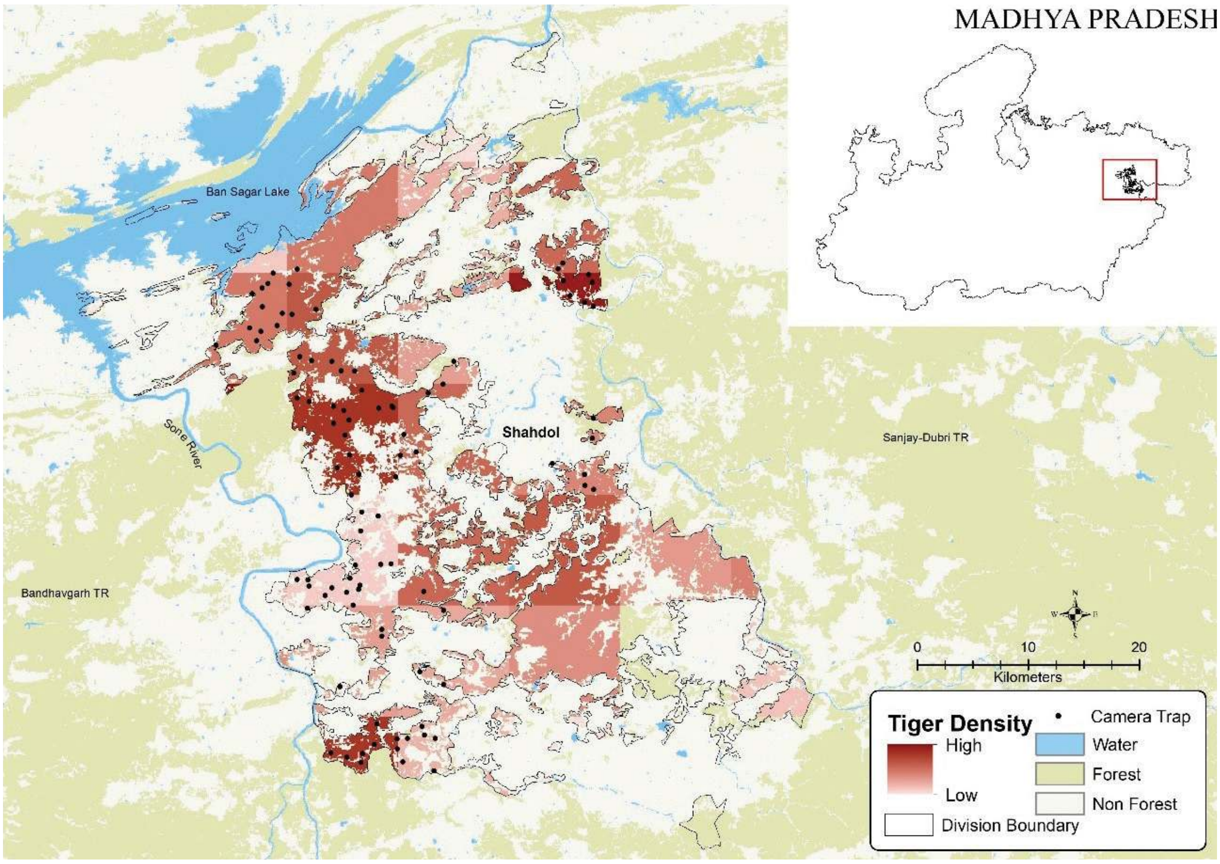

Table V.2. 21

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Shahdol Forest Division, 2022.

Variables	Estimate
Model space (km^2)	2084
Camera points	95
Trap nights (effort)	2699
Unique tigers captured	15
Model	Pmix(sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	1.56(0.45)
σ Female (SE) (km)	2.26(0.29)
σ Male (SE) (km)	6.90(0.94)
g0 Female (SE)	0.05(0.014)
g0 Male (SE)	0.01(0.00)
Pmix Female (SE)	0.75(0.09)
Pmix Male (SE)	0.24(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

SOUTH PANNA TERRITORIAL FOREST DIVISION

The South Panna Territorial Forest Division is situated in the central part of the Bundelkhand plateau, forming a significant part of the larger Panna tiger landscape. Covering an area of approximately 4521.91 km^2., the division is characterized by two primary forest types: southern tropical dry deciduous teak forest and southern dry mixed deciduous forests. In terms of connectivity, the South Panna Territorial Forest Division shares boundaries with the Damoh Forest Division in the west and the Satna Forest Division in the east. It also borders the buffer region of the Panna Tiger Reserve, enhancing its significance as part of the larger conservation landscape.

During the sampling exercise, an effort of 2538 trap nights was invested, but only one tiger image was obtained. However, due to the poor image quality, it was not possible to identify the individual tiger.

Figure V.2.22

Camera trap layout and tiger presence in South Panna Territorial Forest Division, 2022

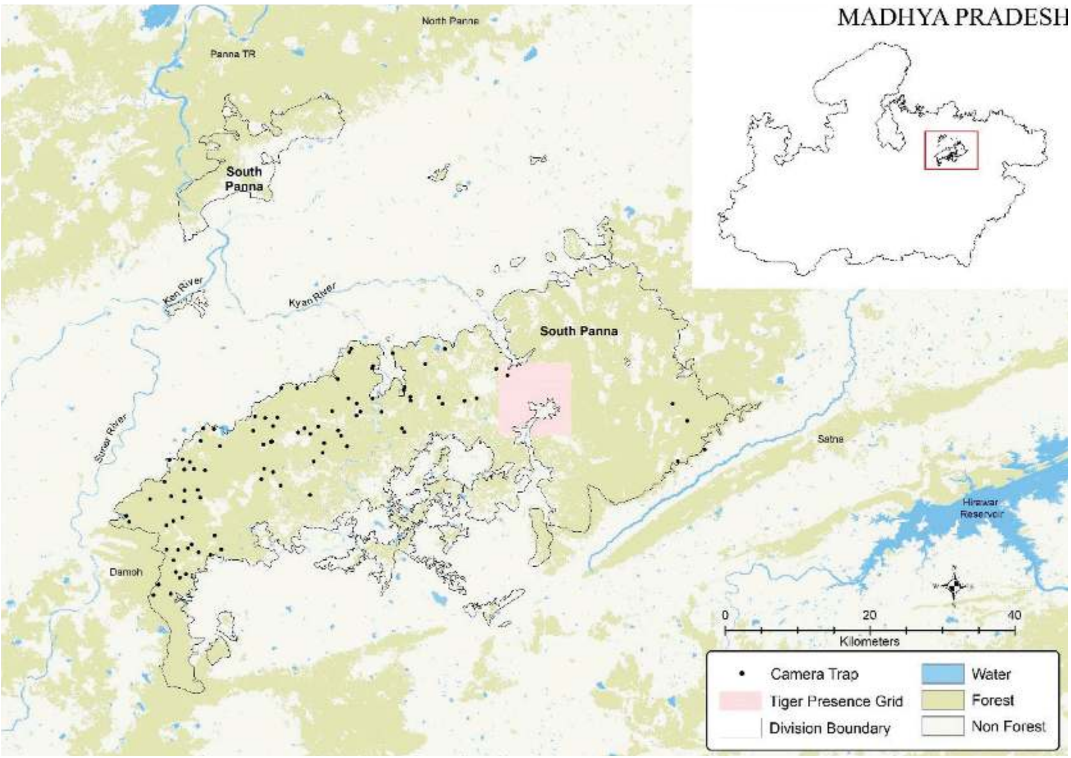

Table V.2. 22

Sampling details of camera trapping exercise in South Panna Territorial Forest Division, 2022.

Variables	Counts
Camera points	94
Trap nights (effort)	2538
Number of tiger photos	1
Unique tigers captured	1*

*poor image quality, it was not possible to identify the individual tiger

UMARIA FOREST DIVISION

Umaria district is situated in the eastern part of Madhya Pradesh, in the Vindhyan region. It is The division have 2022.58 km^2 of forested area (FSI State Forest Report, 2019). The forest of the district comprises the Umaria territorial forest division, Bandhavgarh Tiger Reserve, and Forest Development Corporation Division. The vegetation of the Umaria territorial forest division is mainly categorized as tropical mixed dry deciduous and tropical dry teak forest (Champion and Seth, 1968). Umaria Forest Division is the sink habitat of Bandhavgarh Tiger Reserve. Umaria Forest Division acts as a corridor between Kanha and Bandhavgarh Tiger Reserve. The division provides suitable habitat and potential dispersal routes for wildlife species.

An effort of 3014 trap nights were invested, and 436 tiger photos were obtained, from which 16 tiger individuals (>1 year of age) were identified. The tiger density was estimated at 3.54 (SE 0.92) tigers per 100 km^2 (Table V.2.23). The detection-corrected tiger sex ratio in Umaria Forest Division was 6.6 females per male (Table V.2.23).

Figure V.2.23

Camera trap layout and spatial tiger density in Umaria Forest Division, 2022

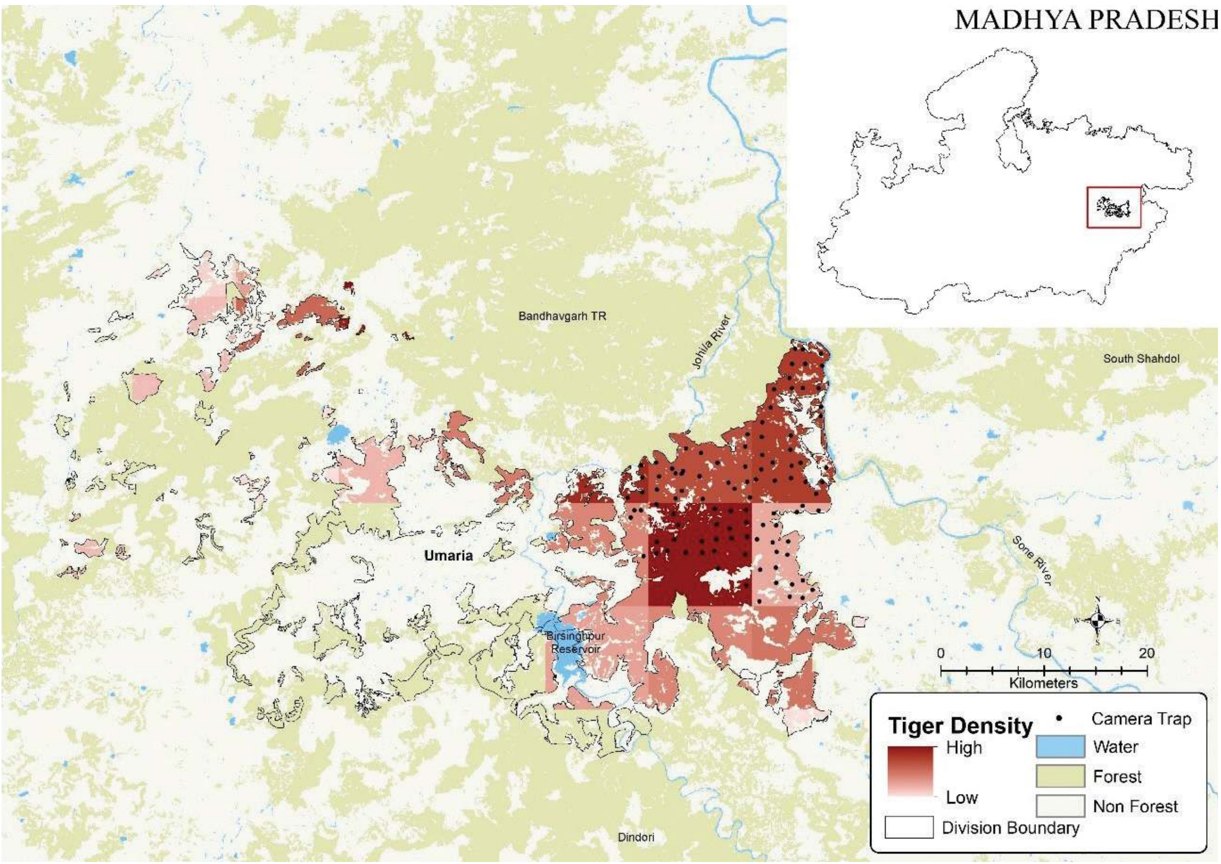

Table V.2.23

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Umaria Forest Division, 2022.

Variables	Estimate
Model space (km^2)	843
Camera points	102
Trap nights (effort)	3014
Unique tigers captured	16
Model	Pmix(sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	3.54(0.92)
σ Female (SE) (km)	1.3(0.4)
σ Male (SE) (km)	2.7(0.1)
g0 Female (SE)	0.06(0.01)
g0 Male (SE)	0.009(0.003)
Pmix Female (SE)	0.65(0.17)
Pmix Male (SE)	0.37(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Section V.2

WEST BETUL FOREST DIVISION

The West Betul Division is situated in the Satpura mountain range; it features a hilly terrain with scattered small hillocks throughout the area. The division encompasses 1996.56 km^2, with 1139.904 km^2, of forest land. These diverse forest types contribute to the region's rich biodiversity. Importantly, the area serves as a vital wildlife corridor between the Satpura and Melghat Tiger Reserves, providing a crucial habitat for various wildlife species.

However, the forest area in the West Betul division faces challenges and degradation due to multiple factors. One significant factor is the heavy reliance of local forest-dwelling communities on the forests for their livelihoods. This excessive dependence often leads to overexploitation of forest resources through activities such as excessive grazing, illegal tree felling, and recurrent forest fires. These unsustainable practices have resulted in the degradation of the forests over time. To address the degradation and enhance forest cover in the region, one potential solution is the restoration activity and addressing local needs. By fostering community engagement and awareness, and supporting afforestation initiatives, it is possible to ensure the long-term conservation of wildlife in this area.

During the camera trap survey, a comprehensive effort of 3219 trap nights was undertaken. However, no tiger was photo-captured during the sampling period, although signs of their presence were recorded.

Figure V.2.24

Camera trap layout and tiger presence in West Betul Forest Division, 2022

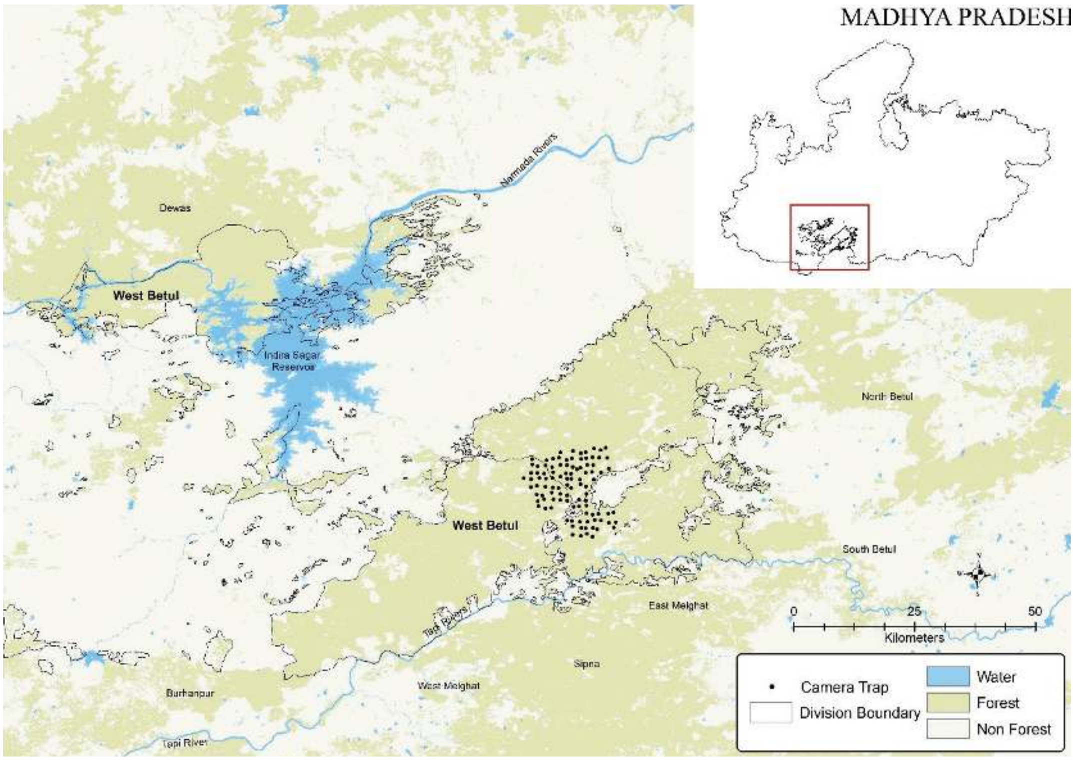

Table V.2. 24

Sampling details of camera trapping exercise in West Betul Forest Division, 2022.

Variables	Counts
Camera points	100
Trap nights (effort)	3219
Number of tiger photos	0

MAHARASHTRA

BOR TIGER RESERVE

Bor Tiger Reserve is situated in the Wardha district of eastern Maharashtra. Bor is spread over an 816.27 km^2 area, encompassing a core area of 138.12 km^2 and a buffer area of 678.15 km^2. It is fragmented into two parts by the Bor Dam reservoir. Bor Forest is primarily covered with dry savannahs and dry deciduous forests. It has the second-smallest core area after Orang (79.28 km^2). Its geographical position, being almost at the center of eastern Maharashtra's tiger landscape, makes it the most potential site for maintaining the tiger meta-population.

There are three Tiger Reserves present around Bor: Pench Tiger Reserve, Nawegaon Nagzira Tiger Reserve on the North-eastern side, and Tadoba Andhari Tiger Reserve on the South-eastern side. The corridors in between these tiger reserves are fragmented by linear infrastructure, agricultural lands, and human settlements. Locals in the area have a positive attitude toward the presence of the tiger in the area (Reddy & Yosef 2016).

An effort of 5961 trap nights was invested, and a total of 374 photos of tigers were obtained, from which 9 unique tigers (<1 year of age) were identified, and tiger density was estimated at 1.02 (SE 0.35) tigers per 100 km^2 (Table V.2.25). The detection-corrected tiger sex ratio was female-biased by 4.34 females per male (Table V.2.25).

Figure V.2.25

Camera trap layout and spatial tiger density in Bor Tiger Reserve, 2022.

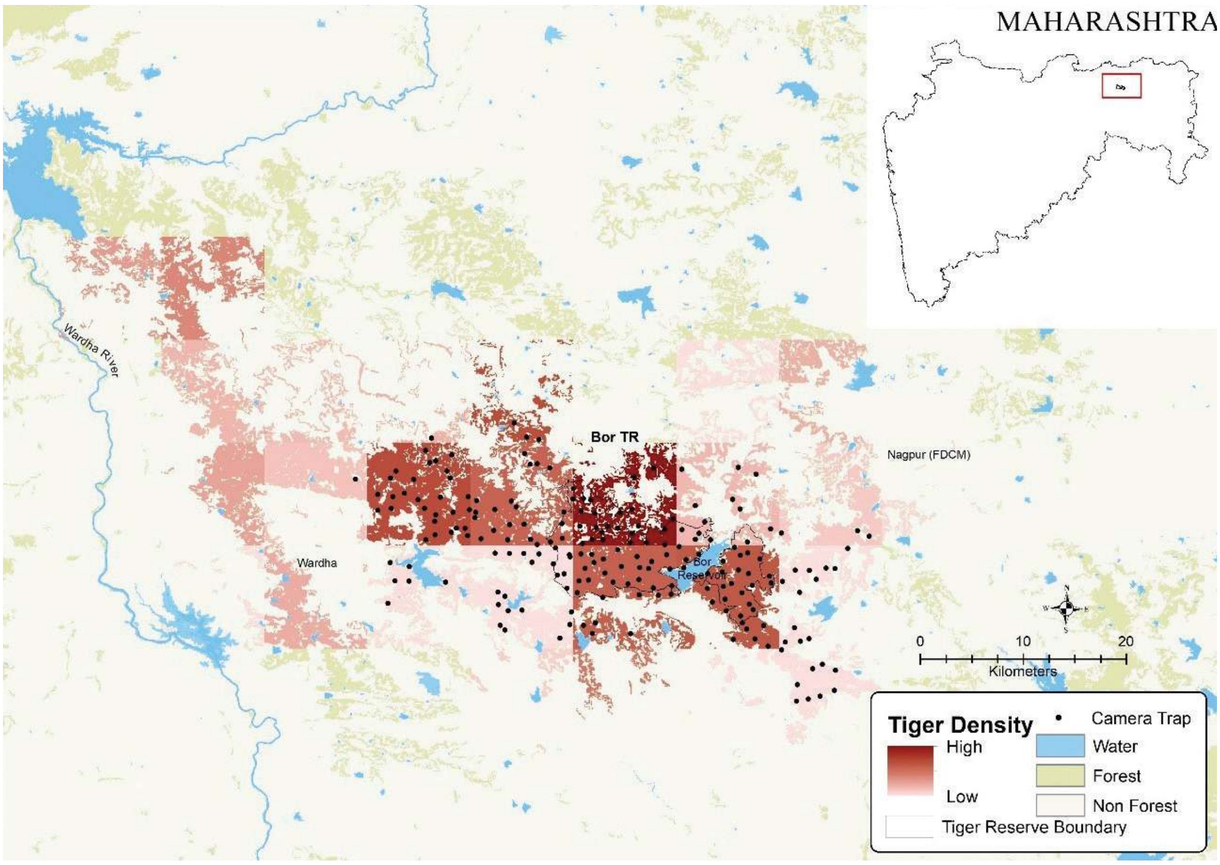

Table V.2. 25

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Bor Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	1122.5
Camera points	206
Trap nights (effort)	5961
Unique tigers captured	9
Model	Pmix(sex)g0(.)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	1.02 (0.35)
σ Female (SE) (km)	3.61 (0.24)
σ Male (SE) (km)	6.58 (0.65)
g0 Female (SE)	0.03 (0.003)
g0 Male (SE)	0.03 (0.003)
Pmix Female (SE)	0.81 (0.12)
Pmix Male (SE)	0.19 (0.12)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Situated amidst a densely populated human landscape, Bor Tiger Reserve acts as an important link between Pench (MH) and Tadoba Andhari Tiger Reserve. Although, individual tiger number has increased since the inception of this tiger reserve, it faces numerous development pressures around its boundary. However, the notification of 678 km^2 area as eco-sensitive zone around the tiger reserve, and bringing under unified control of administration is expected to ease down the pressure of development activities. To safeguard the island population and to reduce negative human tiger interaction, initiatives such as improved law enforcement activities, appropriate mitigation measures for the development activities, sensitization of local people, and early alarm system for any untoward situations should be implemented in and around this tiger reserve.

MELGHAT TIGER RESERVE

Melghat Tiger Reserve is situated in the south-western Satpura mountain ranges and spreads across Amravati and Buldana districts of Maharashtra. Melghat's name actually describes the geography of the area, i.e., a large tract of unending hills and ravines scarred by jagged cliffs and steep climbs. It is spread across a 2,768.52 km^2 area consisting of a 1,500.49 km^2 core and a 1,268.03 km^2 buffer. Melghat includes the Sipna Wildlife Division, the Gugamal Wildlife Division, and the Akot Wildlife Division. Melghat Tiger Reserve was first established as a wildlife sanctuary; later, in 1974, under Project Tiger, it was declared a Tiger Reserve. It 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). According to Champion and Seth (1968), its forest is classified as southern tropical dry deciduous (5A).

In the northeastern side, Melghat is connected to Satpura Tiger Reserve through Narmadpuram, Betul, and East Nimar forest division of Madhya Pradesh, and towards east to Pench Tiger Reserve of Maharashtra (Qureshi *et al* 2014). However, the connectivity between Pench and Melghat is weak and passes through a mixture of human land-use areas. Towards south this tiger reserve is connected to Dnyanganga, Katepurna and Karanjia Sohol wildlife sanctuaries through weak linkages.

An effort of 26751 trap nights were invested, and a total of 2974 photos of tigers were obtained, from which 57 unique tigers (>1 year of age) were identified, and tiger density was estimated at 1.92 (SE 0.26) tigers per 100 km^2 (Table V.2.26). The detection-corrected tiger sex ratio was female-biased by 1.75 females per male (Table V.2.26).

Figure V.2.26

Camera trap layout and spatial tiger density in Melghat Tiger Reserve, 2022.

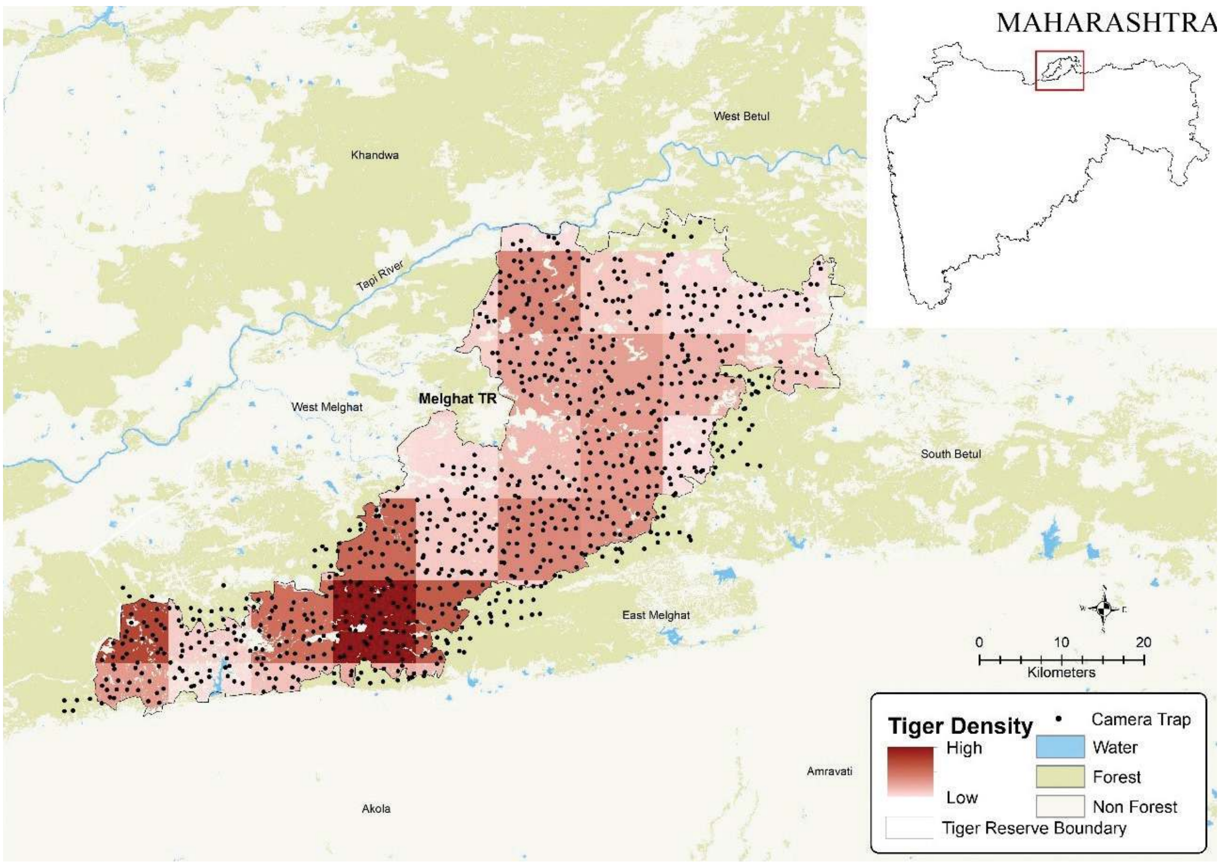

Table V.2.26

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Melghat Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	3558
Camera points	885
Trap nights (effort)	26751
Unique tigers captured	57
Model	Pmix(sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	1.92 (0.26)
σ Female (SE) (km)	2.14 (0.05)
σ Male (SE) (km)	3.85 (0.11)
g0 Female (SE)	0.04 (0.003)
g0 Male (SE)	0.03 (0.002)
Pmix Female (SE)	0.64 (0.06)
Pmix Male (SE)	0.36 (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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

As compared to previous tiger estimation cycles, tiger population in Melghat shows an increasing trend owing to the substantial amount of incentivized voluntary village relocation (Jhala *et al* 2020). Together, Satpura and Melghat act as a single population block, and the corridor connectivity between these two tiger reserves, and adjoining tiger population blocks should be maintained to retain the genetic flow of tigers in this block. However, several linear infrastructure, such as railway line between Betul and Itarsi, widening of NH46 between Betul and Obedullaganj, NH 47 between Betul and Indore, and Satpura Thermal Power Plant situated adjacent to Betul act as major barrier to the movement of tigers in this landscape (Kulkarni *et al.* 2023). Gauge conversion of a railway line connecting Akola and Khandwa, passing through the core habitat has also been proposed, however, it will severely affect integrity of the inviolate area and for an alternative route for has been requested (Indian Express 2022). Appropriate mitigation measures while developing infrastructure and legal framework to protect forested habitats outside protected areas should be implemented to ensure recovery of tiger population and associated biota in this population block.

NAWEGAON NAGZIRA TIGER RESERVE

Nawegaon Nagzira Tiger Reserve (NNTR), situated in Gondia and Bhandara Districts in the north-eastern corner of Maharashtra, It is spread across an 1894.94 km^2 area consisting of a 653.67 km^2 core and a 1241.27 km^2 buffer. The NNTR was established in 2013. It is comprised of Nawegaon National Park, Nawegaon Wildlife Sanctuary, Nagzira Wildlife Sanctuary, New Nagzira Wildlife Sanctuary, and Koka Wildlife Sanctuary. Recently, the government had approved the translocation of five tigers in the first phase, and of these, two tigresses were released in May 2023 from Bhramhapuri Forest Division.

It have a proximity to three major Tiger reserves: Tadoba Andhari, Pench, and Kanha in the Central Indian Landscape; Bor Tiger Reserve on the western side; and Indravati Tiger Reserve on the south-eastern side. The Tadoba is connected to the Nawegaon-Nagzira TRs through Gadchiroli Forest Division, Umred Paoni Karhandla Wildlife Sanctuary, and Bhramhapuri Forest Division, while Pench Tiger Reserve and Kanha Tiger Reserve are connected to the it through Balaghat Forest Divisions. The area between Nawegaon and Nagzira is the most fragmented part of the reserve, which is occupied by Human settlements. In Nawegaon-Nagzira, most conflict situations occurred along NH-6, State highways, and the Gondia-Chando extension railway that is passing through NNTR, which discriminates biotic pressure along the structures (Yadav *et al.* 2012).

An effort of 16269 trap nights was invested, and a total of 422 photos of tigers were obtained, from which 11 unique tigers (>1 year of age) were identified, and tiger density was estimated at 0.64 (SE 0.20) tigers per 100 km^2 (Table V.2.27). The detection-corrected tiger sex ratio is 1.15 females per male, with almost no bias (Table V.2.27).

Figure V.2.27

Camera trap layout and spatial density of tigers in Nawegaon Nagzira Tiger Reserve, 2022.

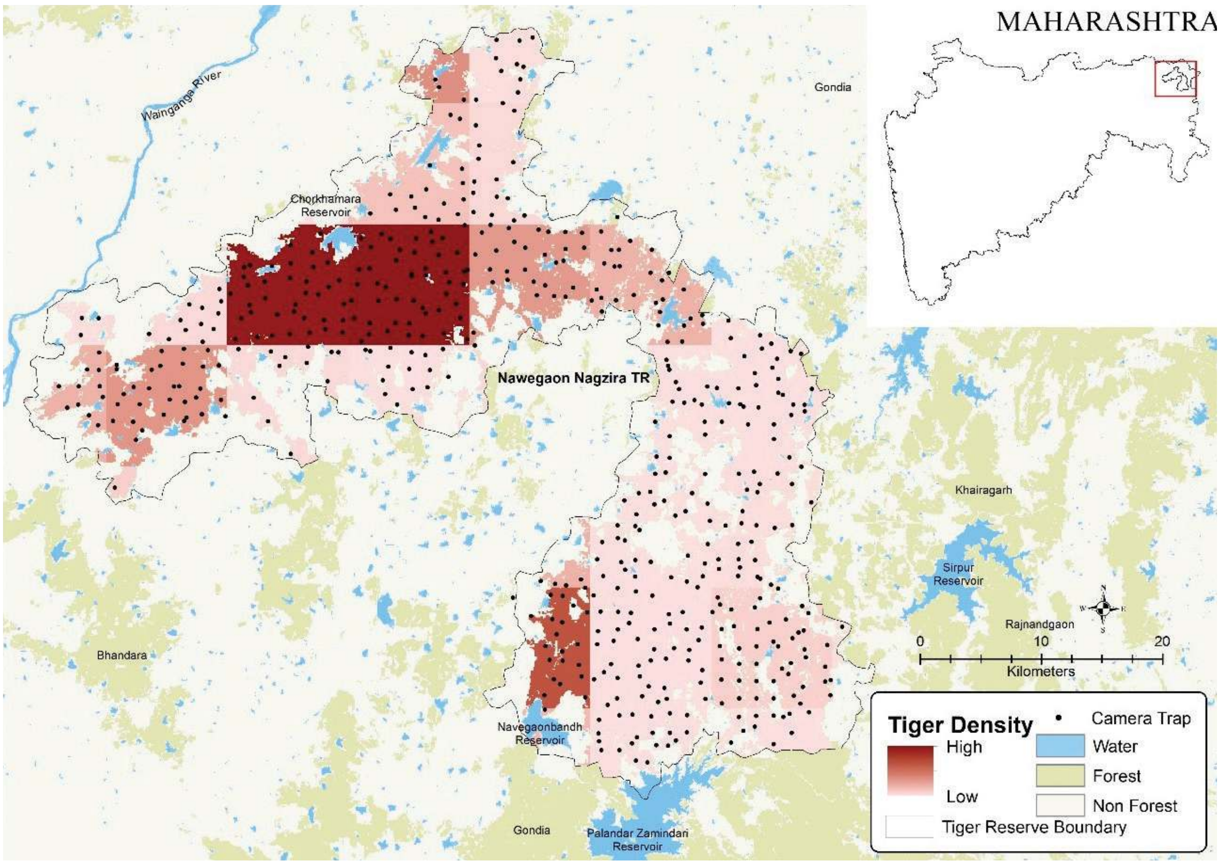

Table V.2.27

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Nawegaon Nagzira Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	2098
Camera points	526
Trap nights (effort)	16269
Unique tigers captured	11
Model	Pmix(sex)g0(.)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	0.64 (0.20)
σ Female (SE) (km)	3.31 (0.31)
σ Male (SE) (km)	7.74 (0.46)
g0 Female (SE)	0.02 (0.002)
g0 Male (SE)	0.02 (0.002)
Pmix Female (SE)	0.54 (0.16)
Pmix Male (SE)	0.46 (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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Although, there is an increase in tiger population of Nawegaon Nagzira Tiger Reserve as compared to previous cycle (Jhala *et al.* 2020), abundance of tigers in this tiger reserve is substantially low. In a recent development, The Govt. of Maharashtra approved translocation of five tigers from the Brahmapuri Forest Division, and two female tigers have already been translocated in May 2023 as first phase of the initiative. However, to reduce negative human-tiger interaction around the tiger reserve, active management initiatives such as supplementation of prey, improved law enforcement monitoring, and sensitization of adjoining forest dwelling communities are solicited.

PENCH TIGER RESERVE, MAHARASHTRA

Pench Tiger Reserve is situated in the Satpura Maikal hills of Nagpur district, Maharashtra. It spans an area of 741.22 km^2, consisting of a 257.26 km^2 core and a 483.96 km^2 buffer. The reserve includes Pench National Park and Mansingh Deo Wildlife Sanctuary. It falls under the biotic province 6E-Central Highlands and the Satpura Maikal landscape. The forest type in Pench Tiger Reserve is classified as southern tropical dry deciduous forests (5A) (Champion and Seth,1968).

Pench Tiger Reserve shares contiguous boundary with Pench MP Tiger Reserve which connects to Kanha Tiger Reserve through Kanha-Pench corridor. The corridors connecting these reserves require careful management to ensure persistence of connectivity and mitigate human-wildlife conflict for long term sustenance of one of the largest metapopulation of tigers.

During the camera trap survey of 8,470 trap nights 1,043 tiger photos were obtained. From these photos, 48 unique tigers (>1 year of age) were identified, and the tiger density was estimated at 5.11 (SE 0.74) tigers per 100 km^2 (Table V.2.28). The detection-corrected sex ratio showed a female bias, with 1.51 females per male (Table V.2.28).

Figure V.2.28

Camera trap layout and spatial tiger density in Pench Tiger Reserve, Maharashtra, 2022.

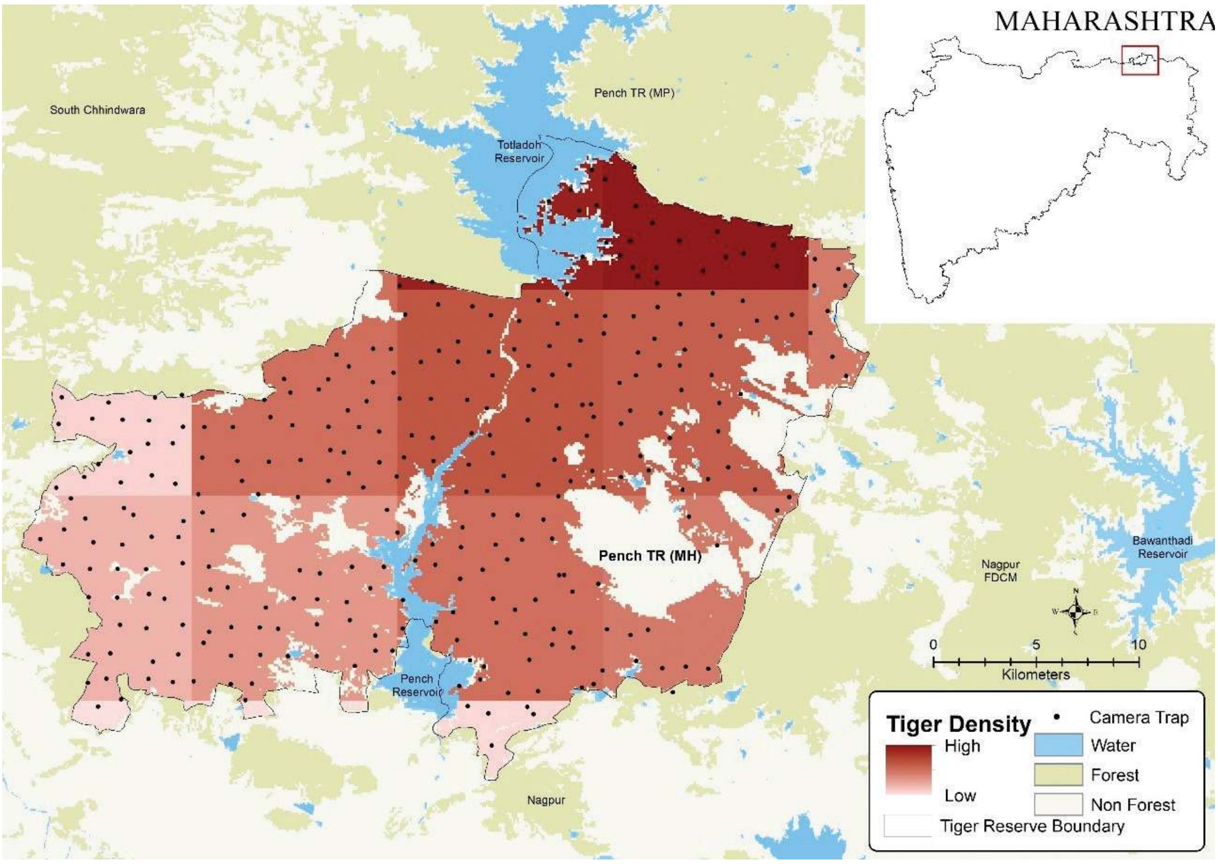

Table V.2.28

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Pench Tiger Reserve, Maharashtra, 2022.

Variables	Estimate
Model space (km^2)	1500
Camera points	302
Trap nights (effort)	8470
Unique tigers captured	48
Model	Pmix(sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	5.11 (0.74)
σ Female (SE) (km)	2.06 (0.08)
σ Male (SE) (km)	3.35 (0.14)
g0 Female (SE)	0.04 (0.003)
g0 Male (SE)	0.02 (0.002)
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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Pench Tiger Reserve (MH) and Pench Tiger Reserve (MP) acts a single population block, and are connected to a larger landscape formally known as Eastern Vidarbha Landscape and Kanha-Achanakmar landscape. There is an increase in tiger population in this tiger reserve since last cycle (Jhala *et al* 2020). However, the connectivity of Pench Tiger Reserve to adjoining tiger reserves are likely to be hampered by several infrastructure developments in the Vidarbha landacape (Times of India, 2022). This tiger population is one of the source population in this landscape, and appropriate mitigation measures backed by scientific inputs should be implemented before developing any infrastructure.

SAHYADRI TIGER RESERVE

The Sahyadri Tiger Reserve is situated in the southeastern part of Maharashtra, covering Ratnagiri, Nagpur, and Kolhapur districts. It is the northernmost tiger reserve in the Western Ghats. The reserve spans a total area of 1165.57 km^2, with a core area of 600.12 km^2 and a buffer area of 565.45 km^2. Established in 2008, it includes Sahyadri Tiger Reserve, Koyna Wildlife Sanctuary, and Chandoli National Park, extending across the Koyana River and Vasant Sagar Reservoir.

The Sahyadri Tiger Reserve comprises tropical semi-evergreen forests and tropical moist mixed deciduous forests (Champion and Seth 1968). The region's terrain is predominantly basaltic, featuring hills and dry savannahs, with mesic savannah patches During the monsoon season, the plateaus in the area bloom with ephemeral vegetation. The Sahyadri Tiger Reserve is connected to Radhanagari Wildlife Sanctuary in the south, along with Amboli Reserved Forest, forming the Sahyadri-Konkan Corridor spanning 10,489 km^2. These forest patches are further connected to Mhadei Wildlife Sanctuary in Goa, Bhimgad Wildlife Sanctuary, and Kali Tiger Reserve in Karnataka.

The camera trapping was done for 17,400 trap nights, no tiger captures were recorded in the camera traps. The Sahyadri Tiger Reserve does not have a known stable tiger population. However, signs of tiger presence have been recorded within the Sahyadri Tiger Reserve and the surrounding forests. Recently, in 2022, the presence of tigers was captured through camera traps in Radhanagari Wildlife Sanctuary.

Section V.2

Figure V.2.29

Camera trap layout in Sahyadri Tiger Reserve 2022.

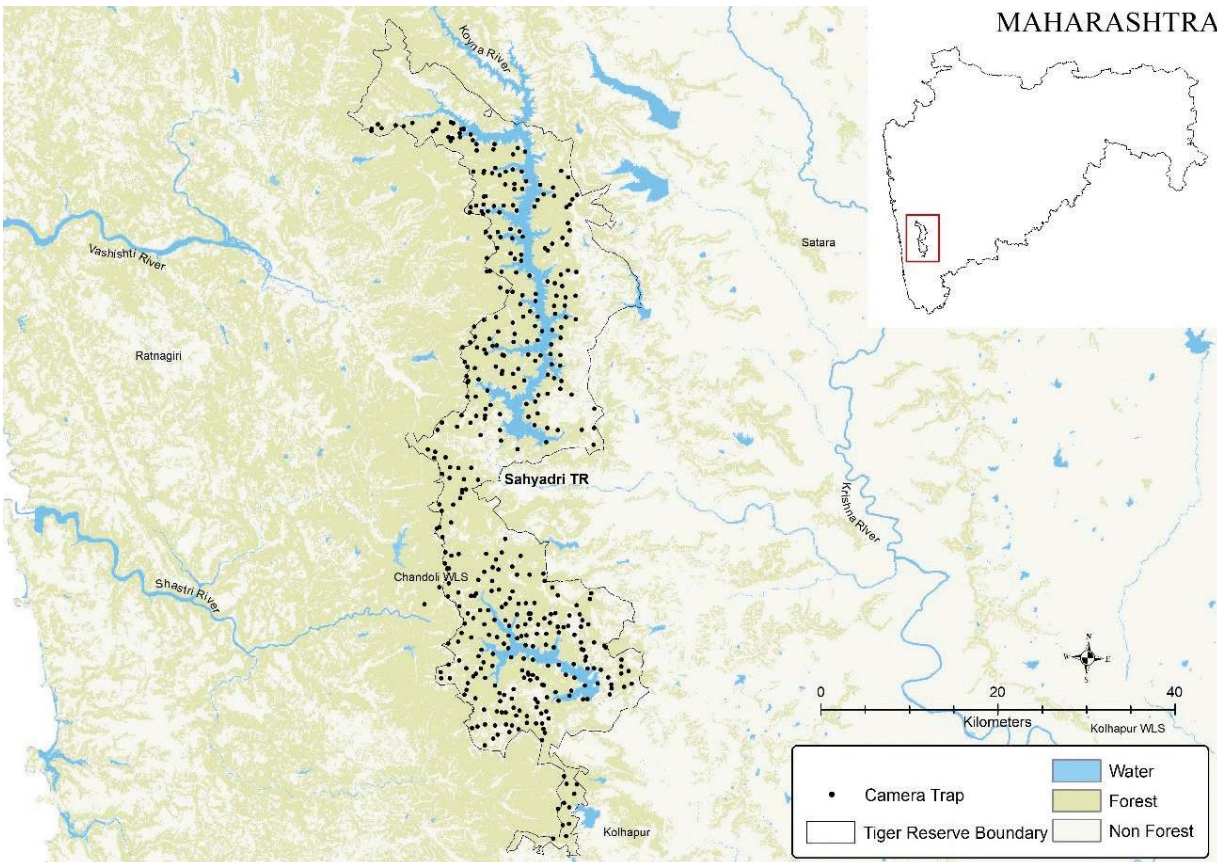

Table V.2.29

Sampling details of camera trapping exercise in Sahyadri Tiger Reserve, 2022.

Sampling Details	Counts
Camera points	435
Trap nights (effort)	17400
Number of tiger photos	0

Although, considered as a part of Central Indian landscape, geographically, Sahyadri is situated in the Northern Western Ghats. This tiger reserve is connected further southwards to Anshi- Dandeli Tiger Reserve in Western Ghats ridges through Radhanagari Wildlife Sanctuary and few forested patches, which are considered as stepping stones for tigers. However, these corridors patches vary in width, and faces high degree of anthropogenic pressure in terms of human habitation and agricultural lands. No tiger has been photo-captured during the camera trapping exercise in Sahyadri. Recovery of tigers in Northern Western Ghats is low (Jhala *et al.* 2021), and it requires active management initiatives such as improved law enforcement monitoring, incentivized voluntary village relocation, prey augmentation, followed and formation of eco-development committees for community benefits. In addition, securing corridor connectivity between Western Ghats population through Sahyadri- Konkan corridor would help restore the tiger population in this tiger reserve.

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TADOBA ANDHARI TIGER RESERVE

Tadoba Andhari Tiger Reserve (TATR), situated in the Chandrapur district of Maharashtra, It is spread across a 1727 km^2 area consisting of a 625.82 km^2 core and an 1101.77 km^2 buffer. TATR was established in 1993. It is comprised of Tadoba National Park and Andhari Wildlife Sanctuary. Tadoba is one of the oldest national parks, created in 1955, and Andhari Wildlife Sanctuary was established in 1986. Tadoba Andhari Tiger Reserve is situated in the 6-B Central Plateau Biotic Province in the 6-Deccan Peninsula Biogeographic Zone (Rodgers and Panwar 1988). The vegetation is classified as southern tropical dry deciduous teak forests (5A) (Champion and Seth 1968).

Tadoba acts as a source population in this landscape, and is surrounded by a number of forest divisions namely Chandrapur, Bhramhapuri, and Central Chanda forest divisions. These forest divisions facilitate as corridors and maintain the connectivity to other tiger population in this landscape. Tiger population of Tadoba is connected Gadchiroli forest division and Umred Paoni Karhandla Wildlife Sanctuary through Bharamhapuri forest division. Further the the population is connected to Kawal Tiger Reserve, Nawegaon Nagzira Tiger Reserve and other sink populations through some fragmented forest patches. However, the connectivity of these forest patches is fragmented due to human settlements, agricultural land, road highways, mining areas, and other developmental projects. These factors have a negative impact on tiger movement and contribute to an increase in human-wildlife conflict within the landscape (Dudhapachare 2013; Puranik 2020).

An effort of 21063 trap nights was invested, and a total of 3942 photos of tigers were obtained, from which 97 unique tigers (>1 year) were identified, and tiger density was estimated at 6.33 (SE 0.64) tigers per 100 km^2 (Table V.2.30). The detection-corrected tiger sex ratio is 1.57 females per male (Table V.2.30).

Figure V.2.30

Camera trap layout and spatial tigers density in Tadoba Andhari Tiger Reserve, 2022.

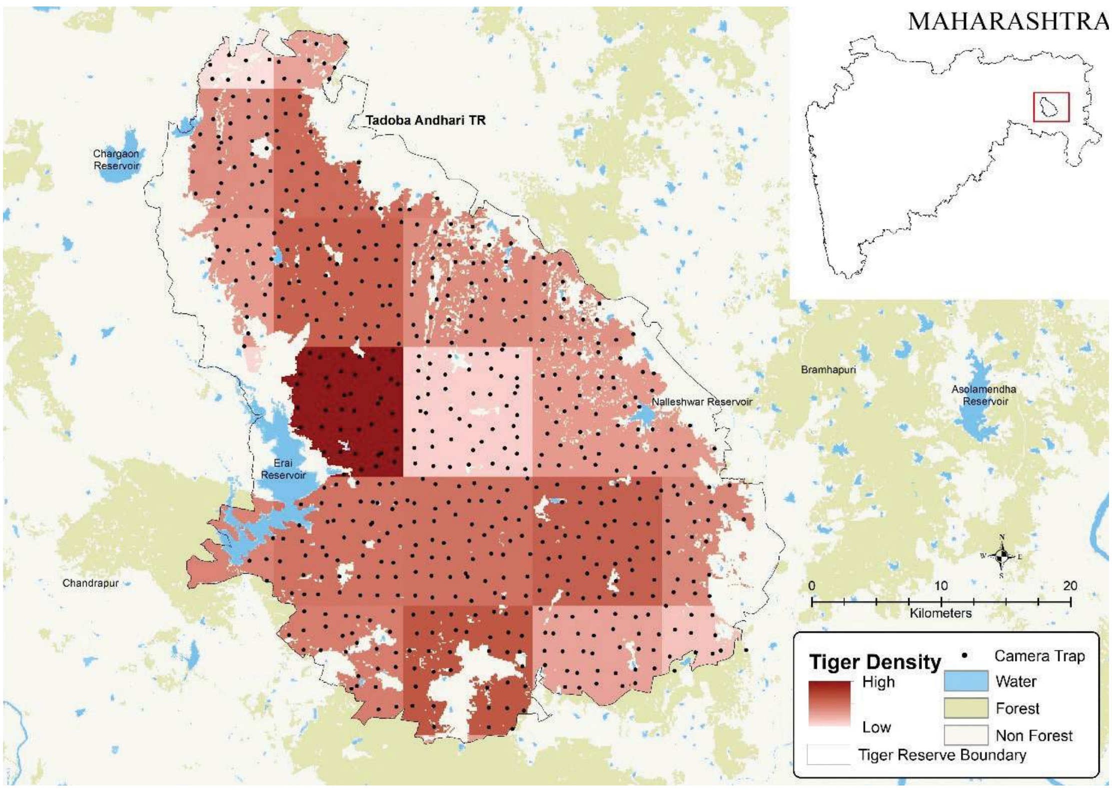

Table V.2.30

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Tadoba Andhari Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	1926
Camera points	630
Trap nights (effort)	21063
Unique tigers captured	97
Model	Pmix(sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	6.33 (0.64)
σ Female (SE) (km)	1.93 (0.04)
σ Male (SE) (km)	2.98 (0.07)
g0 Female (SE)	0.05 (0.002)
g0 Male (SE)	0.03 (0.002)
Pmix Female (SE)	0.61 (0.05)
Pmix Male (SE)	0.39 (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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Tiger density of Tadoba Andhari Tiger Rerserve is almost stable as compared to previous cycle (in 2018) (Jhala *et al*. 2020). This tiger population acts as source population in this landscape, and continue to supplement tiger population to adjoining forest divisions. However, density of major prey species are low in this tiger reserve (Habib *et al.* 2023), and tigers often predate on livestock in this landscape matrix. To minimize the negative human tiger influence in this landscape, prey supplementation in this tiger reserve is solicited.

CHANDRAPUR COMPLEX:

Chandrapur complex is comprised of three forest divisions: Bramhapuri, Chandrapur, and Central Chanda Forest. At the district level, Chandrapur district has the highest tiger population in the World. These divisions are highly affected by encroachment and mining activities, which lead to the degradation of the forest corridors. Degraded forest corridors and the availability of livestock are potential factors leading to an increase in human-wildlife conflict in the area (Dudhapachare 2013; Puranik 2020). Chandrapur is one of the most known human-wildlife conflict-prone areas in India.

A) BRAHMAPURI FOREST DIVISION

Bramhapuri Forest Division is situated in the north-eastern part of Chandrapur district, Maharashtra. The total area of the Bramhapuri Forest Division is 2840 km^2. The territorial area is further divided into reserved forest, protected forest, and unclassified forest. The major forest type here is southern tropical dry deciduous forests (5A) (Champion and Seth 1968).

It has seen a surge in the tiger population by 1.5 times from 2018 countrywide estimates. It serves as an extra buffer for Tadoba Andhari Tiger Reserve on the North-Eastern side, potentially harboring the spillover tiger population from Tadoba Andhari Tiger Reserve. It also serves as a corridor between Tadoba Andhari Tiger Reserve, Gadchiroli Division, Umred Paoni Karhandla Wildlife Sanctuary, and Nawegaon Nagzira Tiger Reserve. Bramhapuri is also connected to Chandrapur Forest Division on the south-western side. This is the most affected division in Chandrapur by encroachment and mining and has the highest number of conflict incidences of all three (Puranik 2020).

An effort of 19139 trap nights was invested, and a total of 1486 photos of tigers were obtained, from which 66 unique tigers (>1 year) were identified, and tiger density was estimated at 4.02 (SE 0.50) tigers per 100 km^2 (Table V.2.31). The detection corrected tiger sex ratio is female biased by 2.03 females per male (Table V.2.31).

B) CHANDRAPUR FOREST DIVISION

Chandrapur Forest Division is situated at the centre of Chandrapur district, Maharashtra. The total area of the Chandrapur Forest Division is 3158 km^2. The territorial area is further divided into reserved forest, protected forest, and unclassified forest. According to Champion and Seth (1968), the forest type of Chandrapur is southern-tropical dry mixed deciduous forests (5A).

It works as an extra buffer for Tadoba Andhari Tiger Reserve on the west-southern side, potentially harbouring the spill over tiger population from Tadoba Andhari Tiger Reserve. It also connects Tadoba Andhari Tiger Reserve to the Central Chanda Forest Division. The eastern part of Chandrapur also serves as a corridor between Tadoba Andhari Tiger Reserve and Gadchiroli Division.

An effort of 8422 trap nights was invested, and a total of 1037 photos of tigers were obtained, from which 52 unique tigers (>1 year of age) were identified, and tiger density was estimated at 3.87 (SE 0.55) tigers per 100 km^2 (Table V.2.31). The detection-corrected tiger sex ratio is female-biased by 3.12 females per male (Table V.2.31).

C) CENTRAL CHANDA FOREST DIVISION

The Central Chanda Forest Division is situated in the southern part of Chandrapur district, Maharashtra. The total area of the Central Chanda Forest Division is 3446 km^2. The territorial area is further divided into reserved forest, protected forest, and unclassified forest. According to Champion and Seth (1968), the forest type is southern tropical dry deciduous forests (5A). It is connected to Chandrapur Forest Division on the northern boundary, Pandharkawada on the western boundary, and Kagaznagar Forest Division (Telangana) on the southern boundary. It is a potential corridor connecting the forest patch of Chandrapur District to forest patches in Yawatmal District and Kawal Tiger Reserve in Telangana.

An effort of 12094 trap nights was invested, and a total of 996 photos of tigers were obtained, from which 36 unique tigers (>1 year) were identified, and tiger density was estimated at 2.87 (SE 0.48) tigers per 100 km^2 (Table V.2.31). The detection-corrected tiger sex ratio is female-biased by 1.47 females per male (Table V.2.31).

Figure V.2.31

Camera trap layout and spatial tiger density in Bramhapuri, Chandrapur and Central Chanda Forest Division, 2022.

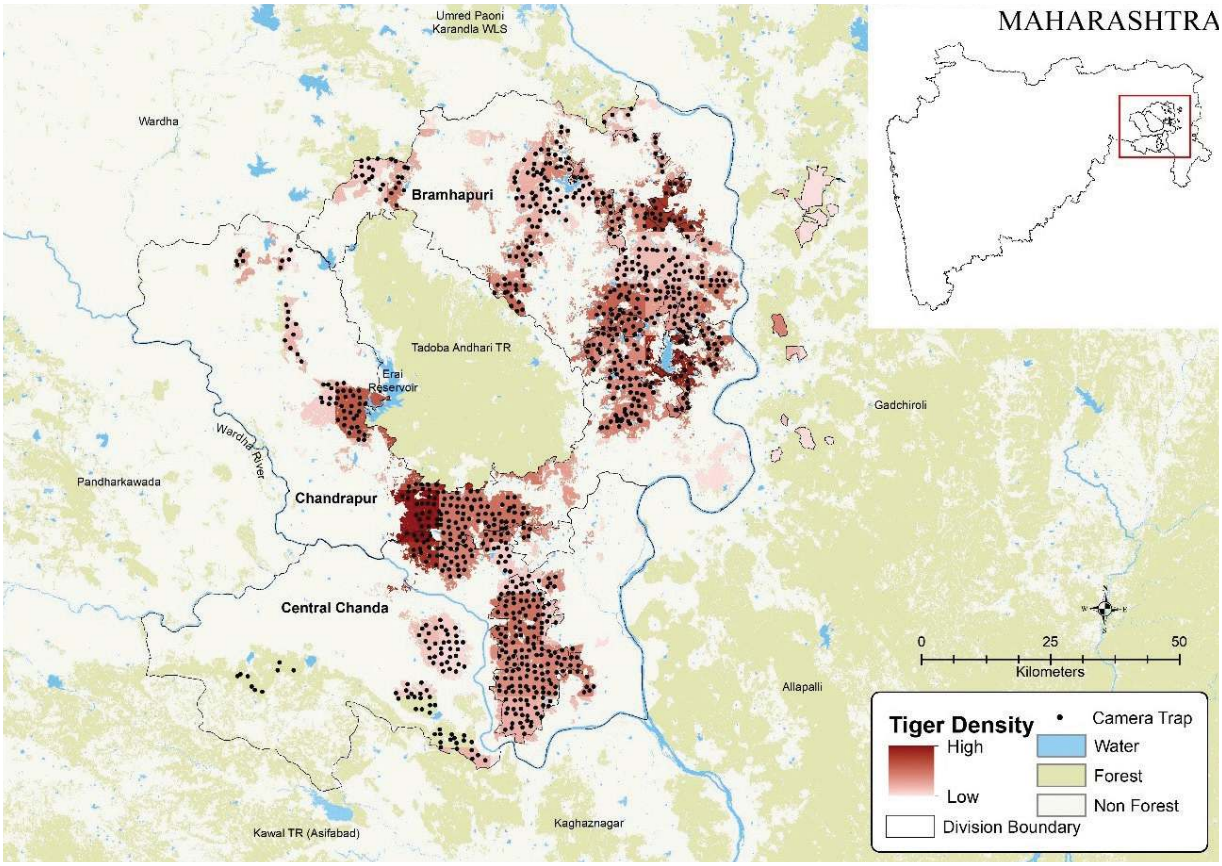

Table V.2.31

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Bramhapuri, Chandrapur and Central Chanda Forest Division, 2022.

Variables	Estimate		
	Bramhapuri FD	Chandrapur FD	Central Chanda FD
Model space (km^2)	2180	2517	1617
Camera points	417	223	308
Trap nights (effort)	19139	8422	12094
Unique tigers captured	66	52	36
Model	Pmix(sex)g0(.) σ(sex)	Pmix(sex)g0(.) σ(sex)	Pmix(sex)g0(.) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	4.02 (0.50)	3.87 (0.55)	2.87 (0.48)
σ Female (SE) (km)	2.32 (0.07)	2.21 (0.10)	3.60 (0.17)
σ Male (SE) (km)	4.43 (0.12)	6.54 (0.34)	2.84 (0.11)
g0 Female (SE)	0.03 (0.001)	0.04 (0.003)	0.02 (0.002)
g0 Male (SE)	0.03 (0.001)	0.04 (0.003)	0.05 (0.004)
Pmix Female (SE)	0.67 (0.06)	0.76 (0.05)	0.60 (0.09)
Pmix Male (SE)	0.33 (0.06)	0.24 (0.05)	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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

There is steady increase in individual tiger number in this landscape since 2018 (Jhala *et al.* 2020). However, as this complex shares common tigers between Tadoba Andhari landscape matrix. Central Chanda forest division acts as important corridors from Tadoba to the tiger habitats of Telengana and Chhatishgarh state. However, this landscape matrix is interspersed with human habitation and agricultural fields, which often lead to human tiger conflict. To reduce the intensity of conflicts in this landscape, early warning system for the people, and increased awareness between communities are needed.

DNYANGANGA WILDLIFE SANCTUARY

Dnyanganga Wildlife Sanctuary is part of Akola Wildlife Division in Buldhana districts in Northern Maharashtra. It is spread across 204 km^2. It derives its name from the river Dnyanganga that is a tributary of River Tapi. According to Champion and Seth (1968), the forest type of Dnyanganga Wildlife Sanctuary is a Southern tropical dry deciduous and dry teak forest. Dnyanganga has Melghat Tiger Reserve on its north-eastern side.

Melghat Tiger Reserve lies on the north-eastern side of the Sanctuary. In 2019, 1 sub-adult tiger T1-C1 travelled to Dnyanganga Wildlife Sanctuary from Tipeshwar Wildlife Sanctuary (Hussain *et al.* 2022). It stayed there for more than a year. Since Feb 2021, that tiger hasn't been observed in the area. It was the 1st and only record of a tiger in the area. The movement to tiger provides insight for the protection of corridor across the landscape. Sanctuary can act as a sink habitat for the dispersing tigers of Melghat Tiger Reserve.

An effort of 2136 trap-nights were invested but there were no captures of Tiger had been recorded in the camera trap during the sampling period.

Figure V.2.32

Camera trap layout in Dnyanganga Wildlife Sanctuary, 2022.

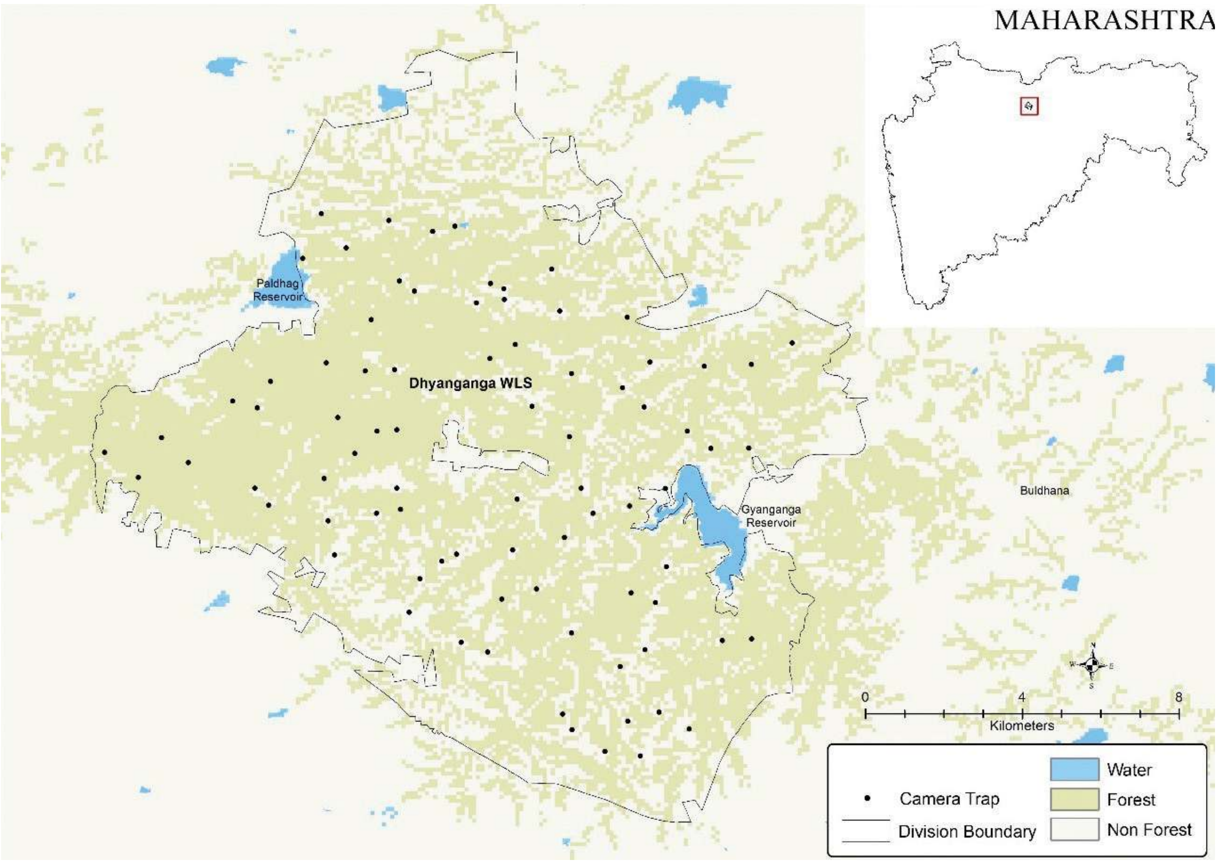

Table V.2.32

Sampling details of camera trapping exercise in Dnyanganga Wildlife Sanctuary, 2022.

Sampling Details	Counts
Camera points	82
Trap nights (effort)	2136
Number of tiger photos	0

No tiger was photo-captured during the camera trap exercise in this wildlife sanctuary. However, a study by Hussain *et al.* 2022 mentioned dispersal of a male sub-adult tigers from Tipeshwar Wildlife Sanctuary to Dnyanganga Wildlife Sanctuary in 2021. Transient tigers also use this sanctuary during their dispersal. During dispersal, these tigers venture through many human land use areas, and often engage in to human wildlife conflict. These wildlife sanctuaries are situated like islands in this human dominated landscape, and appropriate management initiatives need to be implemented to safeguard the connectivity between the metapopulation.

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GADCHIROLI - CHAPRALA COMPLEX

The Gadchiroli-Chaprala Complex is situated in the eastern part of Maharashtra. Gadchiroli-Chaprala Complex comprises Wadsa Forest Division, Gadchiroli Forest Division, Allapalli Forest Division, and Chaprala Wildlife Sanctuary. The Gadchiroli-Chaprala Complex covers an 8058 km^2 area. According to Champion and Seth (1968), the Gadchiroli forest division is covered by the sub-groups Southern tropical dry deciduous forests (5A) and South Indian moist deciduous forests (3B).

The Gadchiroli-Chaprala Complex is an extension of the Bhramhapuri and Central Chanda forest divisions separated by the Wainganga River. It serves as a buffer for the growing tiger population in Bhramhapuri. It is also connected to Nawegaon Nagzira Tiger Reserve on southern side. Indravati Tiger Reserve, Chattisgarh, is present on the eastern side of the Gadchiroli district. Since 2021, there has been a spike in tiger attacks, and proper management efforts and awareness among the locals about how to tackle the situation are crucial (Katkurwar 2023; Pinjarkar 2021; Lajurkar 2022).

An effort of 19249 trap nights was invested, and a total of 390 photos of tigers were obtained, from which 16 unique tigers (>1 year of age) were identified, and tiger density was estimated at 0.72 (SE 0.18) tigers per 100 km^2 (Table V.2.33). The detection-corrected tiger sex ratio is female biased by 2.91 females per male (Table V.2.33).

Figure V.2.33

Camera trap layout and spatial tiger density in Gadchiroli – Chaprala Complex, 2022.

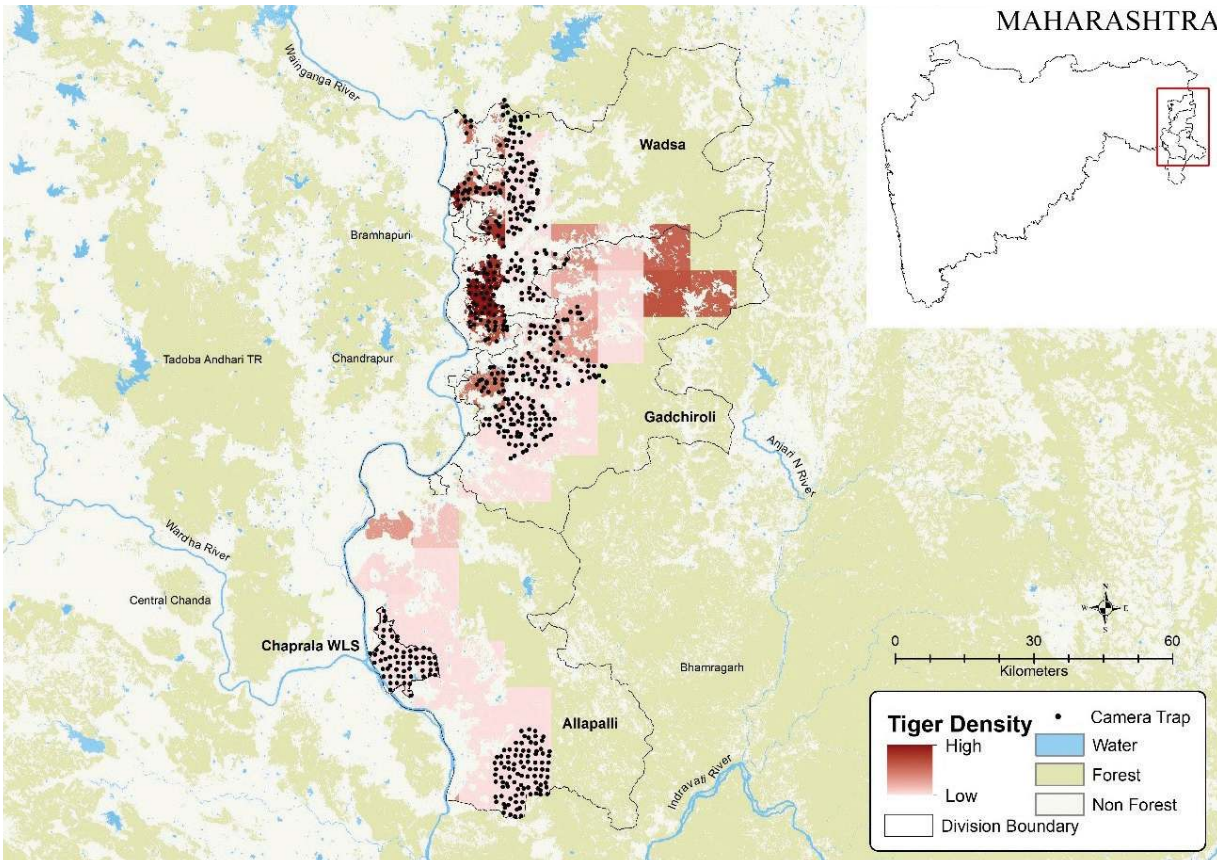


Table V.2.33

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Gadchiroli – Chaprala Complex, 2022.

Variables	Estimate
Model space (km^2)	3932
Camera points	541
Trap nights (effort)	19249
Unique tigers captured	16
Model	Pmix(sex)g0(.)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	0.72 (0.18)
σ Female (SE) (km)	2.29 (0.15)
σ Male (SE) (km)	9.02 (0.44)
g0 Female (SE)	0.03 (0.004)
g0 Male (SE)	0.03 (0.004)
Pmix Female (SE)	0.74 (0.10)
Pmix Male (SE)	0.26 (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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Camera trapping exercise was conducted for the first time in this landscape to estimate tigers. In addition, tiger has been reported in this complex after almost a decade (Media reports, Scroll 2021). Tigers living outside the protected areas need larger space due to mixed human land-use pattern, and in absence of natural prey, this will lead to conflicts. Appropriate mitigation measures to reduce the conflicts in this landscape matrix need to be devised.

KATEPURNA & KARANJA SOHOL COMPLEX

Katepurna & Karanja Sohol Complex includes 2 sites Katepurna Wildlife Sanctuary and Karanja Sohol Wildlife Sanctuary situated in north-eastern Maharashtra.

A) Katepurna Wildlife Sanctuary

Katepurna Wildlife Sanctuary is situated in Akola District of Maharashtra. It is spread across 73.69 km^2 around the catchment area of Katepurna Reservoir. It derives its name from the river Katepurna, which flows south to northward from the centre of the Sanctuary. According to Champion and Seth (1968), its forest is classified as a tropical dry deciduous forest.

An effort of 371 trap-nights were invested but there were no captures of Tiger had been recorded in the camera trap during the sampling period.

B) Karanja Sohol Wildlife Sanctuary

Karanja Sohol Wildlife Sanctuary is part of Akola Forest Division in Washim district Maharashtra. It is spread across 18.32 km^2 around the catchment area of the Aadan reservoir. It is created in 2000 for the conservation of Black Buck. According to Champion and Seth (1968), Karanja Sohol Wildlife Sanctuary forest is classified as a tropical dry deciduous forest. An effort of 207 trap-nights were invested but there were no captures of Tiger had been recorded in the camera trap during the sampling period. In November 2021, one tiger has been captured in a camera trap in Karanja Sohol (Pinjarkar 2021). Later in December in Khamgaon near Karanja Sohol, a tiger image was captured on a CCTV camera (Pinjarkar 2021).

Karanja Sohol & Katepurna Wildlife Sanctuaries have Melghat tiger reserve towards the north-western side, towards the eastern side it has Bor tiger reserve, Pandharkawada Forest Division, Painganga Wildlife Sanctuary, further towards east whole Chandrapur district with source tiger population. This area is a potential stepping corridor for tiger movement across the surrounding tiger-bearing area, as they are at fare distance from each other.

Figure V.2.34

Camera trap layout in Katepurna & Karanja Sohol Complex, 2022.

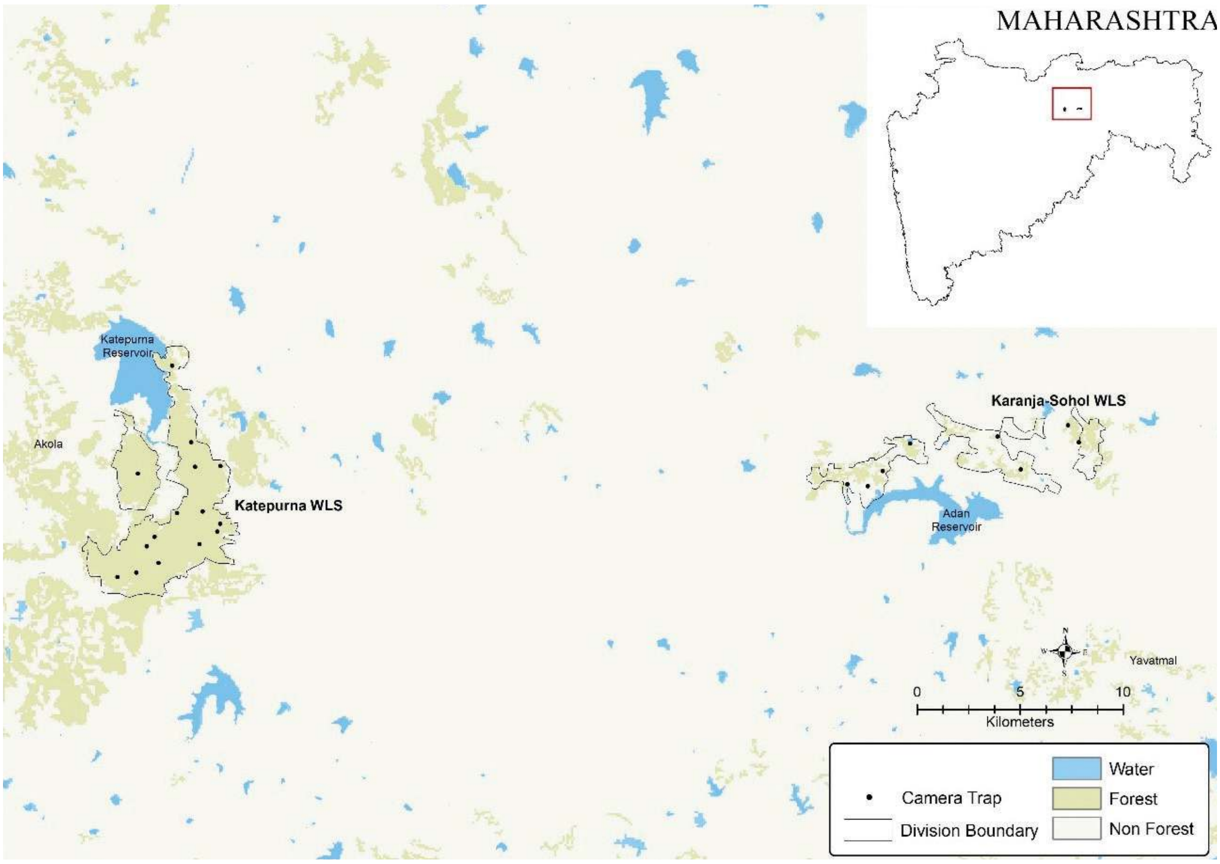


Table V.2.34

Sampling details of camera trapping exercise in Katepurna Wildlife Sanctuary and Karanja Sohol Wildlife Sanctuary, 2022.

Sampling Details	Katepurna Wildlife Sanctuary	Karanja Sohol Wildlife Sanctuary
Camera points	15	8
Trap nights (effort)	371	207
Number of tiger photos	0	0

No tiger has been photo-captured in this complex during the sampling session. However, tigers from Melghat could colonize in these wildlife sanctuaries given the proximity of this complex to forests of Akola division. In addition, this complex have excellent faunal assemblage, and should be conserved to retain habitat connectivity in the landscape.

PAINGANGA WILDLIFE SANCTUARY

Painganga Wildlife Sanctuary is situated in the Yawatmal district of Maharashtra. Painganga Wildlife Sanctuary is spread across 406 km^2, Situated on the banks of river Painganga. According to Champion and Seth 1968, its forest type is classified as a Southern tropical dry deciduous.

The geographical location of the Painganga Wildlife Sanctuary makes it one of the important sink habitats for tiger meta-population. It serves as a corridor between Tipeshwar on the north-eastern side, Kawal on the south-eastern side, and Karanja Sohol, Katepurna, as well as Dnyanganga on the north-western side. There is a record of a tiger moving across these forest divisions, fragmented by roads, highways, human settlements, and agricultural land (Hussain *et al*, 2022). The connecting forest patches across these divisions are majorly savanna forests which are legally not considered as forests. Making them prone to be utilized for developmental activities including mining projects. It is crucial to conserve and manage this area considering its ecological as well as developmental value to maintain viable habitat for tiger and other wild animal movement.

An effort of 1174 trap-nights were invested and a total 46 photos of tigers were obtained from which 2 unique tigers were identified. The detections of the tigers were insufficient for SECR model to compute. Sampling details is give in (Table V.2.35).

Figure V.2.35

Camera trap layout and tiger presence in Painganga Wildlife Sanctuary, 2022.

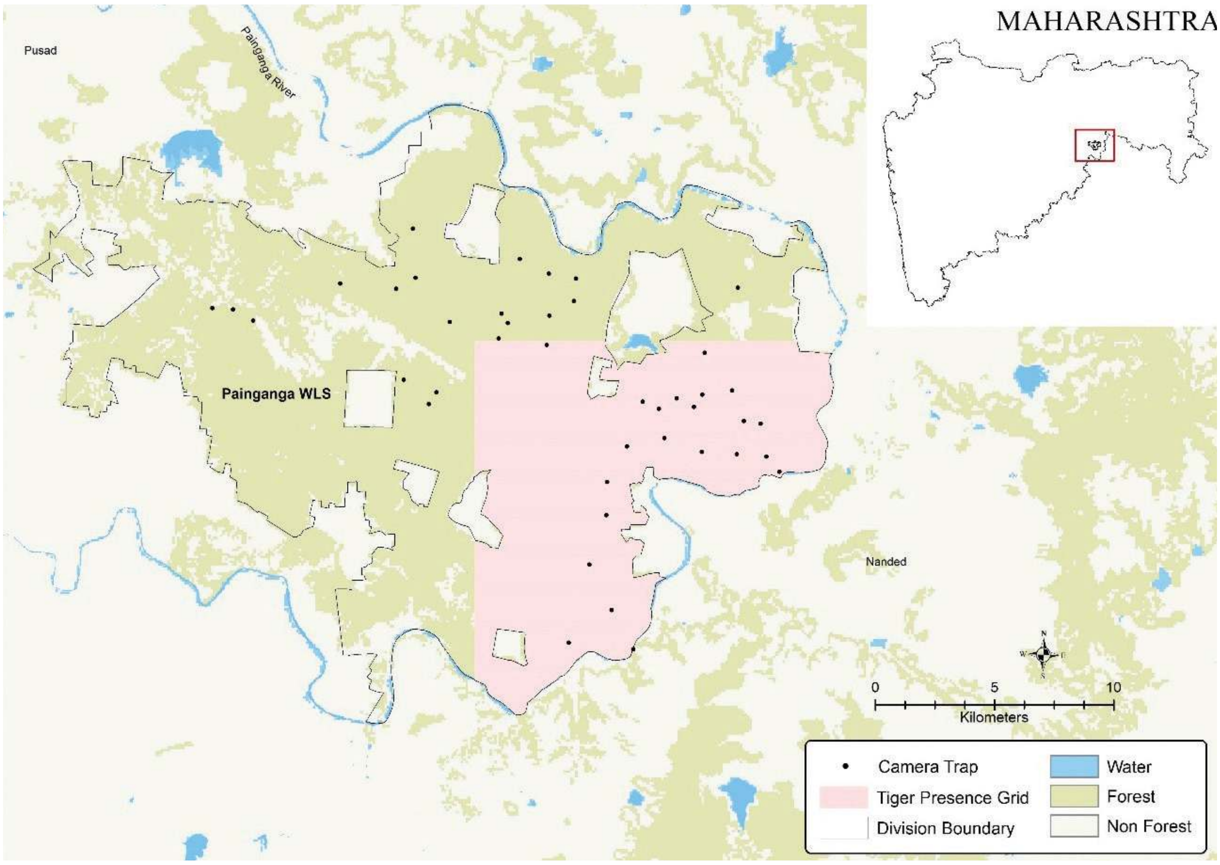


Table V.2.35

Sampling details of camera trapping exercise in Painganga Wildlife Sanctuary, 2022.

Variables	Counts
Camera points	42
Trap nights (effort)	1174
Number of tiger photos	46
Unique tigers captured	2

Tiger density estimate for Painganga Wildlife Sanctuary could not be modelled due to small sample size, and only one tiger was photo-captured in this wildlife sanctuary during last cycle of tiger estimation. However, mostly transient tigers from the Eastern Vidarbha Landscape use this wildlife sanctuary as stepping-stone. Supplementation of prey, improved law enforcement monitoring, capacity building of frontline staff of the protected area could help maintain the ecological integrity of this wildlife sanctuary.

PANDHARKAWDA-TIPESHWAR COMPLEX

Pandharkawda-Tipeshwar Complex includes two sites Pandharkawada Forest Division and Tipeshwar Wildlife Sanctuary situated in Yavatmal District of Maharashtra.

A) PANDHARKAWDA FOREST DIVISION:

Pandharkawada Forest Division is situated in Yavatmal District of Maharashtra. It is spread across a 4487 km^2 area, which is divided into Reserve forest, protected forest, and unclassified forest. According to Champion and Seth (1968), Pandharkawada forest is classified as Dry Teak Bearing forests (5A/C).

Only ~17% area of Pandharkawada Forest Division is under forested land, the rest of the area is covered with human settlements, agricultural land, mines, etc. Pandharkawada FD is connected to Bor and Tadoba andhari Tiger Reserve through adjoining forest divisions. Tipeshwar Wildlife Sanctuary is situated in the southern part of Pandharkawada Forest Division. Being Human dominated and one of the potential tiger corridor the human-wildlife conflict cases in the area are also high.

An effort of 3279 trap-nights were invested and a total of 865 detections of tigers were obtained from which 13 unique tigers were identified and tiger density was estimated at 1.73 (SE 0.50) tigers per 100 km^2 (Table V.2.36). The detection corrected tiger sex ratio is female biased by 1.58 females per male (Table V.2.36).

B) TIPESHWAR WILDLIFE SANCTUARY:

Tipeshwar Wildlife Sanctuary is situated in the Yawatmal district of Maharashtra. Tipeshwar Wildlife Sanctuary is spread across 148.63 km^2. It is a part of Pandharkawda Forest Division. According to Champion and Seth (1968), the forests of Tipeshwar wildlife sanctuary are classified as Dry Teak Bearing forests (5A/C).

In 2019, 1 sub-adult tiger T1-C1 travelled from Tipeshwar Wildlife Sanctuary to Dnyanganga Wildlife Sanctuary on the western side traveling a maximum line distance of 315 km in a human-dominated landscape via Painganga Wildlife Sanctuary (Hussain *et al*. 2022).

An effort of 2252 trap-nights were invested and a total 820 photos of tigers were obtained from which 11 unique tigers (>1 year of age) were identified and tiger density was estimated at 7.05 (SE 1.92) tigers per 100 km^2 (Table V.2.36). The detection corrected tiger sex ratio is female biased by 1.07 females per male (Table V.2.36).

Figure V.2.36

Camera trap layout and spatial tiger density in Pandharkawda-Tipeshwar Complex, 2022.

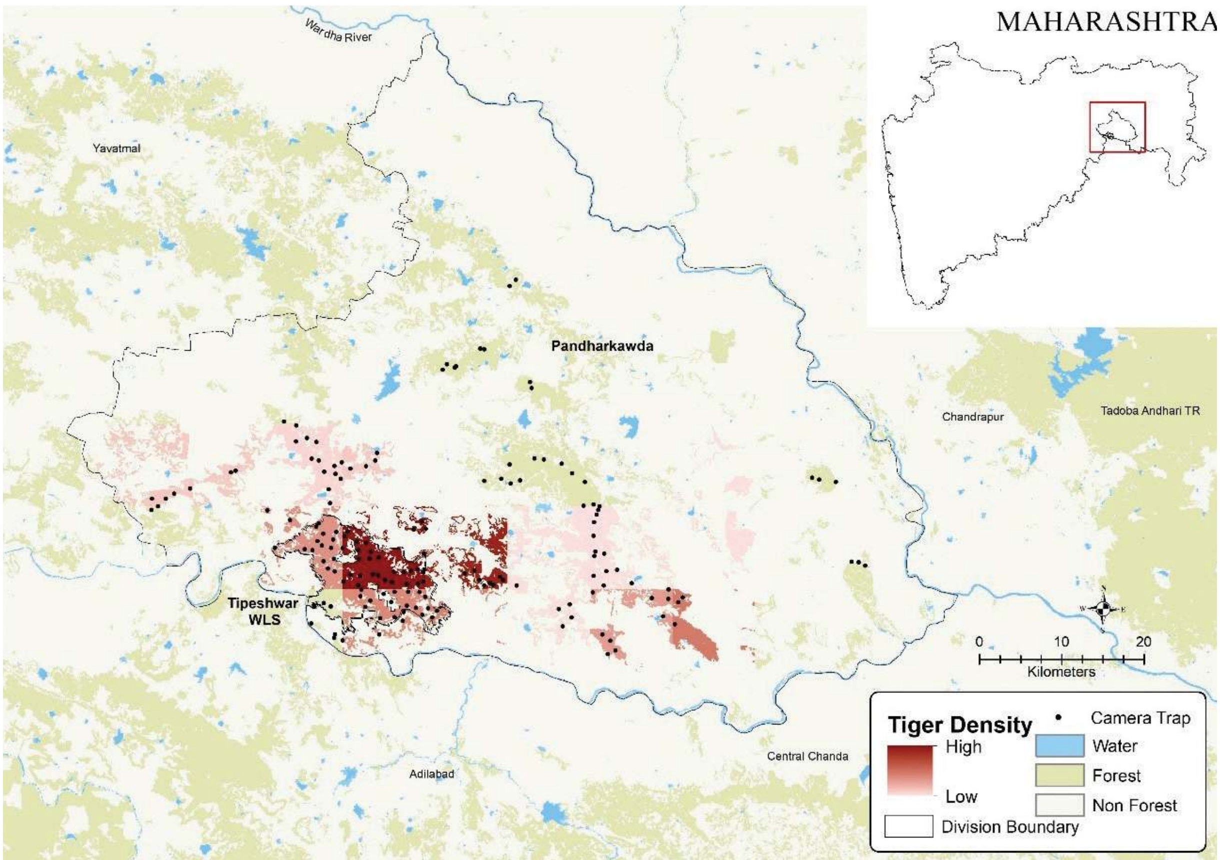


Table V.2.36

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Pandharkawda Forest Division and Tipeshwar Wildlife Sanctuary, 2022.

Variables	Estimate	
	Padharkawda Forest Division	**Tipeshwar Widlife Sacntuary**
Model space (km^2)	900	255
Camera points	106	62
Trap nights (effort)	3279	2252
Unique tigers captured	13	11
Model	Pmix(sex)g0(.)σ(sex)	Pmix(sex)g0(.)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	1.73 (0.50)	7.05 (1.92)
σ Female (SE) (km)	1.79 (0.14)	1.73 (0.10)
σ Male (SE) (km)	6.05 (0.34)	2.41 (0.19)
g0 Female (SE)	0.21 (0.003)	0.10 (0.012)
g0 Male (SE)	0.05 (0.006)	0.04 (0.007)
Pmix Female (SE)	0.61 (0.13)	0.52 (0.15)
Pmix Male (SE)	0.39 (0.13)	0.48 (0.15)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Tipeshwar Wildlife Sanctuary is a part of Pandharkawda forest division, and is connected with other protected areas of Eastern Vidarbha Landscape matrix. The tiger population of this complex is part of Tadoba metapopulation. Communities around the forest patches of this landscape are dependent on forest resources for livestock grazing, forest product collection etc. that leads frequent conflict in this landscape matrix. In 2017, a tigress in this block was held accountable for claiming several human lives (Media reports), and later was gunned down by a professional hired by the Govt. of Maharashtra. To minimize the human-tiger conflict, and to avoid any untoward incident, prey supplementation in Tipeshwar Wildlife Sanctuary, an early alarm system for the people living around this landscape block should be implemented.

UMRED PAONI KARHANDLA WILDLIFE SANCTUARY

Umred Paoni Karhandla Wildlife Sanctuary (UPK WLS) is situated in Bhandara and Nagpur districts in eastern Maharashtra. On the north-eastern boundary, it's connected to the Wainganga River. It is spread across 189 km^2. According to Champion and Seth 1968, its forest type is classified as a Southern tropical dry deciduous.

Umred Paoni Karhandla Wildlife Sanctuary is connected to the Tadoba-Andhari Tiger Reserve through forests along the River Wainganga. In the southwest, sanctuary is connected with Nawegaon Nagzira Tiger Reserve. Furthermore, Pench Tiger Reserve and Bor Tiger Reserve are two nearby tiger reserves that are connected to the UPK WLS. Sanctuary serves as a corridor for the movement of tigers across the landscape. 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. In order to conserve these corridors management with the proper action plan is very crucial.

An effort of 2631 trap-nights were invested and a total 364 photos of tigers were obtained from which 5 unique tigers (>1 year of age) were identified and tiger density was estimated at 1.72 (SE 0.82) tigers per 100 km^2 (Table V.2.37). The detection corrected tiger sex ratio is female biased by 1.50 females per male (Table V.2.37).

Figure V.2.37

Camera trap layout and spatial tiger density in Umred Paoni Karhandla Wildlife Sanctuary, 2022

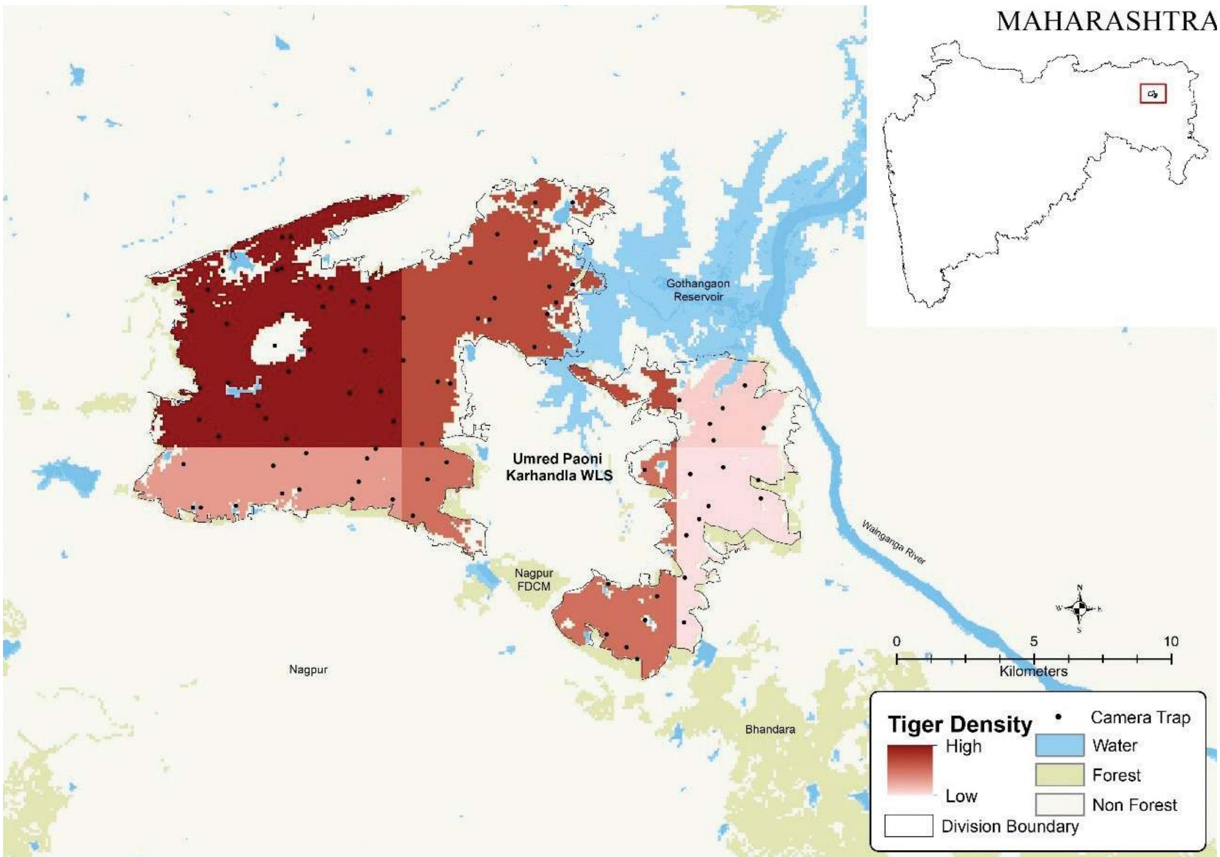


Table V.2.37

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Umred Paoni Karhandla Wildlife Sanctuary, 2022.

Variables	Estimate
Model space (km^2)	445
Camera points	85
Trap nights (effort)	2631
Unique tigers captured	5
Model	Pmix(sex)g0(.)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	1.72 (0.82)
σ Female (SE) (km)	5.03 (0.37)
σ Male (SE) (km)	5.03 (0.37)
g0 Female (SE)	0.04 (0.005)
g0 Male (SE)	0.04 (0.005)
Pmix Female (SE)	0.60 (0.22)
Pmix Male (SE)	0.40 (0.22)

SE: Standard error
D̂ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

The tiger density in the sanctuary has decreased since National Tiger Estimation Cycle 2018. There is need to focus on increasing the protection and conservation of corridors around UPK WLS.

ODISHA

SATKOSIA TIGER RESERVE

Satkosia Tiger Reserve is situated at the bank of the Mahanadi River. It is expanded in the districts of Anugul, Nayagarh, Dhenkanal, Cuttack, and Boudh in Odisha. The tiger reserve consists of two sanctuaries: Satkosia Gorge Wildlife Sanctuary and Baisipalli Wildlife Sanctuary. The combined area of these two sanctuaries is 963.87 km^2, and they have been officially designated as the Satkosia Tiger Reserve. The reserve consists of a core area spanning 523.61 km^2 and a buffer area covering 440.26 km^2. Satkosia Tiger Reserve is known for its unique landscape of hills along the gorge. Satkosia is situated in a transitional zone that stretches between the Chhota Nagpur Plateau and the Deccan Plateau. The tiger reserve showcases unique and indigenous species from both biotic provinces. It is also known as a breeding center for endangered freshwater fauna such as magar, ghariyal, and Chitra turtles.

An effort of 18886 trap nights was invested, and not a single photograph of a tiger was obtained. Sampling details are given in Table V.2.38.

Figure V.2.38

Camera trap layout in Satkosia Tiger Reserve, 2022

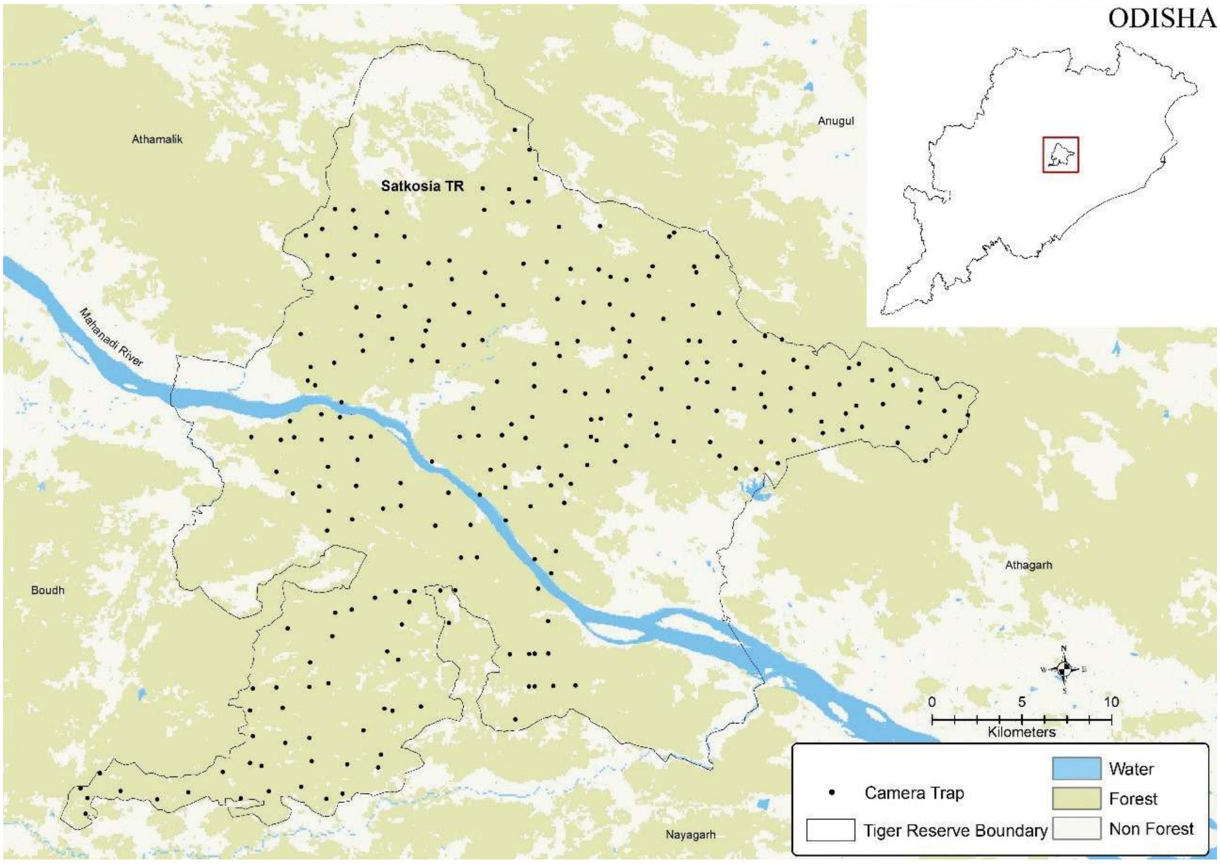


Table V.2.38

Sampling details of camera trapping exercise in Satkosia Tiger Reserve, 2022.

Sampling Details	Counts
Camera points	258
Trap nights (effort)	1886
Number of tiger photos	0

The tiger population in Satkosia Tiger Reserve has experienced a significant decline due to habitat loss and poaching. To address this issue and restore ecological balance, a tiger reintroduction project was initiated. Tigers from reserves like Bandhavgarh and Kanha Tiger Reserves in Madhya Pradesh were identified as potential sources for reintroduction. However, the reintroduction efforts faced challenges and did not achieve the desired success.

To improve future tiger reintroduction endeavors, it is crucial to implement enhanced conservation strategies. These strategies may include focusing on prey recovery to ensure an adequate food source for tigers, promoting voluntary village relocation to minimize human-wildlife conflicts, strengthening law enforcement to combat poaching and illegal activities, engaging local communities in conservation efforts, and addressing habitat limitations.

By adopting these improved conservation approaches, the obstacles faced in the previous reintroduction project can be overcome, leading to a more favourable environment for successful tiger reintroduction in Satkosia Tiger Reserve. These efforts are essential for the long-term survival and conservation of tigers in the reserve.

SIMILIPAL TIGER RESERVE

The Similipal Tiger Reserve is situated in the northernmost part of Odisha, specifically in the central portion of the Mayurbhanj district. This reserve spans a total area of 2750 km^2, with the core zone covering 1194.75 km^2 and the buffer zone encompassing 1555.25 km^2. It is situated within the Chhotnagpur biotic province of the Deccan Peninsular biogeographic zone. The terrain of the reserve is predominantly undulating and hilly, featuring open grasslands, mesic savannas, and wooded areas. Similipal Tiger Reserve is known for its unique gene pool of pseudomelanistic tigers. Similipal Tiger Reserve is connected to Satkosia Tiger Reserve through a forest corridor, which further connects to Kalasuni, Badrama, Jamankira, Kuchinda, and Barma wildlife sanctuaries in Odisha. It is also connected with Dalma Wildlife Sanctuary in Jharkhand, which further connects fragmented habitat to Palamau Tiger Reserve through Palkot Wildlife Sanctuary and Gumla Forest Division.

An effort of 20655 trap nights was invested, and a total of 831 photos of tigers were obtained, from which 16 unique tigers (>1 year of age) were identified. The tiger density was estimated at 0.91 (SE 0.23) tigers per 100 km^2 (Table V.2.39). The detection-corrected tiger sex ratio is female-biased by 3 females per male (Table V.2.39).

Figure V.2.39

Camera trap layout and spatial tiger density in Similipal Tiger Reserve, 2022

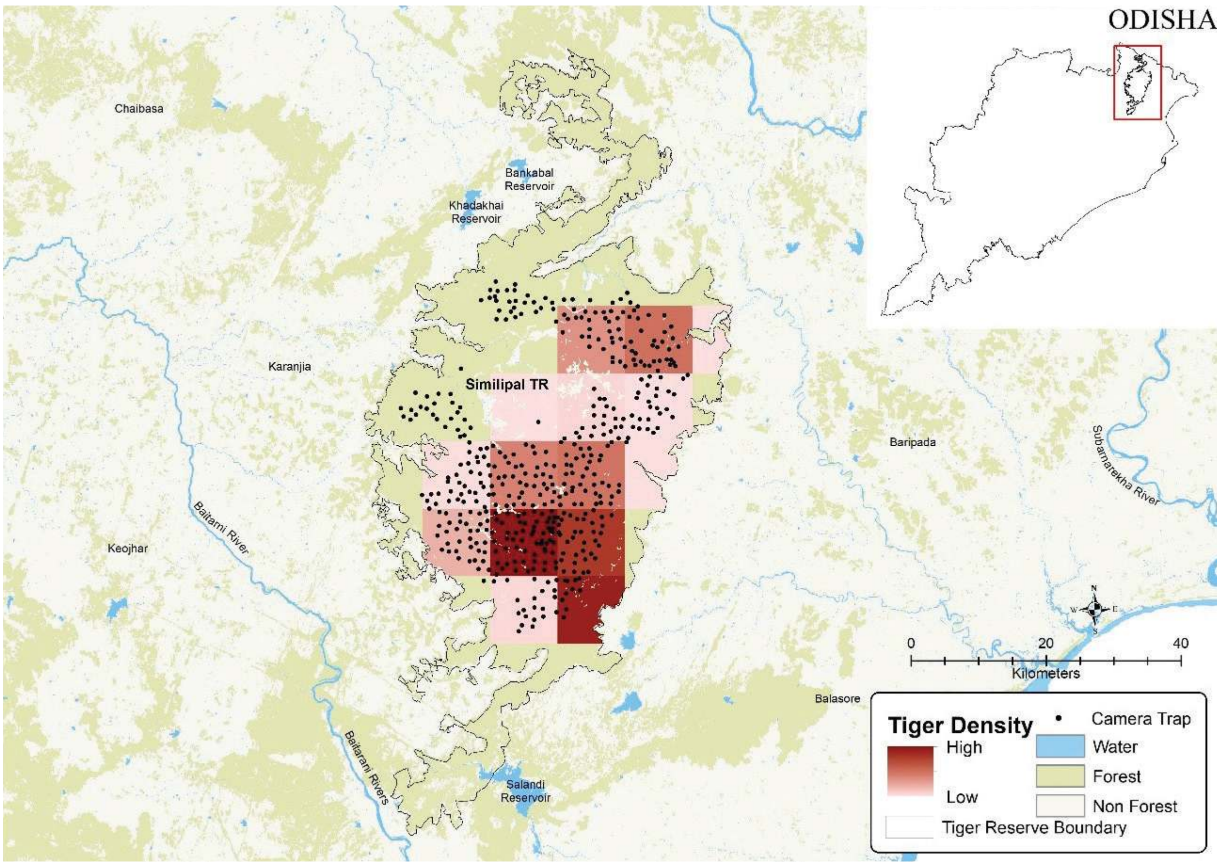


Table V.2.39

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Similipal Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	2209
Camera points	459
Trap nights (effort)	20655
Unique tigers captured	16
Model	Pmix(sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	0.91 (0.23)
σ Female (SE) (km)	2.15 (0.08)
σ Male (SE) (km)	5.22 (0.32)
g0 Female (SE)	0.03 (0.003)
g0 Male (SE)	0.02 (0.002)
Pmix Female (SE)	0.75 (0.1)
Pmix Male (SE)	0.25 (0.1)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Similipal Tiger Reserve was on its way to recovery, and the tiger population has substantially increased since the last cycle of the National Tiger Estimation Exercise in 2018. The recent incidents of the killing of forest guards and poaching activity are a major setback to this effort. A major threat to the Similipal tiger reserve is an organized poaching gang. Efforts should be made to deputize an armed special tiger protection force in Similipal. We may lose the opportunity to ensure the recovery of the unique tiger population in this landscape if urgent action is not initiated.

KULDIHA WILDLIFE SANCTUARY

Kuldiha Wildlife Sanctuary is situated in the south-western part of Balasore district in Odisha. It plays a significant role as a potential corridor for the movement of tigers and elephants between Similipal Tiger Reserve and Satkosia Tiger Reserve. The sanctuary encompasses the forests of Kuldiha, Devgiri, and Tenda, as well as portions of the adjacent Sarisua protected forests. Camera trapping was conducted in the sanctuary, and although there were only two photo-captures of one adult tiger, it marks the first recorded instance of a tiger presence in the area. Due to the limited number of photo captures, the tiger density could not be estimated using SECR (Spatially Explicit Capture-Recapture) methodology. The identification of an adult tiger in Kuldiha Wildlife Sanctuary highlights the importance of the sanctuary as a potential habitat and corridor for tigers. The conservation efforts are needed to monitor and protect the tiger population in this sanctuary, ensuring the continued connectivity between Similipal and Satkosia Tiger Reserves.

Figure V.2.40

Camera trap layout and tiger presence in Kuldiha Wildlife Sanctuary, 2022

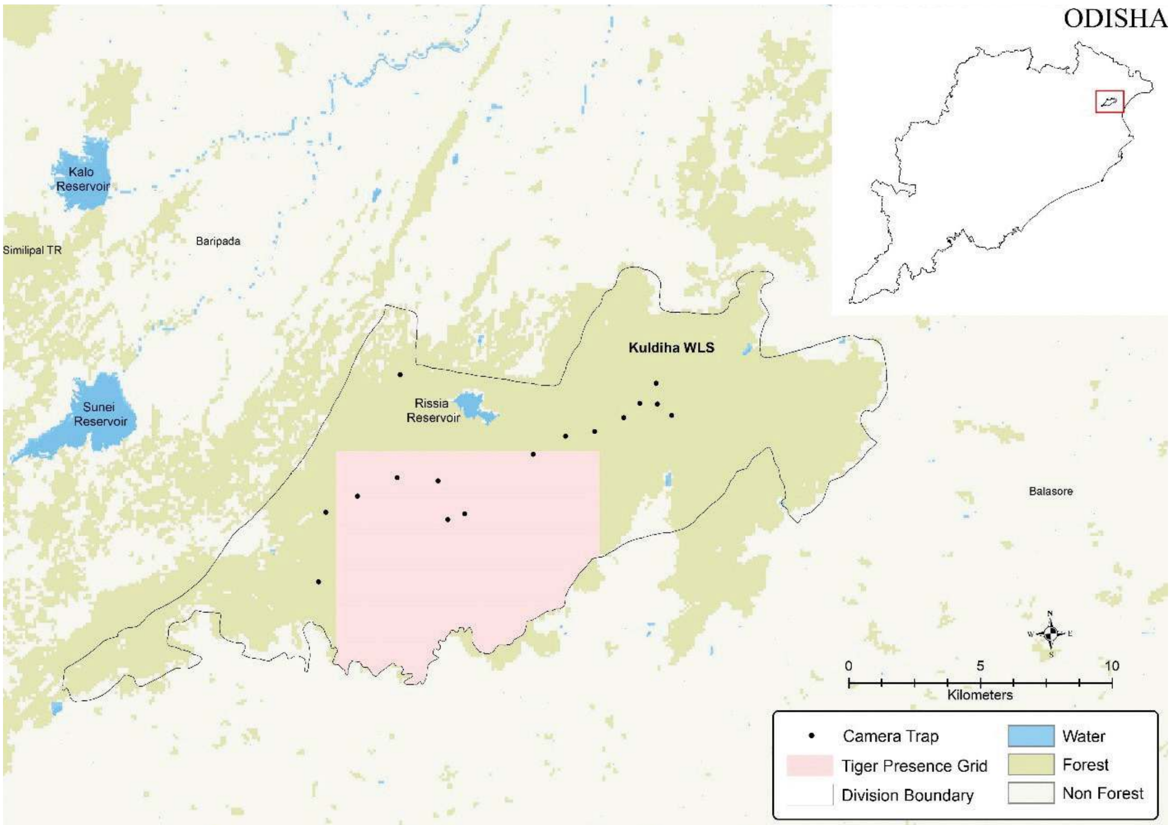


Table V.2.40

Sampling details of camera trapping exercise in Kuldiha Wildlife Sanctuary, 2022.

Sampling Details	Counts
Camera points	16
Trap nights (effort)	973
Number of tiger photos	2
Unique tigers captured	1

RAJASTHAN

MUKUNDARA HILLS TIGER RESERVE

Mukundara Hills Tiger Reserve (MHTR) spanning across 759 km^2 over the districts of Bundi, Chittorgarh, Jhalawar and Kota (core 417.17 km^2, buffer 342.82 km^2 (Figure V.2.41). MHTR is a part of greater Ranthambhore ecosystem. In April 2018, the first tiger from Ranthambhore was translocated to MHTR, however, it was declared as a tiger reserve in 2013. Camera trapping was carried out by the forest department, with an effort of 8451 trap-nights. A total of 43 tiger images were obtained from which one female tiger was identified (Table V.2.41).

Figure V.2.41

Camera trap layout and tiger presence in Mukundara Hills Tiger Reserve, 2022

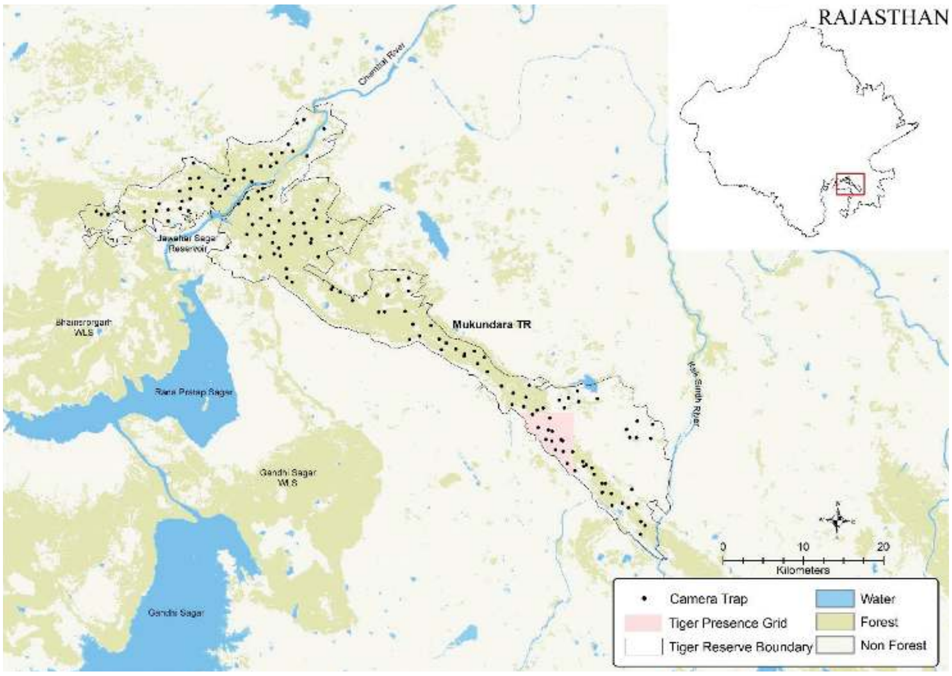


Table V.2.41

Sampling details of camera trapping exercise in Mukundara Hills Tiger Reserve, 2022.

Sampling Details	Counts
Camera points	169
Trap nights (effort)	8451
Number of tiger photos	43
Unique tigers captured	1

At present MHTR is harbouring a low density tiger population, but along with Bhainsrodgarh Wildlife Sanctuary (Rajasthan) and Gandhi Sagar WLS (Madhya Pradesh) it can serve as a sink population in the Ranthambhore tiger metapopulation. To sustain a resident tiger population in MHTR, the wild prey population need to be augmented, inviolate core areas should be created within the reserve (by voluntary relocation of villages from the Tiger Reserve). The linear shape of the TR is a major challenge for the management to harbour sizable tiger population without causing conflicts with human.

RAMGARH-VISDHARI TIGER RESERVE

Ramgarh Visdhari Tiger Reserve (RVTR) is located in the southeastern region of Rajasthan, (Bundi district) with an area of 1501.88 sq. km (core 481.9 km^2, buffer 1019.98 km^2) (Figure V.2.42). This newly formed tiger reserve (declared in 2022) represents both the Aaravalli and Vindhyan ecosystems. Camera trapping was carried out by the forest department with the help of Wildlife Institute of India research team, where 40 tiger images were obtained and one male tiger was identified (Table V.2.42).

Figure V.2.42

Camera trap layout and tiger presence in Ramgarh-Visdhari Tiger Reserve, 2022

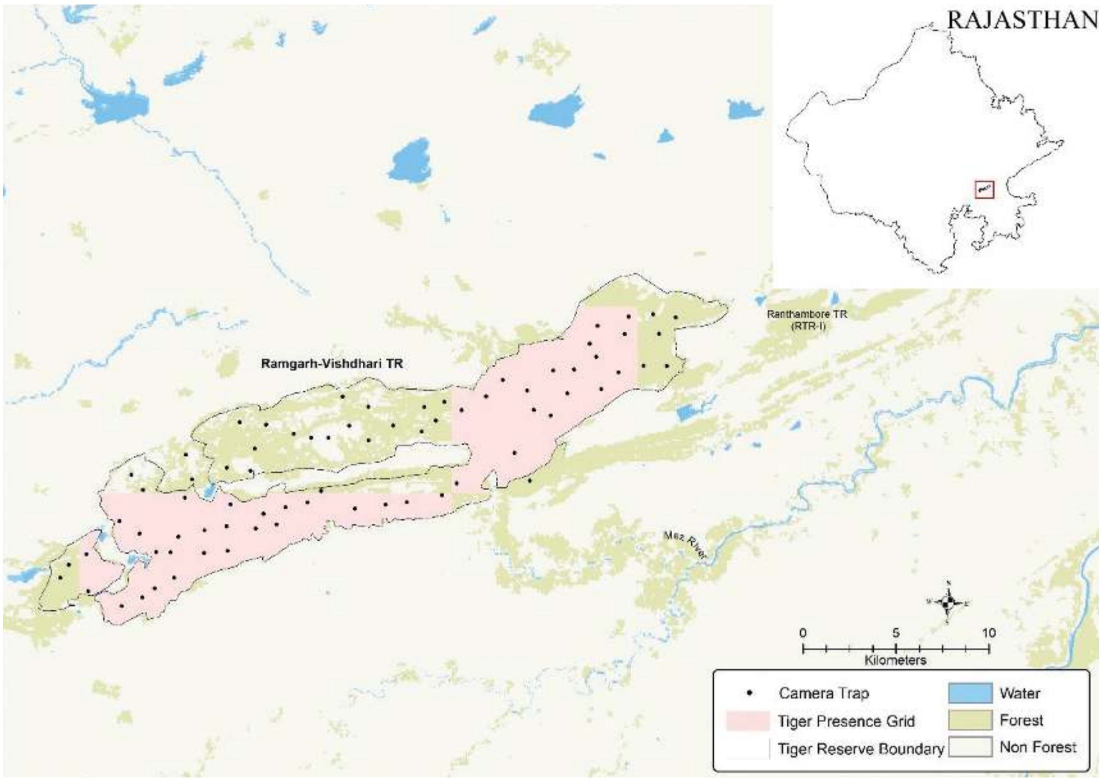


Table V.2.42

Sampling details of camera trapping exercise in Ramgarh-Visdhari Tiger Reserve, 2022.

Sampling Details	Counts
Camera points	74
Trap nights (effort)	5215
Number of tiger photos	40
Unique tigers captured	1

The hills forests of RVTR is well connected with the Ranthambhore Tiger Reserve (RTR), thus can harbour the dispersing tigers of RTR and an important link in the greater Ranthambhore ecosystem. However, to harbour a resident tiger population, active conservation actions need to be taken, such as prey augmentation and law enforcement to curb human impacts in the core. Voluntary relocation of villages from the Tiger Reserve is needed to create inviolate core area.

RANTHAMBHORE TIGER RESERVE (DIVISION I)

Ranthambhore is one of the earliest tiger reserves in India, established in 1973, and holds a long history of tiger conservation in India. It is located at the intersection of two ancient mountain ranges, the Aravalis and Vindhyas), and at the confluence of seven river systems. The Ranthambhore TR (Division I) is the only source population in the semi-arid western Indian landscape (Sadhu *et al.* 2017). Along with Kailadevi Wildlife Sanctuary, Kuno National Park, Madhav NP, Ramgarh Visdhari TR, Mukundara Hills TR, Ranthambhore TR forms the greater Ranthambhore ecosystem, which marks the westernmost distribution of tigers in the world (Figure V.2.43). Ranthambhore is also one of the best places to see wild tigers, and one of the few places where long-term research on tigers were conducted which contributed substantially in the field of tiger ecology and conservation. The forest department along with the research team from Wildlife Institute of India conducted the camera trapping which resulted into 2390 tiger images and 57 tiger individuals were identified (TableV.2.43). The detection-corrected sex ratio was 1:1 (male to female).

Figure V.2.43

Camera trap layout and spatial tiger density in Ranthambhore Tiger Reserve (Division I), 2022.

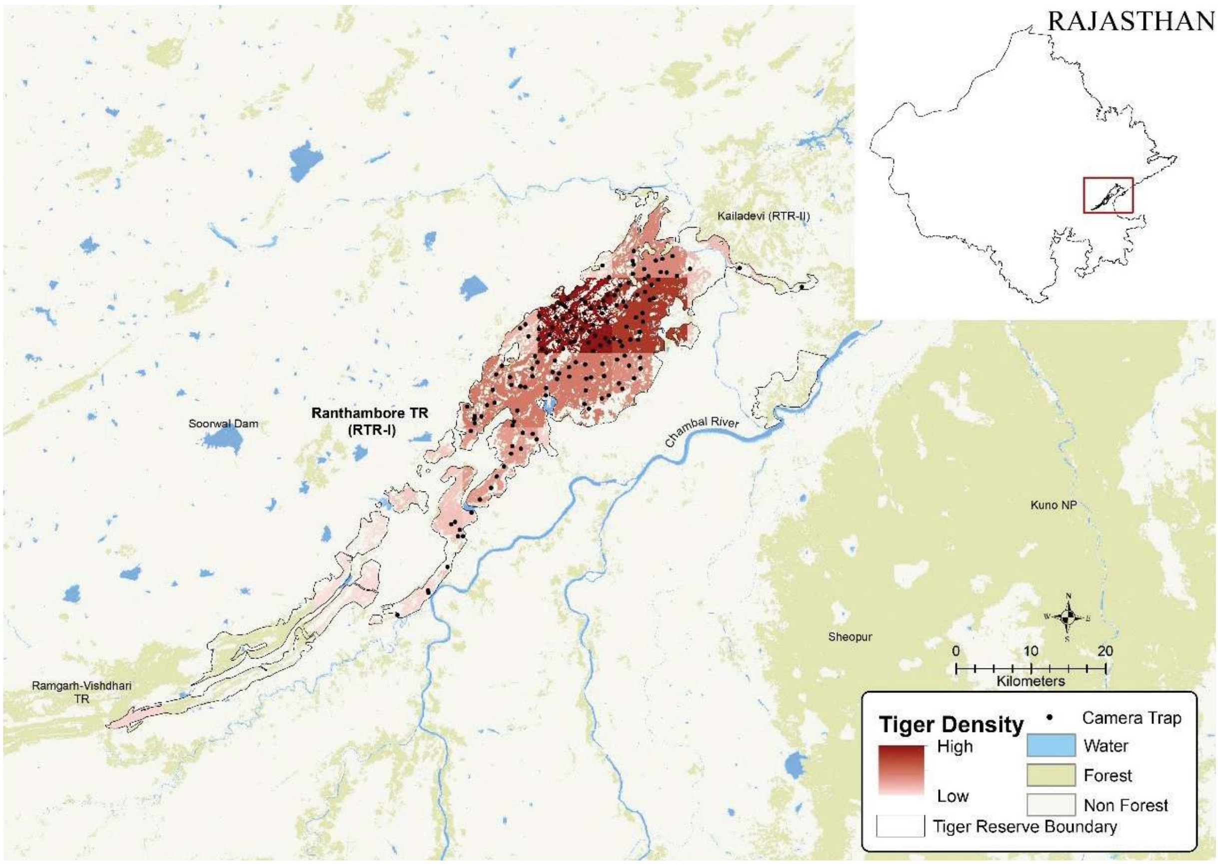


Table V.2.43

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Ranthambore Tiger Reserve (Division I), 2022.

Variables	Estimate
Model space (km^2)	6508
Camera points	158
Trap nights (effort)	13490
Unique tigers captured	57
Model	Pmix(sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	9.6 (1.27)
σ Female (SE) (km)	1.3(0.03)
σ Male (SE) (km)	2.1(0.04)
g0 Female (SE)	0.09(0.01)
g0 Male (SE)	0.08(0.004)
Pmix Female (SE)	0.58(0.07)
Pmix Male (SE)	0.42(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Ranthambhore harbours the highest density of tigers in the central Indian landscape, with a density of 9.6 ± 1.27 tigers per 100 km^2 (TableV.2.43). The tiger density in Ranthambhore remains consistent and is indicative of the population reaching carrying capacity. However, the isolated nature of the reserve is a conservation concern. The Ranthambhore tiger population needs to be conserved as a metapopulation by connecting the nearby tiger-bearing areas through wildlife corridors. Developmental activities in the greater Ranthambhore landscape pose a major threat to connectivity in the area. The sharp boundary between the forests and human habitation often results in tigers straying into the human-dominated landscape, leading to escalated tiger-human conflicts. The spread of invasive species, such as *Prosopis juliflora*, is a major management concern for this semi-arid ecosystem.

RANTHAMBHORE TIGER RESERVE (DIVISION II – KAILADEVI WLS)

Kailadevi Wildlife Sanctuary, which is a part of the Ranthambhore Tiger Reserve (Division II, 674 km^2), is comprised of the forest blocks of Karauli and Sapotra and is situated in Karauli district, Rajasthan (Figure V.2.44). Opportunistic camera trapping was conducted by the forest department, where 18 tiger images were obtained and two adult tigers were identified (Table V.2.44). Three young tigers were photo-captured during the camera trapping exercise.

Figure V.2.44

Camera trap layout in Kailadevi Wildlife Sanctuary, 2022.

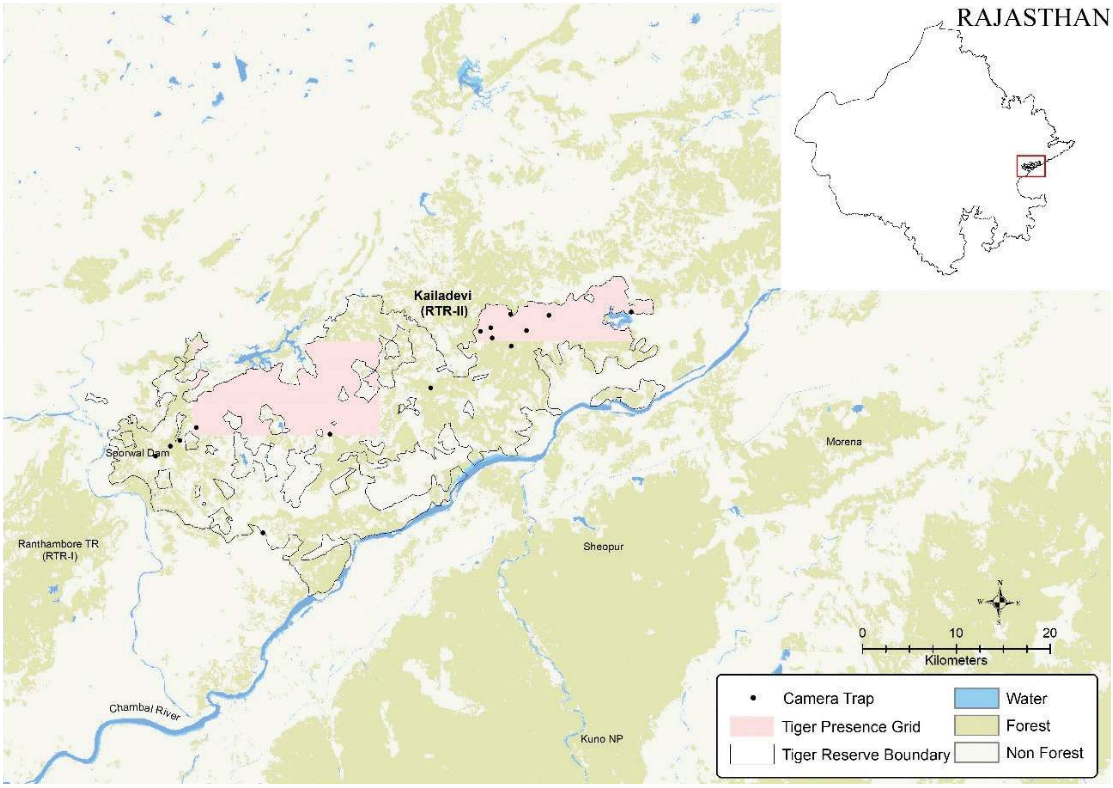


Table V.2.44

Sampling details of camera trapping exercise in Kailadevi Wildlife Sanctuary, 2022.

Sampling Details	Counts
Camera points	14
Trap nights (effort)	673
Number of tiger photos	18
Unique tigers captured	2

Kailadevi, which serves as the buffer of Ranthambhore Tiger Reserve, holds potential for harboring low-density tiger populations in the isolated patches within and on the periphery of the reserve. However, intense human disturbance, mining, and the development of linear infrastructure are the major threats to this area. Apart from tigers, Kailadevi holds immense potential for conserving caracal, Indian wolf, sloth bear, striped hyena, ratel, and other important species in the greater Ranthambhore ecosystem. Habitat restoration, active management practices (prey augmentation and village relocation) and law enforcement are required in order to conserve this fragile ecosystem.

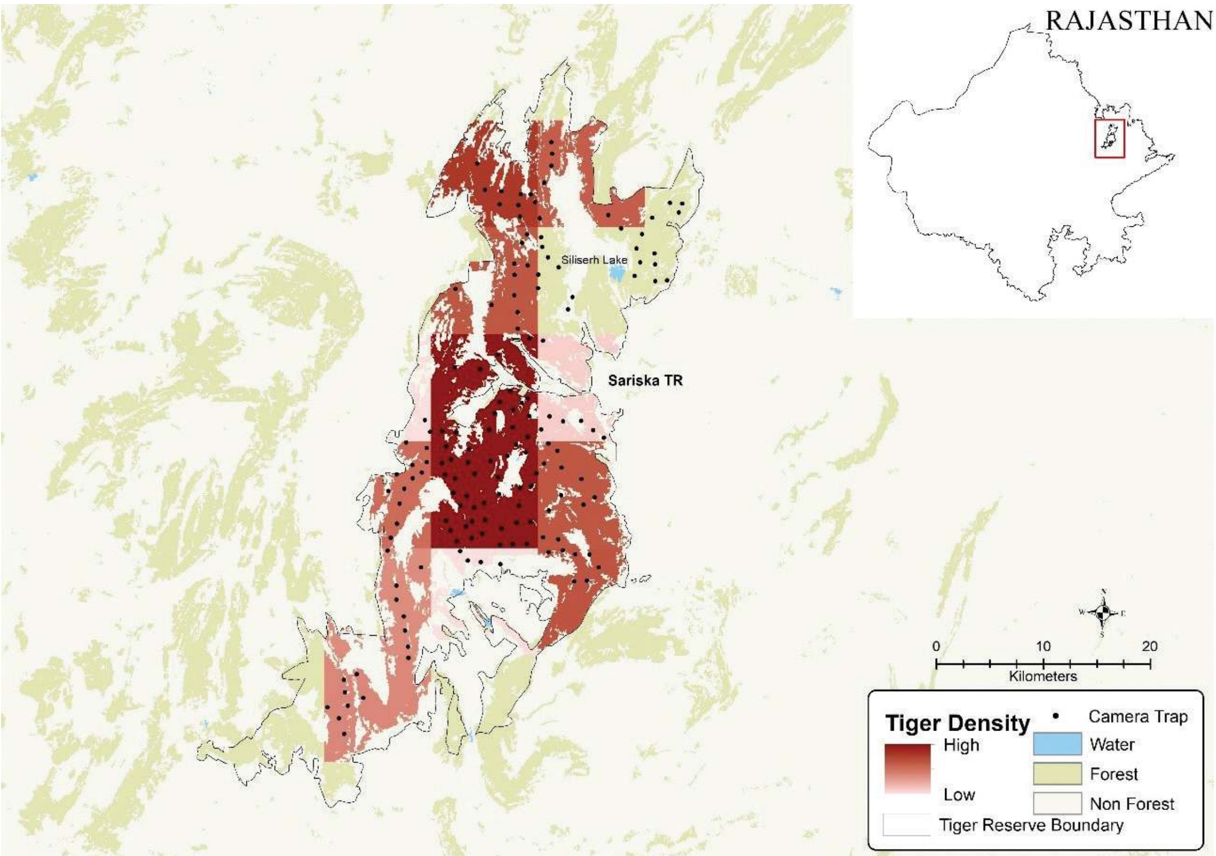
Section V.2

SARISKA TIGER RESERVE

Sariska Tiger Reserve, situated in Rajasthan's Alwar district, is part of the Aravali mountain system. The loss of tigers from Sariska in 2004, paved the way for change in management of tigers in the country and resulted in the implementation of an evidence-based tiger monitoring system backed by robust science. With an area of 1203.34 km^2 (core 881.11 km^2 and buffer 322.23 km^2), the reserve is stretched out throughout the fragmented hill forests of Aravalli (Figure V.2.45). The forest department along with the Wildlife Institute of India research team conducted the camera trapping exercise which resulted into 694 tiger images. Nineteen adult tiger individual were identified (Table V.2.45), and a total of three young tigers were photo-captured. As the Sariska tiger population is known and monitored, we have not estimated the abundance, but use the total count. At present there are 24 adult tigers in Sariska Tiger Reserve.

Figure V.2.45

Camera trap layout and spatial density of tigers in Sariska Tiger Reserve, 2022



Section V.2

Table V.2.45

Sampling details of camera trapping exercise in Sariska Tiger Reserve, 2022.

Sampling Details	Counts
Camera points	158
Trap nights (effort)	8359
Number of tiger photos	694
Unique tigers captured	19

The increasing tiger population reflects effective management practices and the presence of suitable habitats within the reserve. However, the pervasive impact of human activities poses a significant obstacle to the recovery of wildlife, including tigers, in Sariska. Extensive human disturbance over time has led to degradation in various areas of the reserve, resulting in a decline in prey populations and the invasion of weeds. The presence of religious tourism and highways within the reserve poses significant threats to the wildlife. To address these challenges, it is crucial to prioritize the voluntary relocation of villages and mitigate the disturbances caused by existing developmental activities. These measures are necessary for the conservation and preservation of Sariska's ecosystem and its wildlife.

BHAINSRODGARH WILDLIFE SANCTUARY

The Bhainsrodgarh Wildlife Sanctuary, established in 1983, covers an expanse of 229 km^2 in the Chittorgarh district of Rajasthan. It is interconnected with the Mukundara Hills Tiger Reserve in Rajasthan and the Gandhi Sagar Wildlife Sanctuary in Madhya Pradesh (Figure V.2.46). The forest department, in collaboration with the research team from the Wildlife Institute of India, conducted camera trapping activities in the sanctuary. However, no tiger was captured in any of the photos taken during the camera trapping session (Table V.2.46).

Figure V.2.46

Camera trap layout in Bhainsrodgarh Wildlife Sanctuary, 2022.

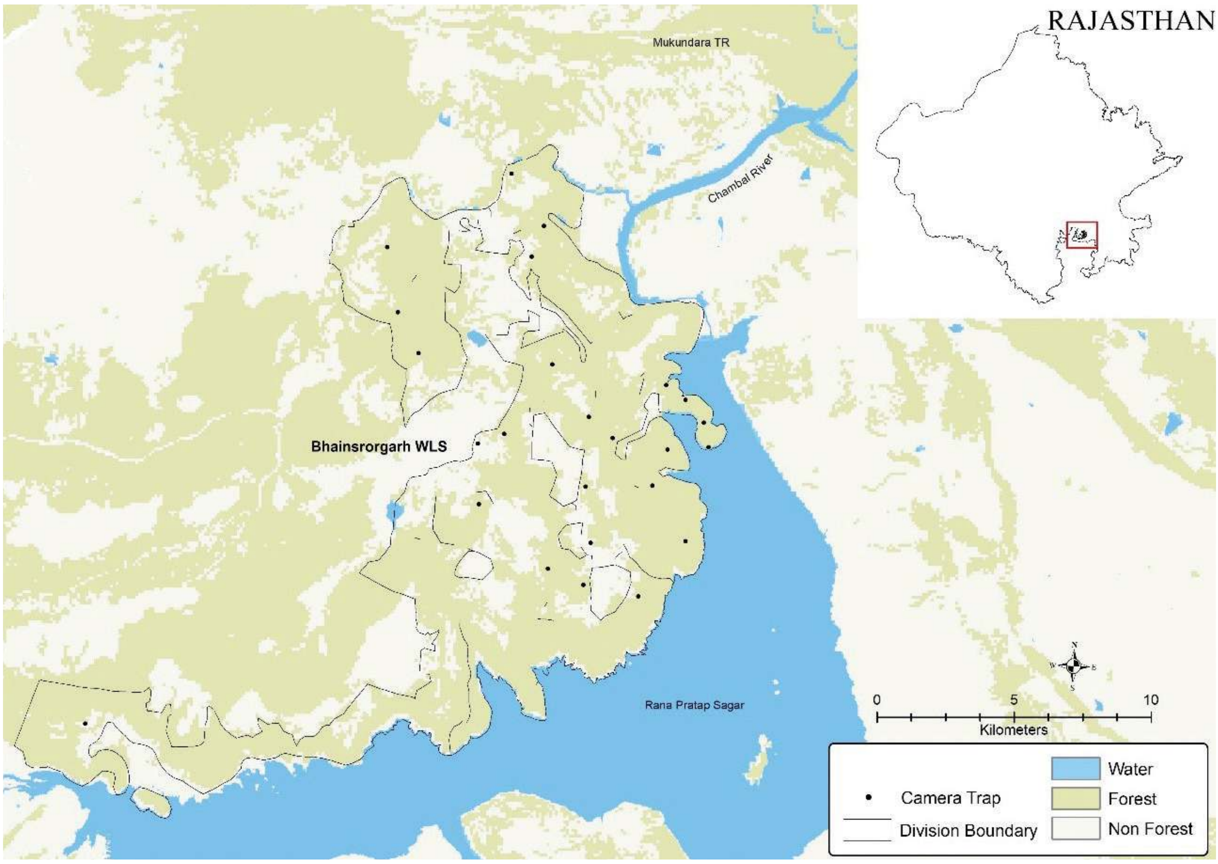


Table V.2. 46

Sampling details of camera trapping exercise in Bhainsrodgarh Wildlife Sanctuary, 2022.

Sampling Details	Counts
Camera points	29
Trap nights (effort)	1608
Number of tiger photos	0

The restoration of degraded habitats within the sanctuary is of utmost importance and should be accompanied by law enforcement measures to address human impacts. Bhainsrodgarh forms an integral part of the greater Ranthambhore ecosystem and holds potential as a habitat for various significant semi-arid species such as cheetah, caracal, wolf, hyena, ratel, and others. While Bhainsrodgarh may not be an ideal location to support a substantial resident tiger population, it can still play a crucial role as a stepping stone corridor.

KUMBHALGARH WILDLIFE SANCTUARY

Kumbhalgarh Wildlife Sanctuary in Rajasthan is situated majorly in Rajsamand district but also cover parts of Pali and Udaipur districts along the Aravalli's spanning over more than 610 km^2. The sanctuary is connected to Todgarh-Raoli WLS in the northern side and Phulwari Ki Nal and Mount Abu WLS in the southern side (Figure V.2.47). Camera trapping was carried out by the forest department with the help of Wildlife Institute of India research team, where no tiger photos were obtained with an effort of 4029 trap-nights (Table V.2.47). During the camera trapping exercise, no tigers were photo-captured.

Figure V.2.47

Camera trap layout in Kumbhalgarh Wildlife Sanctuary, 2022.

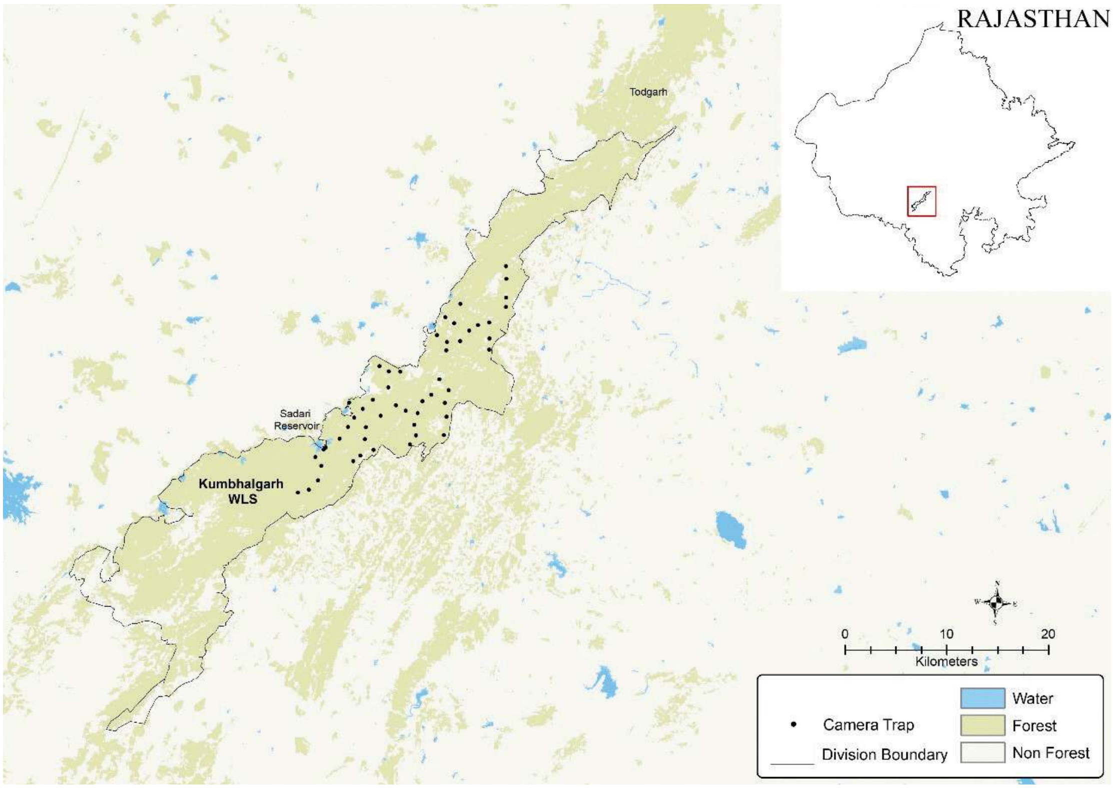


Table V.2.47

Sampling details of camera trapping exercise in Kumbhalgarh Wildlife Sanctuary, 2022.

Sampling Details	Counts
Camera points	52
Trap nights (effort)	4029
Number of tiger photos	0

Although Kumbhalgarh was not inhabited by tigers, but it was ear-marked for tiger reintroduction by the state government. Therefore, the present survey was conducted to assess the status of wildlife species under the ambit of All India Tiger Estimation. The linear shape of the sanctuary and low density prey population is a major concern for sustaining a viable tiger population in the reserve. Procurement of adjacent revenue and forest lands needs to be done on priority to create suitable habitat for tiger prey species. Once the prey population is recovered and inviolate core area (of at least 200 km^2) is secured, tiger reintroduction can be planned.

SHERGARH WILDLIFE SANCTUARY

Shergarh Wildlife Sanctuary, situated in the Baran district of Rajasthan is spread over an area of 81 km^2 (Figure V.2.48). It is a part of the greater Ranthambhore ecosystem. Camera trapping was carried out by the forest department with the help of Wildlife Institute of India research team. There was no tiger photo-captured during the camera trapping session (Table V.2.48).

Figure V.2.48

Camera trap layout in Shergarh Wildlife Sanctuary, 2022.

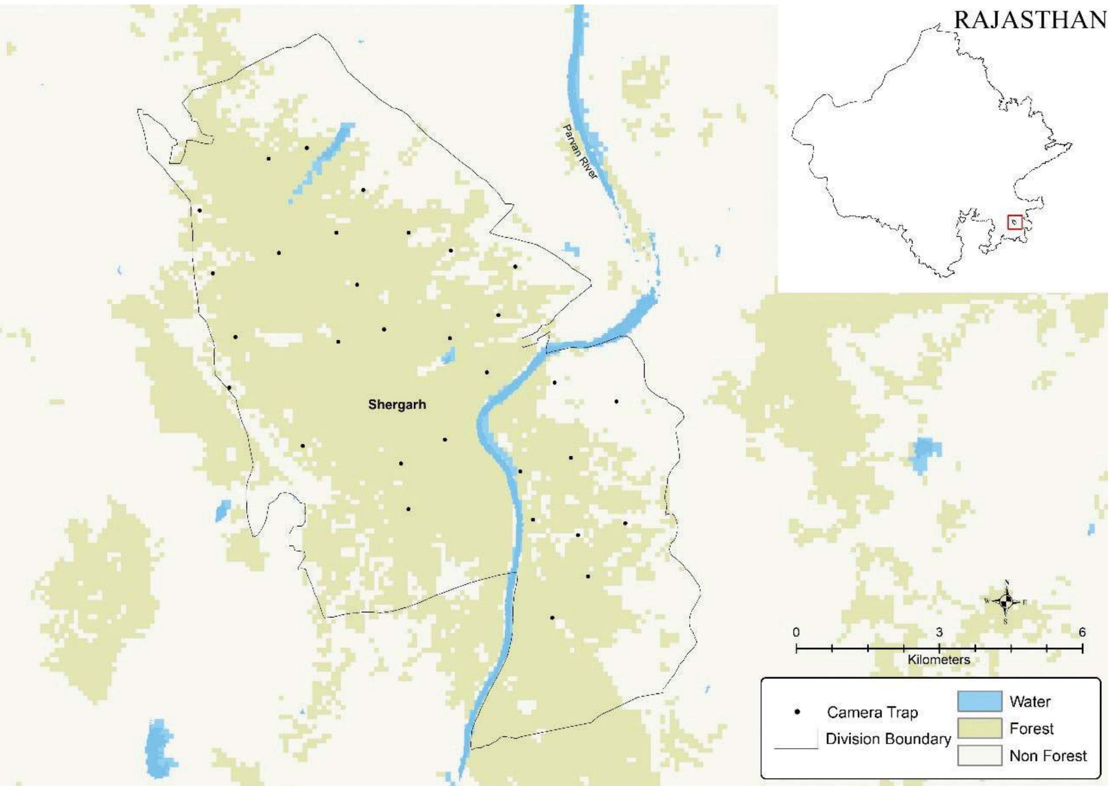


Table V.2.48

Sampling details of camera trapping exercise in Shergarh Wildlife Sanctuary, 2022.

Sampling Details	Counts
Camera points	31
Trap nights (effort)	1532
Number of tiger photos	0

Shergarh WLS sanctuary is small in size, and exposed to human disturbances. The sanctuary along with the adjacent forest blocks holds (~1000 km^2) potential for sustaining caracal, wolf, chinkara, black buck, striped hyena, jackal and other associated species. However, the human disturbances need to be regulated in order to create space for wildlife. Targeted conservation investments are needed to serve the needs of the semi-arid species assemblage. Eradication of *Prosopis julifora* is a major conservation concern in the sanctuary.

TELANGANA

AMRABAD TIGER RESERVE

Amrabad Tiger Reserve was part of the Greater Nagarjuna Srisilam Tiger Reserve before the reorganization of Andhra Pradesh. It is situated in the Nallamala Hills of the Eastern Ghats of Telangana State. The reserve extends till Mahabubnagar and Nalgonda districts and is about 150 km south of Hyderabad on the southern bank of the Krishna. The core covers a total area of 2166.37 km^2 and has a buffer area of 445.02 km^2.

An effort of 25822 trap nights was invested, and a total of 286 tiger photos were obtained, from which 12 tigers (1>year of age) were identified, and the tiger density was estimated at 0.40 (SE 0.12) tigers per 100 km^2 (Table V.2.49). The detection-corrected sex ratio is female-biased by 1.5 females per male (Table V.2.49).

Figure V.2.49

Camera trap layout and spatial tiger density in Amrabad Tiger Reserve, 2022

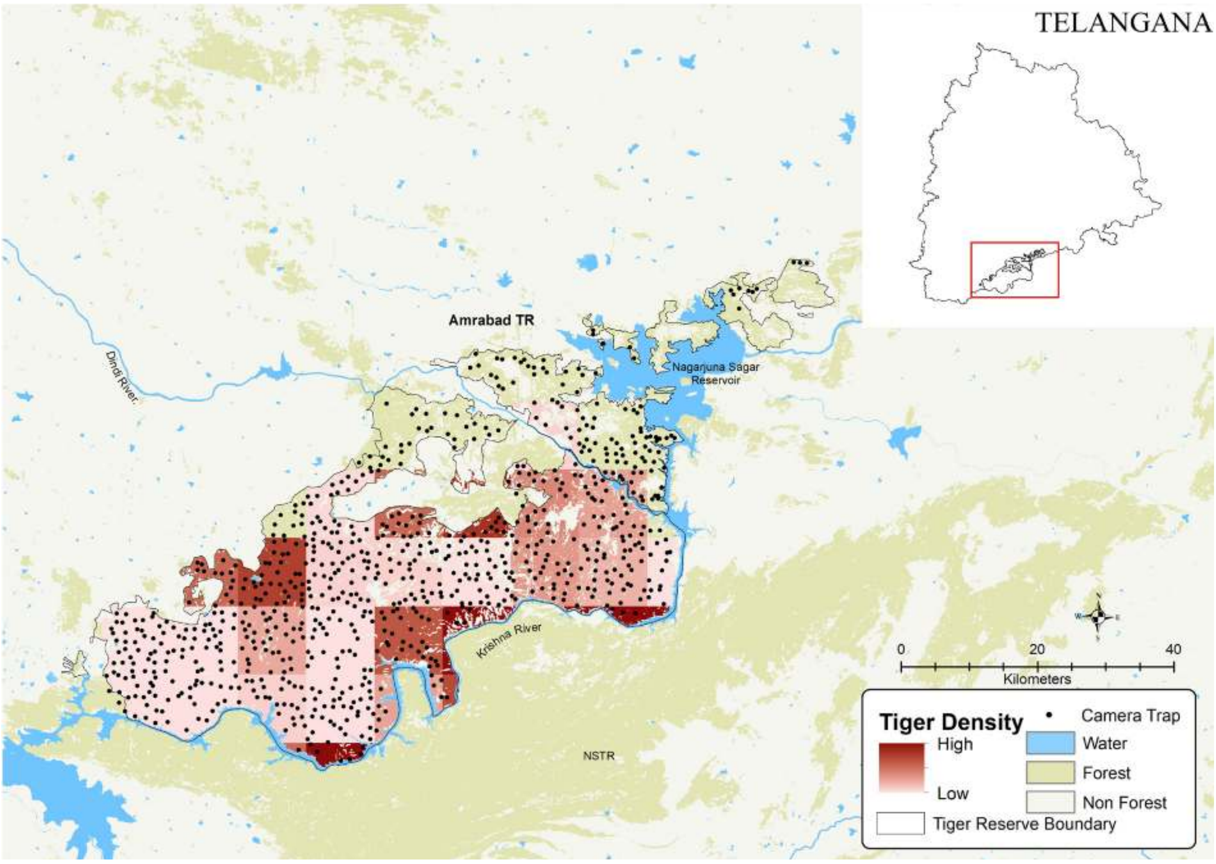


Table V.2.49

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Amrabad Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	3980
Camera points	812
Trap nights (effort)	25822
Unique tigers captured	12
Model	Pmix(sex)g0(.)σ(.)
$\hat{D}$ SECR (per 100 km^2)	0.40 (0.12)
σ Female (SE) (km)	3.56 (0.27)
σ Male (SE) (km)	3.56 (0.27)
g0 Female (SE)	0.003 (0.001)
g0 Male (SE)	0.003 (0.001)
Pmix Female (SE)	0.60(0.15)
Pmix Male (SE)	0.40 (0.15)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Amrabad is contiguous with Nagarjunsagar Srisailam Tiger Reserve and forms the largest population of Tigers in the Eastern Ghat landscape. Efforts are needed to augment the ungulate population and, if need be, supplement the tigers in this part with appropriate protection measures.

KAWAL TIGER RESERVE

Kawal Tiger Reserve is located in the north-eastern region of Telangana in the Mancherial (Old Adilabad) district. It is bordered by the Godavari River on one side and the state of Maharashtra on the other. This tiger reserve serves as a crucial watershed for the southward-flowing rivers Godavari and Kadam.This tiger reserve encompasses an area of 1015.35 km^2, out of which an area of 892.23 km^2 is managed as critical core habitat for the tiger and buffer is 123.12 km^2. Bio-geographically, it is a part Deccan Plateau (Rodgers and Panwar 1988). Faunal assemblage of this tiger reserve is typical of Indo-Malayan region. The vegetation is classified as southern tropical dry deciduous (5A) (Champion and Seth 1968). Kawal Tiger Reserve is a vital part of the Central Indian tiger landscape, located in the southernmost region. It shares connectivity with Tadoba-Andhari Tiger Reserve, which is approximately 100 km to the north, and Indravati Tiger Reserve, situated around 150 km to the east. This reserve plays a crucial role in facilitating the movement of tigers between Tadoba-Indravati-Tipeshwars, provided that the intervening habitats remain connected. Camera trap survey (Figure V.2.50) was done with an effort of 9471 trap nights but not a single tiger photograph (Table V.2.50) was obtained.

Figure V.2.50

Camera trap layout in Kawal Tiger Reserve, 2022..

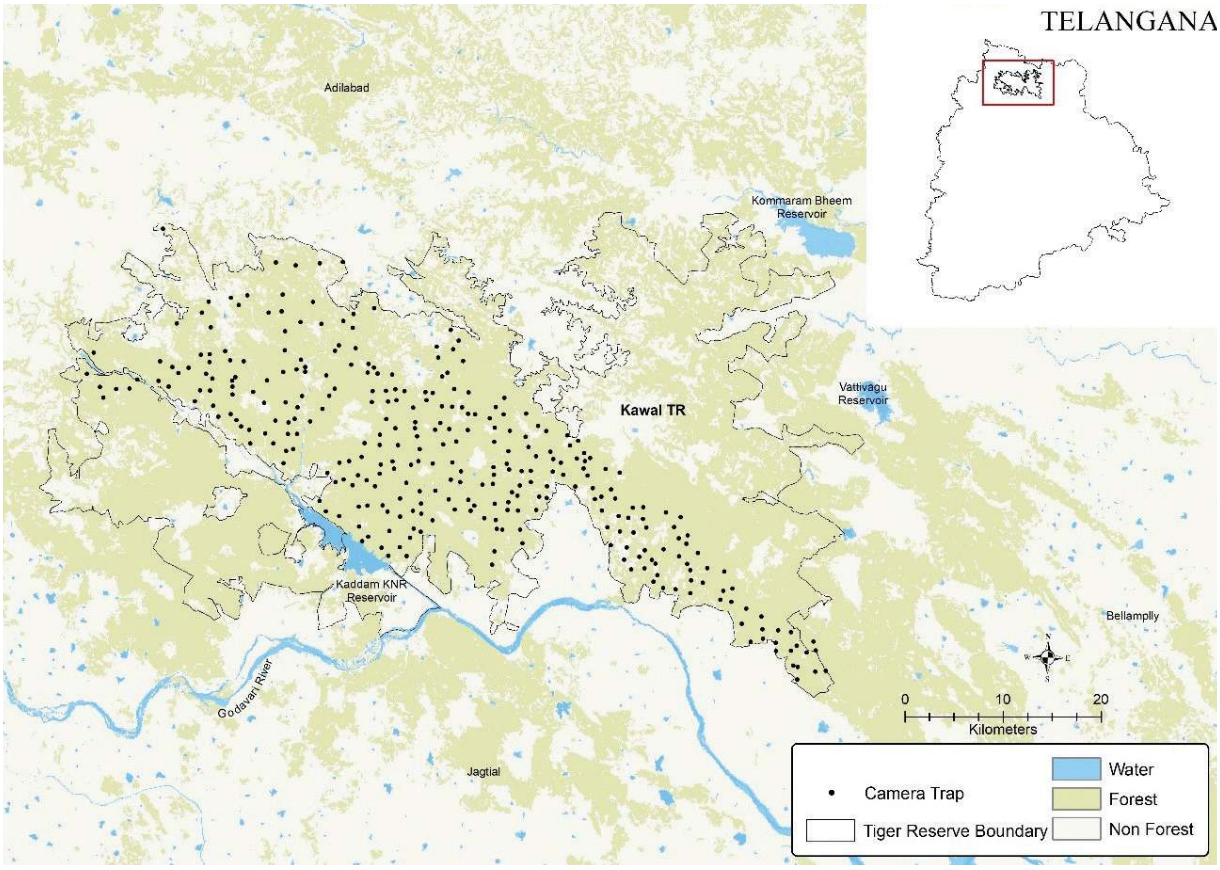


Table V.2.50

Sampling details of camera trapping exercise in Kawal Tiger Reserve, 2022.

Sampling Details	Counts
Camera points	316
Trap nights (effort)	9471
Number of tiger photos	0

Tiger population in Kawal tiger reserve is locally extirpated and currently no tiger presence was reported. However, Four Adults and three cubs were photo-captured in the Kawal corridor (in Kagaznagar) within the greater Kawal landscape can act as a source for recovery. The department has put lots of effort into habitat management and a prey recovery programme is underway. This tiger reserve should be conserved to maintain the genetic heterogeneity of tigers of Tadoba meta-population block. To ensure the recovery of this Tiger Reserve, it is essential to invest in various conservation measures. Active management initiatives such as improved law enforcement monitoring, incentivized voluntary relocation of human settlements, community engagement through participatory community benefits, supplementation of prey, followed by reintroduction of spill-over tiger population from Tadoba meta-population could eventually help in colonizing tigers in this tiger reserve.

ETURNAGARAM WILDLIFE SANCTUARY & KOTHAGUDEM FOREST DIVISION COMPLEX

This complex consists of two sites (Eturnagarma and Kothagudem) where camera trapping was done during the National Exercise of Tiger Co-Predator and Prey Estimation 2022.

A) ETURNAGARAM WILDLIFE SANCTUARY:

Eturnagaram Wildlife Sanctuary is situated in Jayashankar Bhupalpally (formerly part of Warangal) district of Telangana state and spreads over an area of 806 km^2. It is one of the oldest wildlife sanctuaries in South India. Camera trapping was carried out for the first time as a part of the national tiger estimation exercise, with an effort of 2639 trap nights (Table V.2.51). During the camera trapping exercise, no tigers were captured.

B) KOTHAGUDEM COMPLEX

Kothagudem is situated in the Bhadradri Kothagudem district of Telangana. A camera trapping effort of 1256 trap-nights was made (Table V.2.51). During the camera trapping exercise, no tigers were captured. This region includes Kineerasani Wildlife Sanctuary, Paloncha, and Kothagudem Forest Divisions.

Figure V.2.51

Camera trap layout in Eturnagaram and Kothagudem, 2022.

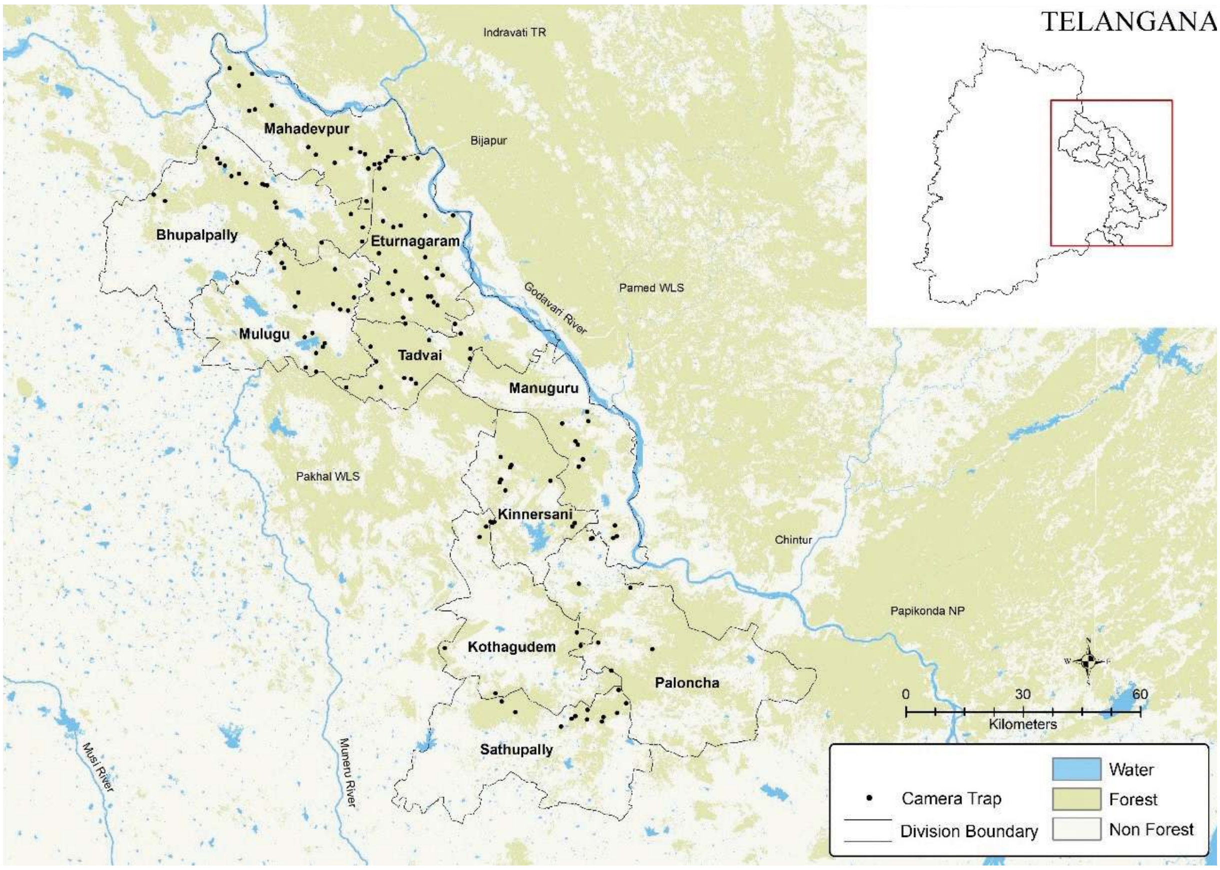


Table V.2.51

Sampling details of camera trapping exercise in Eturnagaram-Kothagudam, 2022.

Sampling Details	Eturnagaram Wildlife Sanctuary	Kothagudem forest division
Camera points	96	56
Trap nights (effort)	2639	1256
Number of tiger photos	0	0

Both together, Eturnagaram & Kothagudem forests forms an integral part of the vast forested landscape in the Godavari basin, which is interconnected with Indravati and Kawal. It serves as the focal point of an expansive forest complex on the eastern side, stretching all the way to Papikonda National Park. This sanctuary boasts extensive stretches of pristine forests and mature woodlands, making it a highly favourable habitat for various species, including tigers and other wildlife. There were reports of tigers sighting, during 2020 in both the sites.

KAGAZNAGAR & CHENNUR FOREST DIVISIONS COMPLEX

This complex consists of two sites (Kagaznagar and Chennur) where camera trapping was done during the National Exercise of Tiger Co-Predator and Prey Estimation 2022.

A) KAGAZNAGAR FOREST DIVISION:

Kagaznagar forest division, situated in the Telangana state, comprises five ranges, namely Kagaznagar, Sirpur, Karjelli, Bejjur, and Penchikalpet, in the Eastern Ghats landscape with an area of 917.19 km^2. Camera trapping was carried out by the forest department, with an effort of 4749 trap nights. Total of 195 tiger photos were obtained from which 4 tiger individuals were identified (Table V.2.52). The detections of the tigers were insufficient for the abundance estimation.

B) CHENNUR FOREST DIVISION:

Chennur forest division is situated in Mancherial district of Telangana state with an area of 1126.49 km^2. Camera trapping was carried out with an effort of 4518 trap nights (Table V.2.52). During the camera trapping exercise, no tigers were captured.

Figure V.2.52

Camera trap layout and tiger presence in Kagaznagar and Chennur Forest Divisions, 2022.

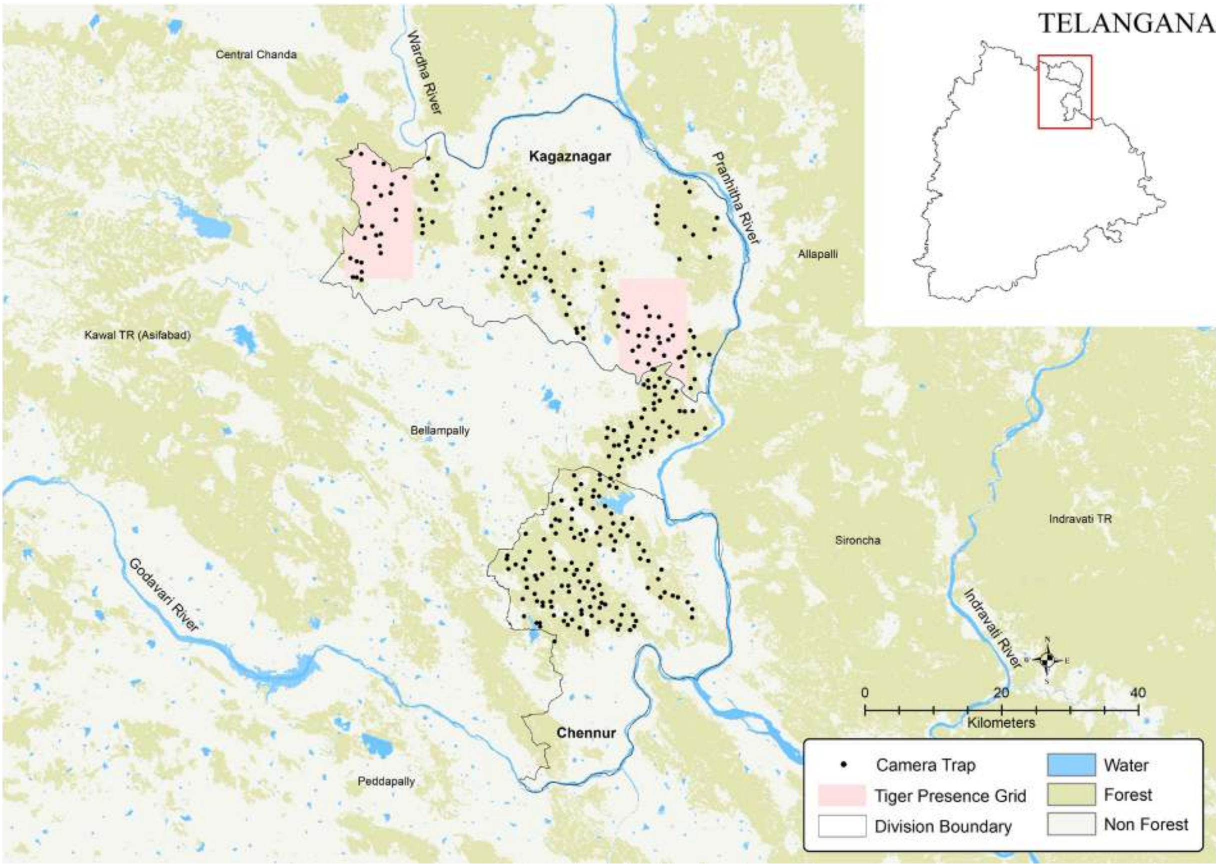


Table V.2.52

Sampling details of camera trapping exercise in Kagaznagar and Chennur Forest Division, 2022.

Sampling Details	Kagaznagar Forest Division	Chennur Forest Division
Camera points	147	151
Trap nights (effort)	4749	4518
Number of tiger photos	195	0
Unique tigers captured	4	0

Both division forms stepping stone for the dispersing tigers from the Tadoba tiger reserve and other divisions of eastern Vidhrabha tiger landcape Maharashtra. Both together forms a key connecting habitat between Kawal, Tadoba Tiger Reserves and Tipeshwar Wildlife Sanctuary and appropriate protection and habitat restoration efforts are needed.

Section V.3

Western Ghats Site Chapters

The Western Ghats landscape is comprised of the Western Ghats and the Nilgiri hills spanning across the states of Goa, Karnataka, Tamil Nadu and Kerala as one tiger landscape, while the Sahyadri-Sindhudurg area is included in the Central India and Eastern Ghats landscape. There are total of 65 sites which were camera trapped in the All India Tiger Estimation exercise 2022.

GOA

MHADEI WILDLIFE SANCTUARY

Mhadei Wildlife Sanctuary is situated in the northern Western Ghats landscape (North Goa division) and shares continuous boundary with PAs in Goa and the northern Karnataka landscape (Fig. V.3.1). Systematic camera trapping was been carried out for the first time by the forest department as a part of AITE exercise, resulted into photo-captures of two adult tiger individuals (Table V.3.1). No cubs/young tigers were photo-captured during the exercise.

Figure V.3.1

Camera trap layout and tiger presence in Mhadei Wildlife Sanctuary, 2022

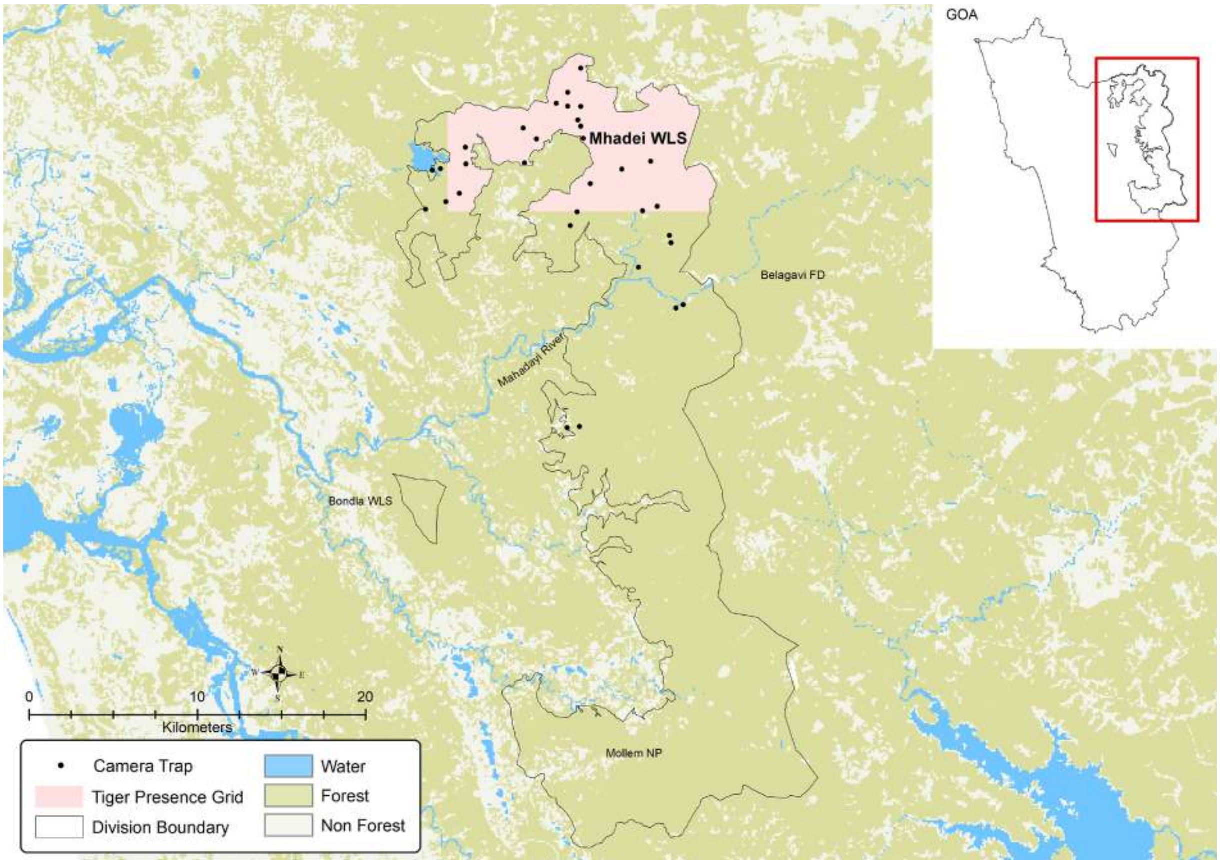


Table V.3.1

Sampling details of camera trapping exercise in Mhadei Wildlife Sanctuary, 2022

Sampling Details	Counts
Camera points	32
Trap nights (effort)	590
Number of tiger photos	14
Unique tigers captured	2

Mhadei WLS holds significant potential for the range expansion of tigers in the Goa as well as in the northern Western Ghats landscape. It is important to enhance protection regime, create inviolate core areas and maintain a healthy prey population within the WLS, ensure rivers are not dammed and secure the connectivity with neighbouring tiger bearing areas by regulation of land use patterns hostile for tiger conservation. It is important to augment ungulate population in sanctuary. The mining industry should pay attention to connectivity of forests for safe passage of animals.

BHAGWAN MAHAVIR (MOLLEM) NATIONAL PARK

Mollem NP is largest Protected Area in Goa. It is located in the northern Western Ghats landscape (North Goa division) and shares continuous boundary with Mhadei WLS (Goa) and Kali TR (Karnataka) (Fig.. V.3.2). Systematic camera trapping was carried out by the forest department for the first time as a part of the AITE exercise, resulted into photo-captures of two adult tiger individuals (Table V.3.2). No cubs/young tigers were photo-captured during the exercise.

Figure V.3.2

Camera trap layout and tiger presence in Mollem National Park, 2022

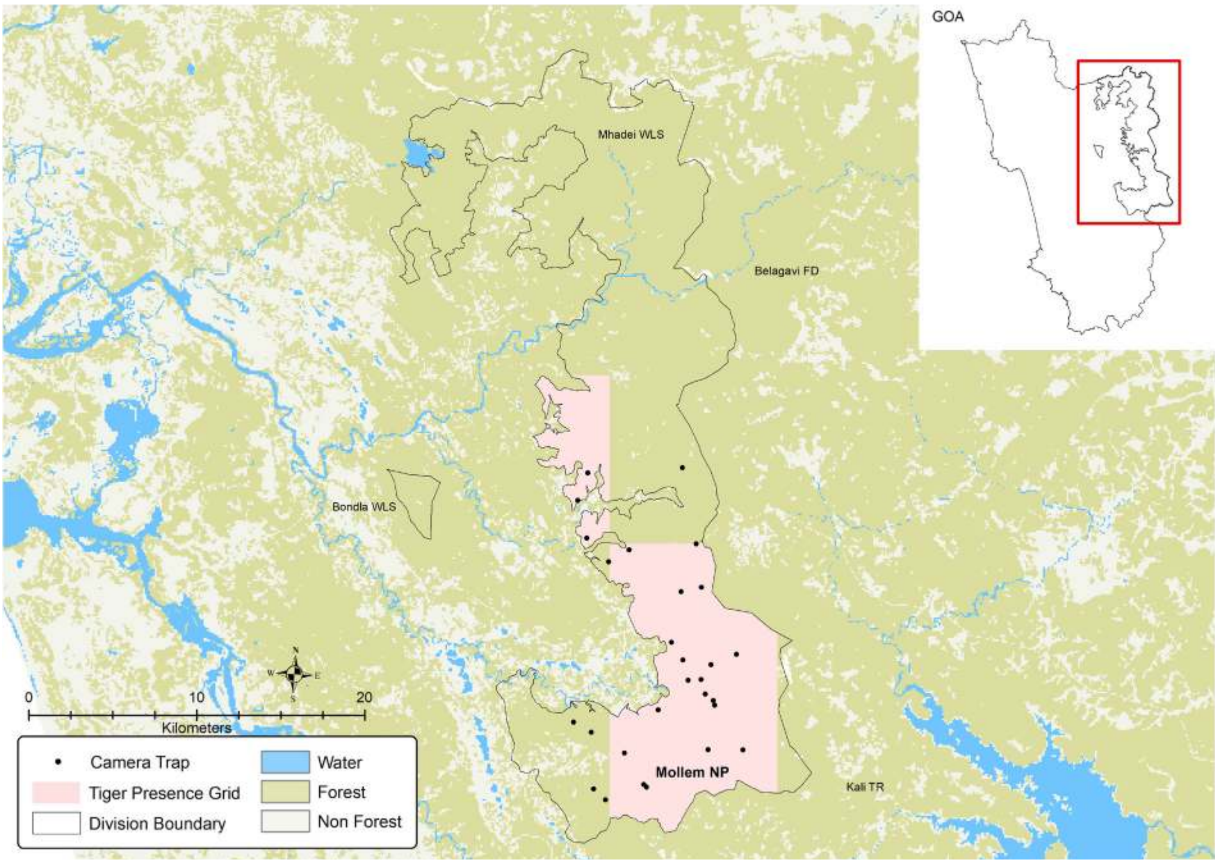


Table V.3.2

Sampling details of camera trapping exercise in Mollem National Park, 2022

Sampling Details	Counts
Camera points	28
Trap nights (effort)	728
Number of tiger photos	21
Unique tigers captured	2

Mollem NP is an important biodiversity area and holds potential for harboring sizable tiger populations in the future. The National Park is facing threats from expansion of linear infrastructures (e.g., roads, railway, and power transmission lines), mining, and encroachment. In order to maintain the sanctity of the area, an inviolate core area needs to be maintained as well as the connectivity with adjacent tiger populations needs to be secured. There is an urgent need to ensure protection and augment ungulate population. The developmental activities need to be assessed and mitigated with suitable strategies backed by sound and long-term ecological understanding.

BONDLA WILDLIFE SANCTUARY

Bondla Wildlife Sanctuary is located in the northern Western Ghats landscape (North Goa Division), adjoining to the Mhadei WLS and Mollem NP in North Goa division (Fig. V.3.3). Camera trapping was carried out for the first time by the forest department as a part of the All India Tiger Estimation, however, no tiger was photo-captured during the sampling period (Table V.3.3).

Figure V.3.3

Camera trap layout in Bondla Wildlife Sanctuary, 2022

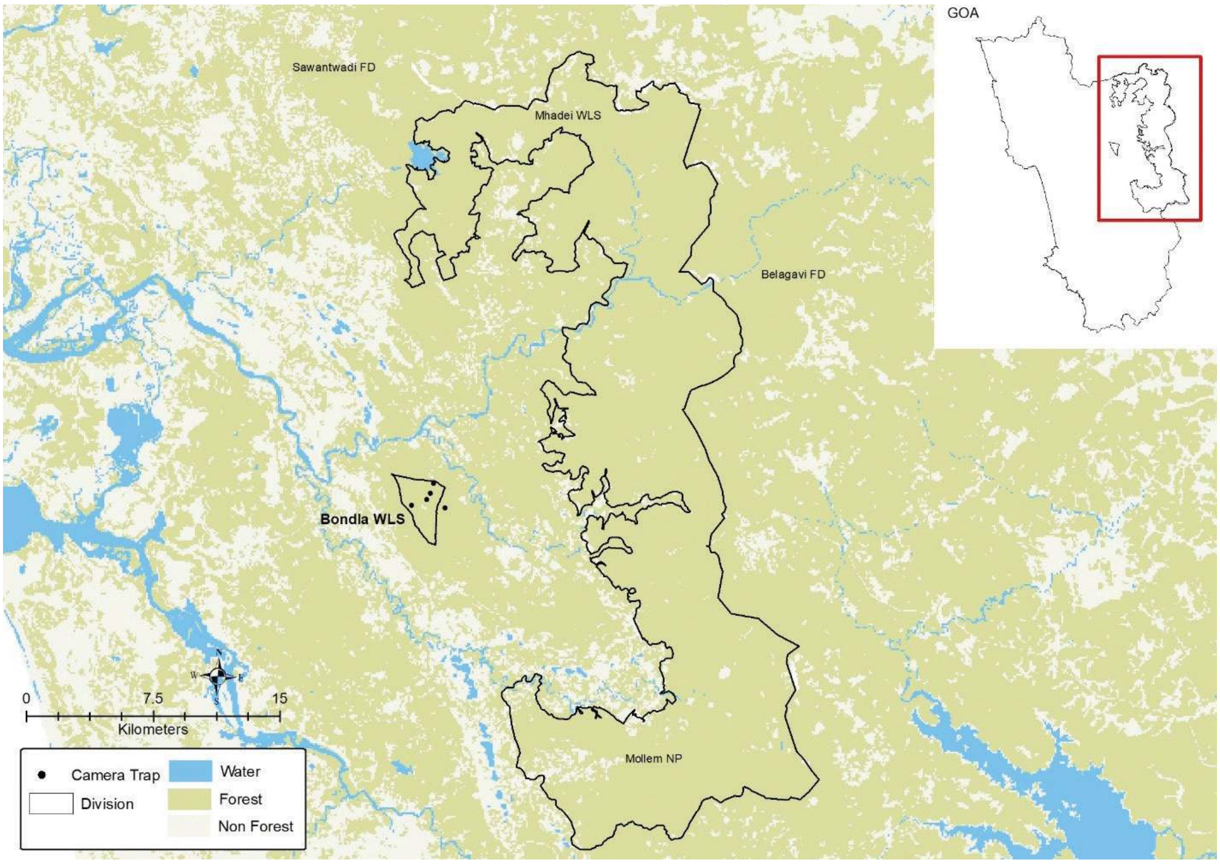


Table V.3. 3

Sampling details of camera trapping exercise in Bondla Wildlife Sanctuary, 2022

Sampling Details	Counts
Camera points	5
Trap nights (effort)	171
Number of tiger photos	0

Bondla WLS is small in size but plays important role as a part of large protected landscape. Safeguarding the connectivity with adjoining tiger populations is crucial in order to maintain the northern Western Ghats tiger population in a metapopulation framework.

COTIGAO WILDLIFE SANCTUARY

Cotigao Wildlife Sanctuary is located in the northern Western Ghats (South Goa Division) (Fig. V.3.4). The forest is contiguous with the northern Karnataka landscape cluster through Kali tiger reserve and Karwar forest division of Karnataka. Camera trapping was carried out for the first time by the forest department as a part of the All India Tiger Estimation, however, no tiger was photo-captured during the sampling period (Table V.3.4).

Figure V.3.4

Camera trap layout in Cotigao Wildlife Sanctuary, 2022

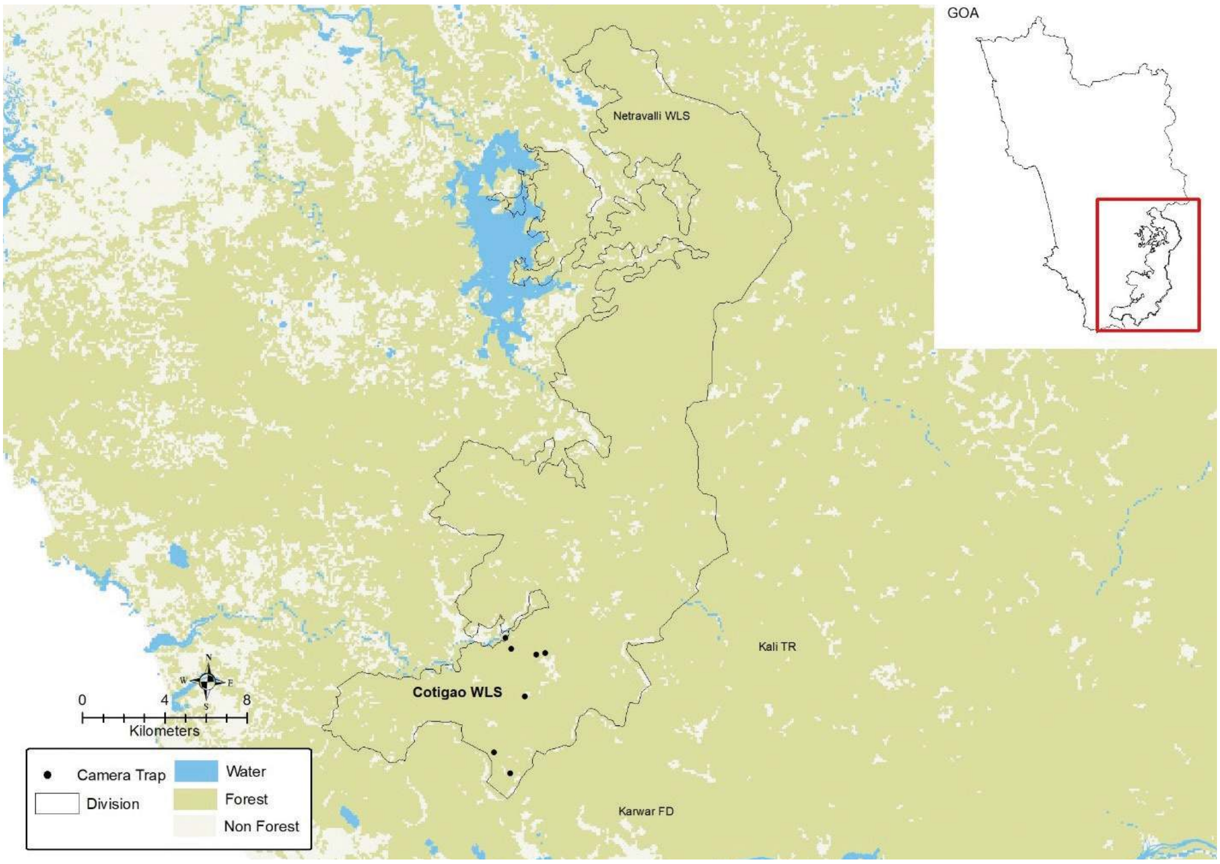


Table V.3. 4

Sampling details of camera trapping exercise in Cotigao Wildlife Sanctuary, 2022

Sampling Details	Counts
Camera points	7
Trap nights (effort)	81
Number of tiger photos	0

Although, Cotigao did not have any tiger recorded during the exercise, it is an important habitat for the movement of tigers and elephants from Kali tiger reserve, and can act as a sink population for the tigers in the greater Anshi-Dandeli landscape. Periodic systematic grid-based camera trapping should be encouraged in order to get the status of this important protected area. There is an urgent need of enhancing protection and ungulate augmentation.

NETRAVALI WILDLIFE SANCTUARY

Netravali Wildlife Sanctuary is located in the northern Western Ghats (South Goa Division) (Fig. V.3.5). River Netraveli and many small streams originate from here. The forest is contiguous with the northern Karnataka landscape cluster along with Cotigaon and forest blocks of Anshi-Dandeli. Camera trapping was carried out for the first time by the forest department as a part of the All India Tiger Estimation, however, no tiger was photo-captured during the sampling period (Table V.3.5).

Figure V.3.5

Camera trap layout in Netravali Wildlife Sanctuary, 2022

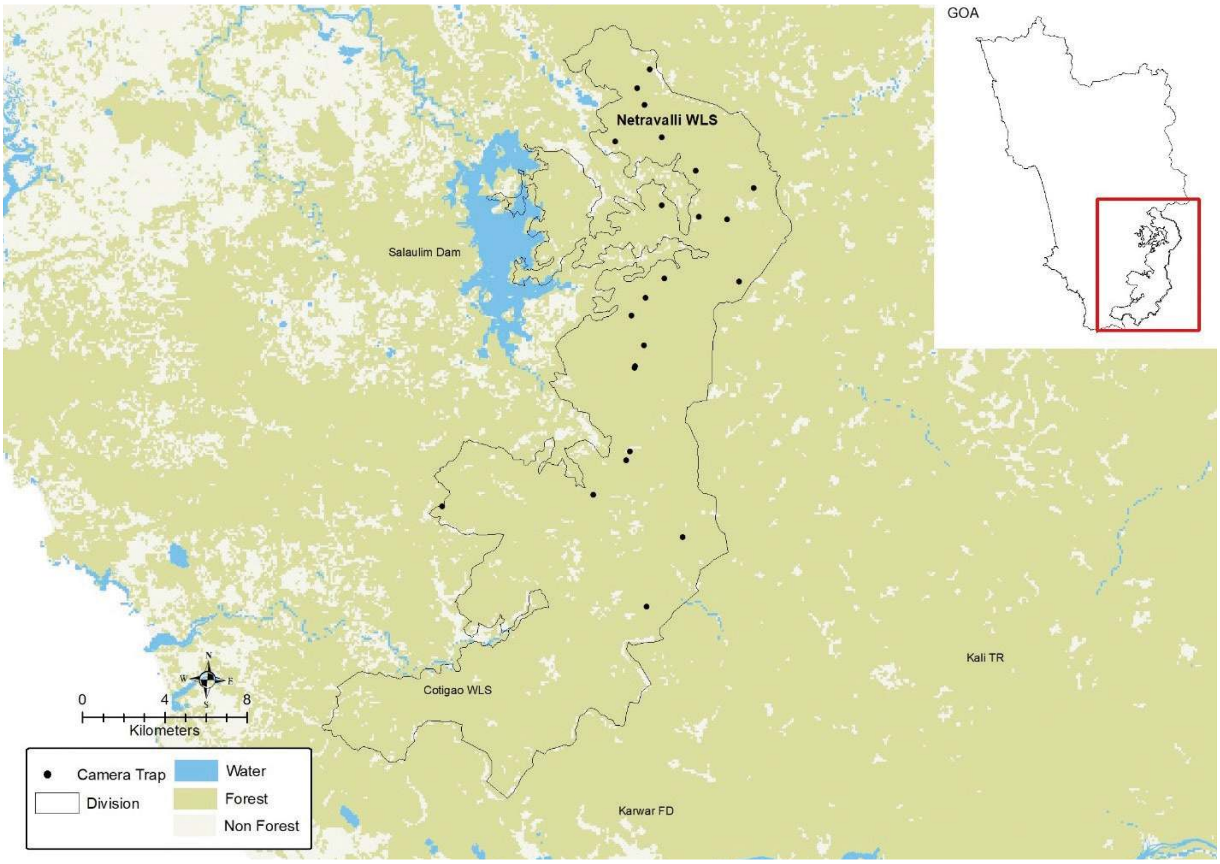


Table V.3. 5

Sampling details of camera trapping exercise in Netravali Wildlife Sanctuary, 2022

Sampling Details	Counts
Camera points	23
Trap nights (effort)	542
Number of tiger photos	0

Although no tiger was detected in Netravali during the exercise, the sanctuary acts as an important linkage within the Western Ghats landscape. Periodic systematic grid-based camera trapping should be encouraged in order to get the status of this important protected area. Ungulate augmentation and enhanced protection is a need of the hour.

KARNATAKA

KALI (ANSHI-DANDELI) TIGER RESERVE

Kali Tiger Reserve (1097 km^2) is situated in the northern part of the Western Ghats landscape. It is contiguous with the protected areas of Goa and the forest divisions of Haliyal, Karwar, Belagavi and Yellapura in Karnataka (Fig V.3.6). Camera trapping was carried out by the forest department, with an effort of 9920 trap-nights. Total of 208 tiger images were obtained from which 17 tiger individuals were identified and tiger density was estimated at 0.57 (SE 0.14) tiger per 100 km^2 (Table V.3.6). The detection corrected sex ratio for tigers in Kali TR was nearly 2.5 males:1female (Table V.3.6). No young tiger was photo-captured.

Figure V.3.6

Camera trap layout and spatial tiger density in Kali Tiger Reserve, 2022

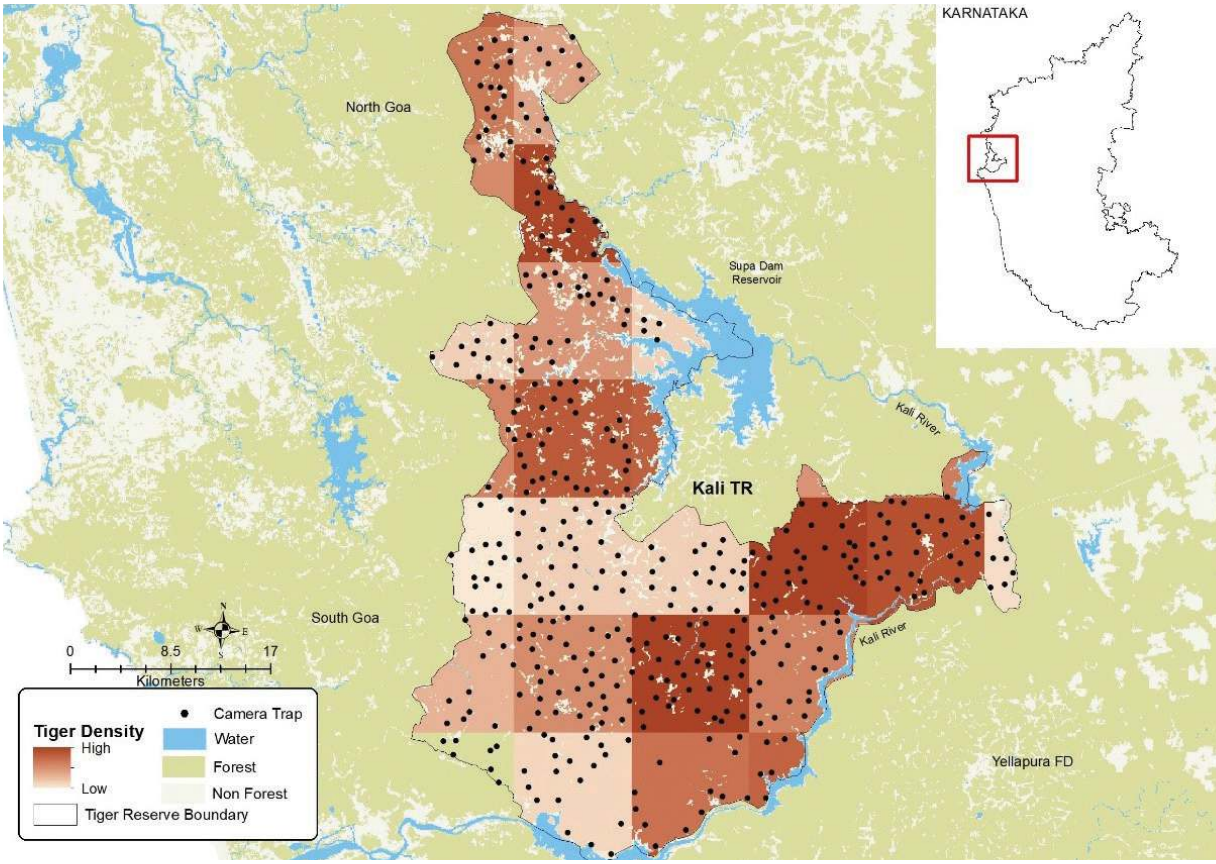


Table V.3. 6

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Kali Tiger Reserve, 2022

Variables	Estimate
Model space (km^2)	5091
Camera points	399
Trap nights (effort)	9920
Unique tigers captured	17
Model	Pmix (sex) g0(.) σ(.)
$\hat{D}$ SECR (per 100 km^2)	0.57 (0.14)
σ (SE) (km)	4.9(0.4)
g0 (SE)	0.01(0.001)
Pmix Female (SE)	0.29 (0.12)
Pmix Male (SE)	0.71 (0.12)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

In 2018, four individual tigers were photo-captured in Kali TR. The tiger numbers have increased in recent years in Kali TR. The TR has potential for becoming a source tiger population in the northern Western Ghats landscape. Management actions in terms of incentivized voluntary resettlement of villages from TR, stringent protection regime, mitigation of developmental projects and minimizing human-wildlife conflict in and around the TR are essential to achieve this. The grasslands need to be maintained as such and any kind of tree plantation activities in grasslands should be discouraged.

BANDIPUR TIGER RESERVE

Bandipur Tiger Reserve (1456 km^2) is situated in the Nilgiri landscape cluster in Karnataka (Fig. V.3.7) and one of the first tiger reserves in India declared in 1973, completing 50 years in 2023. It is amongst the first tiger reserves which recorded impressive tiger growth and is an example of good management. Bandipur TR, along with Nagarahole, Mudumalai, Sathyamangalam, BRT TRs and adjoining forested areas, constitute one of the largest tiger populations in the world. Camera trapping was carried out by the forest department, with an effort of 19407 trap-nights. Total of 3761 tiger images were obtained from which 150 tiger individuals were identified and tiger density was estimated at 9.50 (SE 0.77) tiger per 100 km^2 (Table V.3.7). The detection corrected sex ratio for tigers in Bandipur was nearly 1 male: 2 females (Table V.3.7). A total of 11 young tigers were photo-captured.

Figure V.3.7

Camera trap layout and spatial tiger density in Bandipur Tiger Reserve, 2022

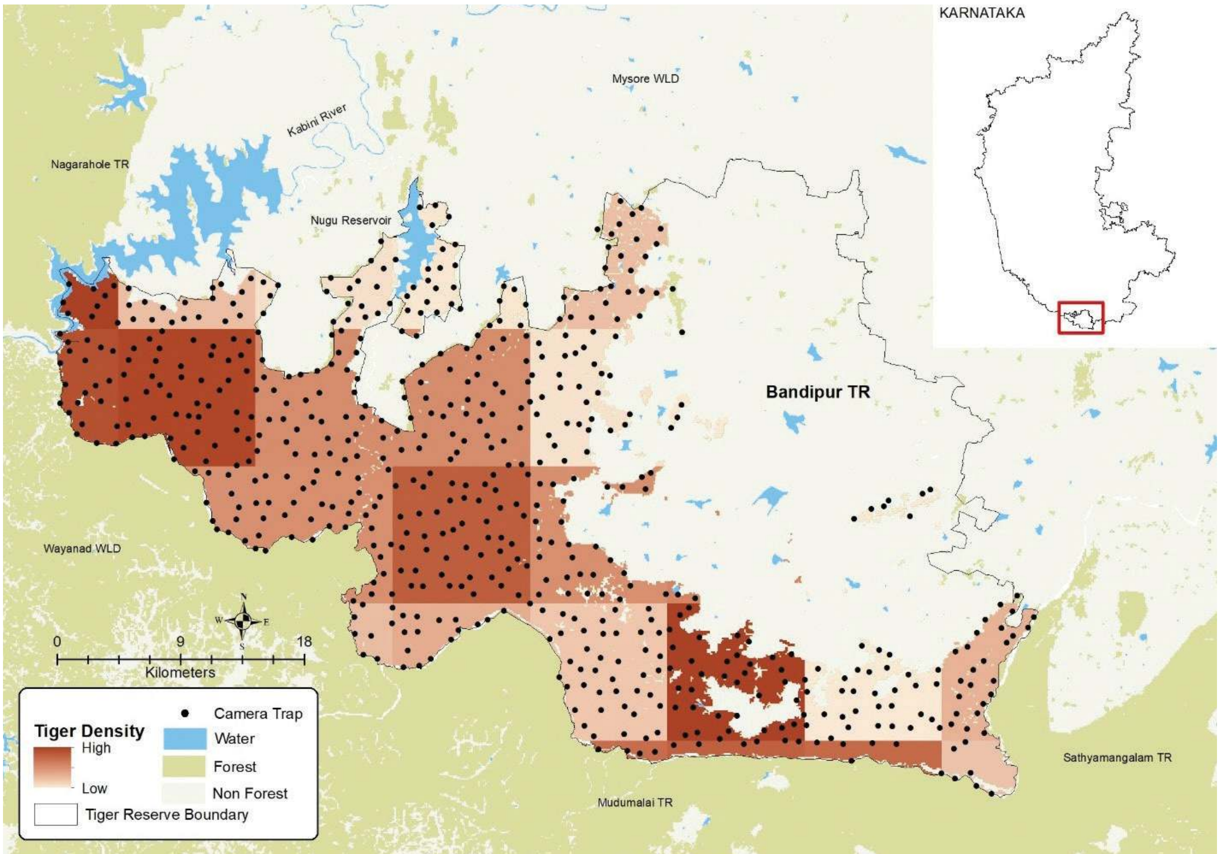


Table V.3.7

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Bandipur Tiger Reserve, 2022

Variables	Estimate
Model space (km^2)	2009
Camera points	612
Trap nights (effort)	19407
Unique tigers captured	150
Model	Pmix (sex) g0(sex) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	9.50(0.77)
σ Female (SE) (km)	1.75(0.03)
σ Male (SE) (km)	3 (0.06)
g0 Female (SE)	0.04(0.002)
g0 Male (SE)	0.03(0.001)
Pmix Female (SE)	0.61(0.04)
Pmix Male (SE)	0.39(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Bandipur TR harbors one of the highest density of tigers most likely attributed to high densities of prey, inviolate cores, good connectivity with nearby PAs, and effective management practices by the Karnataka Forest department. However, major conservation challenges for Bandipur include i) proliferation of several invasive species which are degrading the tiger habitats, ii) increasing fire incidents and iii) escalating tiger-human conflicts at the peripheral areas; which require immediate management attentions.

BHADRA TIGER RESERVE

Bhadra Tiger Reserve (1072 km^2) is located in the northern Western Ghats landscape (Karnataka) and is connected with Shimoga, Bhadravathi, Koppa and Chikmagalur forest divisions (Fig V.3.8). Camera trapping was carried out by the forest department, with an effort of 10808 trap-nights. Total of 495 tiger images were obtained from which 28 tiger individuals were identified and tiger density was estimated at 2.34 (SE 0.44) tiger per 100 km^2 (Table 8). The detection corrected sex ratio of tigers in Bhadra was nearly 1 male:1 female (Table V.3.8). A total of 3 young tigers were photo-captured.

Figure V.3.8

Camera trap layout and spatial tiger density in Bhadra Tiger Reserve, 2022

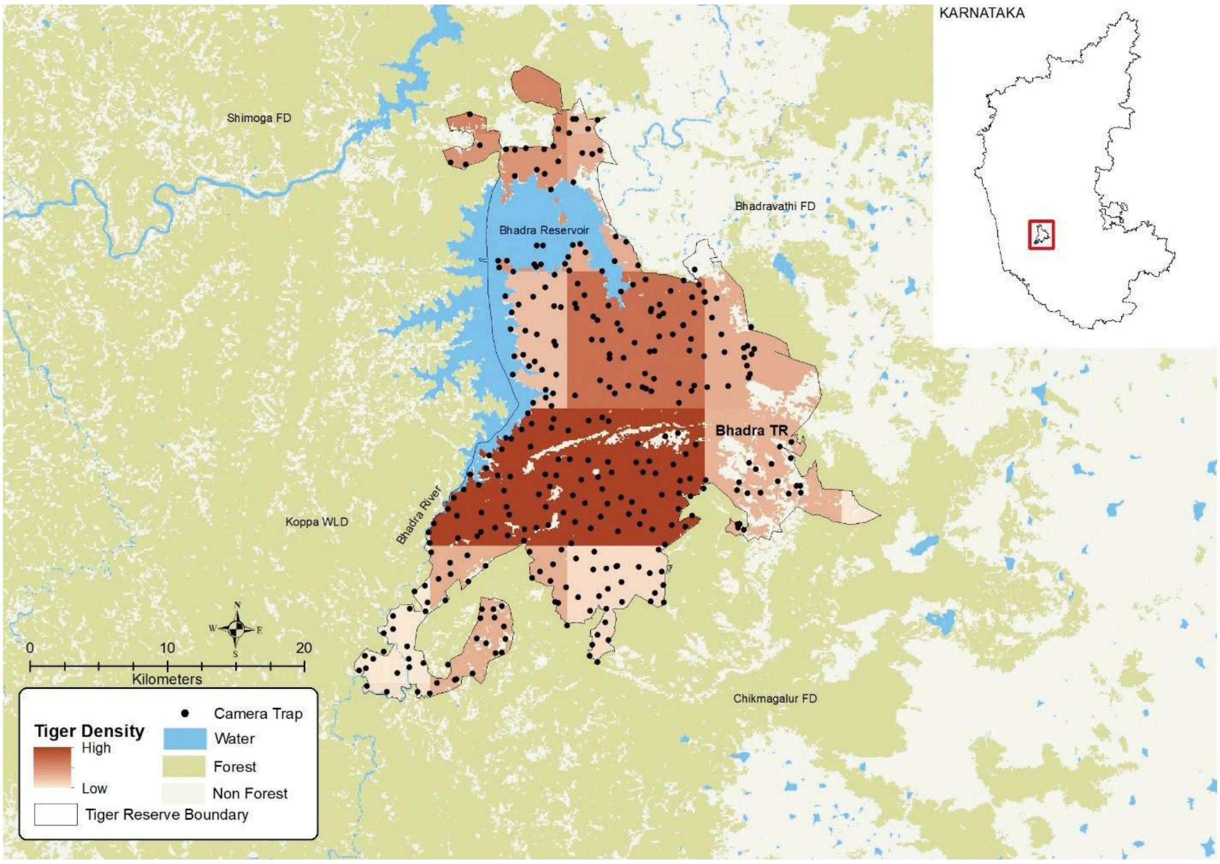


Table V.3. 8

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Bhadra Tiger Reserve, 2022

Variables	Estimate
Model space (km^2)	1866
Camera points	332
Trap nights (effort)	10808
Unique tigers captured	28
Model	Pmix (sex) g0(sex) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	2.34 (0.44)
σ Female (SE) (km)	2.1(0.11)
σ Male (SE) (km)	2.9(0.15)
g0 Female (SE)	0.03(0.004)
g0 Male (SE)	0.02(0.002)
Pmix Female (SE)	0.57(0.11)
Pmix Male (SE)	0.43(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

The tiger population in Bhadra TR increased over the years and expanded into areas adjoining landscape, while the tiger density within the TR remains constant. Bhadra landscape harbors low to medium density tiger population. However, the reserve has great potential to support more tigers and act as a source population for the northern Karnataka landscape cluster. This can be achieved by active management practices, habitat management and strengthening connectivity in the landscape.

BILIGIRI RANGANATHASWAMY TEMPLE (BRT HILLS) TIGER RESERVE

BRT Hills Tiger Reserve (574.82 km^2) is located in the Nilgiri landscape cluster (Karnataka). The reserve is connected with Bandipur tiger reserve, MM Hills WLS and Mysore Forest division of Karnataka (Fig V.3.9). Camera trapping was carried out by the forest department, with an effort of 9028 trap-nights. Total of 637 tiger images were obtained from which 37 tiger individuals were identified and tiger density was estimated at 4.18 (SE 0.69) tiger per 100 km^2 (Table 9). The detection corrected sex ratio of tigers in BRT Hills was nearly 1 male :2 females (Table V.3.9). No young tigers were photo-captured.

Figure V.3.9

Camera trap layout and spatial tiger density in BRT Hills Tiger Reserve, 2022

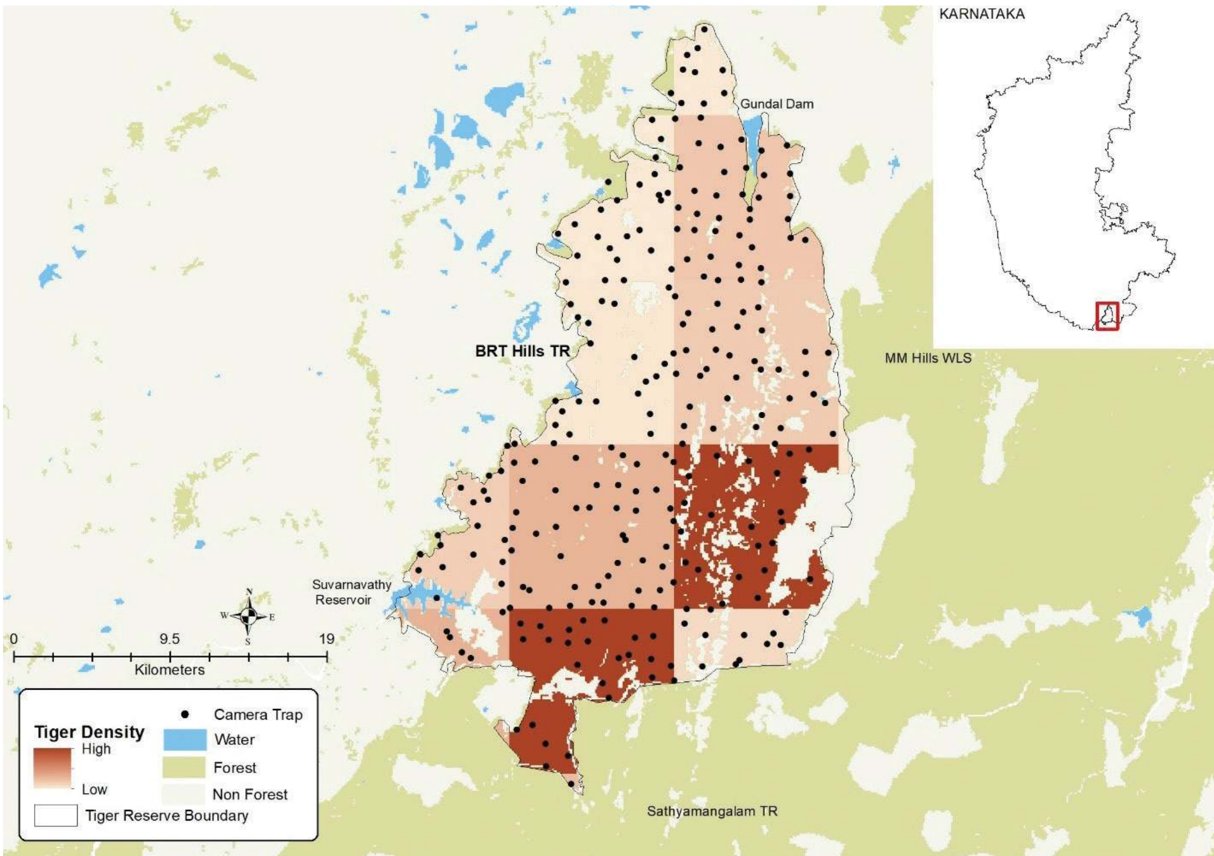


Table V.3.9

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for BRT Hills Tiger Reserve, 2022

Variables	Estimate
Model space (km^2)	1445
Camera points	260
Trap nights (effort)	9028
Unique tigers captured	37
Model	Pmix (sex) g0(sex) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	4.18(0.69)
σ Female (SE) (km)	2.3(0.1)
σ Male (SE) (km)	4.3(0.2)
g0 Female (SE)	0.02(0.003)
g0 Male (SE)	0.02(0.002)
Pmix Female (SE)	0.69(0.07)
Pmix Male (SE)	0.31(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

The tiger number has decreased from past two cycles in BRT Hills, which needs to be investigated in order to take pertinent measures [11.29 (1.32 SE) in 2014 and 4.96 (0.71 SE) in 2018, Jhala et. al., 2015 and 2020]. The presence of human settlements inside the TR is a major concern, which in turn degraded the habitats. Moreover, proliferation of the invasive species need to be appropriately addressed. BRT Hills harbours huge potential for expanding tiger populations in the north-east region of Nilgiri clusters (MM Hills to Cauvery WLS to Bannerghatta NP).

NAGARAHOLE TIGER RESERVE

Nagarahole Tiger Reserve (1205.76 km^2) is located in the Nilgiri landscape cluster of Western Ghats (Karnataka), and constitutes the single largest tiger population in the world along with Bandipur, Wayanad, Mudumalai, Sathyamangalam, BRT Hills and adjoining forested areas (Fig. V.3.10). Camera trapping was carried out by the forest department, with an effort of 17859 trap-nights. Total of 2933 tiger images were obtained from which 140 tiger individuals were identified and tiger density was estimated at 11.15 (SE 0.95) tiger per 100 km^2 (Table 10). The detection corrected sex ratio of tigers in Nagarahole was nearly 1 male:1 female (Table 10). A total of 1 young tiger were photo-captured.

Figure V.3.10

Camera trap layout and spatial tiger density in Nagarahole Tiger Reserve, 2022

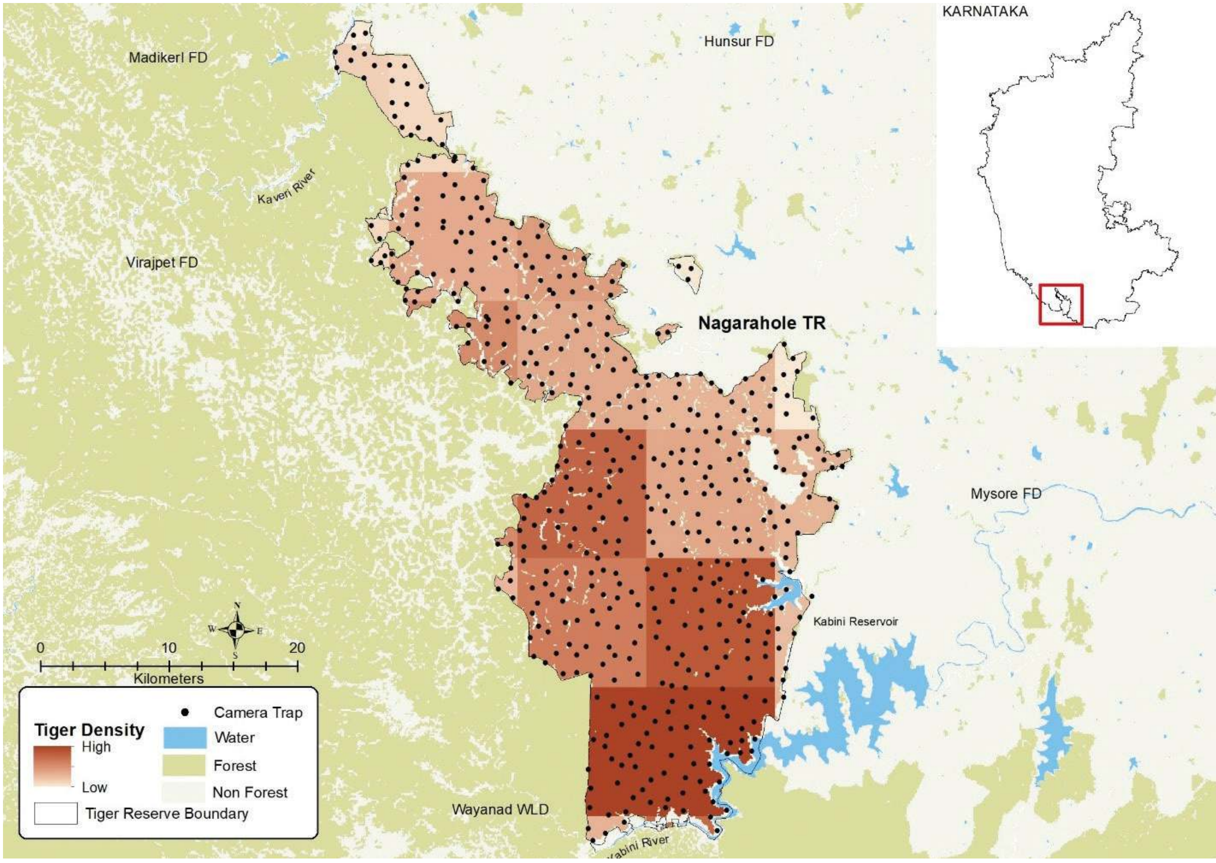


Table V.3. 10

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Nagarahole Tiger Reserve, 2022

Variables	Estimate
Model space (km^2)	1649
Camera points	489
Trap nights (effort)	17859
Unique tigers captured	140
Model	Pmix (sex) g0(sex) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	11.15 (0.95)
σ Female (SE) (km)	1.3(0.03)
σ Male (SE) (km)	2.3(0.05)
g0 Female (SE)	0.06(0.004)
g0 Male (SE)	0.03(0.002)
Pmix Female (SE)	0. 55 (0.05)
Pmix Male (SE)	0.45(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

The tiger density in Nagarahole TR remains constant over the cycles of All India Tiger Estimation [11.09 (0.91 SE) in 2014 and 11.82 (1.05 SE) in 2018, Jhala *et. al.,* 2015 and 2020] and continues to be one of the highest density of tigers in India. The reserve is threatened due to presence of tribal settlements inside the core area, continuous increase of invasive species and passage of state highways (problem of traffic and littering) through the critical wildlife habitats. Focused mitigation measures can help in the reinforcement of corridors for the dispersal and establishment of meta-population of tigers in the adjoining forest divisions.

BALLARI FOREST DIVISION

Ballari Forest Division is located in the northern Karnataka landscape cluster. It is connected with Raichur, Koppal, Haveri, Gadag, Davanagere and Chitradurga forest divisions of Karnataka (Fig V.3.11). Camera trapping was carried out by the forest department with an effort of 970 trap-nights (Table V.3.11). During the camera trapping exercise, no tiger was photo-captured.

Figure V.3.11

Camera trap layout in Ballari Forest Division, 2022

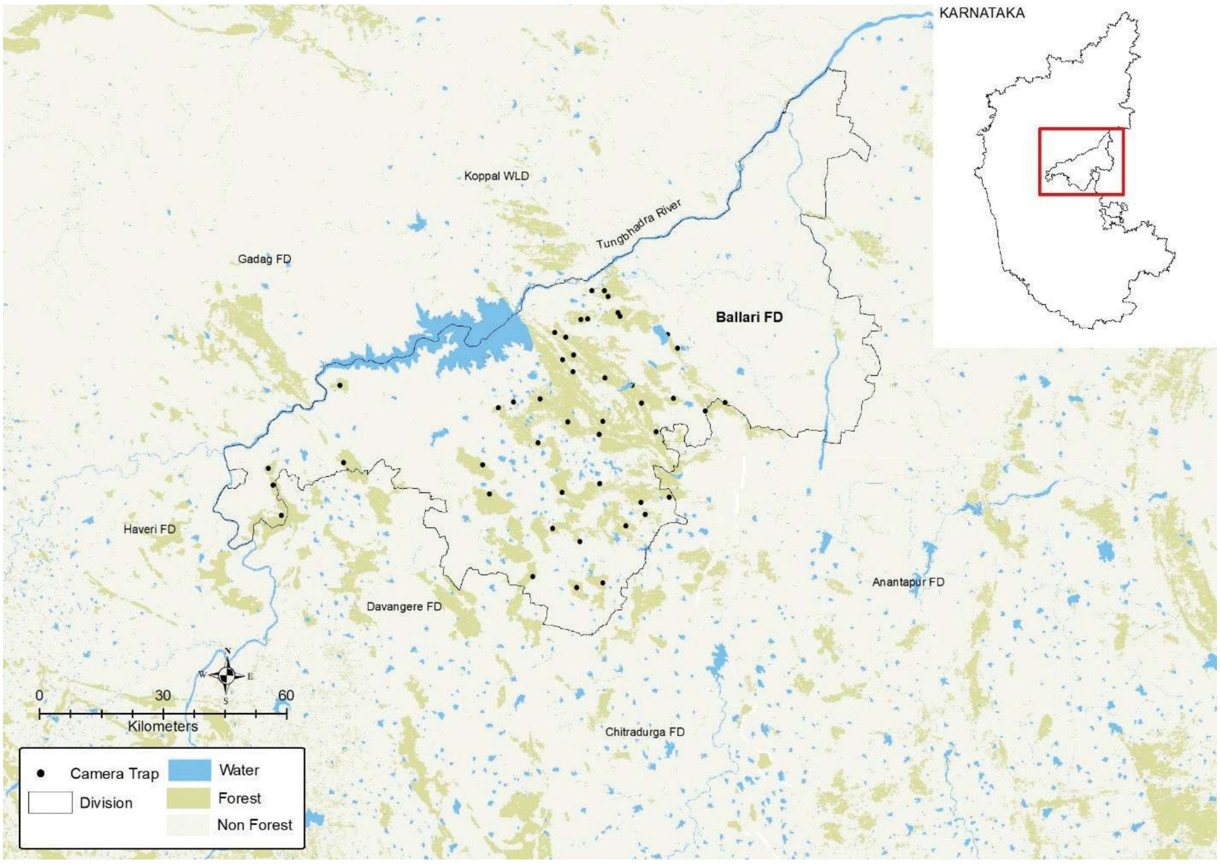


Table V.3.11

Sampling details of camera trapping exercise in Ballari Forest Division, 2022

Sampling Details	Counts
Camera points	46
Trap nights (effort)	970
Number of tiger photos	0

Ballari Forest Division is mosaic of small forest patches interspersed between agricultural fields, human habitations and traversed by a network of state and national highways. The division is rich in iron ore, making it a mining hub. In 2012, a blanket ban on mining operations was imposed by the Supreme Court of India. However, many legal mines are still operational in the division. The division can act as a functional tiger sink habitat if proper connectivity is established and maintained with the source populations of the landscape.

BANGALORE RURAL DIVISION

Bangalore Rural Division is located in the northern Karnataka landscape cluster. It is connected to Tumkur, Chikkaballapura, Kolar, Bangalore Urban and Ramanagara forest divisions of Karnataka (Fig V.3.12). Camera trapping was carried out by the forest department, with an effort of 1127 trap-nights (Table V.3.12). During the camera trapping exercise, no tiger was photo-captured.

Figure V.3.12

Camera trap layout in Bangalore Rural Division, 2022

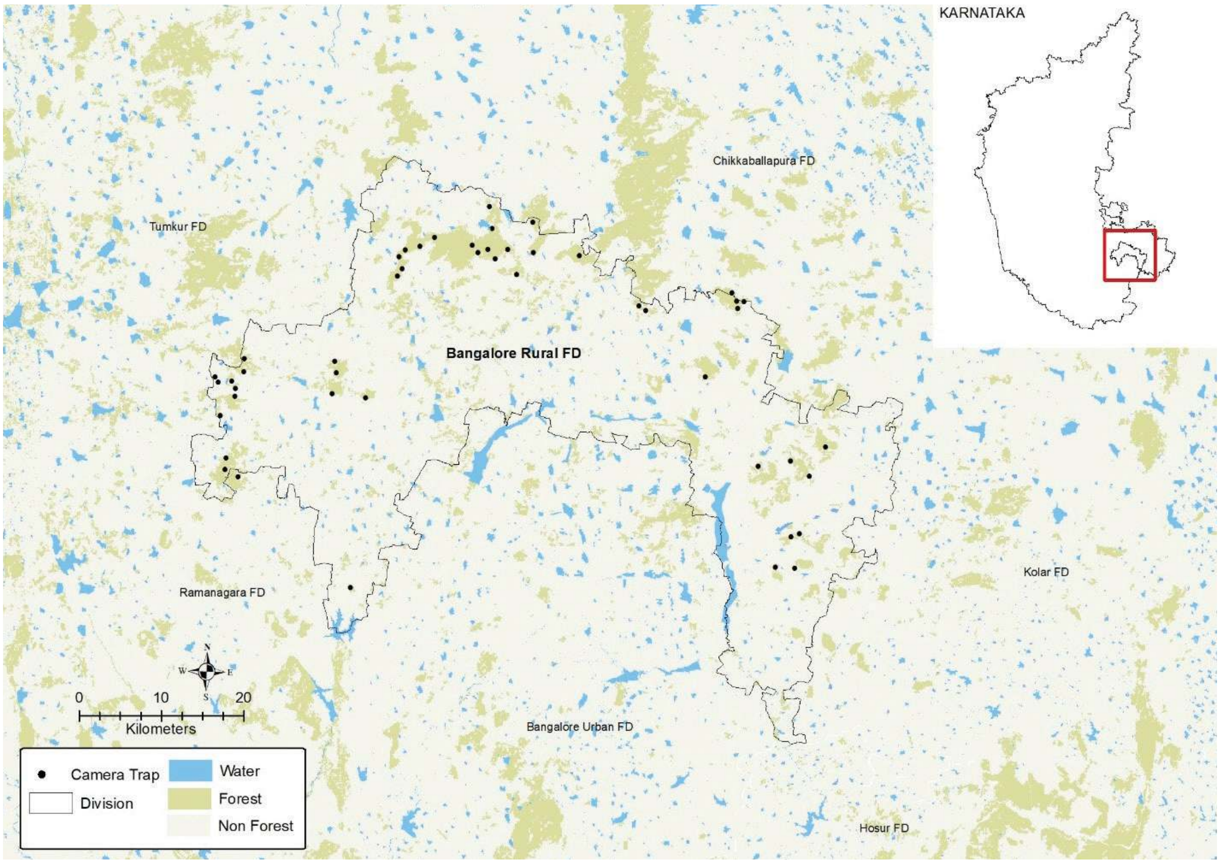


Table V.3.12

Sampling details of camera trapping exercise in Bangalore Rural Division, 2022

Sampling Details	Counts
Camera points	48
Trap nights (effort)	1127
Number of tiger photos	0

Bangalore Rural division is mosaic of small forest patches interspersed between agricultural fields, human habitations and traversed by a web of state and national highways. The metropolitan city of Bengaluru is present adjoining the division, which further adds to the disturbance. The division can act as a functional tiger sink habitat if proper connectivity is established and maintained with the source populations of the landscape.

BANNERGHATTA NATIONAL PARK

Bannerghatta NP is located in the northern Karnataka landscape cluster adjoining Ramanagara, Bangalore Urban and Hosur divisions of Karnataka (Fig V.3.13). Camera trapping was carried out by the forest department, with an effort of 1951 trap-nights. Total of 55 tiger images were obtained from which 2 tiger individuals were identified (Table V.3.13). No young tiger was photo-captured.

Figure V.3.13

Camera trap layout and tiger presence in Bannerghatta National Park, 2022

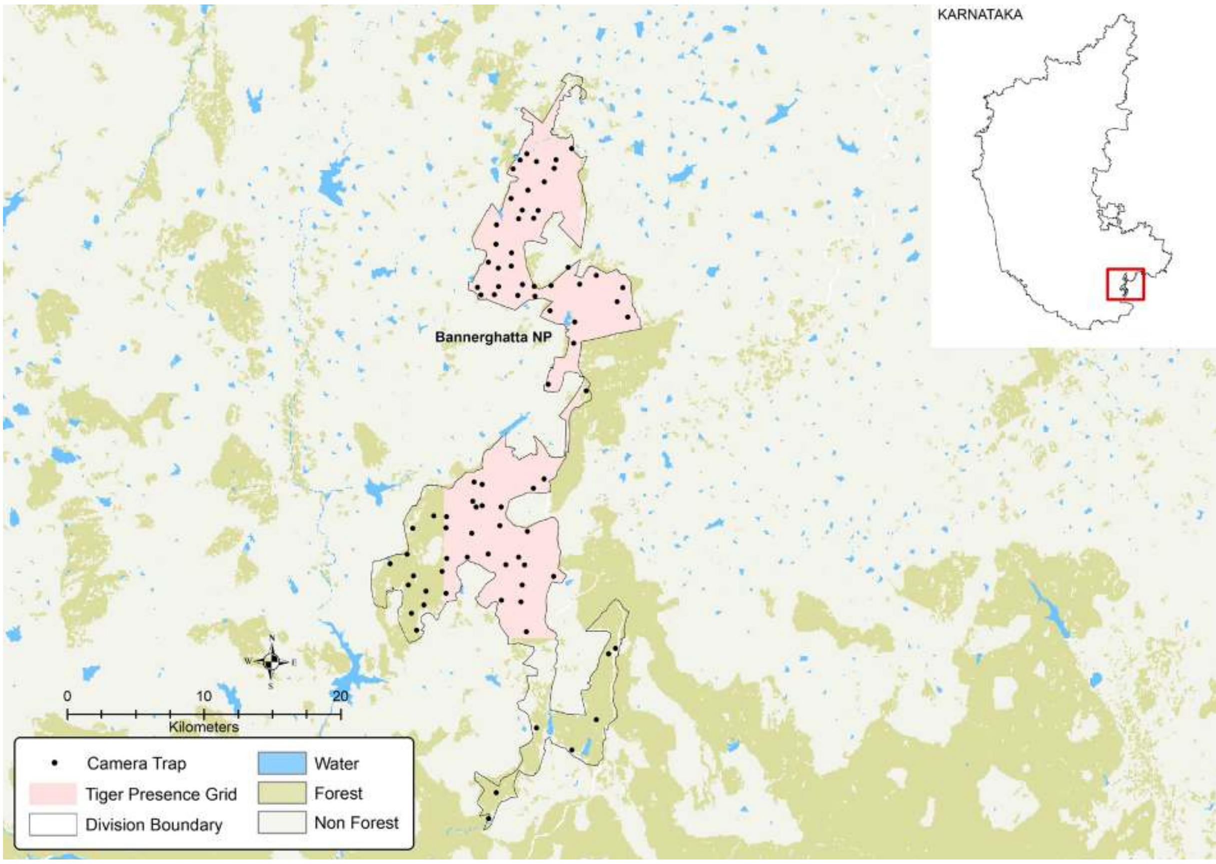


Table V.3.13

Sampling details of camera trapping exercise in Bannerghatta National Park, 2022

Sampling Details	Counts
Camera points	83
Trap nights (effort)	1951
Number of tiger photos	55
Unique tigers captured	2

Even though only two tigers were detected, the detections validate the importance of Bannerghatta National Park as a stepping stone patch for maintaining the meta-population of tigers in this landscape. However, due to its proximity to the city of Bengaluru, it faces threat due to high tourism. The linearity of the park has made it more susceptible to disturbances and has also led to the increase in human-wildlife conflict in the area. Therefore, proper protection and management is required to make the park more conducive to wildlife movement.

BELAGAVI FOREST DIVISION

Belagavi Forest Division is located in the northern Karnataka landscape cluster adjoining Kali tiger reserve and the protected areas of Goa (Fig V.3.14). Camera trapping was carried out by the forest department, with an effort of 2721 trap-nights. Total of 45 tiger images were obtained from which 5 tiger individuals were identified (Table V.3.14). Single young tiger was photo-captured.

Figure V.3.14

Camera trap layout and tiger presence in Belagavi Forest Division, 2022

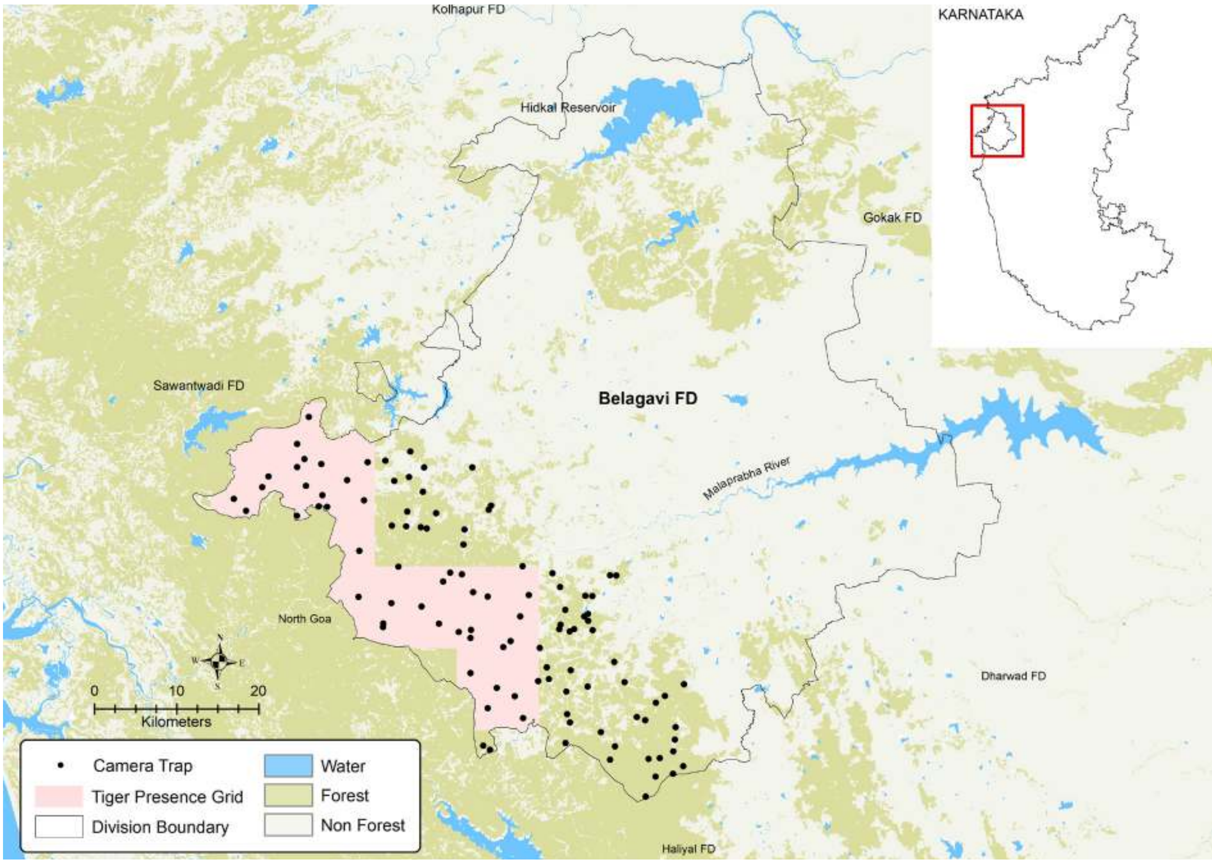


Table V.3. 14

Sampling details of camera trapping exercise in Belagavi Forest Division, 2022

Sampling Details	Counts
Camera points	107
Trap nights (effort)	2721
Number of tiger photos	45
Unique tigers captured	5

Belagavi Forest Division forms an important habitat corridor for tigers dispersing between Kali Tiger Reserve and protected areas of Goa and any developmental project in the area, such as the expansion of national highway 748AA, should be appropriately mitigated.

BHADRAVATHI FOREST DIVISION

Bhadravathi Forest Division is situated in the northern Karnataka landscape cluster. It is connected to the Bhadra tiger reserve and Shivamogga, Davanagere, Chitradurga and Chikmagalur forest divisions of Karnataka (Fig V.3.15). Camera trapping was carried out by the forest department, with an effort of 2759 trap-nights. Total of 23 tiger images were obtained from which 5 tiger individuals were identified and tiger density was estimated at 0.42 (SE 0.2) tiger per 100 km^2 (Table V.3.15). The detection corrected sex ratio of tigers in Bhadravathi was 1 male: 2 females (Table V.3.15). No young tiger was photo-captured.

Figure V.3.15

Camera trap layout and spatial tiger density in Bhadravathi Forest Division, 2022

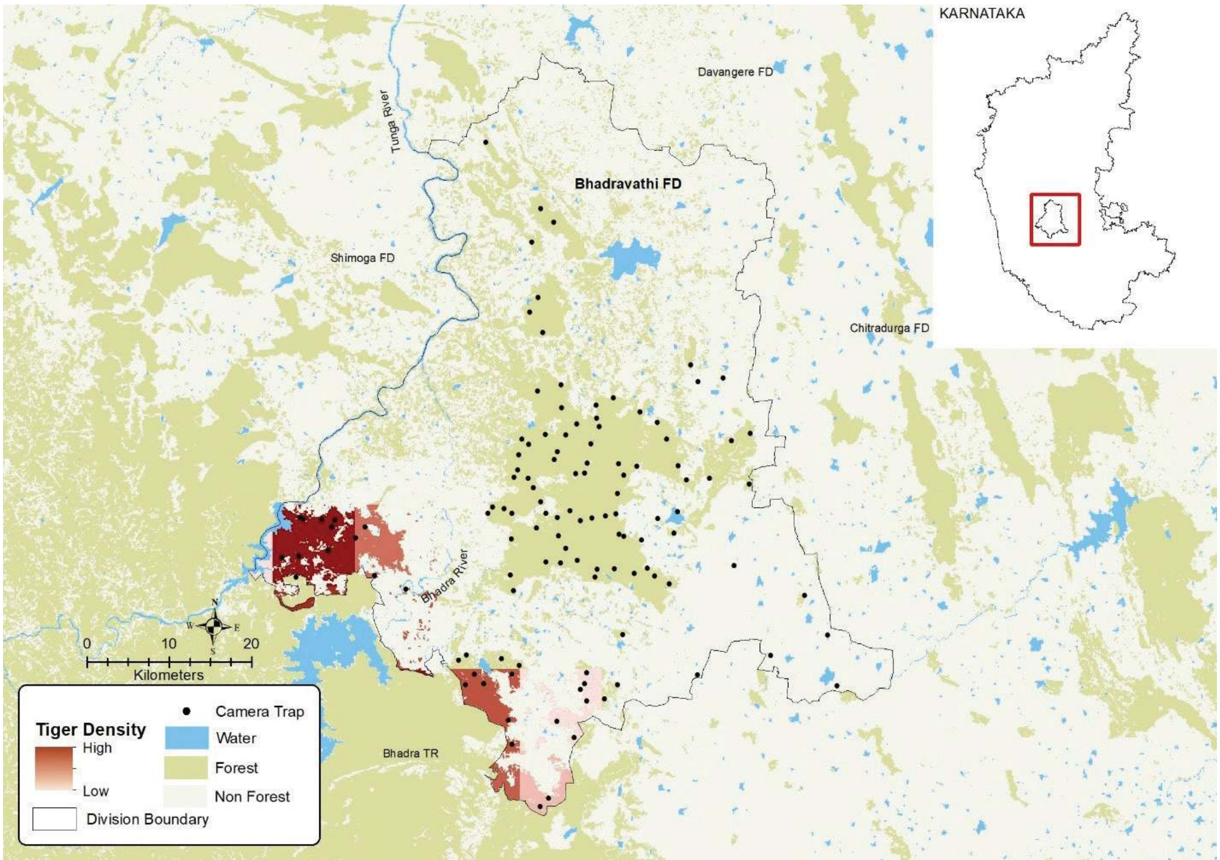


Table V.3. 15

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Bhadravathi Forest Division, 2022

Variables	Estimate
Model space (km^2)	1512
Camera points	120
Trap nights (effort)	2759
Unique tigers captured	5
Model	Pmix (sex)g0(.) σ(.)
$\hat{D}$ SECR (per 100 km^2)	0.42 (0.2)
σ (SE) (km)	3.3(0.7)
g0 (SE)	0.06(0.03)
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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

The tiger density of Bhadravathi Forest Division has been very low since the previous cycles (4 unique tiger captures in 2018). The forests are mostly surrounded by human habitations and agricultural fields, and dissected by several national and state highways. However, the forests serve as sink habitat for dispersing tigers from the adjacent Bhadra tiger reserve.

CAUVERY WILDLIFE SANCTUARY

Cauvery Wildlife Sanctuary is a part of the Nilgiri landscape cluster, adjoining the forests of MM Hills, Erode and Ramanagara and Mysore Forest divisions of Karnataka (Fig V.3.16). Tamilnadu has declared Cauvery South Sanctuary in the adjoining forest of the state. Camera trapping was carried out by the forest department, with an effort of 10656 trap-nights. Total of 10 tiger images were obtained from which 1 tiger individual was identified (Table V.3.16).

Figure V.3.16

Camera trap layout and tiger presence in Cauvery Wildlife Sanctuary, 2022

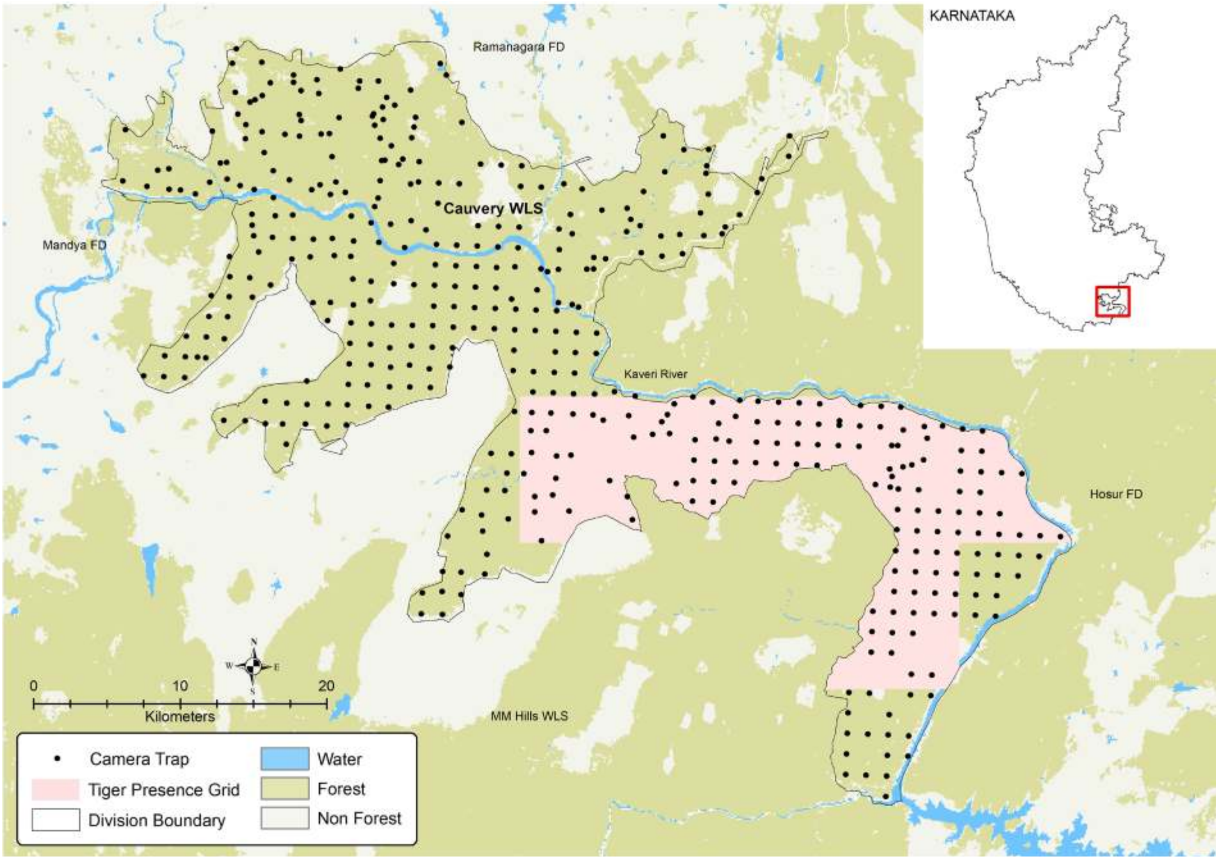


Table V.3. 16

Sampling details of camera trapping exercise in Cauvery Wildlife Sanctuary, 2022

Sampling Details	Counts
Camera points	448
Trap nights (effort)	10656
Number of tiger photos	10
Unique tigers captured	1

Cauvery WLS is an important sink habitat for maintaining the meta-population dynamics of tigers in the landscape. The proposed Mekedatu dam, which could inundate about 50 km^2 of forest, could pose as a major threat for the sanctuary. Mekedatu connects the Biligiri Ranganathaswamy Temple (BRT) Tiger Reserve and the Male Mahadeshwara Hills (MM Hills) wildlife division and is an important connectivity. Any large scale dam will adversely impact the aquatic fauna of Kaveri river. There is a need for protection and ungulate augmentation in this area.

CHIKMAGALUR FOREST DIVISION

Chikmagalur Forest Division is located in the northern Karnataka landscape cluster, contiguous with Bhadra Tiger Reserve and Koppa, Mangalore, Hassan, Tumkur, Chitradurga and Bhadravathi forest divisions of Karnataka (Fig V.3.17). Camera trapping was carried out by the forest department, with an effort of 1068 trap-nights. Total of 30 tiger images were obtained from which 7 tiger individuals were identified and tiger density was estimated at 1.73 (SE 0.9) tiger per 100 km^2 (Table V.3.17). The detection corrected sex ratio of tigers in Chikmagalur was nearly 1 male: 4 females (Table V.3.17). No young tiger was photo-captured.

Figure V.3.17

Camera trap layout and spatial tiger density in Chikmagalur Forest Division, 2022

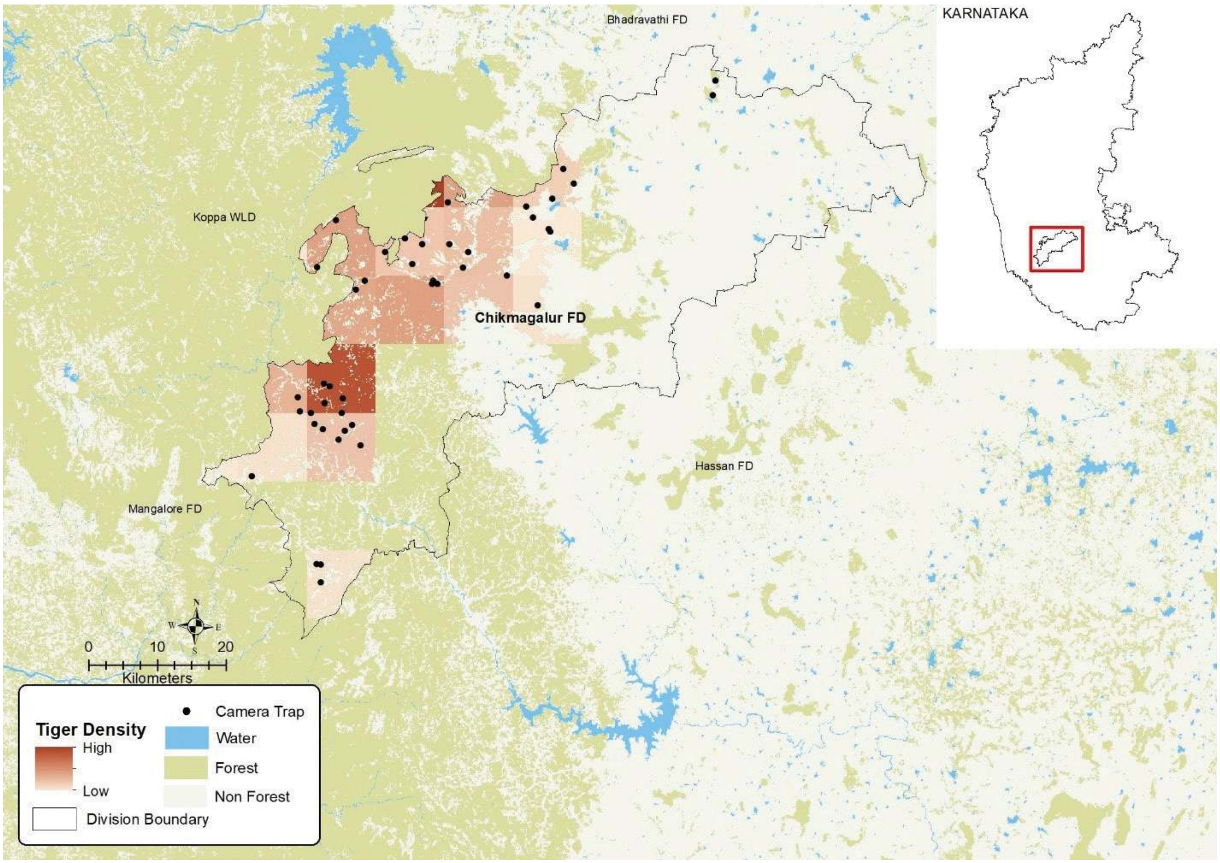


Table V.3. 17

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Chikmagalur Forest Division, 2022

Variables	Estimate
Model space (km^2)	1261
Camera points	44
Trap nights (effort)	1068
Unique tigers captured	7
Model	Pmix (sex)g0(.) σ(.)
$\hat{D}$ SECR (per 100 km^2)	1.73 (0.9)
σ (SE) (km)	1.8(0.5)
g0 (SE)	0.03(0.02)
Pmix Female (SE)	0.8(0.18)
Pmix Male (SE)	0.2(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

The tiger density of Chikmagalur Forest Division was low. However, the division acts as a vital linkage between the northern Karnataka and the Nilgiri landscape clusters. With proper protection, control on enchroachment and management of the forest and the wildlife corridors, Chikmagalur can accommodate a sizeable population of tigers. It is an important stepping stone in movement of wildlife.

DAVANAGERE FOREST DIVISION

Davanagere Forest Division is a part of the northern Karnataka landscape cluster. It shares its boundaries with the forest divisions of Haveri, Sagara, Shivamogga, Bhadravathi, Chitradurga and Ballari (Fig V.3.18). Camera trapping was carried out by the forest department, with an effort of 158 trap-nights (Table V.3.18). During the camera trapping exercise, no tiger was photo-captured.

Figure V.3.18

Camera trap layout in Davanagere Forest Division, 2022

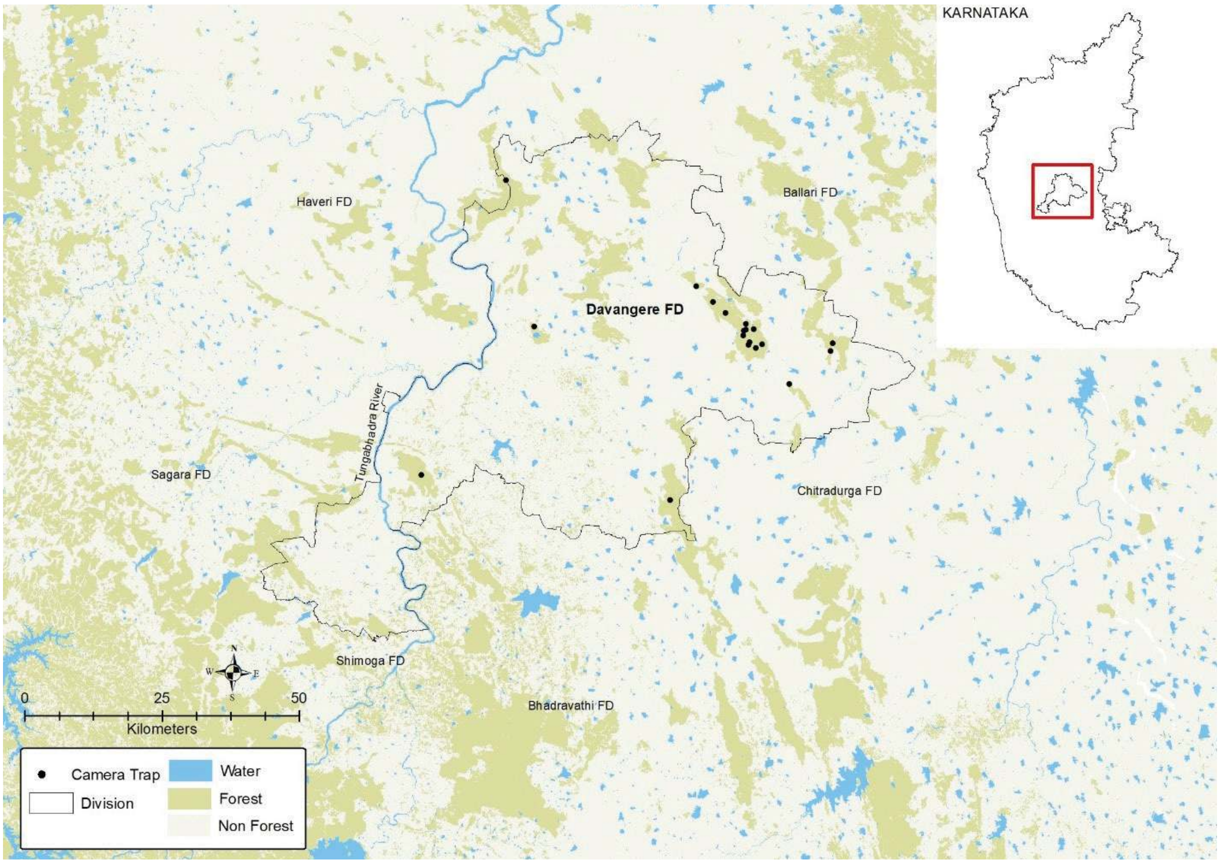


Table V.3. 18

Sampling details of camera trapping exercise in Davanagere Forest Division, 2022

Sampling Details	Counts
Camera points	19
Trap nights (effort)	158
Number of tiger photos	0

Davanagere Forest Division is mosaic of small forest patches interspersed between agricultural fields, human habitations and traversed by a web of state and national highways. The division can act as a functional tiger sink habitat if proper connectivity is established and maintained with the source populations of the landscape.

DHARWAD FOREST DIVISION

Dharwad Forest Division is situated in the northern Karnataka landscape cluster. It shares its boundary with Haveri, Yellapura, Haliyal, Belagavi, Gokak and Gadag forest divisions of Karnataka (Fig V.3.19). Camera trapping was carried out by the forest department, where no tiger photo was obtained with an effort of 605 trap-nights (Table V.3.19).

Figure V.3.19

Camera trap layout in Dharwad Forest Division, 2022

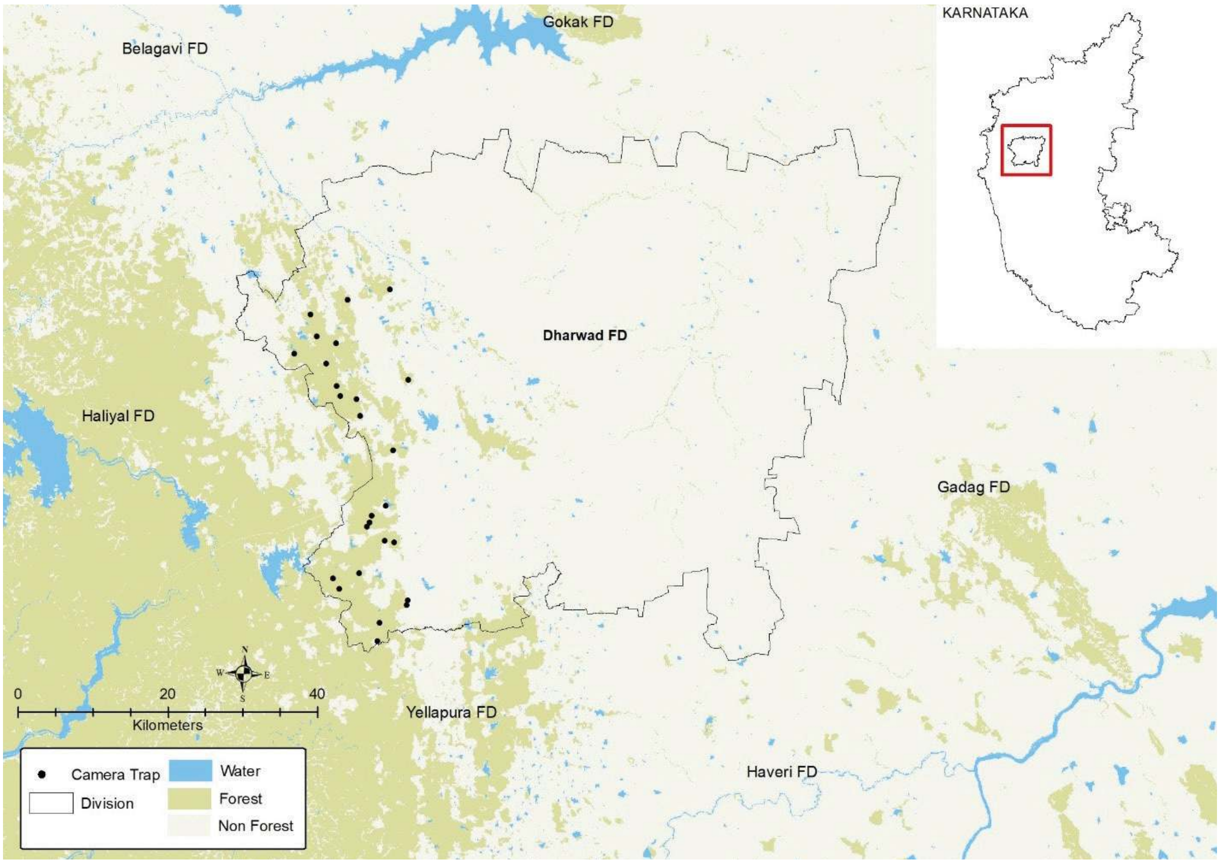


Table V.3. 19

Sampling details of camera trapping exercise in Dharwad Forest Division, 2022

Sampling Details	Counts
Camera points	26
Trap nights (effort)	605
Number of tiger photos	0

Dharwad Forest Division is mosaic of small forest patches interspersed between agricultural fields, human habitations and traversed by a web of state and national highways. However, it acts as a connecting link between Anshi-Dandeli and Bhadra tiger reserves. The proposed Hubli-Ankola railway line would severely fragment this linkage. Therefore, it is important to examine the feasibility of the railway line in the context of tiger conservation objectives and appropriate mitigation and alignment should be chosen to ensure tiger conservation in this landscape.

HALIYAL FOREST DIVISION

Haliyal Forest Division is located in the northern Karnataka landscape cluster, adjoining Kali tiger reserve and the Forest Divisions of Belagavi, Dharwad and Yellapura (Fig V.3.20). Camera trapping was carried out by the forest department with an effort of 2479 trap-nights. Total of 4 tiger images were obtained from which 1 tiger individual was identified (Table V.3.20).

Figure V.3.20

Camera trap layout and tiger presence in Haliyal Forest Division, 2022

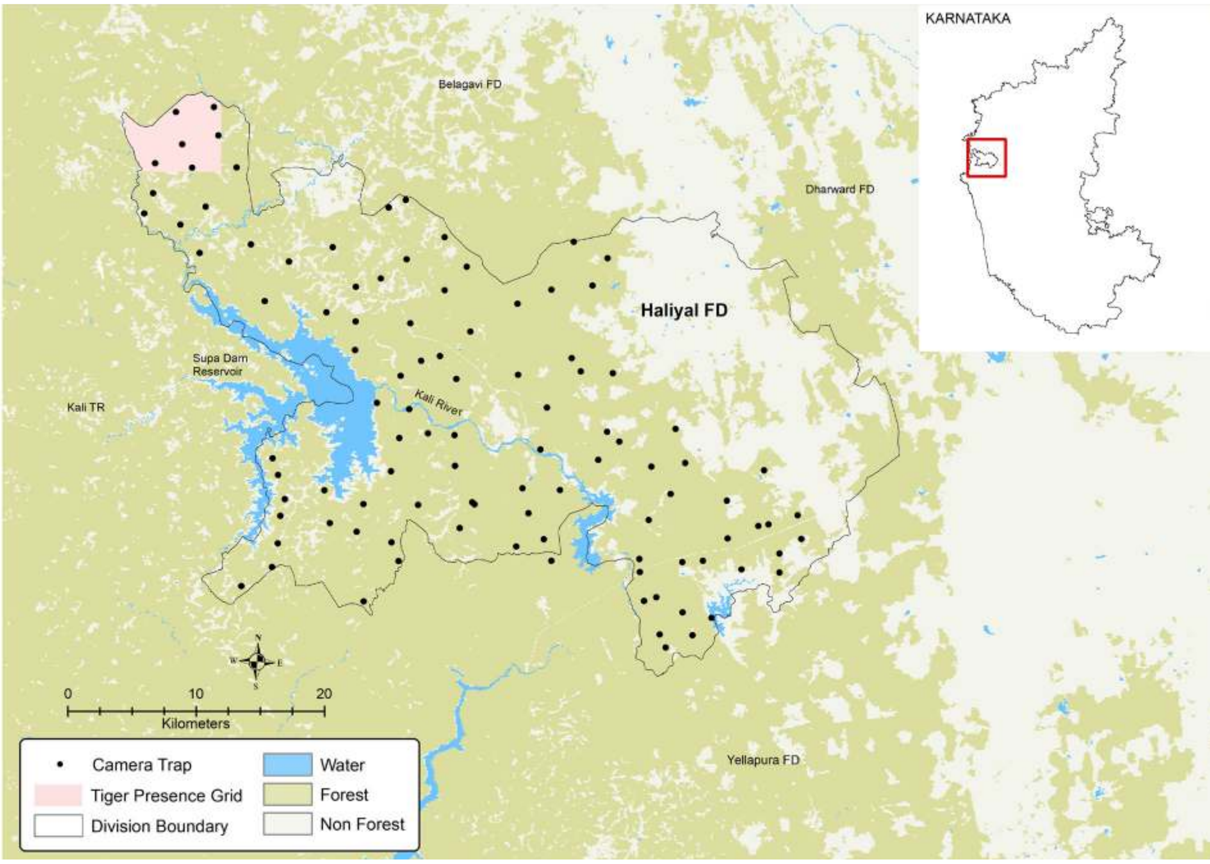


Table V.3.20

Sampling details of camera trapping exercise in Haliyal Forest Division, 2022

Sampling Details	Counts
Camera points	104
Trap nights (effort)	2479
Number of tiger photos	4
Unique tigers captured	1

Haliyal Forest Division is an important sink habitat for tigers from Anshi-Dandeli landscape. It also acts as a connecting link between Anshi-Dandeli and Bhadra tiger reserves. Protection needs to be enhanced in this area.

HASSAN FOREST DIVISION

Hassan Forest Division is located in the northern Karnataka landscape cluster, adjoining Madikeri, Mangalore, Chikmagalur, Tumkur and Mysore Forest divisions of Karnataka (Fig V.3.21). Camera trapping was carried out by the forest department, with an effort of 237 trap-nights (Table V.3.21). During the camera trapping exercise, no tiger was photo-captured.

Figure V.3.21

Camera trap layout in Hassan Forest Division, 2022

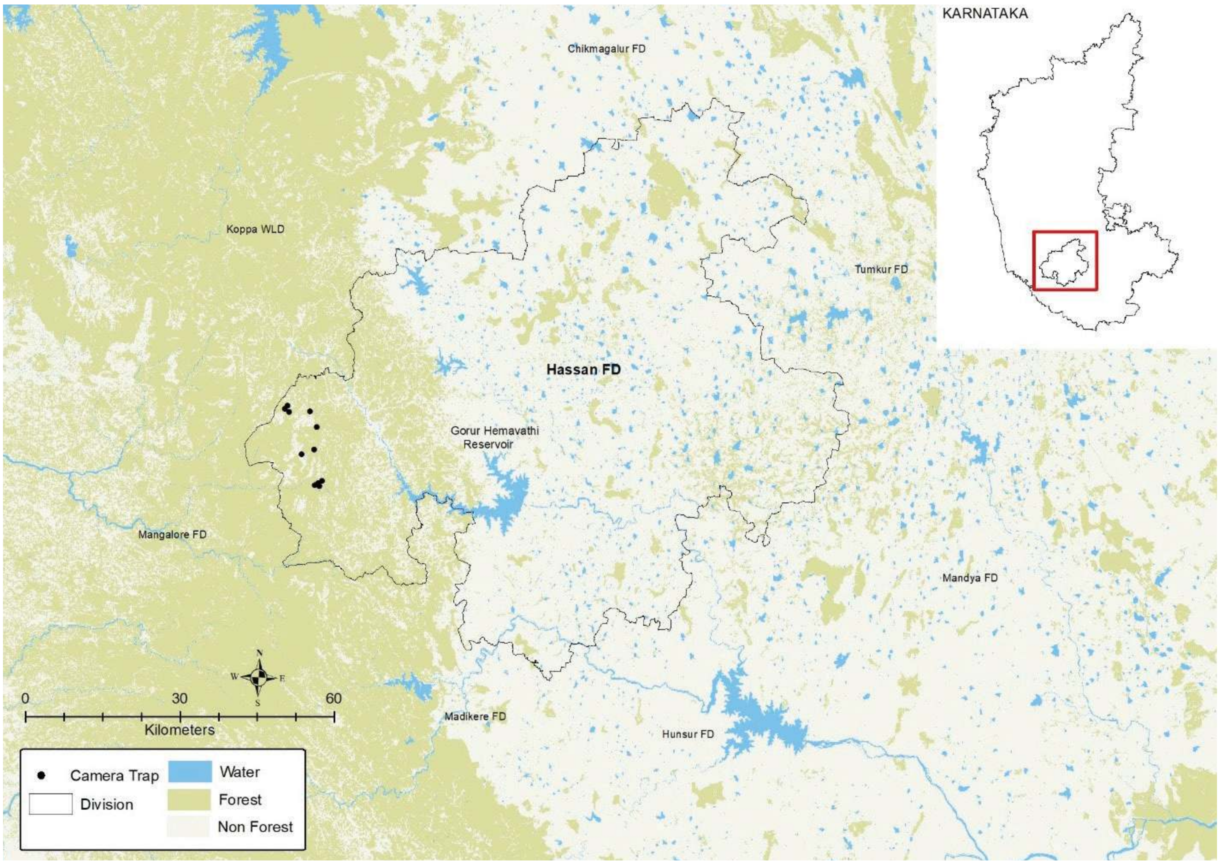


Table V.3.21

Sampling details of camera trapping exercise in Hassan Forest Division, 2022

Sampling Details	Counts
Camera points	11
Trap nights (effort)	237
Number of tiger photos	0

Although no tiger was detected in Hassan Forest division, this division acts as a vital linkage between the northern Karnataka and the Nilgiri landscape clusters. The four-lane highway proposed from Hassan to Adihalli will severe this connectivity. Appropriate mitigation measures are needed to reduce the impact of highway. Human animal conflict is a major issue, forest department is taking required steps to reduce and compensate conflict. Therefore, with proper protection and management of the forest and the wildlife corridors, Hassan can accommodate a sizeable population of tigers.

HAVERI FOREST DIVISION

Haveri Forest Division is located in the northern Karnataka landscape cluster. It is connected with Sagara, Sirsi, Yellapura, Dharwad, Gadag, Ballari and Davanagere forest divisions of Karnataka (Fig V.3.22). Camera trapping was carried out by the forest department, with an effort of 408 trap-nights (Table V.3.22). During the camera trapping exercise, no tiger was photo-captured.

Figure V.3.22

Camera trap layout in Haveri Forest Division, 2022

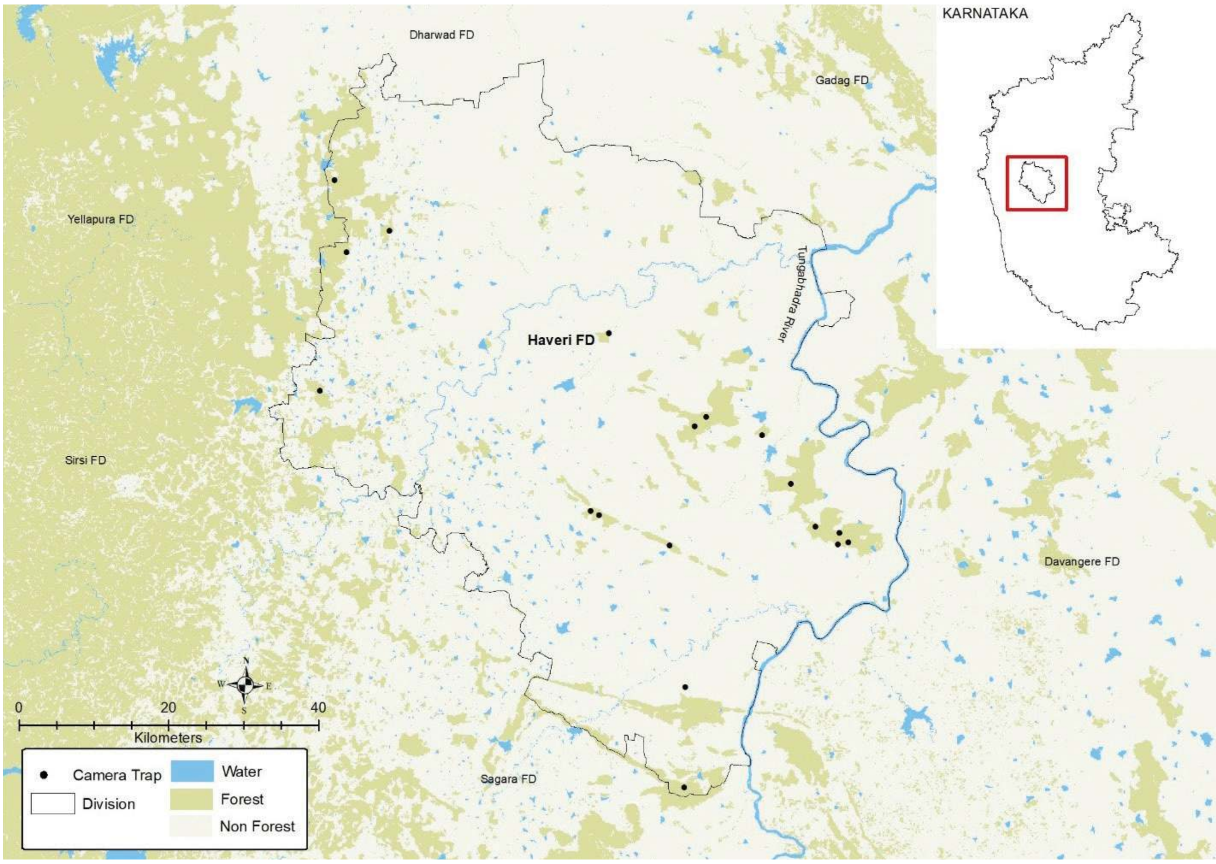


Table V.3.22

Sampling details of camera trapping exercise in Haveri Forest Division, 2022

Sampling Details	Counts
Camera points	18
Trap nights (effort)	408
Number of tiger photos	0

Haveri Forest Division is mosaic of small forest patches interspersed between agricultural fields, human habitations and traversed by a network of state and national highways. Poaching is an issue and strict protection is needed. The division can act as a functional tiger sink habitat if proper connectivity is established and maintained with the source populations of the landscape.

HONNAVAR FOREST DIVISION

Honnavar Forest Division is a part of the northern Karnataka landscape cluster, adjoining the divisions of Karwar, Sirsi, Shivamogga and Kudremukh NP (Fig V.3.23). Camera trapping was carried out by the forest department, with an effort of 2997 trap-nights (Table V.3.23). During the camera trapping exercise, no tiger was photo-captured.

Figure V.3.23

Camera trap layout in Honnavar Forest Division, 2022

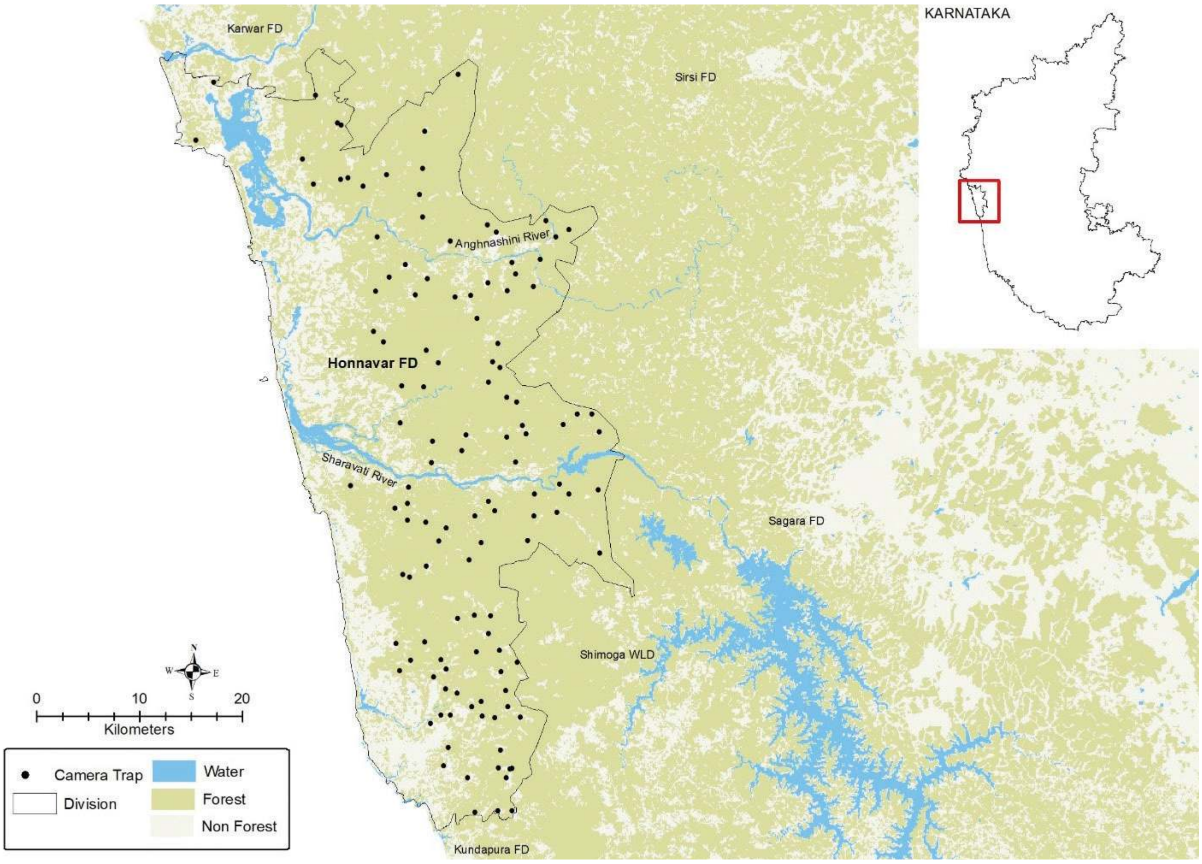


Table V.3.23

Sampling details of camera trapping exercise in Honnavar Forest Division, 2022

Sampling Details	Counts
Camera points	124
Trap nights (effort)	2997
Number of tiger photos	0

Although, no tiger was detected in Honnavar Forest Division, the division has potential habitat for tigers dispersing from Kali tiger reserve. Focused protection and management regimes can make the area more conducive to wildlife.

HUNSUR FOREST DIVISION

Hunsur Forest Division lies in the Niligiri landscape cluster of the Western Ghats. It adjoins the divisions of Madikeri, Hassan, Mysore and Nagarahole tiger reserve (Fig V.3.24). Camera trapping was carried out by the forest department, with an effort of 941 trap-nights (Table V.3.24). During the camera trapping exercise, no tiger was photo-captured.

Figure V.3.24

Camera trap layout in Hunsur Forest Division, 2022

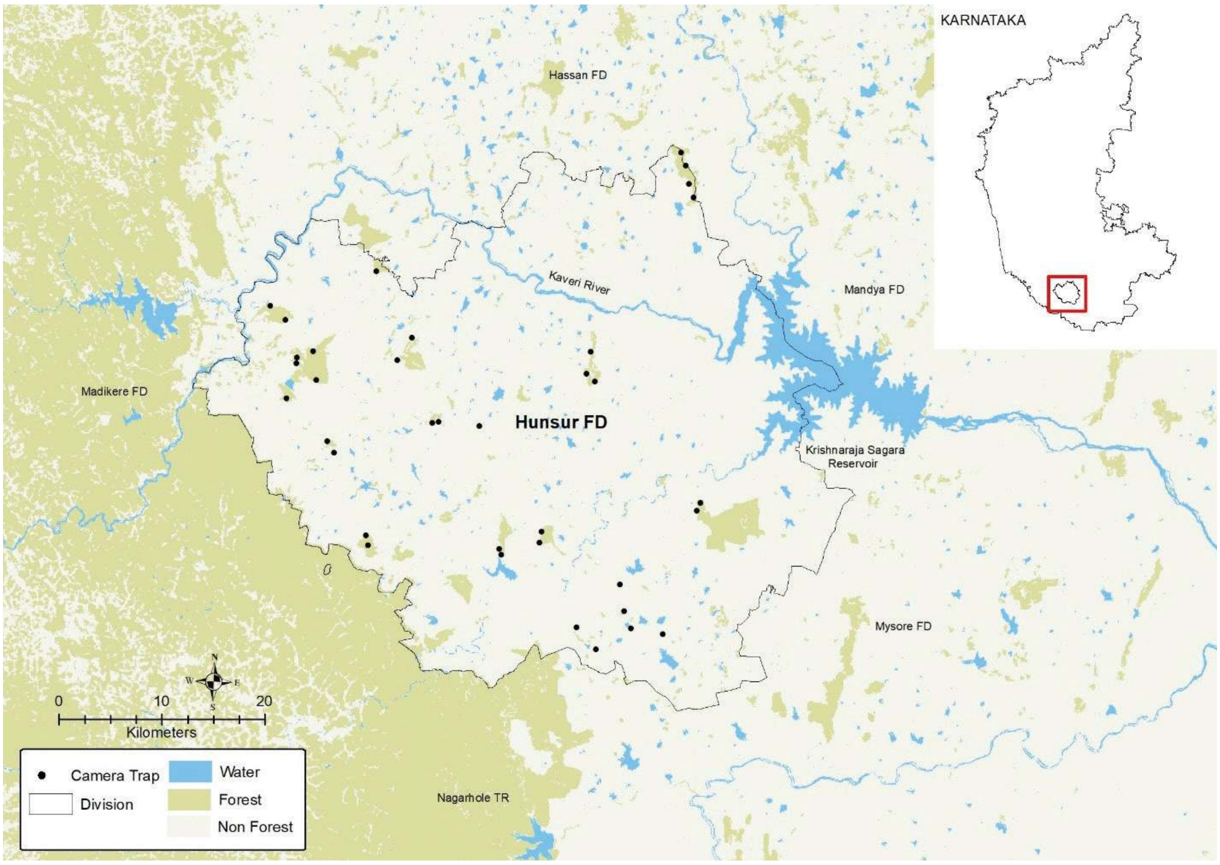


Table V.3. 24

Sampling details of camera trapping exercise in Hunsur Forest Division, 2022

Sampling Details	Counts
Camera points	36
Trap nights (effort)	941
Number of tiger photos	0

Hunsur Forest Division is an important sink habitat for the tigers dispersing out of Nagarahole tiger reserve. Conflict is high in this division and Forest Department is doing efforts to minimize it. Long term strategies are needed to address the conflict issues. It is also a critical linkage between the northern Karnataka and Nilgiri landscape cluster of Western Ghats. Therefore, pro-active management practices are required to minimize the disturbances and making the area susceptible to animal movement.

KALBURGI FOREST DIVISION

Kalburgi is the located in the northern Karnataka landscape cluster adjoining the forest divisions of Bidar, Vijaypura and Yadgir (Figure V.3.25). Camera trapping was carried out by the forest department, with an effort of 295 trap-nights (Table V.3.25). During the camera trapping exercise, no tiger was photo-captured.

Figure V.3.25

Camera trap layout in Kalburgi Forest Division, 2022

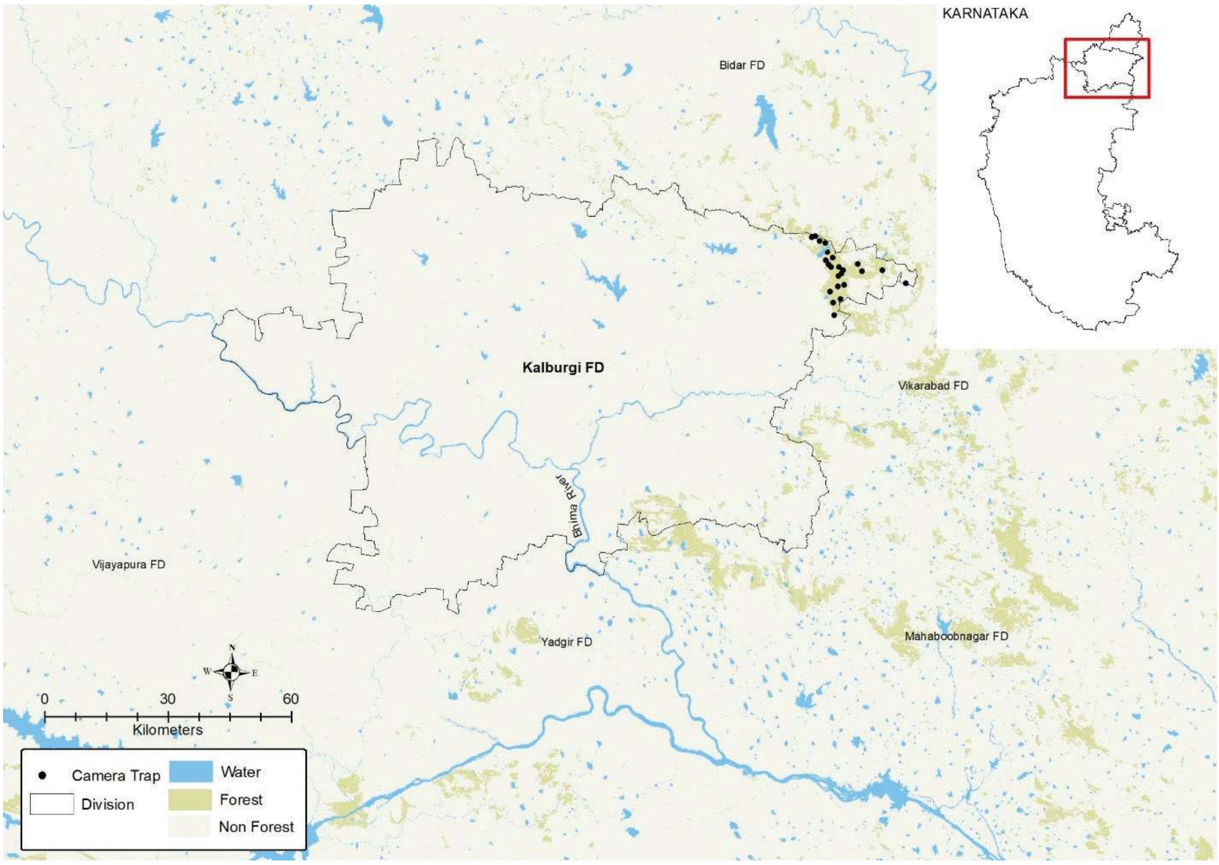


Table V.3. 25

Sampling details of camera trapping exercise in Kalburgi Forest Division, 2022

Sampling Details	Counts
Camera points	23
Trap nights (effort)	295
Number of tiger photos	0

Kalburgi Forest Division is essentially disconnected from the tiger bearing habitats of the Western Ghats landscape, mostly due to the presence of densely inhabited settlements and vast network of highways. However, with appropriate management practices, the habitat can be made conducive to wildlife movement.

KARWAR FOREST DIVISION

Karwar Forest Division is a part of the northern Karnataka landscape cluster. It shares its boundary with Cotigao WLS of Goa, Kali tiger reserve, Yellapura, Sirsi and Honnavar forest divisions of Karnataka (Figure V.3.26). Camera trapping was carried out by the forest department, with an effort of 3041 trap-nights. Total of 9 tiger images were obtained from which 2 tiger individuals were identified (Table V.3.26). No young tiger was photo-captured.

Figure V.3.26

Camera trap layout and tiger presence in Karwar Forest Division, 2022

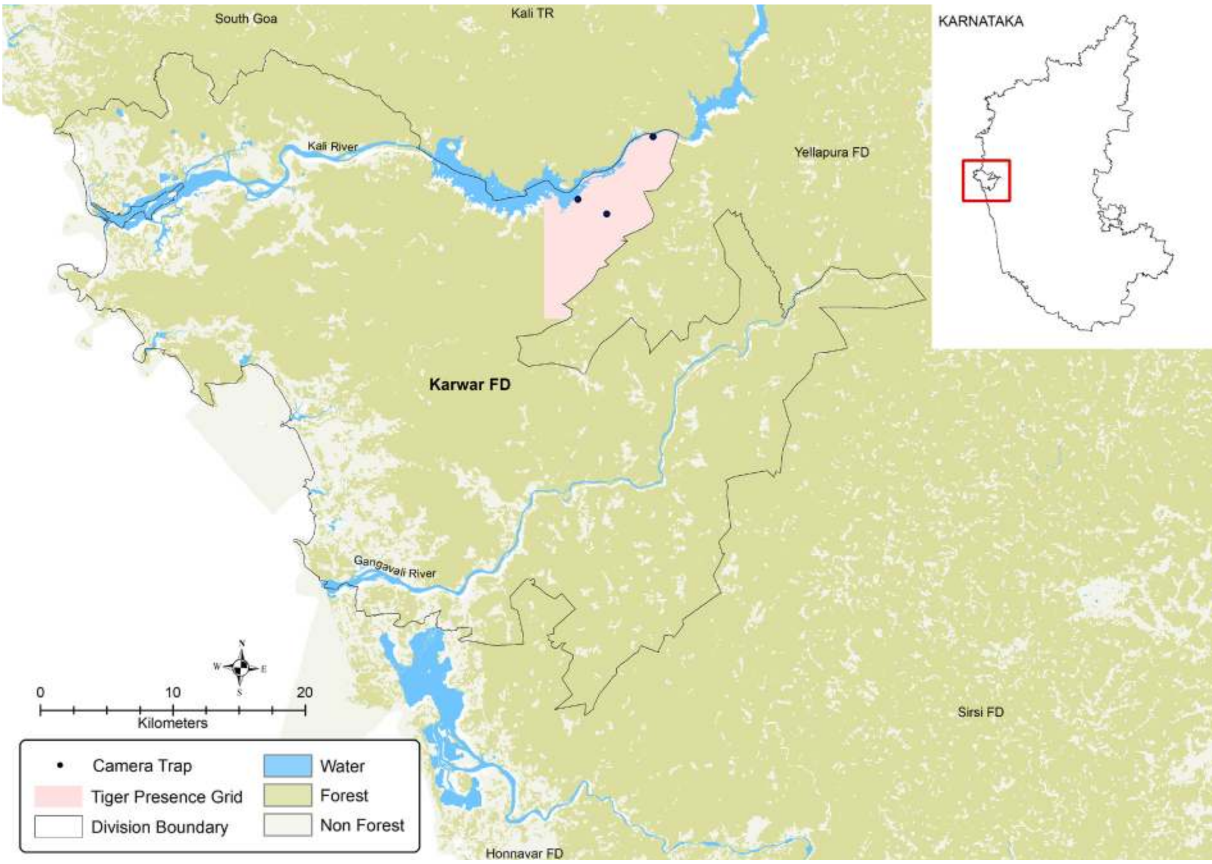


Table V.3. 26

Sampling details of camera trapping exercise in Karwar Forest Division, 2022

Sampling Details	Counts
Camera points	126
Trap nights (effort)	3041
Number of tiger photos	9
Unique tigers captured	2

Karwar forest division is a potential habitat for tigers from Kali tiger reserve. The proposal to develop Karwar as a coastal economic zone may increase disturbance and impact the habitat. Therefore, necessary mitigation plans are required to reduce the consequences.

KOPPA WILDLIFE DIVISION

Koppa Wildlife Division is a part of the northern Karnataka landscape cluster. It is contiguous with Bhadra tiger reserve, Kudremukh NP, Shivamogga, Bhadravathi and Chikmagalur forest divisions of Karnataka (Figure V.3.27). Camera trapping was carried out by the forest department, with an effort of 1363 trap-nights. Total of 37 tiger images were obtained from which 7 tiger individuals were identified and tiger density was estimated at 0.19 (SE 0.08) tiger per 100 km^2 (Table V.3.27). The detection corrected sex ratio of tigers in Koppa was 1 male : 3 females (Table V.3.27). No young tiger was photo-captured.

Figure V.3.27

Camera trap layout and spatial tiger density in Koppa Wildlife Division, 2022

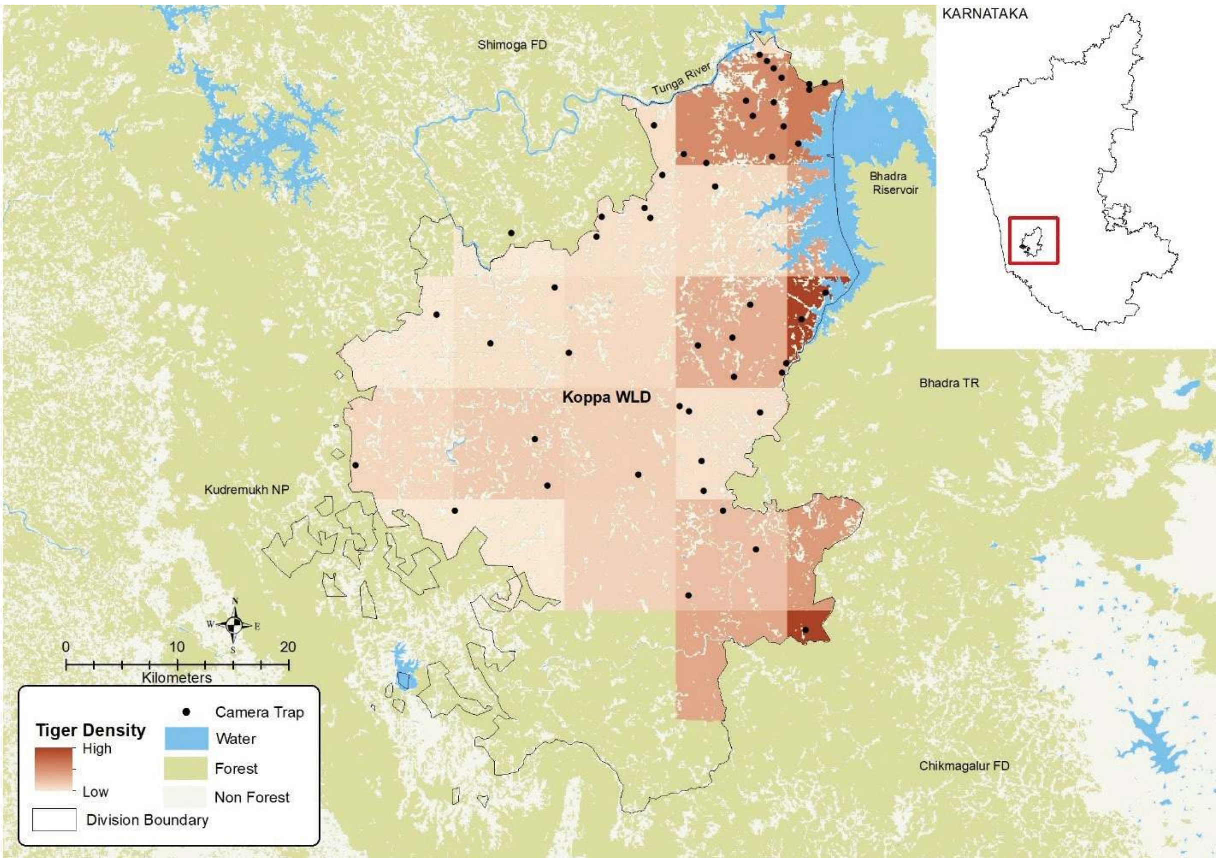


Table V.3. 17

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Koppa Wildlife Division, 2022

Variables	Estimate
Model space (km^2)	6547
Camera points	49
Trap nights (effort)	1363
Unique tigers captured	7
Model	Pmix (sex)g0(.) σ(.)
$\hat{D}$ SECR (per 100 km^2)	0.19 (0.08)
σ (SE) (km)	10.6(1.9)
g0 (SE)	0.01(0.01)
Pmix Female (SE)	0.75(0.22)
Pmix Male (SE)	0.25(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Although Koppa has a low density of tigers, it acts as an important sink and connecting habitat for the tigers dispersing from Bhadra tiger reserve and connects the Tiger Reserve with Kudremukh National Park.

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KUDREMUKH NATIONAL PARK

Kudremukh NP (600.57 km^2) is located in the northern Karnataka landscape cluster, adjoining the forest divisions of Shivamogga, Koppa and Mangalore in Karnataka (Figure V.3.28). Camera trapping was carried out by the forest department, with an effort of 4343 trap-nights. Total of 14 tiger images were obtained from which 2 tiger individuals were identified (Table V.3.28). No young tiger was photo-captured.

Figure V.3.28

Camera trap layout and tiger presence in Kudremukh National Park, 2022

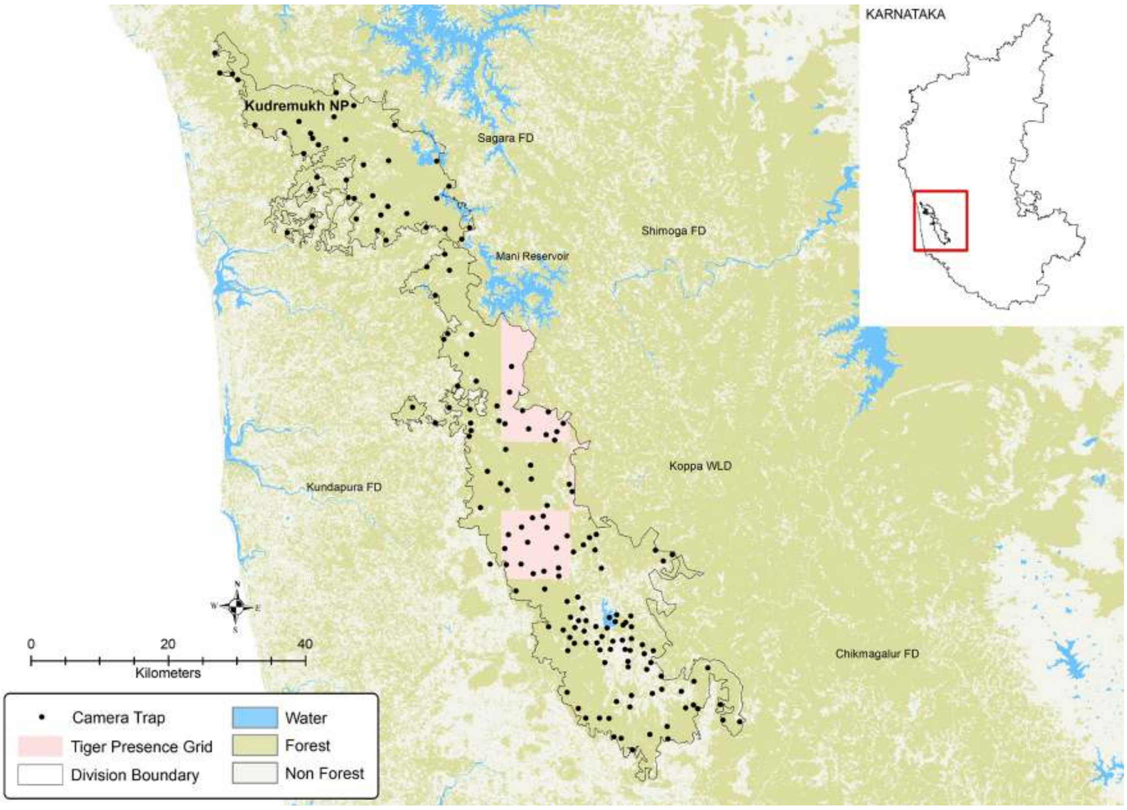

Table V.3. 28

Sampling details of camera trapping exercise in Kudremukh National Park, 2022

Sampling Details	Counts
Camera points	172
Trap nights (effort)	4343
Number of tiger photos	14
Unique tigers captured	2

Tiger detections have been consistently low in Kudremukh NP. However, the park has rich biodiversity and endemism. However, large animals get killed on the road passing through Kudremukh. The proposed road widening and improvement, Shiradi Ghat tunnel project will pose a major threat to this habitat as it will severe the linkage between Kudremukh and Pushpagiri WLS and further connecting with the Nilgiri landscape cluster of Western Ghats.

MADIKERI FOREST (TERRITORIAL) DIVISION

Madikeri Forest Division is situated in the Nilgiri landscape cluster. It has connectivity with Nagarahole tiger reserve, Mangalore, Hassan, Hunsur and Virajpet forest divisons of Karnataka (Figure V.3.29). Camera trapping was carried out by the forest department, with an effort of 3529 trap-nights. Total of 47 tiger images were obtained from which 10 tiger individuals were identified and tiger density was estimated at 0.52 (SE 0.25) tiger per 100 km^2 (Table V.3.29). The detection corrected sex ratio of tigers in Madikeri FD was nearly 2 males:1 female (Table V.3.29). No young tiger was photo-captured.

Figure V.3.29

Camera trap layout and spatial tiger density in Madikeri Forest Division, 2022

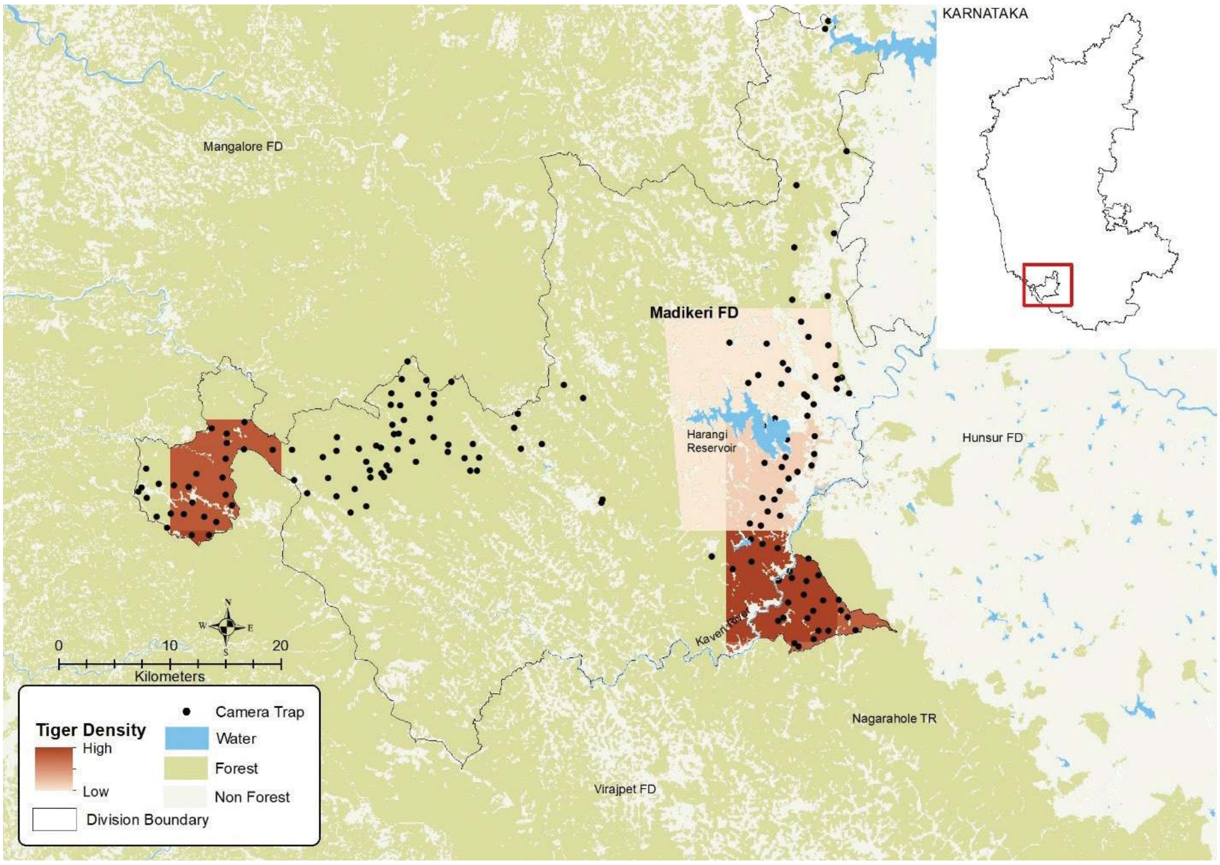

Table V.3. 29

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Madikeri Forest Division, 2022

Variables	Estimate
Model space (km^2)	1654
Camera points	156
Trap nights (effort)	3529
Unique tigers captured	5
Model	Pmix (sex)g0(.) σ(.)
$\hat{D}$ SECR (per 100 km^2)	0.52 (0.25)
σ (SE) (km)	2(0.2)
g0 (SE)	0.05(0.01)
Pmix Female (SE)	0.33(0.27)
Pmix Male (SE)	0.67(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Although Madikeri Forest Division has low density for tigers, it is an important habitat for tigers dispersing from Nagarahole tiger reserve. Therefore, management and protection to reduce the disturbances in the area are essential for fostering long term viability of tigers in this landscape.

MADIKERI WILDLIFE DIVISION

Madikeri Wildlife Division is situated in the Nilgiri landscape cluster. It has connectivity with Nagarahole tiger reserve, Wayanad North, Hassan, Hunsur and Virajpet forest divisons (Figure V.3.30). Camera trapping was carried out by the forest department, with an effort of 4221 trap-nights. Total of 88 tiger images were obtained from which 10 tiger individuals were identified and tiger density was estimated at 0.36 (SE 0.13) tiger per 100 km^2 (Table V.3.30). The detection corrected sex ratio of tigers in Madikeri WLD was nearly 1 male:1 female (Table V.3.30). A total of 2 young tigers were photo-captured.

Figure V.3.30

Camera trap layout and spatial tiger density in Madikeri Wildlife Division, 2022

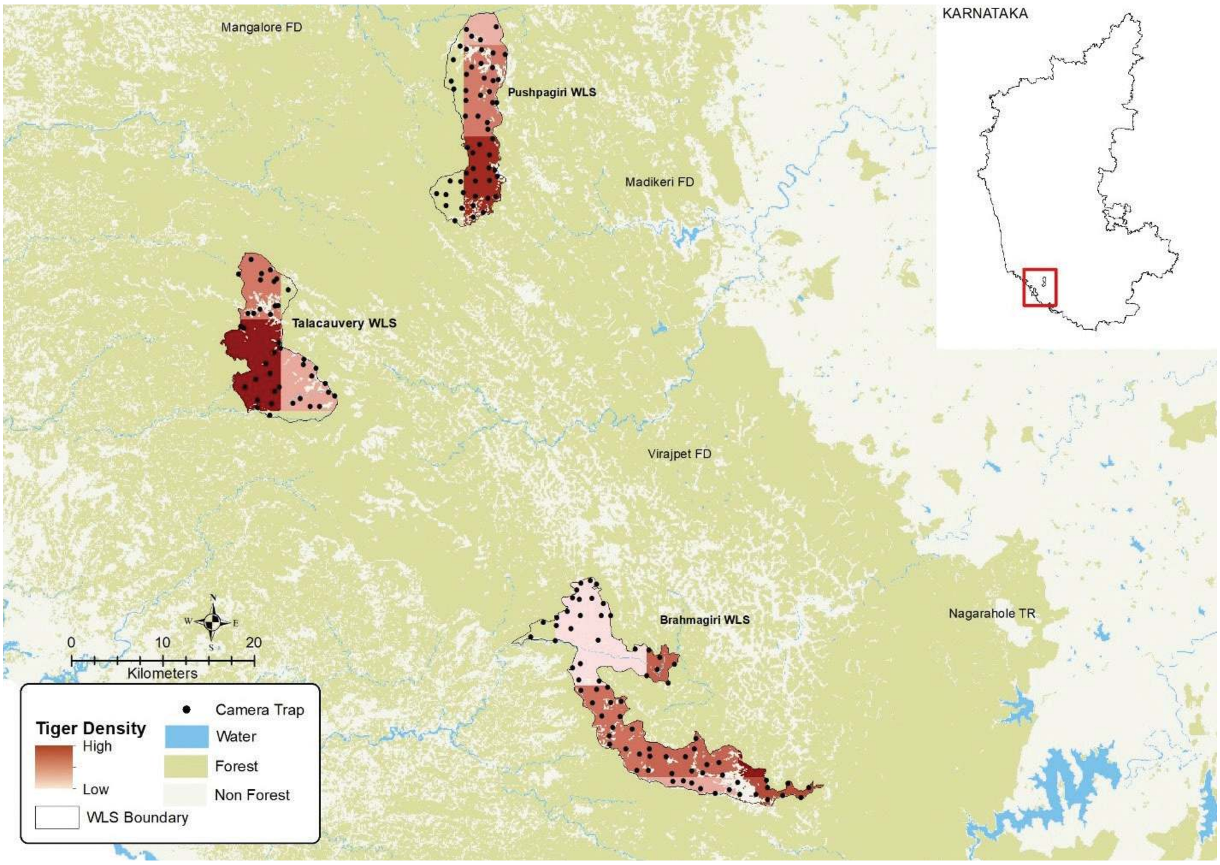

Table V.3. 30

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Madikeri Wildlife Division, 2022

Variables	Estimate
Model space (km^2)	4459
Camera points	169
Trap nights (effort)	4221
Unique tigers captured	10
Model	Pmix (sex)g0(.) σ(.)
$\hat{D}$ SECR (per 100 km^2)	0.36 (0.13)
σ (SE) (km)	5.1(0.8)
g0 (SE)	0.02(0.01)
Pmix Female (SE)	0.5(0.2)
Pmix Male (SE)	0.5(0.2)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Madikeri Wildlife Division has low density for tigers, but it acts as an important sink and connecting link for the adjacent Nagarahole tiger reserve. Therefore, management and protection to reduce the disturbances in the area are essential for fostering long term viability of tigers in this landscape.

MANGALORE FOREST DIVISION

Mangalore Forest Division is a part of the Karnataka landscape cluster, adjoining the forest divisions of Kudremukh NP, Koppa, Chikmagalur, Hassan and Madikeri (Figure V.3.31). Camera trapping was carried out by the forest department, with an effort of 1093 trap-nights (Table V.3.31). During the camera trapping exercise, no tiger was photo-captured.

Figure V.3.31

Camera trap layout in Mangalore Forest Division, 2022

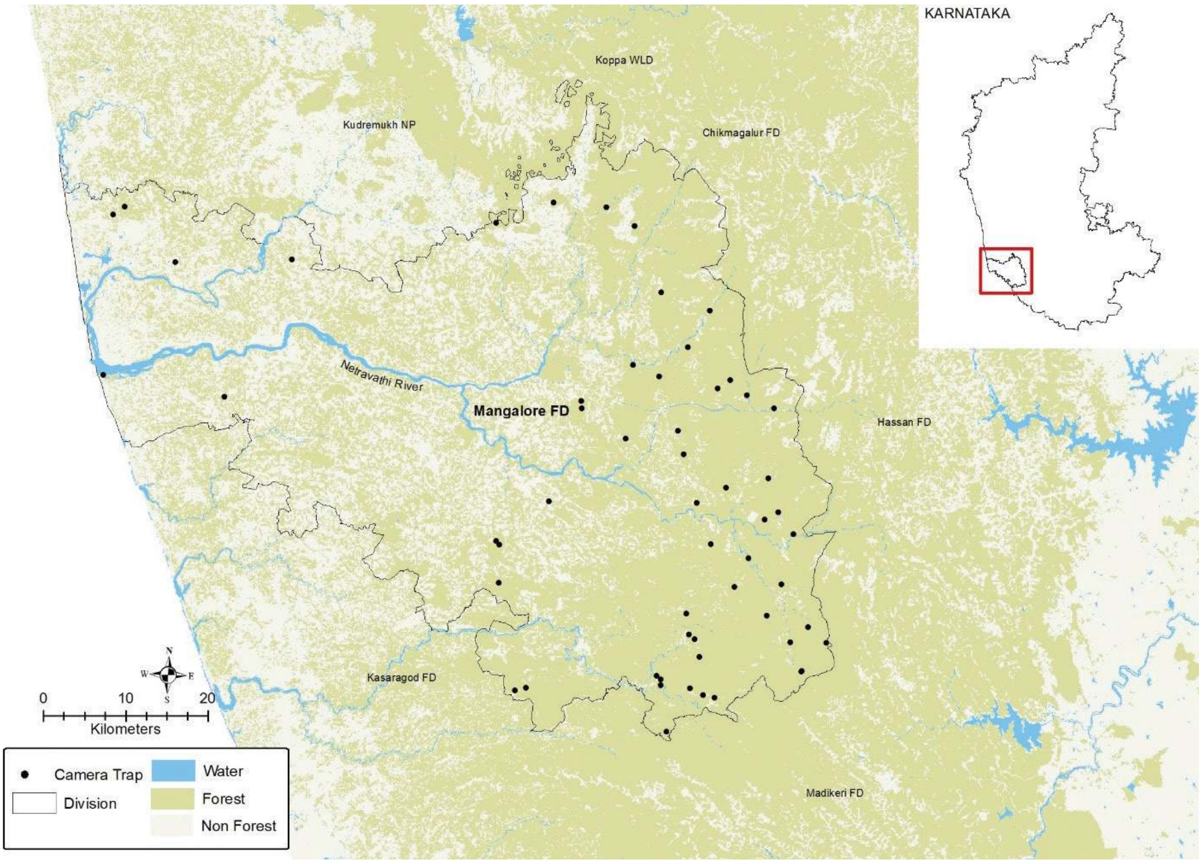

Table V.3. 28

Sampling details of camera trapping exercise in Mangalore Forest Division, 2022

Sampling Details	Counts
Camera points	57
Trap nights (effort)	1093
Number of tiger photos	0

Although no tigers were detected in Mangalore Forest Division, it acts as a vital linkage between the northern Karnataka and the Nilgiri landscape clusters. However, the division is a mosaic of small forest patches interspersed with densely populated habitations, agriculture fields and plantations.

MALE MAHADESHWARA HILLS (MM HILLS) WILDLIFE SANCTUARY

MM Hills WLS is a part of the Nilgiri landscape cluster. It has connectivity with BRT Tiger Reserve, Sathyamangalam tiger reserve, Cauvery WLS, Erode Forest division and Mysore Forest Division (Figure V.3.32). Camera trapping was carried out by the forest department, with an effort of 11094 trap-nights. Total of 54 tiger images were obtained from which 5 tiger individuals were identified and tiger density was estimated at 0.32 (SE 0.15) tiger per 100 km^2 (Table V.3.32). The detection corrected sex ratio of tigers in MM Hills was nearly 1 male: 3 females (Table V.3.32). No young tiger was photo-captured.

Figure V.3.32

Camera trap layout and spatial tiger density in MM Hills Wildlife Sanctuary, 2022

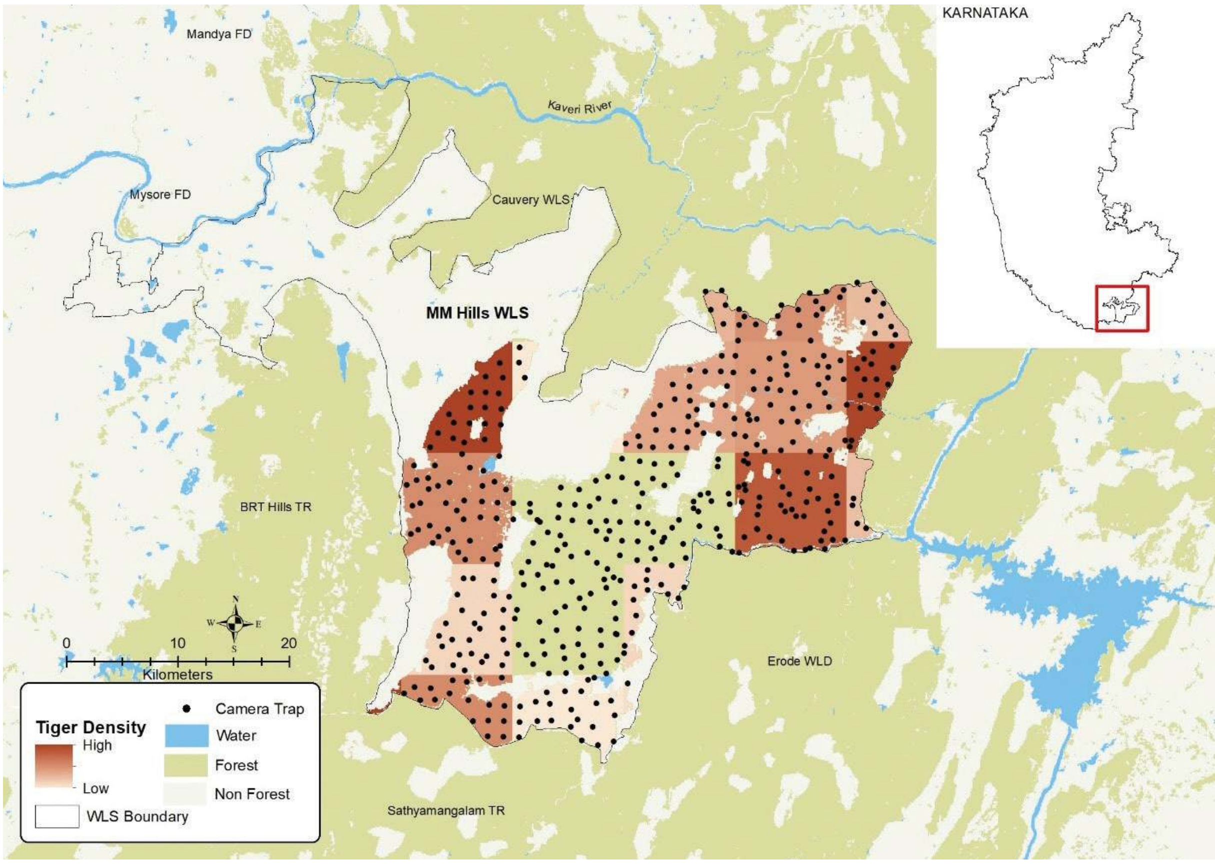

Table V.3. 32

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for MM Hills Wildlife Sanctuary, 2022

Variables	Estimate
Model space (km^2)	2230
Camera points	422
Trap nights (effort)	11094
Unique tigers captured	5
Model	Pmix (sex)g0(.) σ(.)
$\hat{D}$ SECR (per 100 km^2)	0.32 (0.15)
σ (SE) (km)	3.1(0.5)
g0 (SE)	0.02(0.00)
Pmix Female (SE)	0.75(0.2)
Pmix Male (SE)	0.25(0.2)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

The tiger density of MM Hills WLS has been consistently low since the previous cycles. However, the sanctuary is an important part of the Nilgiri landscape cluster as it acts as a sink for tigers moving from BRT and Sathyamangalam Tiger Reserves. The declaration of the sanctuary as a tiger reserve and suffiecient prey and habitat recovery initiatives are essential for the sanctuary to harbor a viable metapopulation of tigers.

MYSORE FOREST (TERRITORIAL) DIVISION

Mysore Forest Division is located in the Nilgiri landscape cluster. It is connected with Nagarahole, Bandipur and BRT Tiger Reserves and Hunsur forest division (Figure V.3.33). Camera trapping was carried out by the forest department, with an effort of 765 trap-nights. Total of 10 tiger images were obtained from which 4 tiger individuals were identified (Table V.3.33). No young tiger was photo-captured.

Figure V.3.33

Camera trap layout and tiger presence in Mysore Forest Division, 2022

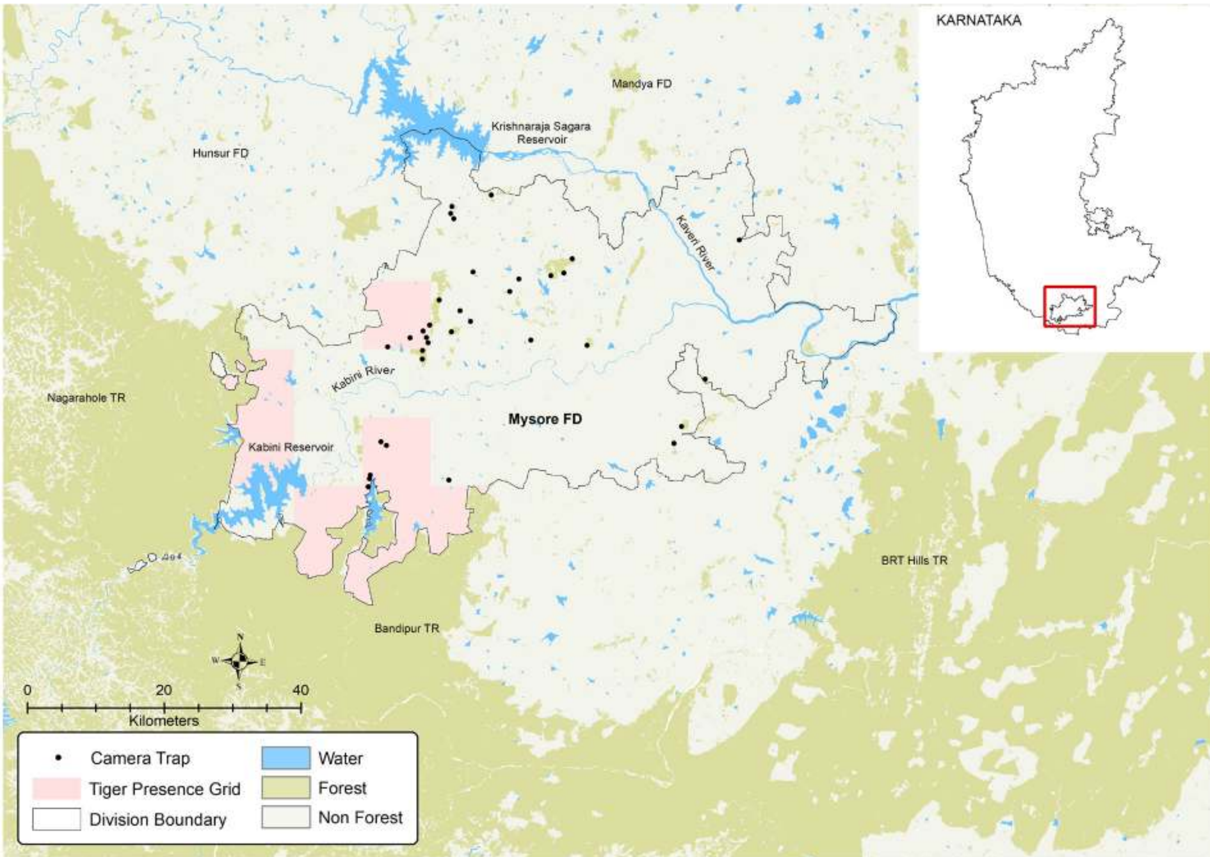

Table V.3. 33

Sampling details of camera trapping exercise in Mysore Forest Division, 2022

Sampling Details	Counts
Camera points	35
Trap nights (effort)	765
Number of tiger photos	10
Unique tigers captured	4

Although only 4 tigers were detected in Mysore Forest Division, it acts as an important stepping-stone between the Niligiri and the northern Karnataka landscape cluster. It is vital to maintain and enhance this linkage for the dispersal and establishment of new meta-populations in the landscape.

MYSORE WILDLIFE DIVISION

Mysore Wildlife Division is located in the Nilgiri landscape cluster. It is connected with Nagarahole, Bandipur and BRT tiger reserves and Hunsur forest division (Figure V.3.34). Camera trapping was carried out by the forest department, with an effort of 744 trap-nights (Table V.3.34). During the camera trapping exercise, no tiger was photo-captured.

Figure V.3.34

Camera trap layout in Mysore Wildlife Division, 2022

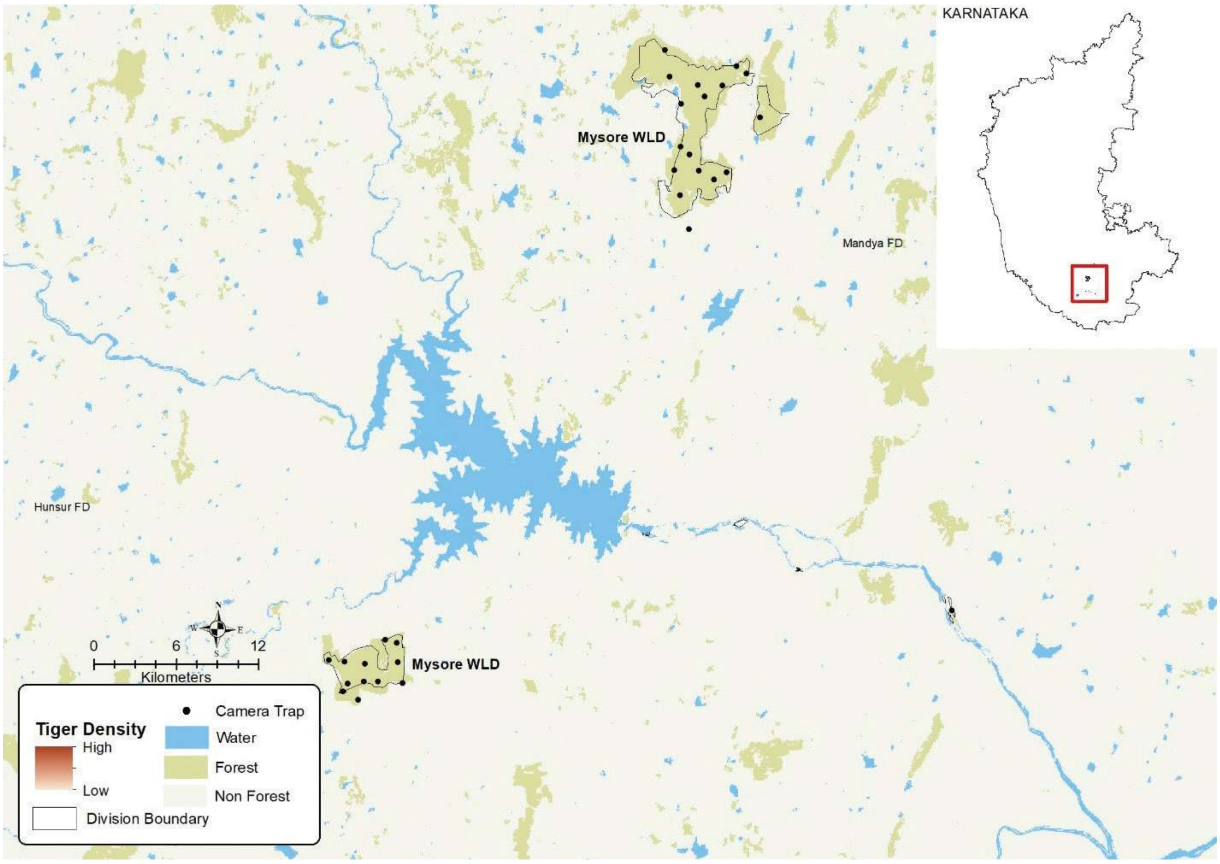

Table V.3. 34

Sampling details of camera trapping exercise in Mysore Wildlife Division, 2022

Sampling Details	Counts
Camera points	30
Trap nights (effort)	744
Number of tiger photos	0

Although no tigers were detected in Mysore Wildlife Division, it acts as an important stepping-stone between the Niligiri and the northern Karnataka landscape cluster. It is vital to maintain and enhance this linkage for the dispersal and establishment of new meta-populations in the landscape.

RAMANAGARA FOREST DIVISION

Ramanagara Forest Division is situated in the northern Karnataka landscape cluster, adjoining the divisions of Bannerghatta NP, Cauvery WLS, Bangalore Rural and Bangalore Urban Forest divisions (Figure V.3.35). Camera trapping was carried out by the forest department, with an effort of 346 trap-nights (Table V.3.35). During the camera trapping exercise, no tiger was photo-captured.

Figure V.3.35

Camera trap layout in Ramanagara Forest Division, 2022

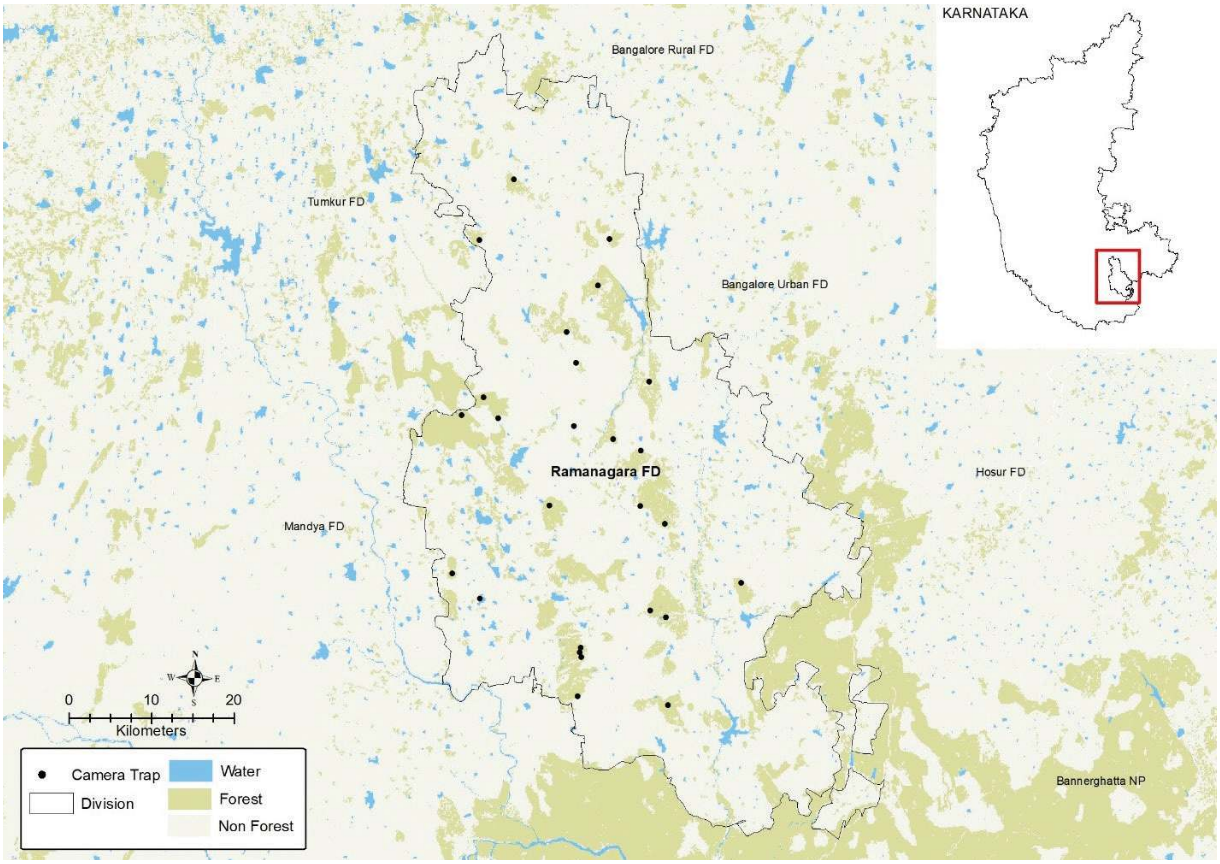

Table V.3. 35

Sampling details of camera trapping exercise in Ramanagara Forest Division, 2022

Sampling Details	Counts
Camera points	26
Trap nights (effort)	346
Number of tiger photos	0

Ramanagara Forest Division is mosaic of small forest patches interspersed between agricultural fields, plantations, human habitations and traversed by a network of state and national highways. The division can act as a corridor between the Nilgiri and northern Karnataka landscape cluster through appropriate habitat management practices.

SAGARA FOREST DIVISION

Sagara Forest Division is located in the northern Karnataka landscape cluster. It shares its boundary with Kudremukh NP, Sirsi, Davanagere, Haveri and Shivamogga forest divisions of Karnataka (Figure V.3.36). Camera trapping was carried out by the forest department, where no tiger photo was obtained with an effort of 1316 trap-nights (Table V.3.36).

Figure V.3.36

Camera trap layout in Sagara Forest Division, 2022

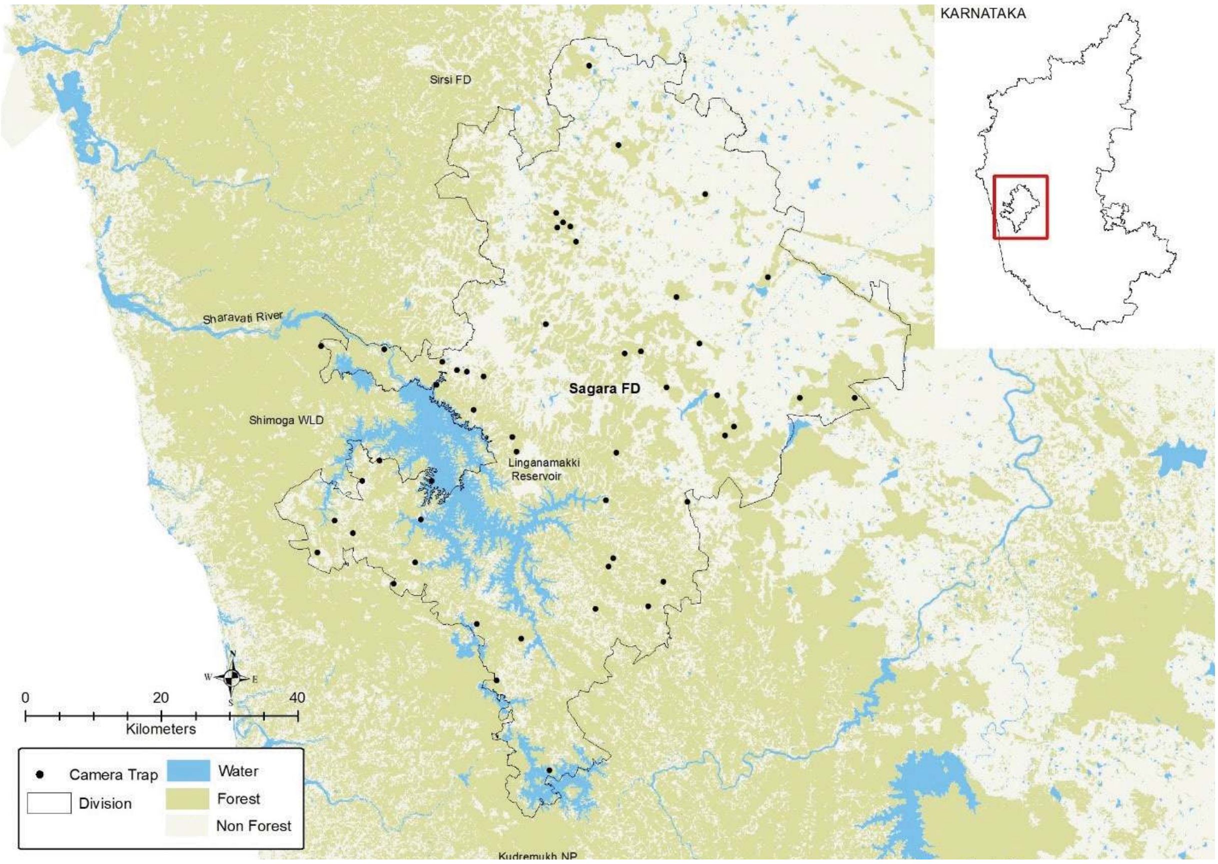

Table V.3. 36

Sampling details of camera trapping exercise in Sagara Forest Division, 2022

Sampling Details	Counts
Camera points	51
Trap nights (effort)	1316
Number of tiger photos	0

Sagara Forest Division is mosaic of small forest patches interspersed between agricultural fields, human habitations and traversed by a complex of state and national highways. However, it acts as a connecting link between Anshi-Dandeli and Bhadra tiger reserves.

SHIVAMOGGA FOREST (TERRITORIAL) DIVISION

Shivamogga (Shimoga) Forest Division is a part of the northern Karnataka landscape cluster, adjoining the forest divisions of Kudremukh NP, Sagara, Davanagere, Bhadravathi and Koppa forest divisions of Karnataka (Figure V.3.37). Camera trapping was carried out by the forest department, with an effort of 845 trap-nights (Table V.3.37). During the camera trapping exercise, no tiger was photo-captured.

Figure V.3.37

Camera trap layout in Shivamogga Forest Division, 2022

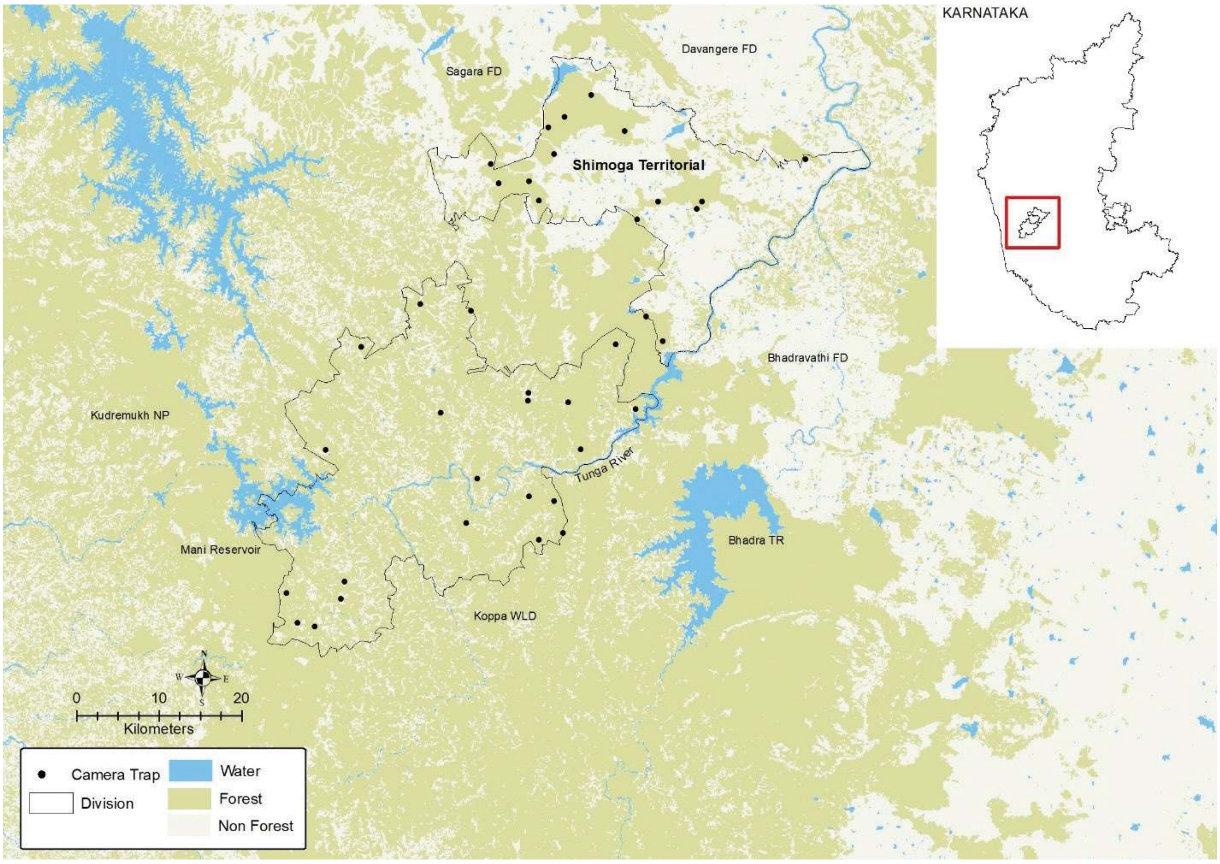

Table V.3. 37

Sampling details of camera trapping exercise in Shivamogga Forest Division, 2022

Sampling Details	Counts
Camera points	38
Trap nights (effort)	845
Number of tiger photos	0

The division would benefit with enhanced protection and reduction of human impacts to improve its biodiversity values and provide habitat for animals in this landscape.

SHIVAMOGGA WILDLIFE DIVISION

Shivamogga (Shimoga) Wildlife Division is a part of the northern Karnataka landscape cluster, adjoining the forest divisions of Kudremukh NP, Sagara, Bhadravathi and Honnavar forest divisions of Karnataka (Figure V.3.38). Camera trapping was carried out by the forest department, with an effort of 4110 trap-nights. A total of 8 tiger images were obtained from which 1 tiger individual was identified (Table V.3.38).

Figure V.3.38

Camera trap layout and tiger presence in Shivamogga Wildlife Division, 2022

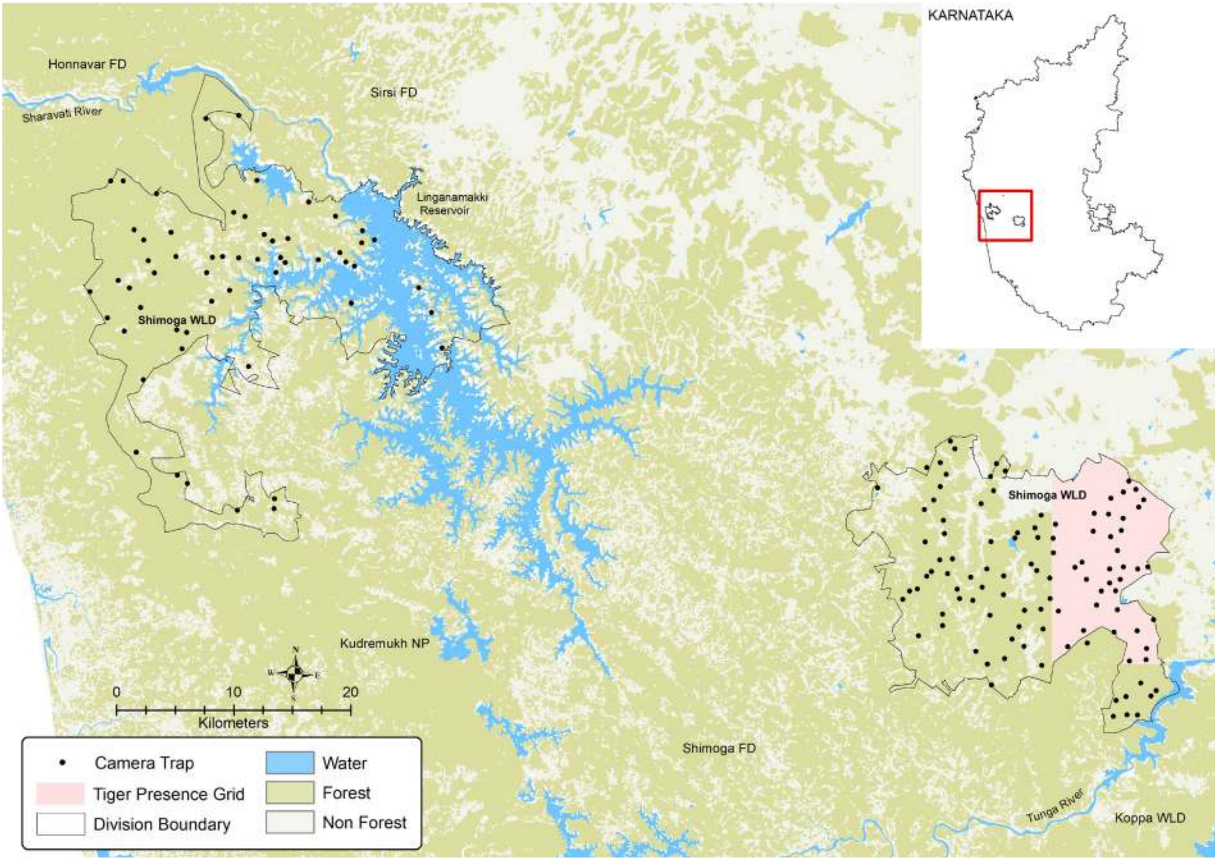

Table V.3. 38

Sampling details of camera trapping exercise in Shivamogga Wildlife Division, 2022

Sampling Details	Counts
Camera points	163
Trap nights (effort)	4110
Number of tiger photos	8
Unique tigers captured	1

The division forest quality declined over time, poaching, fire and anthropogenic disturbance has its impact on flora and fauna. The area would benefit with enhanced protection and reduction of human impacts to improve its biodiversity values.

SIRSI FOREST DIVISION

Sirsi Forest Division is a part of the northern Karnataka landscape cluster, adjoining the forest divisions of Karwar, Yellapura, Haveri, Sagara and Honnavar (Figure V.3.39). Camera trapping was carried out by the forest department, where no tiger photo was obtained with an effort of 2415 trap-nights (Table V.3.39).

Figure V.3.39

Camera trap layout in Sirsi Forest Division, 2022

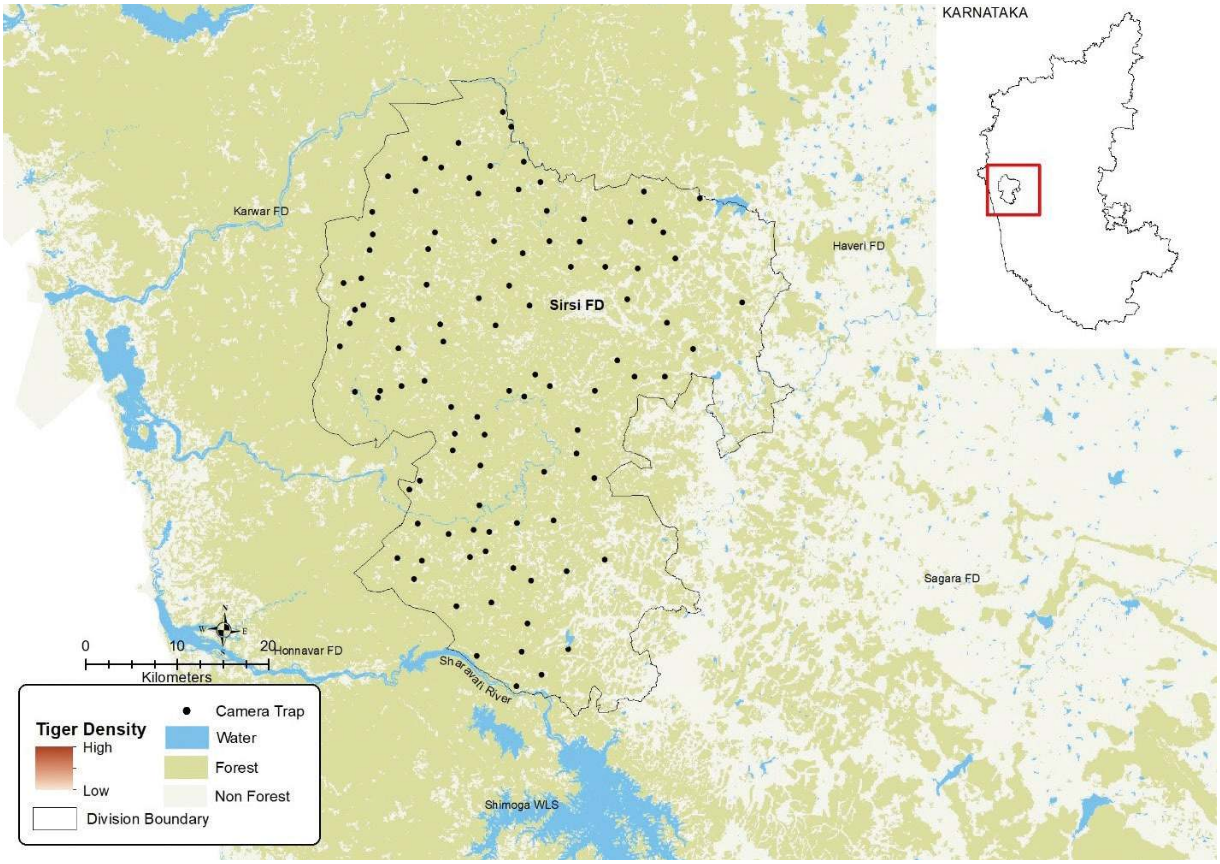

Table V.3. 39

Sampling details of camera trapping exercise in Sirsi Forest Division, 2022

Sampling Details	Counts
Camera points	101
Trap nights (effort)	2415
Number of tiger photos	0

There is a need to improve protection. Even though no tiger was detected, Sirsi Forest Division acts as an important stepping stone patch and linkage between the Anshi-Dandeli and Bhadra Tiger Reserves.

TUMKUR FOREST DIVISION

Tumkur Forest Division is a part of the northern Karnataka landscape cluster. It is contiguous with Bangalore rural, Ramanagara, Mysore, Hassan and Chitradurga forest divisions of Karnataka (Figure V.3.40). Camera trapping was carried out by the forest department, where no tiger photo was obtained with an effort of 575 trap-nights (Table V.3.40).

Figure V.3.40

Camera trap layout in Tumkur Forest Division, 2022

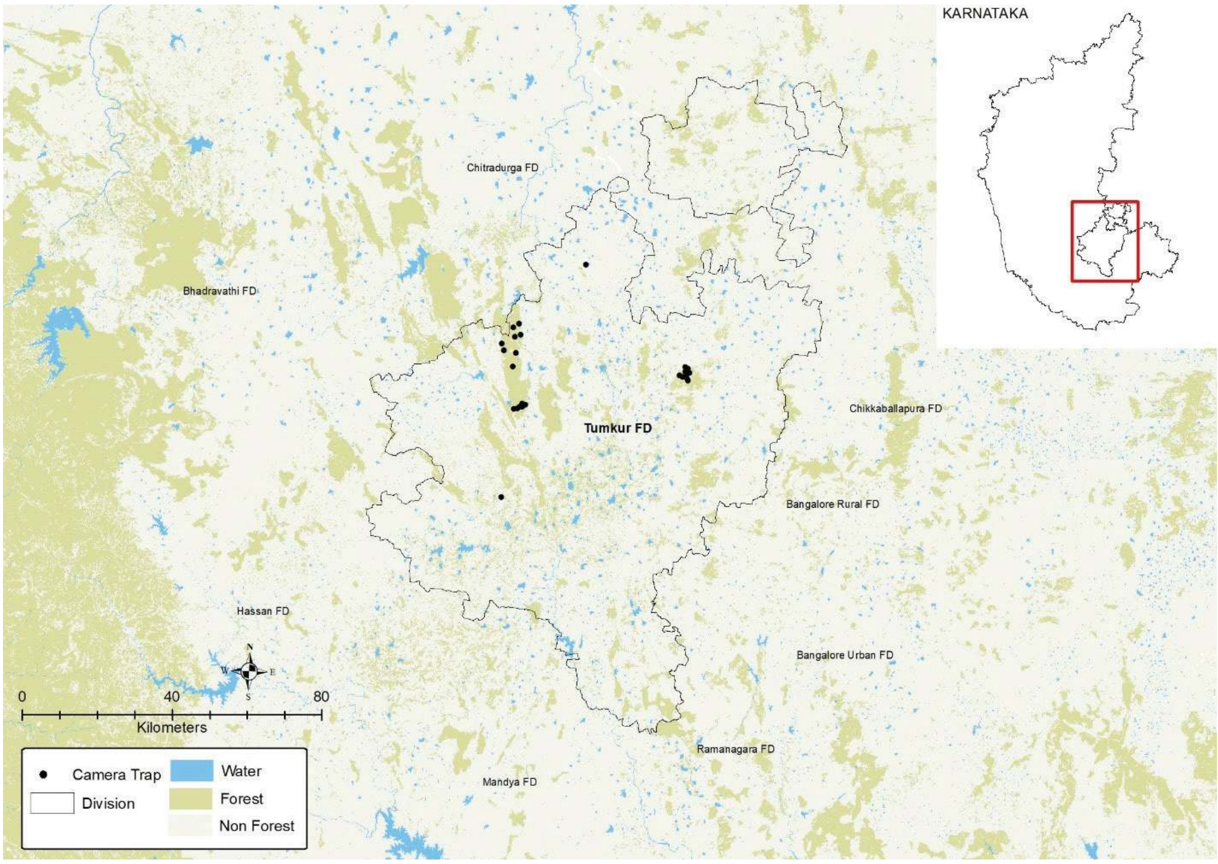

Table V.3. 40

Sampling details of camera trapping exercise in Tumkur Forest Division, 2022

Sampling Details	Counts
Camera points	24
Trap nights (effort)	575
Number of tiger photos	0

Tumkur Forest Division is mosaic of small forest patches interspersed between agricultural fields, plantations, human habitations and traversed by a web of state and national highways. The division can act as a corridor between the Nilgiri and northern Karnataka landscape cluster through appropriate habitat management practices.

VIRAJPET FOREST (TERRITORIAL) DIVISION

Virajpet Forest Division is located in the Nilgiri landscape cluster. It is connected with Nagarahole tiger reserve and Madikeri forest division (Figure V.3.41). Camera trapping was carried out by the forest department, with an effort of 2454 trap-nights. Total of 20 tiger images were obtained from which 3 tiger individuals were identified (Table V.3. 41). No young tiger was photo-captured.

Figure V.3.41

Camera trap layout and tiger presence in Virajpet Forest Division, 2022

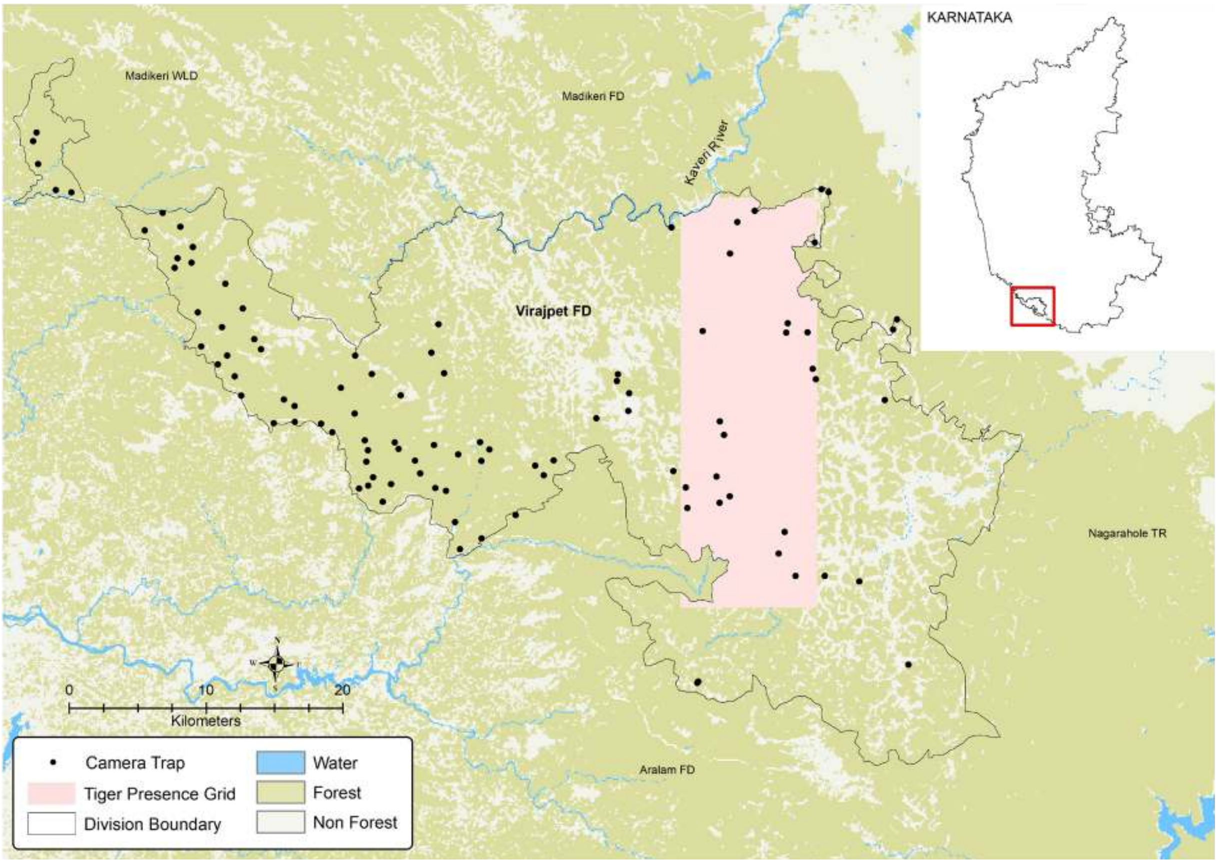

Table V.3. 41

Sampling details of camera trapping exercise in Virajpet Forest Division, 2022

Sampling Details	Counts
Camera points	100
Trap nights (effort)	2454
Number of tiger photos	20
Unique tigers captured	3

Although only 3 tigers were detected in Virajpet division, being located adjacent to Nagarahole tiger reserve and Wayanad-Bandipur-Mudumalai complex, it is an important stepping stone for maintaining tiger meta-population dynamics in the landscape. Regulated human disturbance and developmental activities is necessary to preserve this vital habitat.

YELLAPURA FOREST DIVISION

Yellapura Forest Division is a part of the northern Karnataka landscape cluster. It is contiguous with Anshi-Dandeli Tiger Reserve, Karwar, Haliyal, Dharwad, Haveri and Sirsi forest divisions of Karnataka (Figure V.3.42). Camera trapping was carried out by the forest department, with an effort of 2266 trap-nights. Total of 7 tiger images were obtained from which 3 tiger individuals were identified (Table V.3.42). No young tiger was photo-captured.

Figure V.3.42

Camera trap layout and tiger presence in Yellapura Forest Division, 2022

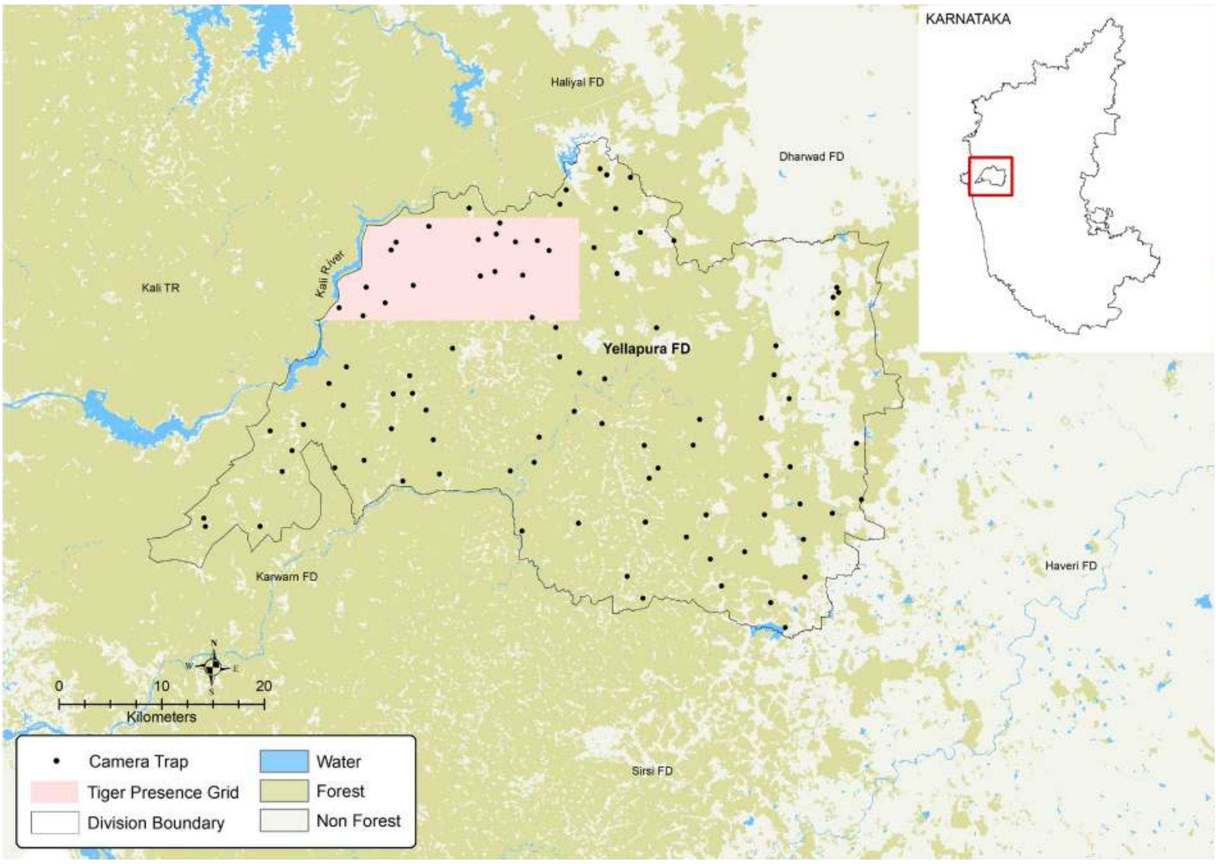

Table V.3. 42

Sampling details of camera trapping exercise in Yellapura Forest Division, 2022

Sampling Details	Counts
Camera points	95
Trap nights (effort)	2266
Number of tiger photos	7
Unique tigers captured	3

Yellapura Forest Division recorded only 3 tigers during the exercise; but it is an important habitat permitting movement of tigers and elephants from Kali Tiger Reserve and also acts as a linkage to the Bhadra Tiger Reserve complex.

TAMIL NADU

ANAMALAI TIGER RESERVE

Anamalai Tiger Reserve (1479.87 km^2) is located in the southern Western Ghats, south of the Palghat gap. It forms a continuous landscape cluster along with Parambikulam tiger reserve, Malayatoor and Vazhachal Forest Divisions (Kerala) and Kodaikanal WLS (Tamil Nadu) (Figure V.3.43). Camera trapping was carried out by the forest department, with an effort of 16747 trap-nights. Total of 288 tiger images were obtained from which 16 tiger individuals were identified and tiger density was estimated at 0.69 (SE 0.17) tiger per 100 km^2 (Table V.3.43). The detection corrected sex ratio of tigers in Anamalai was nearly 1 male:1 female (Table V.3.43). No young tigers were photo-captured.

Figure V.3.43

Camera trap layout and spatial tiger density in Anamalai Tiger Reserve, 2022

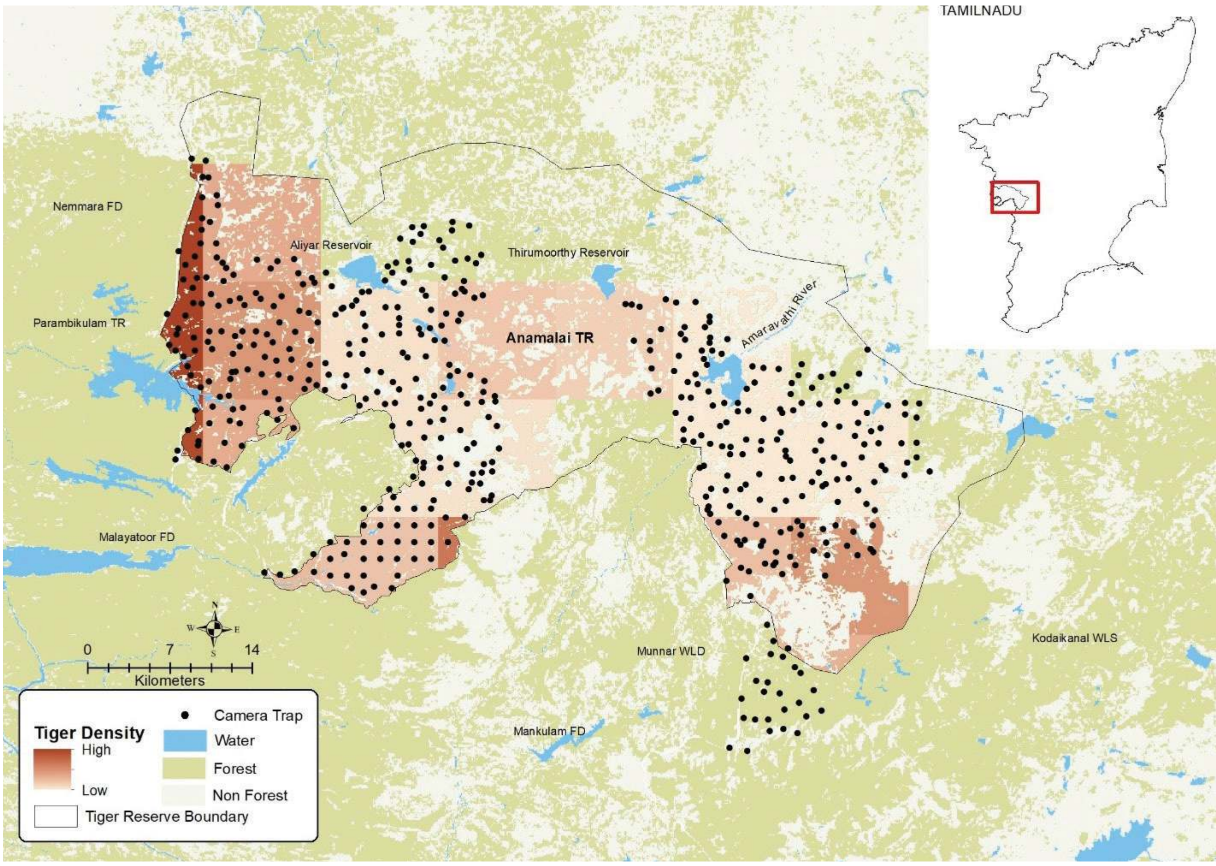

Table V.3. 43

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Anamalai Tiger Reserve, 2022

Variables	Estimate
Model space (km^2)	2930
Camera points	496
Trap nights (effort)	16747
Unique tigers captured	16
Model	Pmix (sex)g0(.) σ(.)
$\hat{D}$ SECR (per 100 km^2)	0.69(0.17)
σ Female (SE) (km)	5(0.3)
σ Male (SE) (km)	5(0.3)
g0 Female (SE)	0.01(0.001)
g0 Male (SE)	0.01(0.001)
Pmix Female (SE)	0.53 (0.13)
Pmix Male (SE)	0.47(0.13)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

The tiger density of Anamalai tiger reserve has been consistently low since the previous cycles [1.18 (0.46 SE) in 2014 and 1.11 (0.26 SE) in 2018, Jhala *et. al.,* 2015 and 2020]. The reserve currently faces threats due to high human-wildlife conflict and presence of many coffee and tea estates inside and around the periphery of the reserve. In addition to this, there are also activities like poaching due to the large number of human habitations inside Anamalai. Further, tourism has led to the increase in plastic waste, 33 settlements inside the core of the Tiger Reserve need to be resettled outside following NTCA's scheme.

KALAKAD-MUNDANTHURAI TIGER RESERVE

KMTR (1602 km^2) is the southern-most tiger reserve of India. It has connectivity with the Kanyakumari and Nellai wildlife sanctuaries of Tamil Nadu (Figure V.3.44). Camera trapping was carried out by the forest department, with an effort of 10416 trap-nights. Total of 84 tiger images were obtained from which 5 tiger individuals were identified and tiger density was estimated at 0.27 (SE 0.12) tiger per 100 km^2 (Table V.3. 44). The detection corrected sex ratio of tigers in KMTR was nearly 3 males: 1 female (Table V.3.44). No young tiger was photo-captured.

Figure V.3.44

Camera trap layout and spatial tiger density in Kalakad Mundanthurai Tiger Reserve, 2022

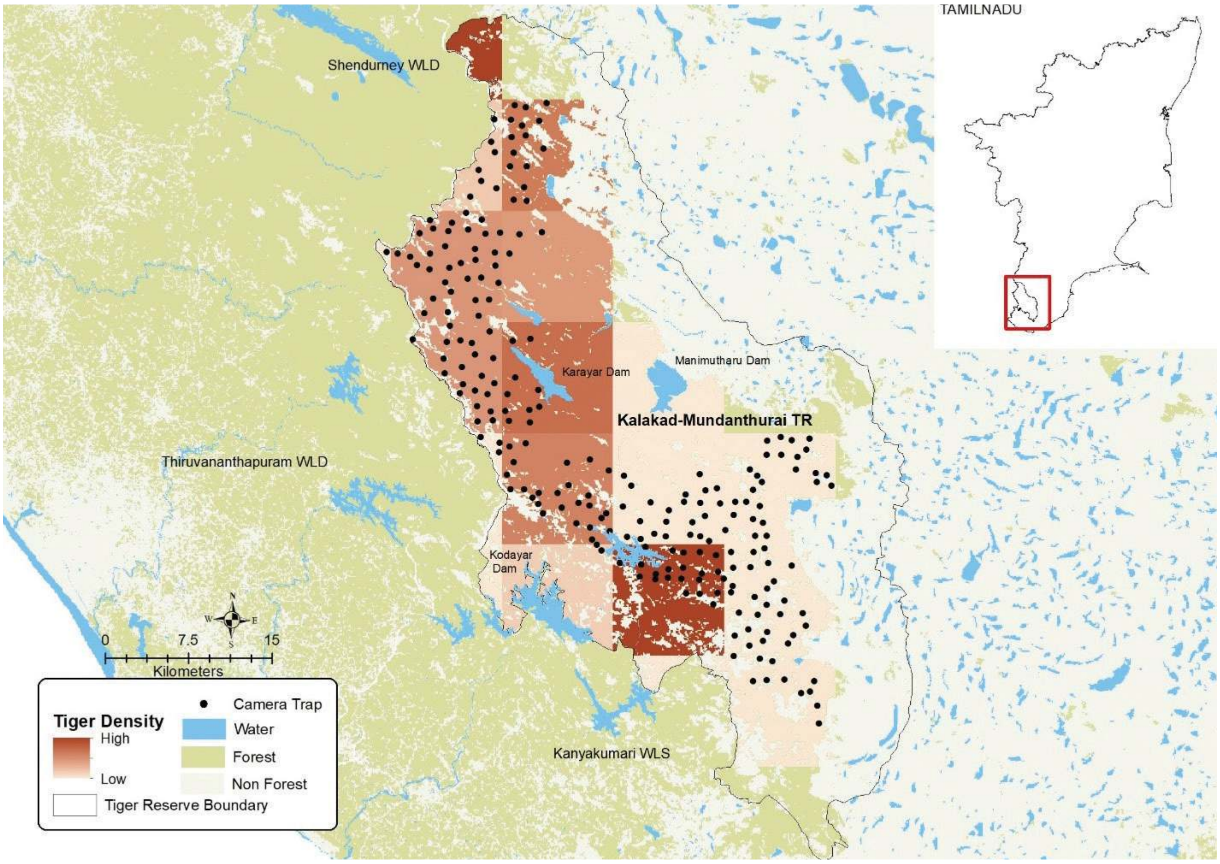

Table V.3. 44

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Kalakad Mundanthurai Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	1981
Camera points	228
Trap nights (effort)	10416
Unique tigers captured	5
Model	Pmix (sex)g0(.) σ(.)
$\hat{D}$ SECR (per 100 km^2)	0.27(0.12)
σ Female (SE) (km)	7(0.7)
σ Male (SE) (km)	7(0.7)
g0 Female (SE)	0.011(0.004)
g0 Male (SE)	0.011(0.004)
Pmix Female (SE)	0.25(0.21)
Pmix Male (SE)	0.75(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

The tiger density of KMTR has been consistently low since the previous cycles [0.88 (0.39 SE) in 2014 and 0.43 (0.17 SE) in 2018, Jhala *et. al.,* 2015 and 2020]. The water bodies of the reserve are dammed up by the Tamil Nadu electricity board and extensive work is ongoing for hydro-power generation. This has led to the shortage of water in certain parts of the park. Densely populated human habitations, tea and coffee plantations and linear infrastructure developments are leading to change in patterns of land use patterns. Focused protection and management actions are required to tackle these issues and preserve this critical habitat. Immediate efforts are required for restoration of grasslands in Mundanthurai Plateau by weed removal and habitat management.

MUDUMALAI TIGER RESERVE

Mudumalai Tiger Reserve (689 km^2) is a part of the Nilgiri landscape cluster of Western Ghats. It is contiguous with the Bandipur (Karnataka) and Sathyamangalam Tiger Reserves, Nilgiri (Tamil Nadu) and Wayanad (Kerala) divisions (Figure V.3.45). Camera trapping was carried out by the forest department, with an effort of 17843 trap-nights. Total of 2889 tiger images were obtained from which 114 tiger individuals were identified and tiger density was estimated at 7.72 (SE 0.72) tiger per 100 km^2 (Table V.3.45). The detection corrected sex ratio of tigers in Mudumalai was nearly 1 males: 1.5 females (Table V.3.45). A total of 10 young tigers were photo-captured.

Figure V.3.45

Camera trap layout and spatial tiger density in Mudumalai Tiger Reserve, 2022

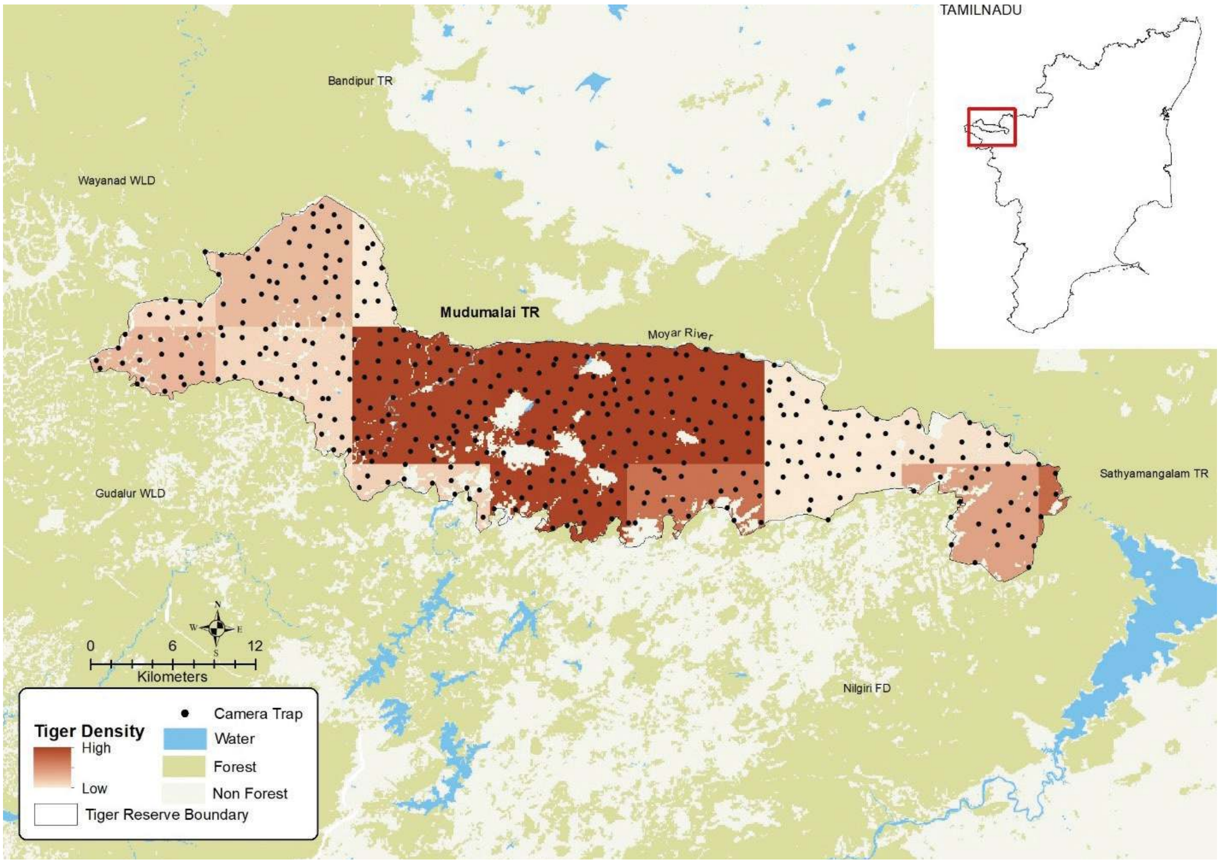

Table V.3. 45

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Mudumalai Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	2159
Camera points	395
Trap nights (effort)	17843
Unique tigers captured	114
Model	Pmix (sex)g0(sex) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	7.72 (0.72)
σ Female (SE) (km)	1.5(0.03)
σ Male (SE) (km)	3(0.08)
g0 Female (SE)	0.06(0.00)
g0 Male (SE)	0.03(0.00)
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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

With high tiger density, Mudumalai TR acts as a major source population of the Western Ghats landscape. Heavy tourism in Mudumalai and the surrounding areas has led to an increase in negative human-wildlife interactions. The increase in the percentage of invasive species is also a cause of concern. Several actions, such as installation of solar fences and regular de-weeding, have been done by the forest department to address these issues. The 30 hamlets located within the core area need to be relocated with priority. Heavy traffic on the 15 km stretch of Mysore–Gudalur NH 766/NH 181 and the 14.3 km of state highways linking Thepakadu, Masinagudi and Udhagamandalam passing through the tiger reserve is the biggest source of disturbance which needs to be appropriately mitigated.

SATHYAMANGALAM TIGER RESERVE

Sathyamangalam Tiger Reserve (1408.4 km^2) is a part of the Nilgiri landscape cluster of Western Ghats. It is contiguous with the Bandipur (Karnataka) and Sathyamangalam tiger reserves, Nilgiri (Tamil Nadu) and Wayanad (Kerala) divisions (Figure V.3.46). Camera trapping was carried out by the forest department, with an effort of 17843 trap-nights. Total of 1520 tiger images were obtained from which 85 tiger individuals were identified and tiger density was estimated at 4.24 (SE 0.46) tiger per 100 km^2 (Table V.3.46). The detection corrected sex ratio of tigers in Sathyamangalam was 1 male: 2 females (Table V.3.46). A total of 7 young tigers were photo-captured.

Figure V.3.46

Camera trap layout and spatial tiger density in Sathyamangalam Tiger Reserve, 2022

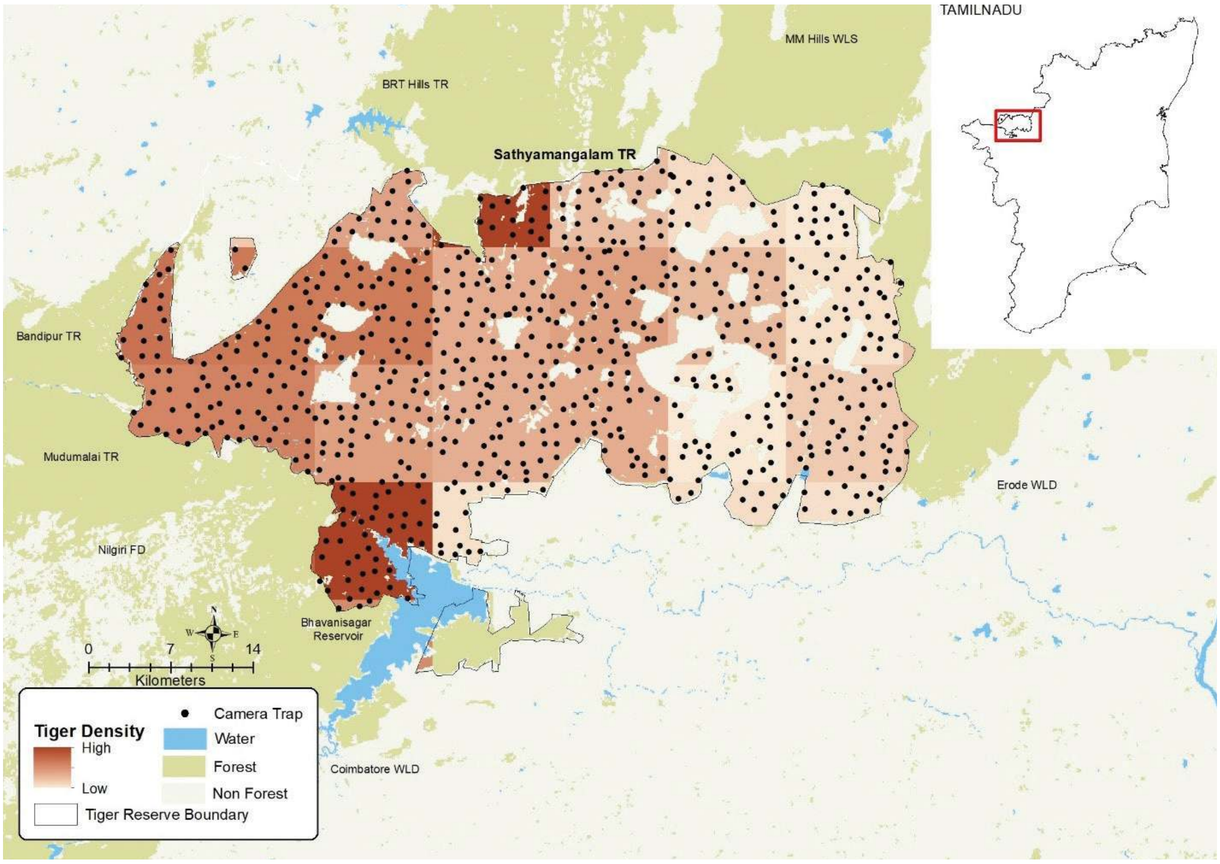

Table V.3. 46

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Sathyamangalam Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	2677
Camera points	694
Trap nights (effort)	21407
Unique tigers captured	85
Model	Pmix (sex)g0(sex) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	4.24(0.46)
σ Female (SE) (km)	2(0.05)
σ Male (SE) (km)	3.4(0.1)
g0 Female (SE)	0.03(0.002)
g0 Male (SE)	0.02(0.001)
Pmix Female (SE)	0.68(0.05)
Pmix Male (SE)	0.32(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Tiger number and density in Sathyamangalam Tiger Reserve has increased compared to the previous estimations and the tiger reserve acts as an important source population in the landscape. The reserve is plagued by the high number of human settlements interspersed between the park and the proliferation of invasive species. Traffic movements on NH 209, passing through the core area is a major source of disturbance. Habitat management, particularly grasslands, is necessary to enhance the quality of the habitat.

SRIVILLIPUTHUR-MEGHAMALAI TIGER RESERVE (SMTR)

SMTR (1017 km^2) is located in the southern Western Ghats, forming a contiguous landscape cluster with Periyar Tiger Reserve, Ranni and Konni divisions (Kerala) (Figure V.3.47). Camera trapping was carried out by the forest department, with an effort of 28107 trap-nights. Total of 167 tiger images were obtained from which 12 tiger individuals were identified and tiger density was estimated at 1.05 (SE 0.31) tiger per 100 km^2 (Table V.3.47). The detection corrected sex ratio of tigers in SMTR was nearly 1 male: 2 females (Table V.3.47). One young tiger was photo-captured.

Figure V.3.47

Camera trap layout and spatial tiger density in Srivilliputhur-Meghamalai Tiger Reserve, 2022

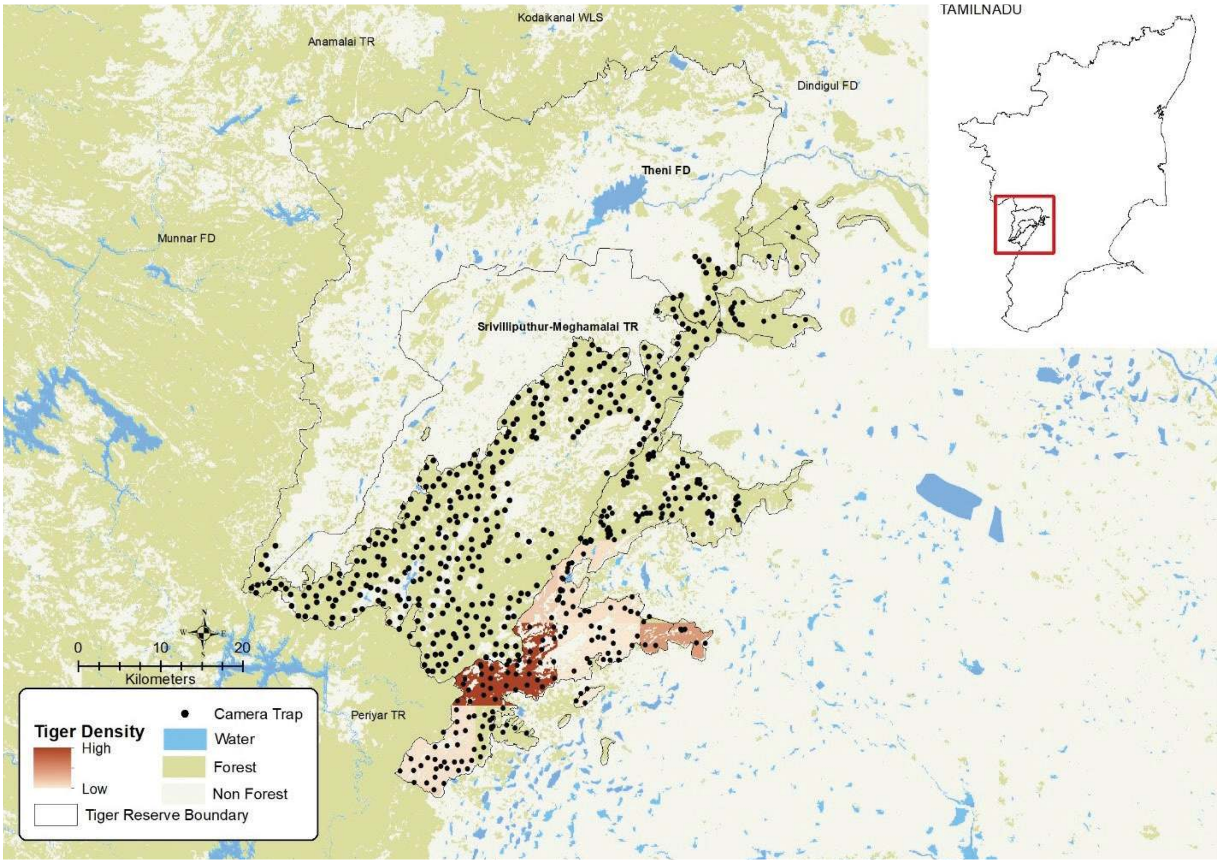

Table V.3. 47

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Srivilliputhur-Meghamalai Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	1674
Camera points	344
Trap nights (effort)	28107
Unique tigers captured	12
Model	Pmix (sex)g0(sex) σ(.)
$\hat{D}$ SECR (per 100 km^2)	1.05(0.31)
σ Female (SE) (km)	2.5(0.17)
σ Male (SE) (km)	2.5(0.17)
g0 Female (SE)	0.01(0.002)
g0 Male (SE)	0.02(0.004)
Pmix Female (SE)	0.61(0.13)
Pmix Male (SE)	0.39(0.13)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

SMTR is a newly formed tiger reserve. Although the tiger density of the reserve is low, with appropriate wildlife and habitat management practices, the reserve can harbour a healthy resident tiger population. By strengthening the linkages, the reserve can become contiguous with the KMTR cluster, which will allow tigers to move between this extended habitat and establish new meta-populations.

COIMBATORE WILDLIFE DIVISION

Coimbatore Wildlife Division is located in the Nilgiri landscape cluster of Western Ghats, contiguous with the Sathyamangalam Tiger Reserves and Nilgiri division (Tamil Nadu) (Figure V.3.48). Camera trapping was carried out by the forest department, with an effort of 4090 trap-nights. Total of 207 tiger images were obtained from which 14 tiger individuals were identified and tiger density was estimated at 1.59 (SE 0.47) tiger per 100 km^2 (Table V.3.48). The detection corrected sex ratio of tigers in Coimbatore was nearly 1 male: 3 females (Table V.3.48). One young tiger was photo-captured.

Figure V.3.48

Camera trap layout and spatial tiger density in Coimbatore Wildlife Division, 2022.

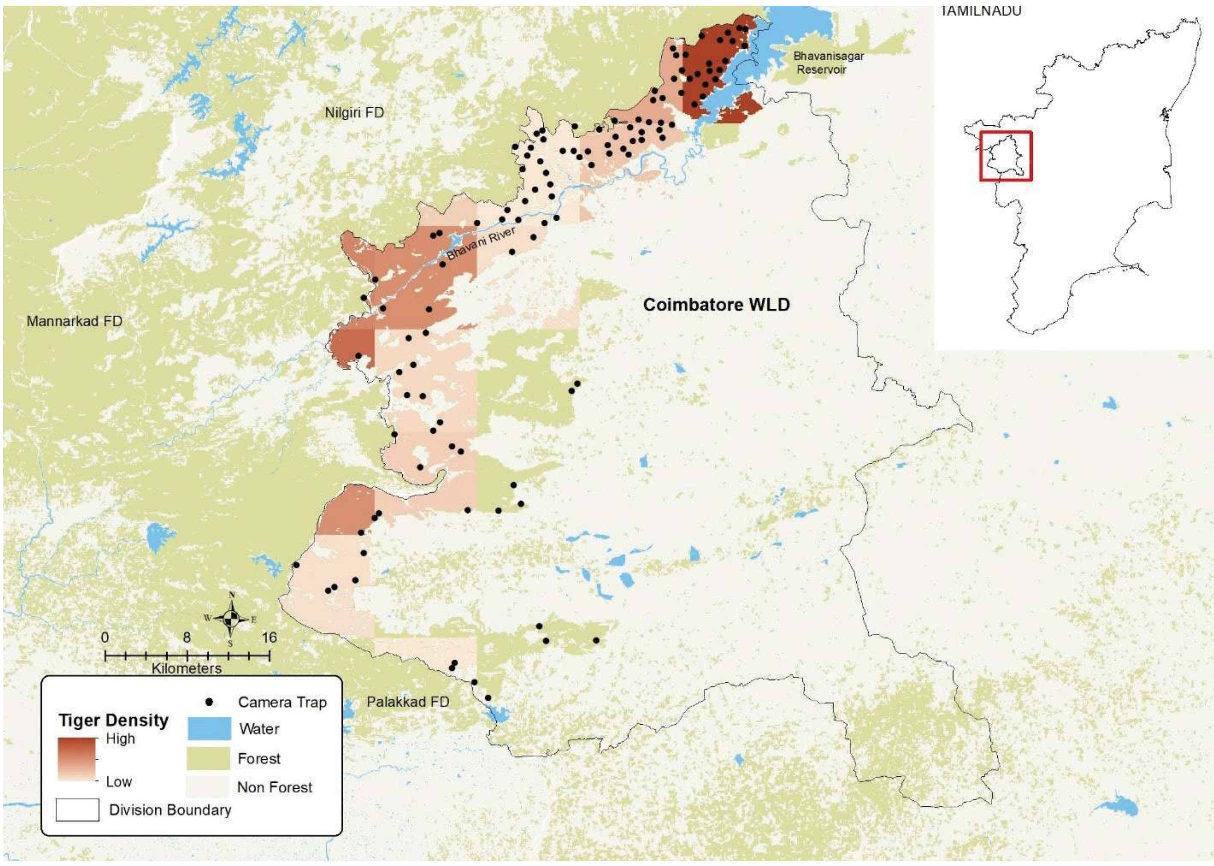

Table V.3. 48

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Coimbatore Wildlife Division, 2022.

Variables	Estimate
Model space (km^2)	1326
Camera points	111
Trap nights (effort)	4090
Unique tigers captured	14
Model	Pmix (sex)g0(sex) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	1.59(0.47)
σ Female (SE) (km)	1.3(0.2)
σ Male (SE) (km)	3.9(0.6)
g0 Female (SE)	0.13(0.04)
g0 Male (SE)	0.02(0.01)
Pmix Female (SE)	0.73(0.12)
Pmix Male (SE)	0.27(0.12)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

The tiger density of Coimbatore Wildlife Division has been consistently low since the previous cycles [1.70 (0.54 SE), Jhala *et. al.*, 2018]. The highways passing through the division are observed to have heavy traffic as they are favored tourism routes. In addition to this, the division also faces very high negative human-wildlife interaction, primarily with respect to elephants. Since Coimbatore is an important tiger habitat, maintaining the meta-population dynamics for the species in the landscape, it is critical to implement better protection and management regimes to tackle the conservation challenges in this division.

ERODE WILDLIFE DIVISION

Erode Wildlife Division is a part of the Nilgiri landscape cluster of Western Ghats. It has connectivity with Sathyamangalam tiger reserve (Tamilnadu), MM Hills and Cauvery Wildlife Sanctuaries (Karnataka) (Figure V.3.49). Camera trapping was carried out by the forest department, with an effort of 11186 trap-nights. Total of 409 tiger images were obtained from which 9 tiger individuals were identified and tiger density was estimated at 0.65 (SE 0.22) tiger per 100 km^2 (Table V.3.49). The detection corrected sex ratio of tigers in Erode was 1 male: 2 females (Table V.3.49). No young tiger was photo-captured.

Figure V.3.49

Camera trap layout and spatial tiger density in Erode Wildlife Division, 2022

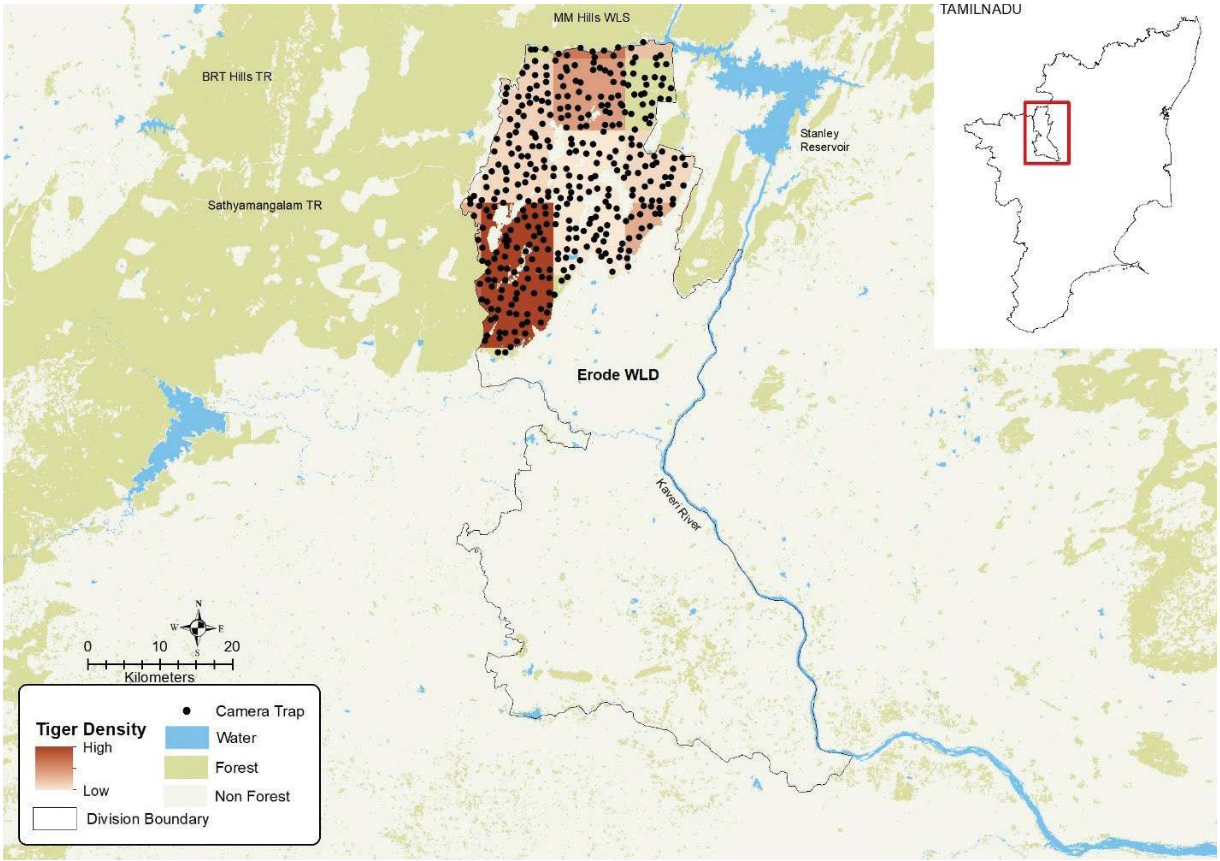

Table V.3. 49

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Erode Wildlife Division, 2022

Variables	Estimate
Model space (km^2)	1746
Camera points	368
Trap nights (effort)	11186
Unique tigers captured	9
Model	Pmix (sex)g0(.) σ(.)
$\hat{D}$ SECR (per 100 km^2)	0.65(0.22)
σ (SE) (km)	4.2(0.3)
g0 (SE)	0.02(0.002)
Pmix Female (SE)	0.62(0.17)
Pmix Male (SE)	0.38(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Erode Wildlife Division comes under the buffer zone of Sathyamangalam Tiger Reserve. Therefore, it acts as an important sink habitat and connecting link for tigers dispersing from the Bandipur-Mudumalai- Sathyamangalam complex.

GUDALUR WILDLIFE DIVISION

Gudalur Wildlife Division is situated in the Nilgiri landscape cluster of Western Ghats. It is contiguous with the Mudumalai tiger reserve, Nilgiri (Tamil Nadu) and Wayanad (Kerala) Wildlife Divisions (Figure V.3.50). Camera trapping was carried out by the forest department, with an effort of 2897 trap-nights. Total of 58 tiger images were obtained from which 10 tiger individuals were identified and tiger density was estimated at 2.63 (SE 1.39) tiger per 100 km^2 (Table V.3.50). The detection corrected sex ratio of tigers in Gudalur was 1 male: 5 females (Table V.3. 50). No young tiger was photo-captured.

Figure V.3.50

Camera trap layout and spatial tiger density in Gudalur Wildlife Division, 2022

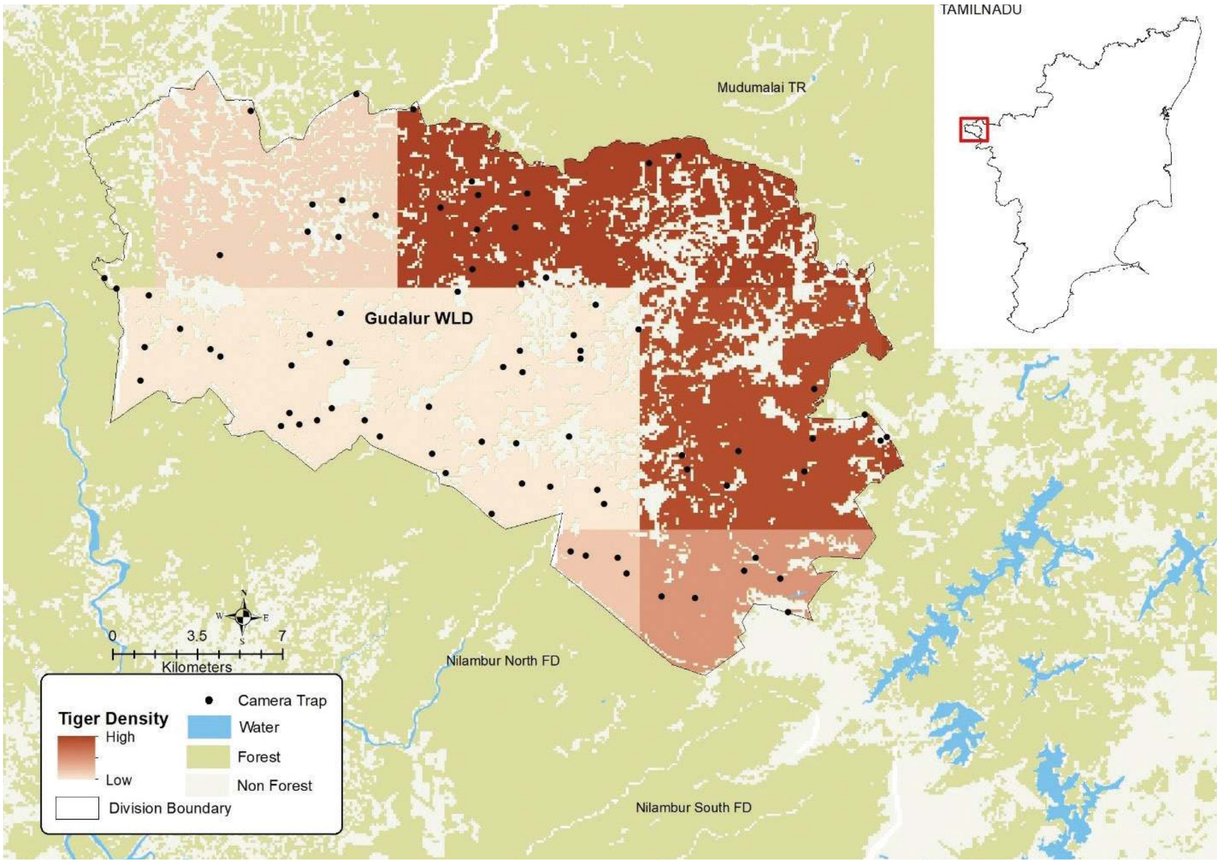

Table V.3. 50

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Gudalur Wildlife Division, 2022.

Variables	Estimate
Model space (km²)	1368
Camera points	80
Trap nights (effort)	2897
Unique tigers captured	10
Model	Pmix (sex)g0(.) σ(sex)
$\hat{D}$ SECR (per 100 km²)	2.63(1.39)
σ Female (SE) (km)	0.8(0.3)
σ Male (SE) (km)	3.3(0.5)
g0 (SE)	0.03(0.02)
Pmix Female (SE)	0.83(0.11)
Pmix Male (SE)	0.17(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Gudalur Wildlife Division shares boundary with Muduamali TR, and acts as a sink habitat in the Nilgiri cluster (Nagarahole-Bandipur-Mudumalai-Sathyamangalam-BRT Hills complex). Many national and state highways traversing the division acting as barrier to wildlife movement.

KANYAKUMARI WILDLIFE SANCTUARY

Kanyakumari WLS is located in the southern Western Ghats, forming a continuous landscape cluster with KMTR (Figure V.3.51). Camera trapping was carried out by the forest department, with an effort of 3023 trap-nights (Table V.3. 51). During the camera trapping exercise, no tiger was photo-captured.

Figure V.3.51

Camera trap layout in Kanyakumari Wildlife Sanctuary, 2022.

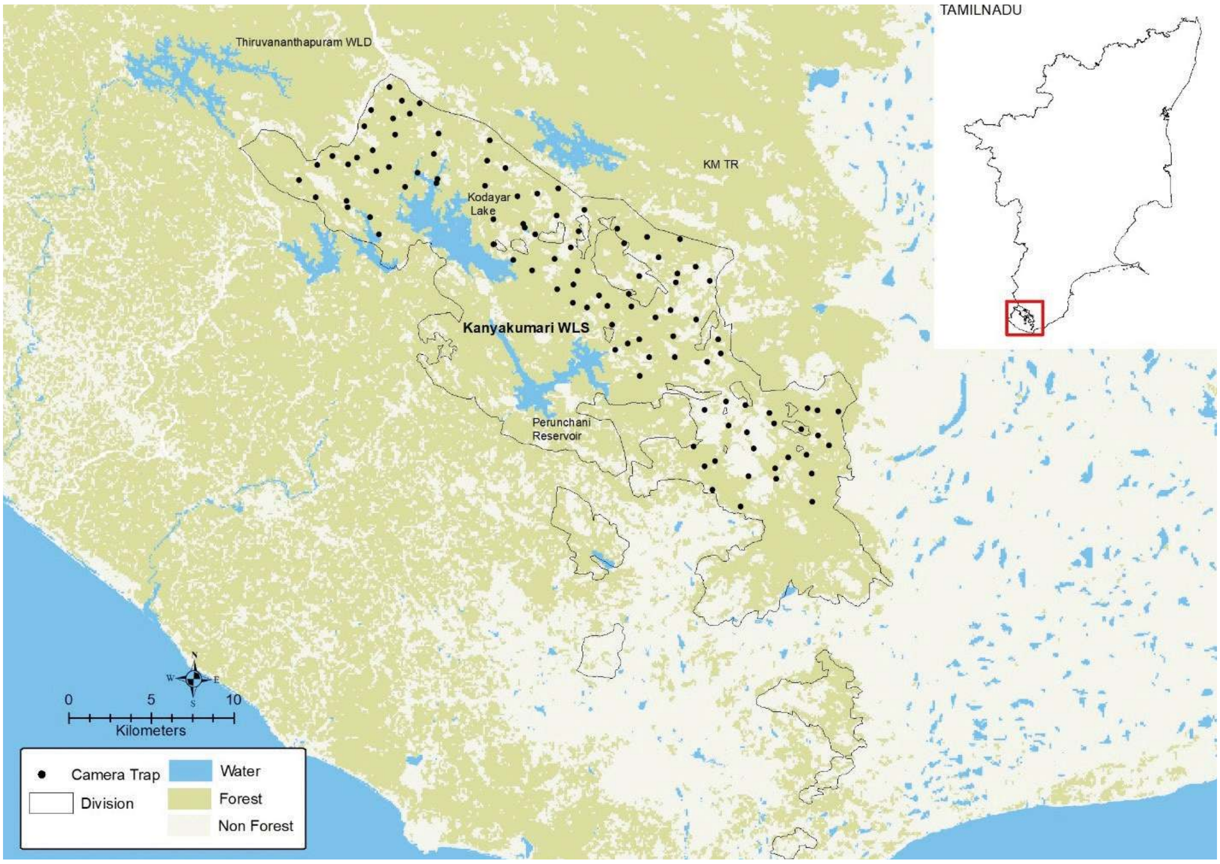

Table V.3. 51

Sampling details of camera trapping exercise in Kanyakumari Wildlife Sanctuary, 2022.

Sampling Details	Counts
Camera points	105
Trap nights (effort)	3023
Number of tiger photos	0

Kanyakumari wildlife sanctuary is the southernmost limit of tiger distribution in India. However, no tigers were detected during this population estimation exercise.

KODAIKANAL WILDLIFE SANCTUARY

Kodaikanal WLS is located in the southern Western Ghats, forming a part of the Anamalai-Parambikulam landscape cluster. Camera trapping was carried out by the forest department, with an effort of 2928 trap-nights. Total of 57 tiger images were obtained from which 3 tiger individuals were identified (Table V.3.52). One young tiger was photo-captured.

Figure V.3.52

Camera trap layout and tiger presence in Kodaikanal Wildlife Sanctuary, 2022

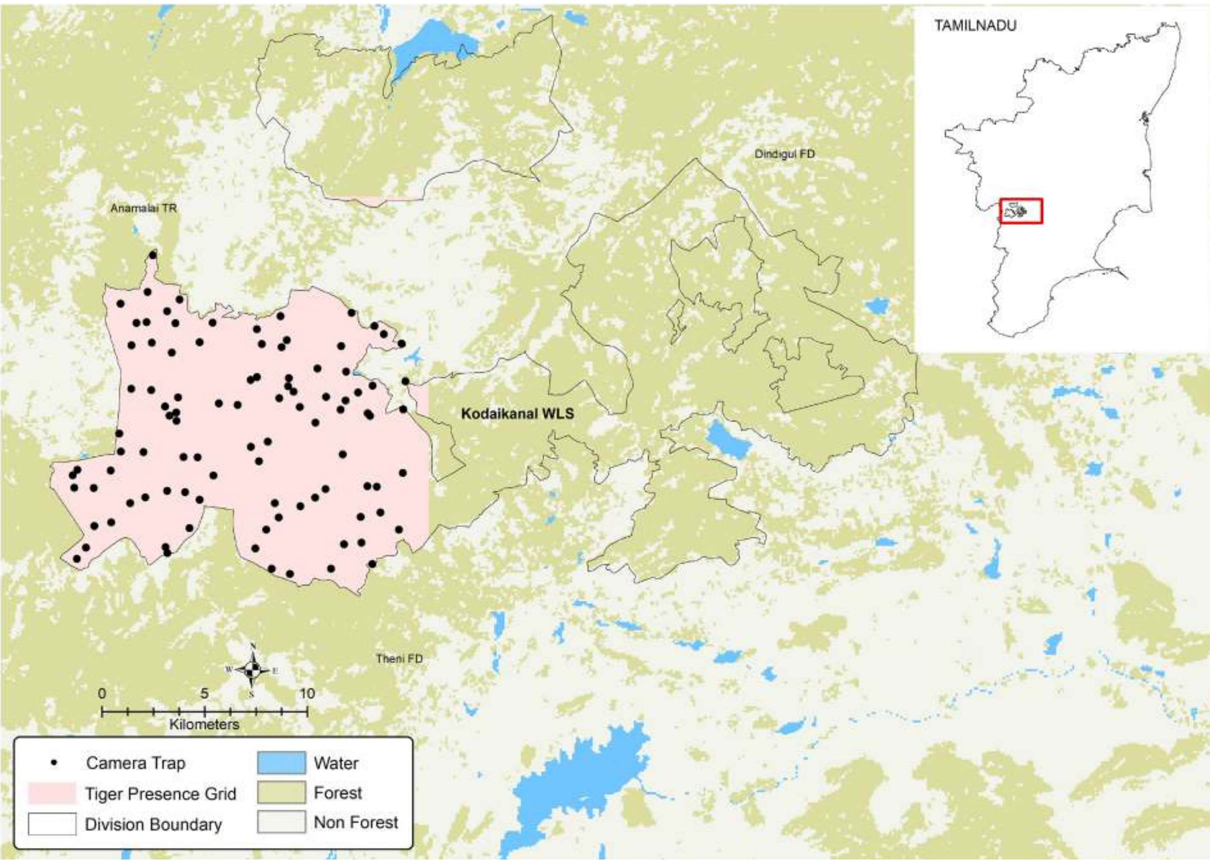

Table V.3. 52

Sampling details of camera trapping exercise in Kodaikanal Wildlife Sanctuary, 2022

Sampling Details	Counts
Camera points	97
Trap nights (effort)	2928
Number of tiger photos	57
Unique tigers captured	3

Although, Kodaikanal Wildlife Sanctuary has only a few tigers, it 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.

MUKURTHI NATIONAL PARK

Mukurthi NP is a part of the Nilgiri landscape cluster of Western Ghats. It is contiguous with the Nilgiri division (Tamil Nadu) and Silent Valley NP (Kerala) (Figure V.3.53). Camera trapping was carried out by the forest department, with an effort of 2328 trap-nights. Total of 142 tiger images were obtained from which 9 tiger individuals were identified and tiger density was estimated at 1.34 (SE 0.5) tiger per 100 km^2 (Table V.3.53). The detection corrected sex ratio of tigers in Mukurthi was 1 male: 2.5 females (Table V.3.53). No young tiger was photo-captured.

Figure V.3.53

Camera trap layout and spatial tiger density in Mukurthi National Park, 2022

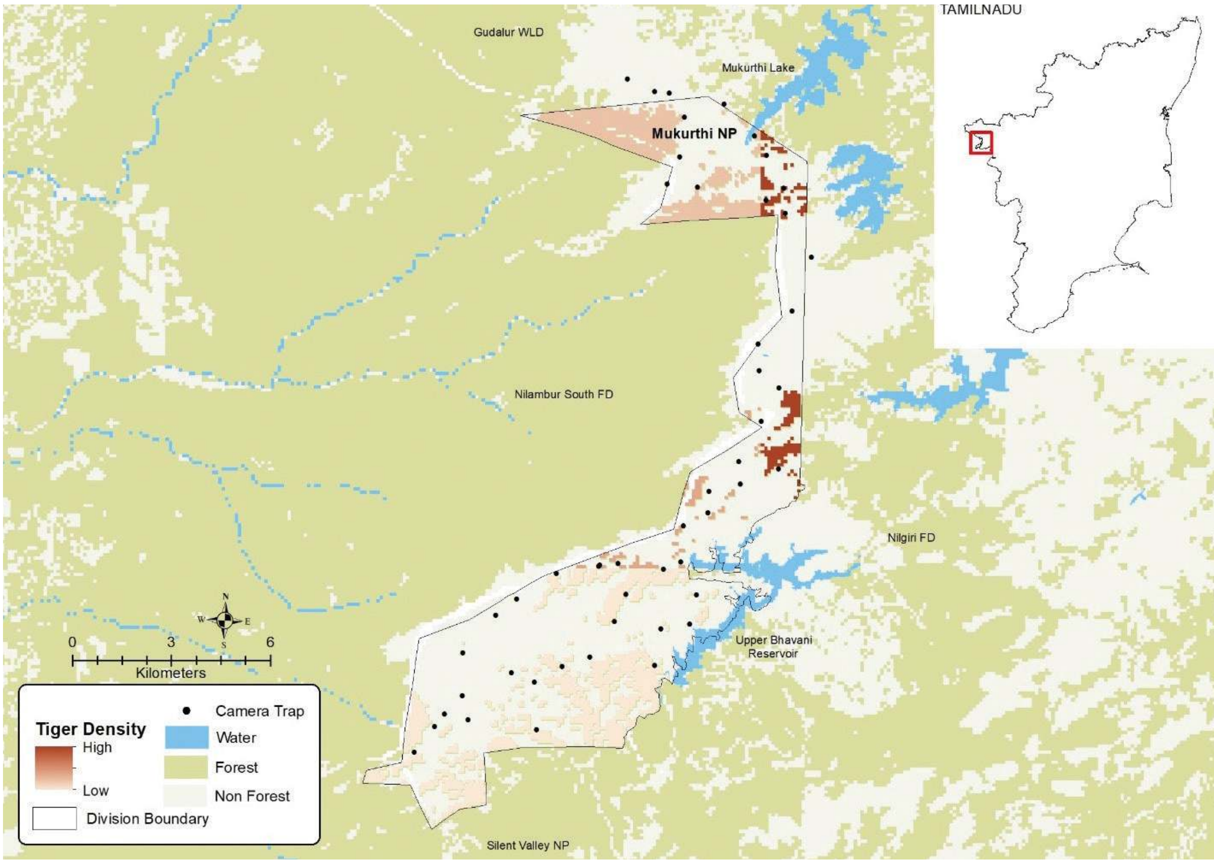

Table V.3. 53

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Mukurthi National Park, 2022

Variables	Estimate
Model space (km^2)	849
Camera points	50
Trap nights (effort)	2328
Unique tigers captured	9
Model	Pmix (sex)g0(.) σ(.)
D̂ SECR (per 100 km^2)	1.34(0.5)
σ Female (SE) (km)	3.7(0.50)
σ Male (SE) (km)	3.7(0.50)
g0 Female (SE)	0.02(0.004)
g0 Male (SE)	0.02(0.004)
Pmix Female (SE)	0.71(0.17)
Pmix Male (SE)	0.29(0.17)

SE: Standard error
D̂ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Mukurthi National Park not only has tigers but also supports a rich assemblage of flora and fauna and endemism. The area has thriving population of endangered Nilgiri tahr. The watershed is a lifeline for people and wildlife of this region and any developmental activity need to ensure the survival of this beautiful and fragile landscape.

NELLAI WILDLIFE SANCTUARY

Nellai WLS is located in the southern Western Ghats, forming a continuous landscape cluster with KMTR (Figure V.3.54). Camera trapping was carried out by the forest department, with an effort of 3421 trap-nights. Total of 28 tiger images were obtained from which 3 tiger individuals were identified (Table V.3.54). No young tiger was photo-captured.

Figure V.3.54

Camera trap layout and tiger presence map in Nellai Wildlife Sanctuary, 2022.

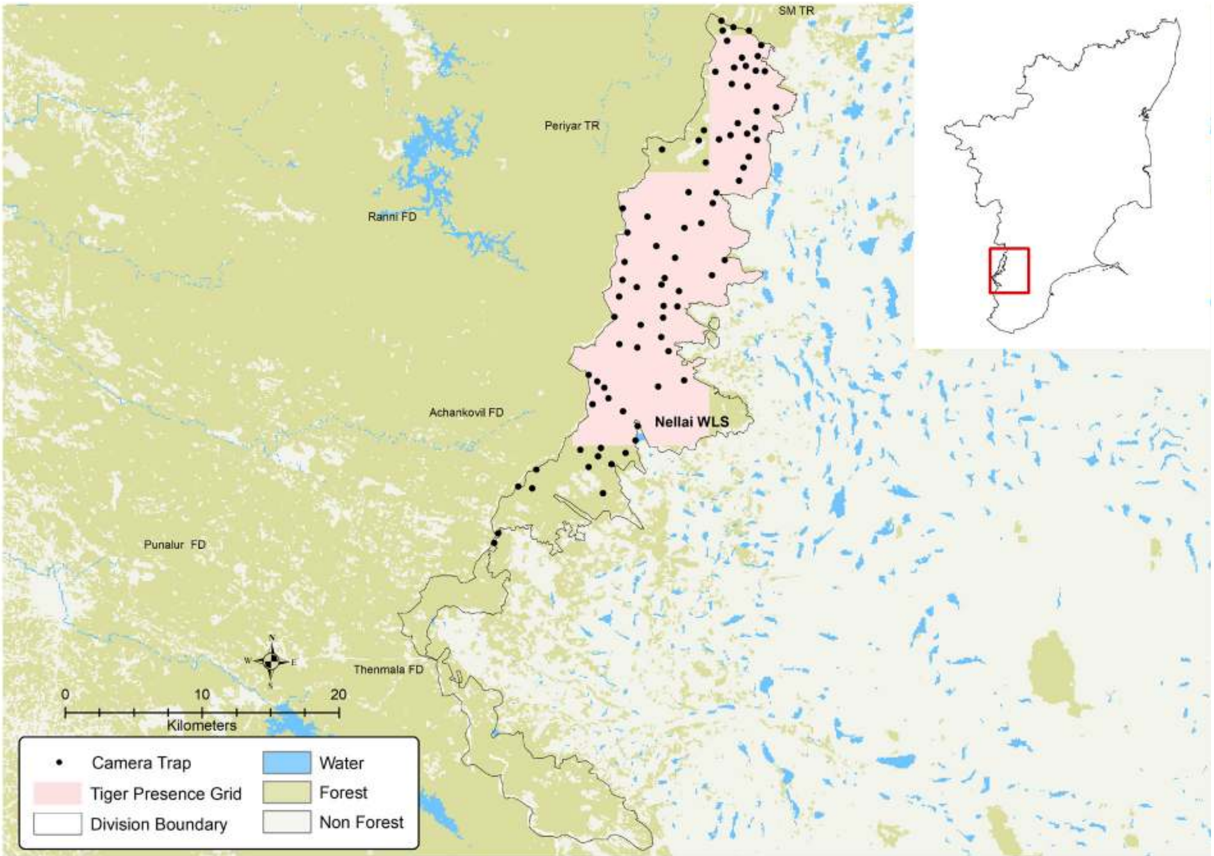

Table V.3. 54

Sampling details of camera trapping exercise in Nellai Wildlife Sanctuary, 2022.

Sampling Details	Counts
Camera points	80
Trap nights (effort)	3421
Number of tiger photos	28
Unique tigers captured	3

Even though only three tigers were photo-captured, 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. It is critical to minimize disturbance and strengthen this linkage further.

NILGIRI FOREST DIVISION

Nilgiri forest division is a part of the Nilgiri landscape cluster of Western Ghats. It is contiguous with the Sathyamangalam and Mudumalai Tiger Reserves, Mukurthi NP, Coimbatore and Gudalur divisions (Tamil Nadu) (Figure V.3.55). Camera trapping was carried out by the forest department, with an effort of 12023 trap-nights. Total of 788 tiger images were obtained from which 50 tiger individuals were identified and tiger density was estimated at 3.08 (SE 0.4) tiger per 100 km^2 (Table V.3.55). The detection corrected sex ratio of tigers in Nilgiri Forest Division was nearly 1 male: 2 females (Table V.3.55). No young tiger was photo-captured.

Figure V.3.55

Camera trap layout and spatial tiger density in Nilgiri Forest Division, 2022

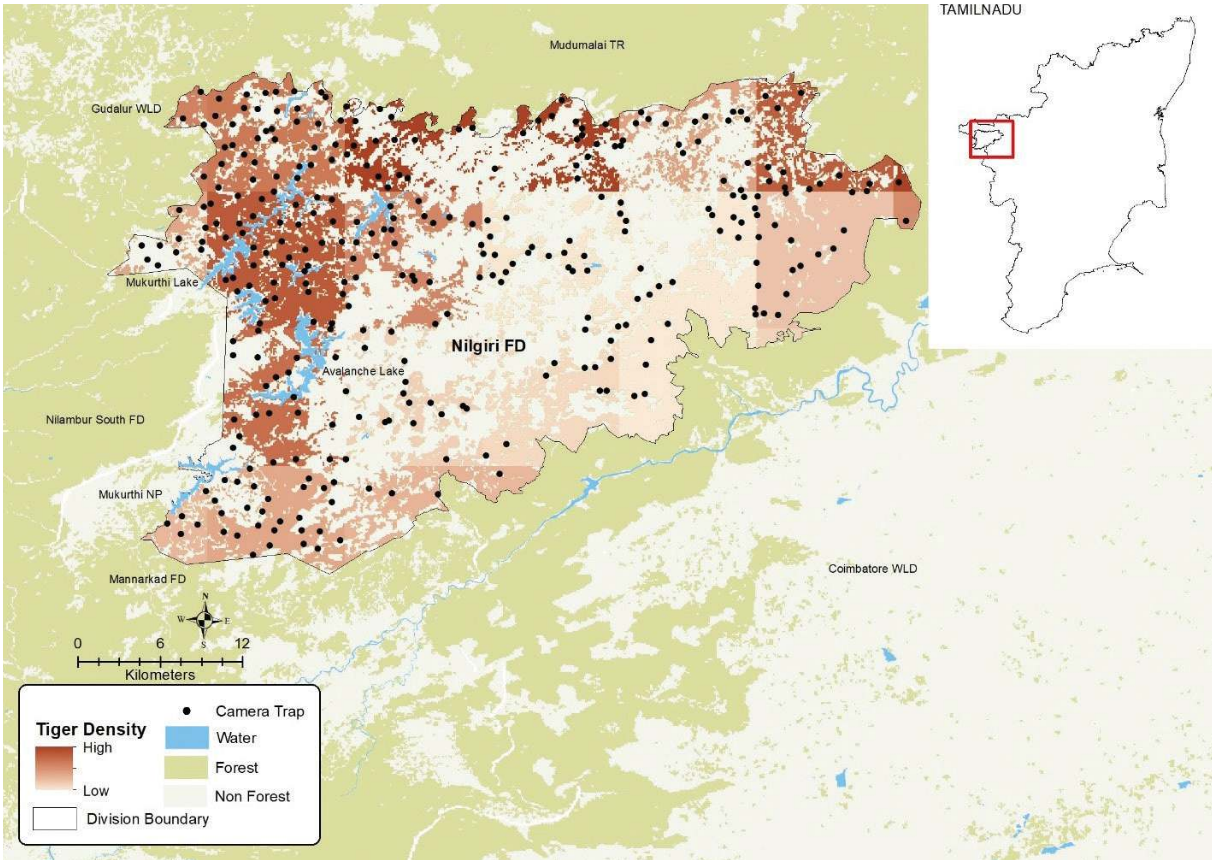

Table V.3. 55

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Nilgiri Forest Division, 2022

Variables	Estimate
Model space (km^2)	2425
Camera points	328
Trap nights (effort)	12023
Unique tigers captured	50
Model	Pmix (sex)g0(sex) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	3.08(0.4)
σ Female (SE) (km)	1.5(0.05)
σ Male (SE) (km)	3.1(0.1)
g0 Female (SE)	0.07(0.01)
g0 Male (SE)	0.03(0.002)
Pmix Female (SE)	0.67(0.07)
Pmix Male (SE)	0.33(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Nilgiri Forest Division is an important habitat for tigers dispersing from the Nagarahole-Bandipur-Mudumalai cluster, also connecting the complex with other forest divisions. The division provides habitat heterogeneity with elevation gradient. However, there are several human habitations interspersed between the forests, many of them being popular tourist destinations. Many tea and coffee plantations are also present in the division and it is also traversed by highways with continuous and heavy vehicular movement. Better protection and controlling/mitigating developmental activities that can act as barriers to wildlife movement and encroach on critical habitats needs to be implemented.

KERALA

PARAMBIKULAM TIGER RESERVE

Parambikulam Tiger Reserve (643.66 km^2) is located in the southern Western Ghats, south of the Palghat gap. It forms a continuous landscape cluster along with Anamalai tiger reserve, Kodaikanal WLS (Tamil Nadu), Malayatoor and Vazhachal forest divisions (Kerala) (Figure V.3.56). Camera trapping was carried out by the forest department, with an effort of 11132 trap-nights. Total of 841 tiger images were obtained from which 31 tiger individuals were identified and tiger density was estimated at 2.29 (SE 0.41) tiger per 100 km^2 (Table V.3.56). The detection corrected sex ratio of tigers in Parambikulam was nearly 1 male: 1.5 females (Table V.3.56). No young tiger was photo-captured.

Figure V.3.56

Camera trap layout and spatial tiger density in Parambikulam Tiger Reserve, 2022

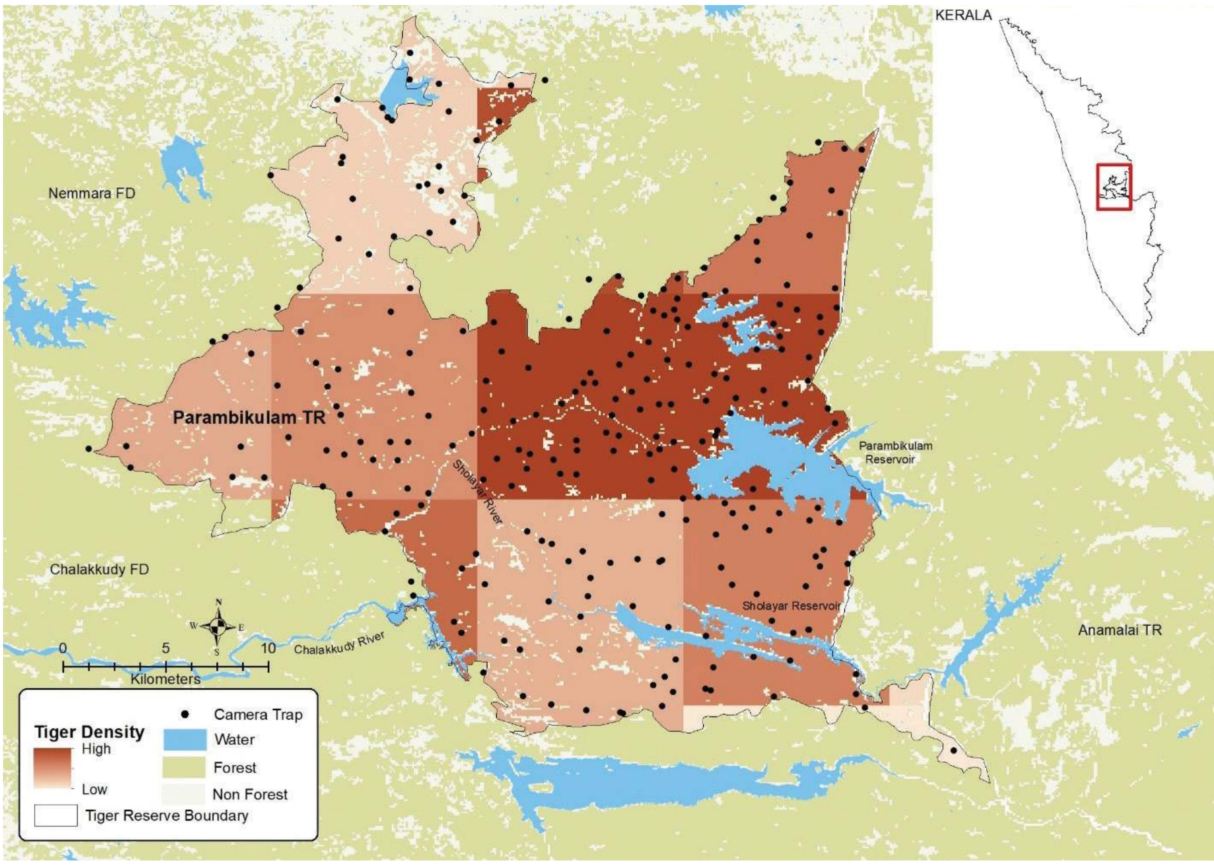

Table V.3. 56

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Parambikulam Tiger Reserve, 2022.

Variables	Estimate
Model space (km^2)	1927
Camera points	242
Trap nights (effort)	11132
Unique tigers captured	31
Model	Pmix (sex)g0(sex) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	2.29(0.41)
σ Female (SE) (km)	2.2(0.1)
σ Male (SE) (km)	4.6(0.27)
g0 Female (SE)	0.04(0.004)
g0 Male (SE)	0.02(0.003)
Pmix Female (SE)	0.64(0.09)
Pmix Male (SE)	0.36(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Tiger density has increased since the previous cycles of estimation [2.33 (0.63 SE) in 2014 and 1.95 (0.39 SE) in 2018, Jhala *et. al.,* 2015 and 2020]. This Southern Western Ghats population of tigers is considered a conservation priority due to its genetic uniqueness and poor status. Tourism has increased manifolds in the recent years, which has increased disturbance in the reserve. Proper management interventions, especially protection to increase prey density would be helpful.

PERIYAR TIGER RESERVE

Periyar Tiger Reserve (925 km^2) is located in southern Western Ghats and forms a contiguous landscape cluster with Srivilliputhur-Meghamalai tiger reserve (Tamil Nadu), Ranni and Konni Divisions (Kerala) (Figure V.3.57). Camera trapping was carried out by the forest department, with an effort of 9758 trap-nights. Total of 1220 tiger images were obtained from which 30 tiger individuals were identified and tiger density was estimated at 1.43 (SE 0.27) tiger per 100 km^2 (Table V.3. 57). The detection corrected sex ratio of tigers in Periyar was nearly 1 male: 1 female (Table V.3. 57). A total of 7 young tigers were photo-captured.

Figure V.3.57

Camera trap layout and spatial tiger density in Periyar Tiger Reserve, 2022

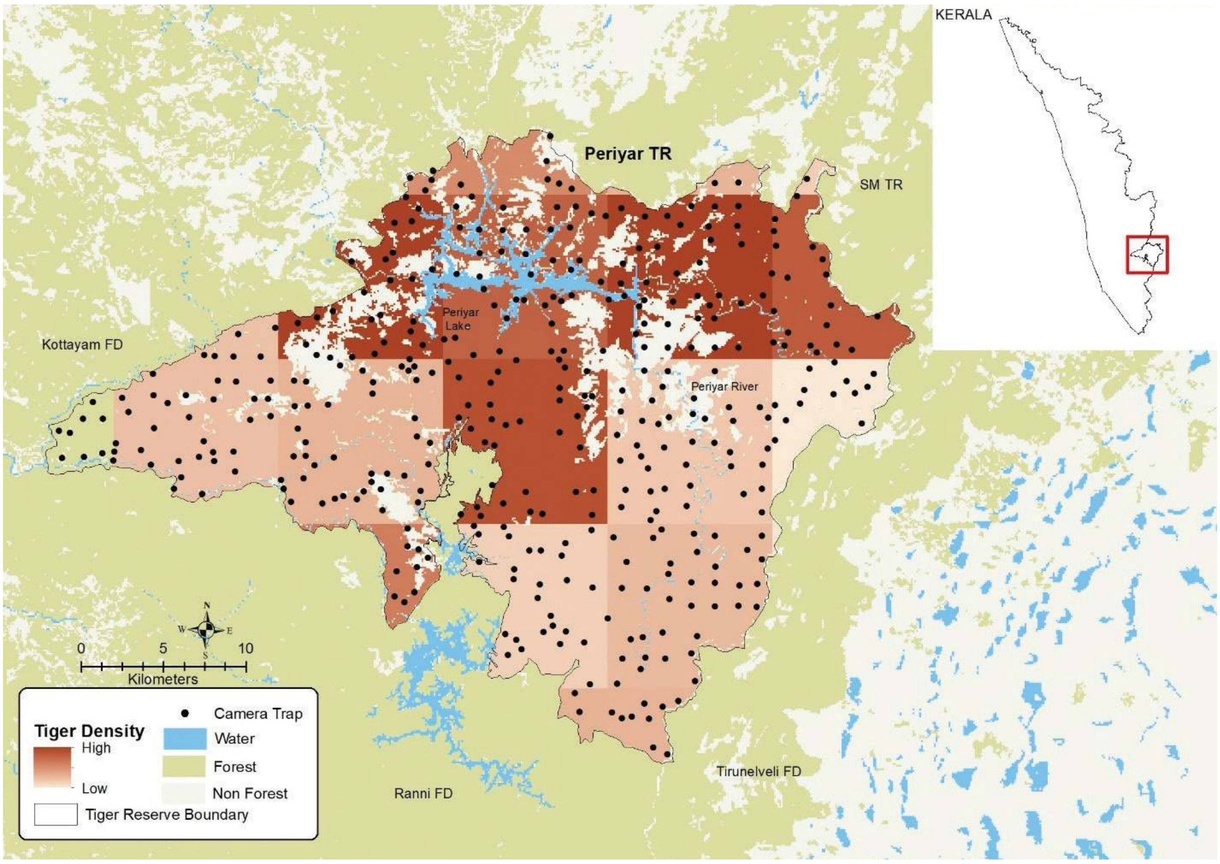

Table V.3. 57

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Periyar Tiger Reserve, 2022

Variables	Estimate
Model space (km^2)	2951
Camera points	396
Trap nights (effort)	9758
Unique tigers captured	30
Model	Pmix (sex)g0(sex) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	1.43(0.27)
σ Female (SE) (km)	4.4(0.3)
σ Male (SE) (km)	5.7(0.3)
g0 Female (SE)	0.008(0.001)
g0 Male (SE)	0.016(0.002)
Pmix Female (SE)	0.54(0.09)
Pmix Male (SE)	0.46(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Tiger density in Periyar tiger reserve has been consistently low since the previous cycles [1.2 (0.26 SE) in 2014 and 1.38 (0.29 SE) in 2018, Jhala *et al.* 2015 and 2020]. One of the conservation issues which need immediate focus and resolution is the proliferation of invasive species in the Shola grasslands and around the Periyar lake, which are prime habitat for faunal diversity in the reserve. The unregulated pilgrimage to the temples situated inside the Tiger Reserve, during certain times of the year. Management issues due to conflicts between state boundaries is also a conservation impediment

ERAVIKULAM NATIONAL PARK

Eravikulam NP lies in the southern Western Ghats, forming a continuous landscape cluster along with Anamalai Tiger Reserve, Kodaikanal WLS (Tamil Nadu), Parambikulam Tiger Reserve, Malayatoor and Vazhachal forest divisions (Kerala) (Figure V.3.58). Camera trapping was carried out by the forest department, with an effort of 791 trap-nights. Total of 41 tiger images were obtained from which 4 tiger individuals were identified (Table V.3.58). No young tiger was photo-captured.

Figure V.3.58

Camera trap layout and tiger presence in Eravikulam National Park, 2022.

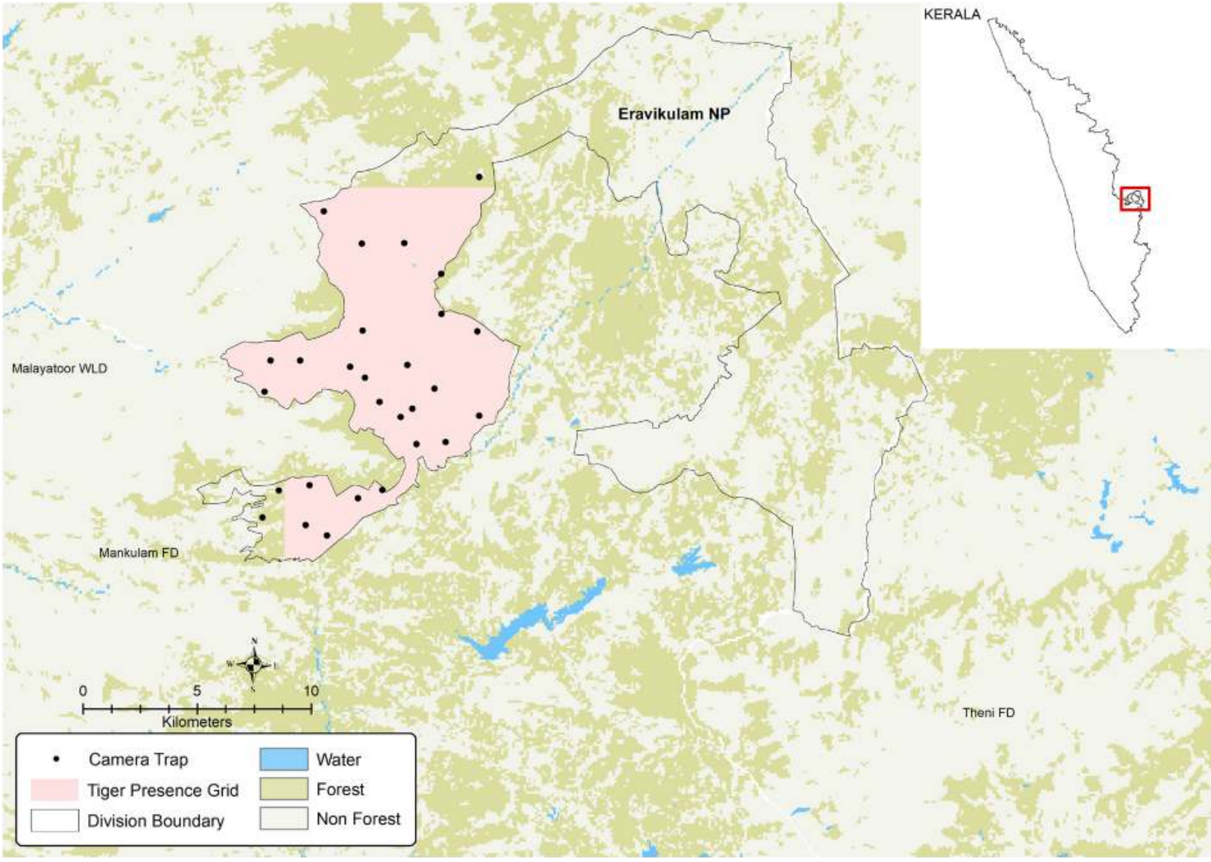

Table V.3. 58

Sampling details of camera trapping exercise in Eravikulam National Park, 2022.

Sampling Details	Counts
Camera points	28
Trap nights (effort)	791
Number of tiger photos	41
Unique tigers captured	4

Eravikulam NP is a vital link for the movement and dispersal of tigers and elephants from the adjoining Tiger Reserves. The park is stronghold for Nilgiri tahrs. Due to proximity of the park to Munnar, there is an increased tourist influx in the area leading to disturbance and associated developmental activities. The area occupied by tea and coffee estates has also increased fragmentations significantly.

KONNI FOREST DIVISION

Konni Forest Division is located in southern Western Ghats and forms a contiguous landscape cluster with Srivilliputhur-Meghamalai Tiger Reserve (Tamil Nadu), Periyar tiger reserve and Ranni division (Kerala) (Figure V.3.59). Camera trapping was carried out by the forest department, with an effort of 2856 trap-nights. Total of 207 tiger images were obtained from which 7 tiger individuals were identified and tiger density was estimated at 0.79 (SE 0.33) tiger per 100 km^2 (Table V.3. 59). The detection corrected sex ratio of tigers in Konni was 2.5 males: 1 female (Table V.3.59). No young tiger was photo-captured.

Figure V.3.59

Camera trap layout and spatial tiger density in Konni Forest Division, 2022.

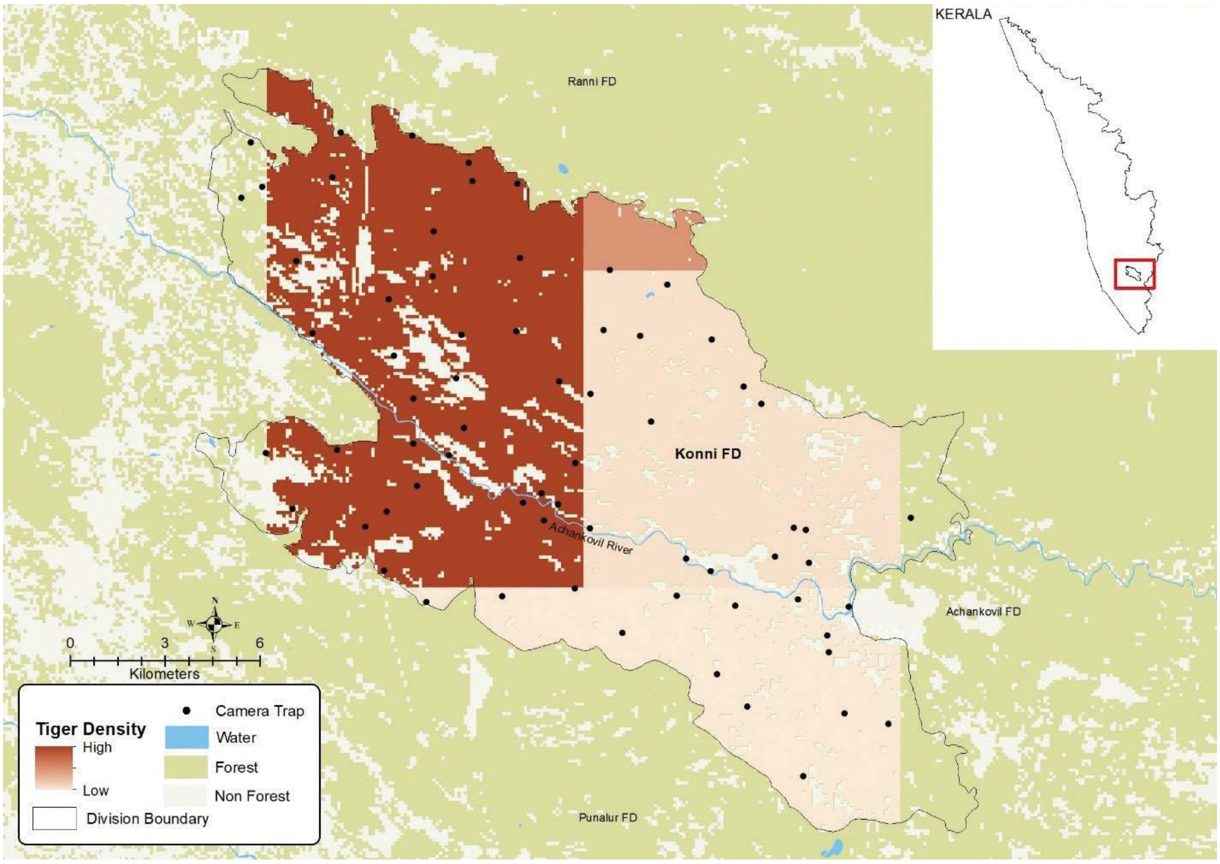

Table V.3. 59

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Konni Forest Division, 2022.

Variables	Estimate
Model space (km^2)	1114
Camera points	68
Trap nights (effort)	2856
Unique tigers captured	7
Model	Pmix (sex)g0(.) σ(.)
$\hat{D}$ SECR (per 100 km^2)	0.79 (0.33)
σ (SE) (km)	6.1(1.1)
g0 (SE)	0.01(0.002)
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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Konni Forest Division acts as a vital sink habitat for the movement and dispersal of tigers and elephants from Periyar Tiger Reserve.

MALAYATOOR WILDLIFE DIVISION

Malayatoor Wildlife Division lies in the southern Western Ghats, forming a continuous landscape cluster along with Anamalai Tiger Reserve, Kodaikanal WLS (Tamil Nadu), Parambikulam tiger reserve and Vazhachal forest division (Kerala) (Figure V.3.60). Camera trapping was carried out by the forest department, with an effort of 2425 trap-nights. Total of 85 tiger images were obtained from which 4 tiger individuals were identified (Table V.3.60). No young tiger was photo-captured.

Figure V.3.60

Camera trap layout and tiger presence in Malayatoor Wildlife Division, 2022.

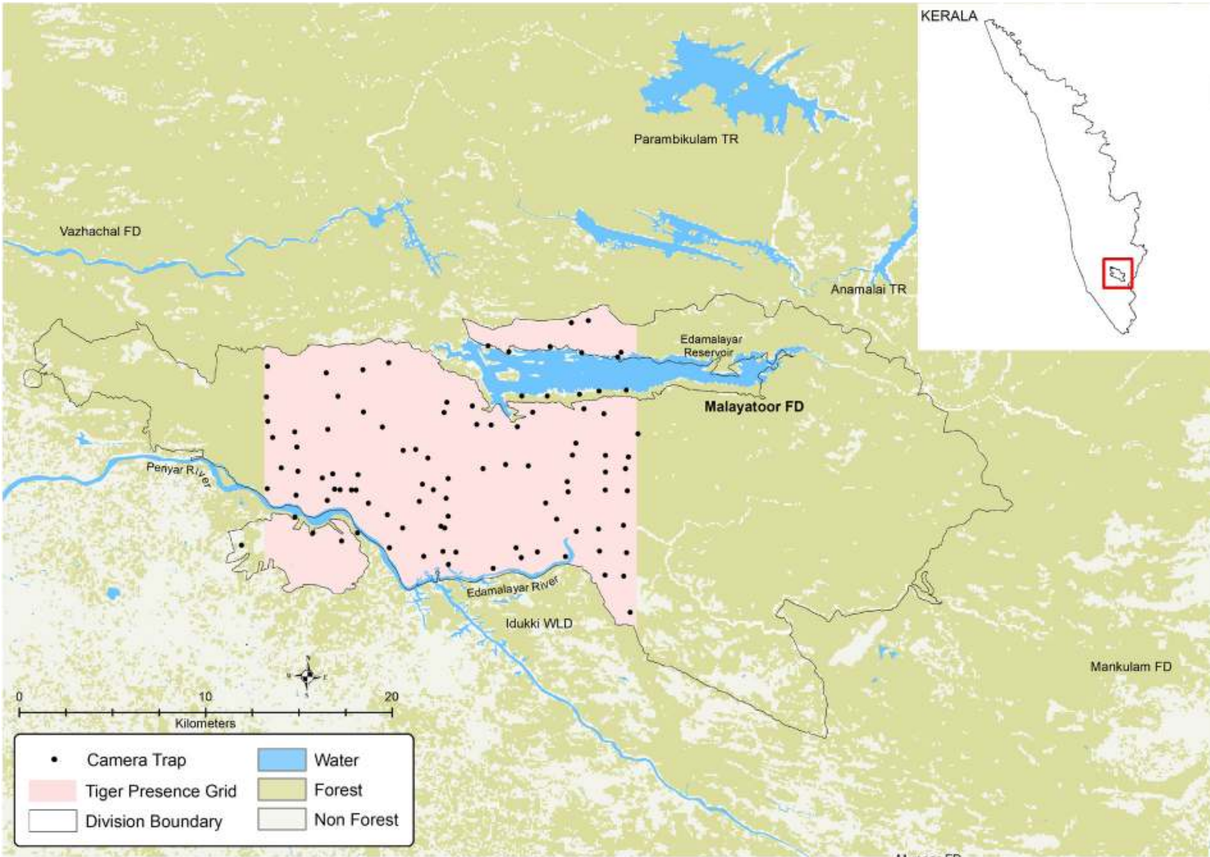

Table V.3. 60

Sampling details of camera trapping exercise in Malayatoor Wildlife Division, 2022.

Sampling Details	Counts
Camera points	100
Trap nights (effort)	2425
Number of tiger photos	85
Unique tigers captured	4

Malayatoor Wildlife Division is an important tiger habitat maintaining the meta-population dynamics for the species in the landscape. Better protection, minimizing human-wildlife conflict and mitigating developmental projects are some of the key actions for conservation of this Division.

RANNI FOREST DIVISION

Ranni Forest Division is located in southern Western Ghats and forms a contiguous landscape cluster with Srivilliputhur-Meghamalai (Tamil Nadu), Periyar Tiger Reserves and Konni division (Kerala) (Figure V.3.61). Camera trapping was carried out by the forest department, with an effort of 2856 trap-nights. Total of 69 tiger images were obtained from which 6 tiger individuals were identified and tiger density was estimated at 0.44 (SE 0.22) tiger per 100 km^2 (Table V.3.61). The detection corrected sex ratio of tigers in Ranni was 3 males: 1 female (Table V.3.61). No young tiger was photo-captured.

Figure V.3.61

Camera trap layout and spatial tiger density in Ranni Wildlife Division, 2022.

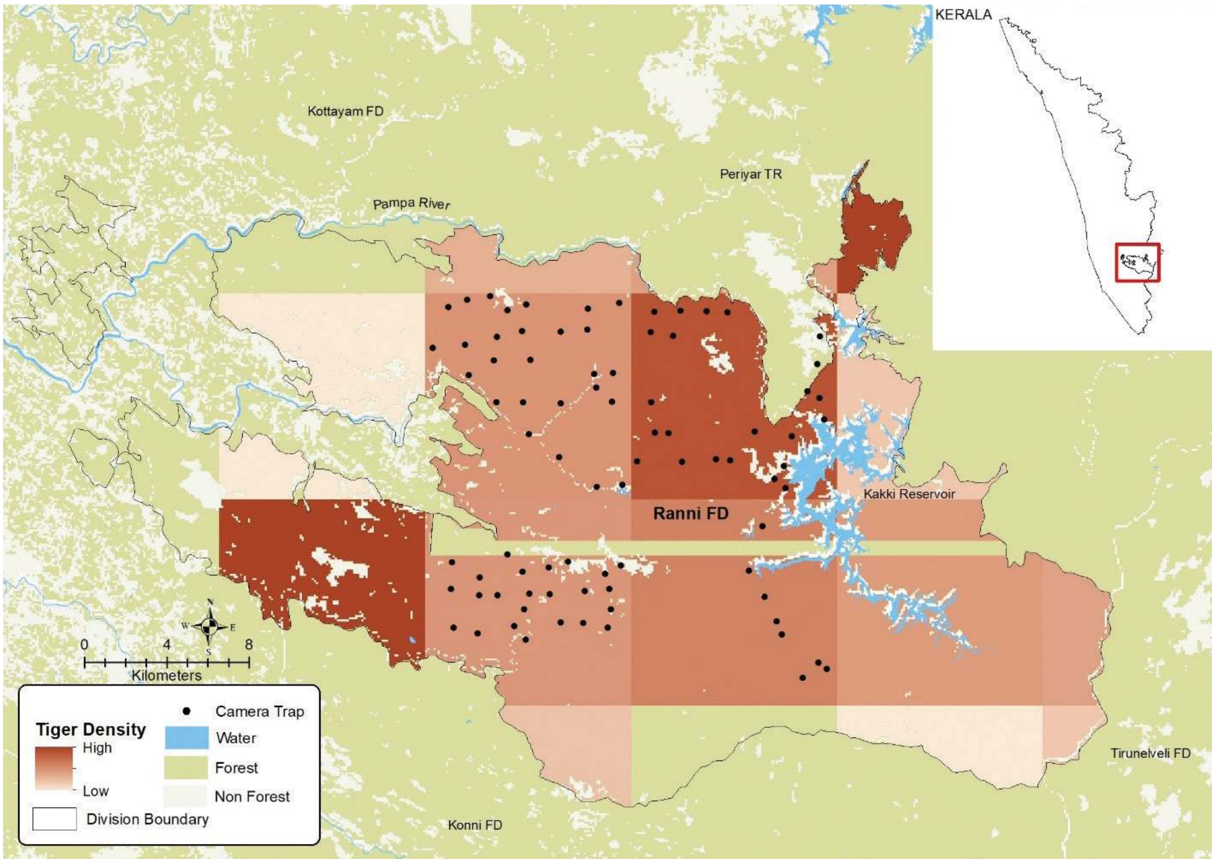

Table V.3. 61

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Ranni Wildlife Division, 2022.

Variables	Estimate
Model space (km^2)	2434
Camera points	82
Trap nights (effort)	1690
Unique tigers captured	6
Model	Pmix (sex)g0(.) σ(.)
$\hat{D}$ SECR (per 100 km^2)	0.44 (0.22)
σ (SE) (km)	5.9(1.1)
g0 (SE)	0.02(0.01)
Pmix Female (SE)	0.25(0.22)
Pmix Male (SE)	0.75(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Ranni Forest Division acts as a vital habitat for the movement and dispersal of tigers and elephants from Periyar Tiger Reserve.

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SILENT VALLEY LANDSCAPE

Silent Valley landscape is a part of the Nilgiri landscape cluster of Western Ghats. It has connectivity with Nilgiri Forest Division and Mukurthi NP (Tamil Nadu) (Figure V.3.62). Camera trapping was carried out by the forest department, with an effort of 2650 trap-nights. Total of 99 tiger images were obtained from which 10 tiger individuals were identified and tiger density was estimated at 1.32 (SE 0.45) tiger per 100 km^2 (Table V.3.62). The detection corrected sex ratio of tigers in Silent Valley was nearly 1 male: 1 female (Table V.3.62). No young tiger was photo-captured.

Figure V.3.62

Camera trap layout and spatial tiger density in Silent Valley landscape, 2022.

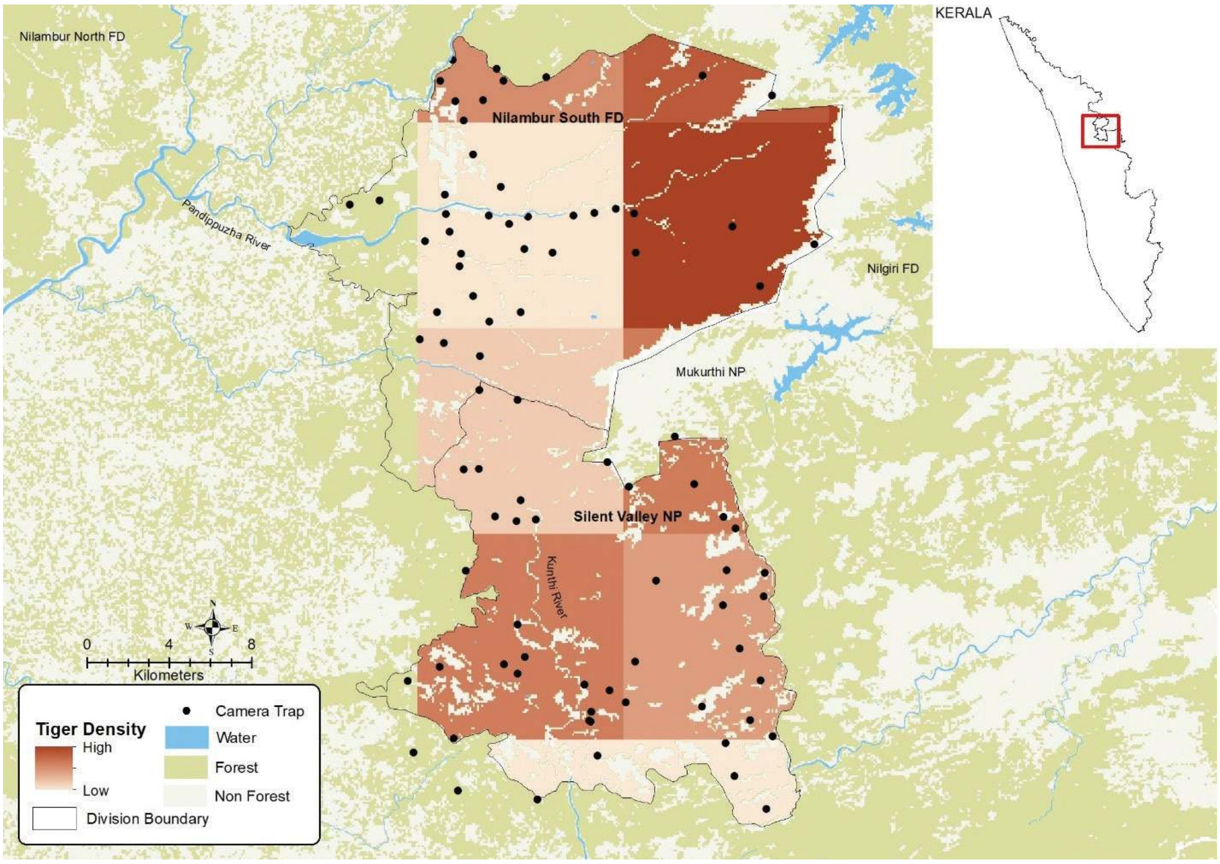

Table V.3. 62

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Silent Valley landscape, 2022

Variables	Estimate
Model space (km)	1313
Camera points	86
Trap nights (effort)	2650
Unique tigers captured	10
Model	Pmix (sex)g0(sex) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	1.32 (0.45)
σ Female (SE) (km)	0.9(0.1)
σ Male (SE) (km)	3.3(0.5)
g0 Female (SE)	0.29(0.1)
g0 Male (SE)	0.01(0.01)
Pmix Female (SE)	0.41(0.26)
Pmix Male (SE)	0.59(0.26)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
^σ (Sigma): Spatial scale of detection function,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Silent Valley 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 Nilgiri is vital for maintaining its biodiversity values.

THATTEKAD BIRD SANCTUARY

Thattekad bird sanctuary is located in the southern Western Ghats, and is a part of the Parambikulam-Anamalai landscape cluster. Camera trapping was carried out by the forest department, where no tiger photographs were obtained with an effort of 314 trap-nights (Table V.3. 63).

Figure V.3.63

Camera trap layout in Thattekad Bird Sanctuary, 2022.

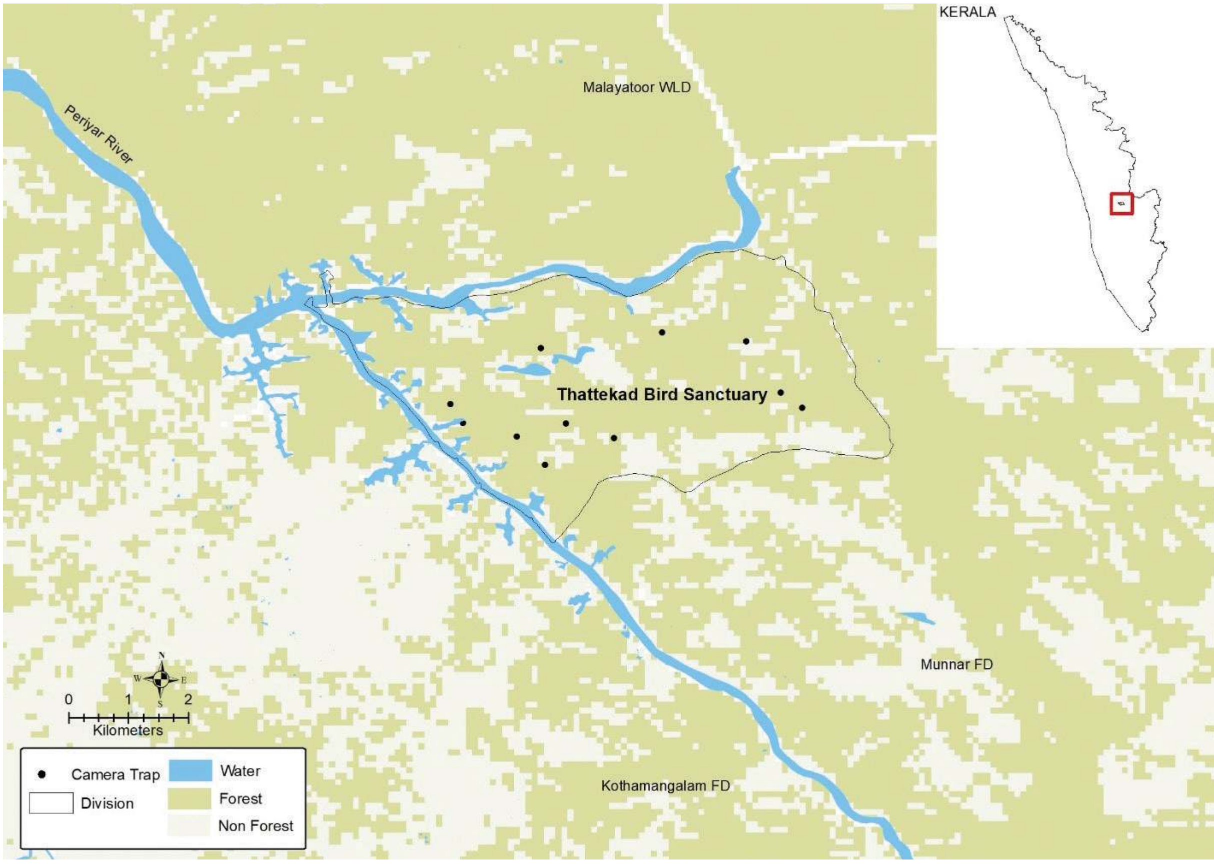

Table V.3. 63

Sampling details of camera trapping exercise in Thattekad Bird Sanctuary, 2022.

Sampling Details	Counts
Camera points	11
Trap nights (effort)	314
Number of tiger photos	0

Thattekad bird sanctuary is a small habitat patch situated in a mosaic of human settlements and plantations. The state government has put forward a proposal to denotify the sanctuary which needs to be critically examined since such small forested patches often act as important stepping stone habitat corridors for tigers and other endangered wildlife. Thattekad would benefit with enhanced protection and reduction of human impacts to improve its biodiversity values.

VAZHACHAL FOREST DIVISION

Vazhachal Forest Division lies in the southern Western Ghats, forming a continuous landscape cluster along with Anamalai Tiger Reserve, Kodaikanal WLS (Tamil Nadu), Parambikulam Tiger Reserve and Malayatoor Wildlife Division (Kerala) (Figure V.3.64). Camera trapping was carried out by the forest department, with an effort of 2425 trap-nights. Total of 7 tiger images were obtained from which 1 tiger individual was identified (Table V.3.64).

Figure V.3.64

Camera trap layout and tiger presence in Vazhachal Forest Division, 2022.

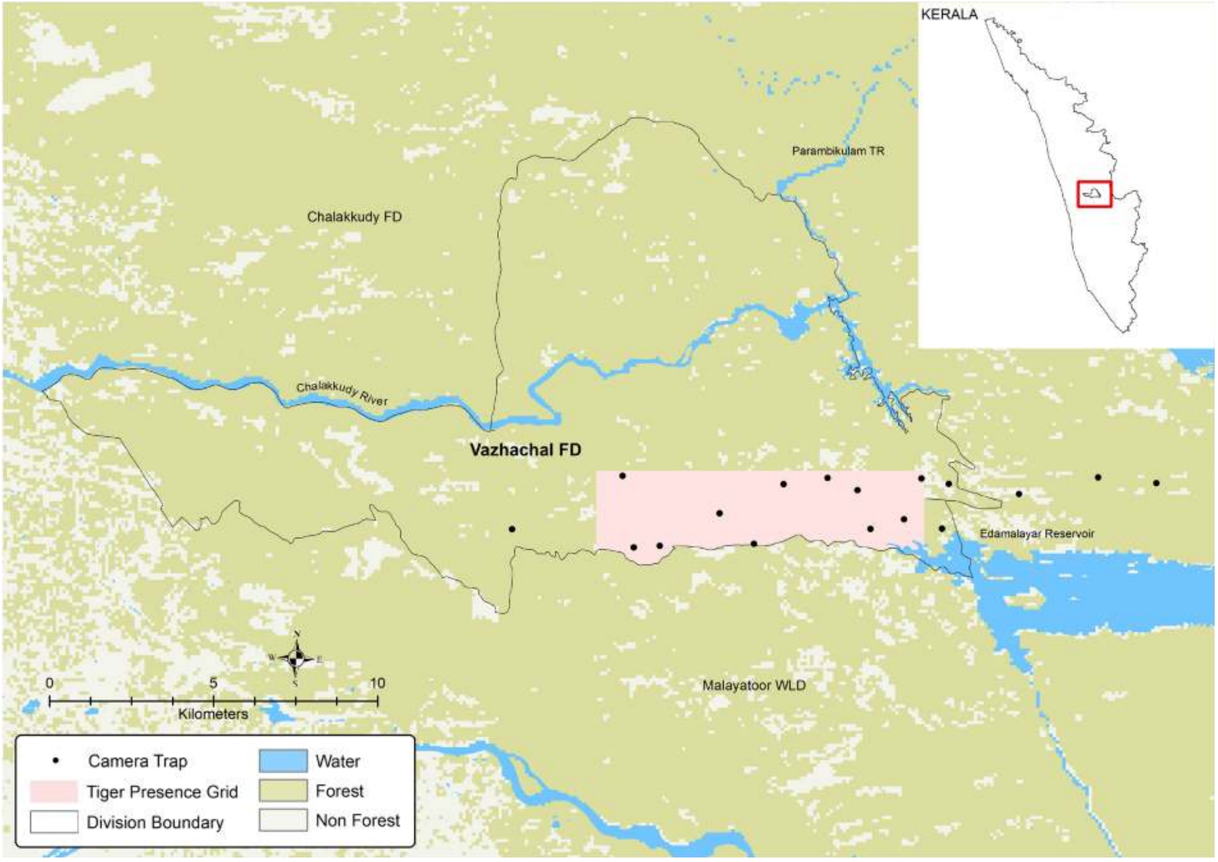

Table V.3. 64

Sampling details of camera trapping exercise in Vazhachal Forest Division, 2022.

Sampling Details	Counts
Camera points	19
Trap nights (effort)	331
Number of tiger photos	7
Unique tigers captured	1

Vazhachal Forest Division supports a rich assemblage of flora and fauna and unique shola habitats. It acts as a vital habitat for the movement and dispersal of tigers and elephants from the adjoining tiger reserves.

WAYANAD LANDSCAPE

Wayanad landscape is a part of the Nilgiri landscape cluster of Western Ghats. It is contiguous with the Nagarahole-Bandipur-Mudumalai complex (Figure V.3.65). Camera trapping was carried out by the forest department, with an effort of 9655 trap-nights. Total of 1445 tiger images were obtained from which 80 tiger individuals were identified and tiger density was estimated at 5.3 (SE 0.6) tiger per 100 km2 (Table V.3.65). The detection corrected sex ratio of tigers in Wayanad was 1 male: 2 females (Table V.3.65). A total of 5 young tigers were photo-captured.

Figure V.3.65

Camera trap layout and spatial tiger density in Wayanad landscape, 2022

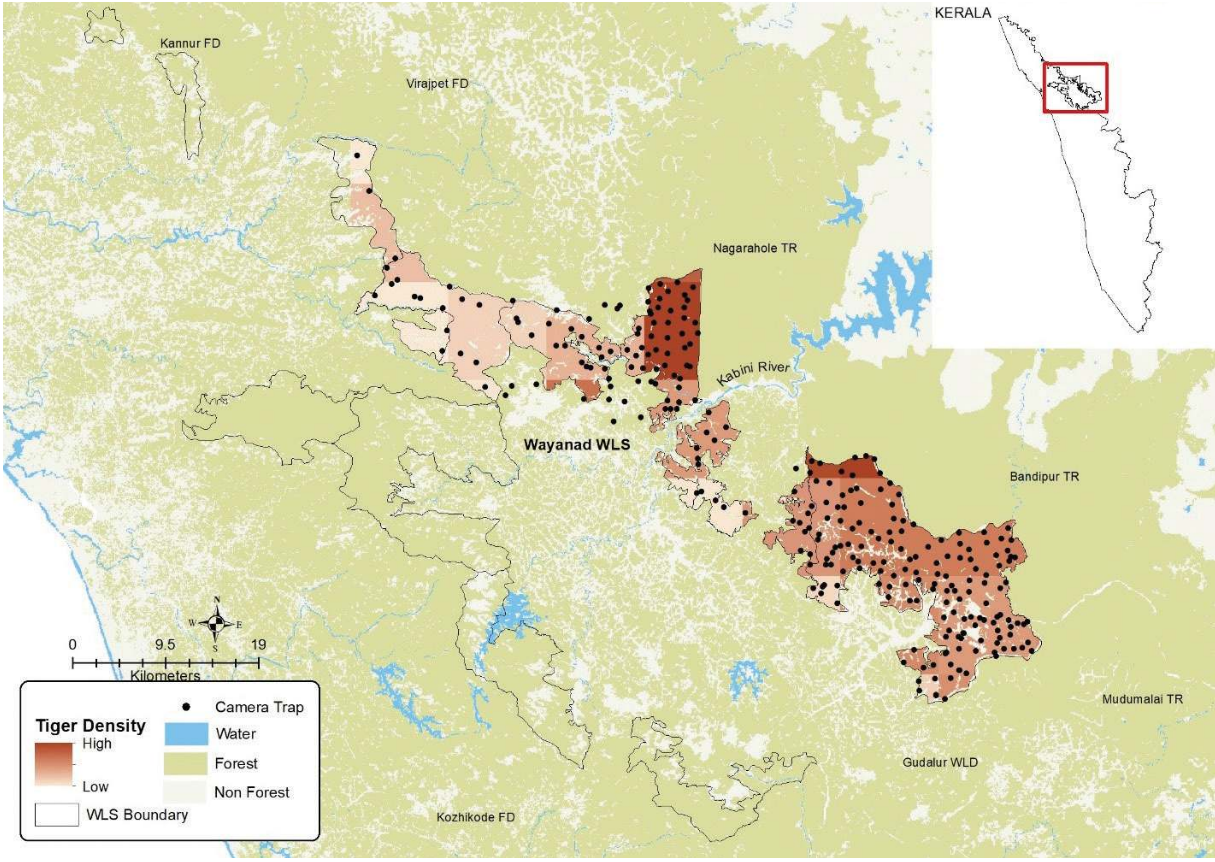

Table V.3. 65

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Wayanad landscape, 2022

Variables	Estimate
Model space (km)	2475
Camera points	281
Trap nights (effort)	9655
Unique tigers captured	80
Model	Pmix (sex)g0(.) σ(sex)
$\hat{D}$ SECR (per 100 km^2)	5.3(0.6)
σ Female (SE) (km)	1.7(0.05)
σ Male (SE) (km)	2.9(0.11)
g0 Female (SE)	0.04(0.002)
g0 Male (SE)	0.04(0.002)
Pmix Female (SE)	0.69(0.05)
Pmix Male (SE)	0.31(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Wayanad landscape has seen a significant decrease in the tiger density in this estimation cycle [11.09 (0.91 SE) in 2014 and 9.33 (0.86 SE) in 2018, Jhala et. al., 2015 and 2020]. However, Wayanad, along with Bandipur, Nagarahole, Mudumalai and Sathyamangalam tiger reserves, play as the major source population of the Western Ghats landscape. The sanctuary has higher density of tigers than many tiger reserves and should be gazetted as a Tiger Reserve. As per the Kerala State Remote Sensing and Environment Centre (KSRSEC), the eco-sensitive zone of Wayanad has the most number of structures (including human settlements, agriculture fields, commercial units, etc.) in the state of Kerala. Necessary management actions to mitigate the disturbances caused by these infrastructures need to be implemented to preserve this critical habitat.


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Section V.4

North East Hills and Brahmaputra Flood Plains Landscape

Camera trap based mark recapture sampling in North East Hills and Brahmaputra flood plains was carried out in 15 sites across four tiger range states namely Arunachal Pradesh, Assam, Mizoram, and West Bengal (north Bengal *Dooars*). A total of 1398 camera trap stations were deployed across the sites which yielded 194 individual tigers in this landscape. However, no tiger was identified through scat DNA in this landscape during sampling period.

Arunachal Pradesh

PAKKE TIGER RESERVE

Pakke was declared as a wildlife sanctuary in 1977 and later as a Tiger Reserve in 1999. It is situated in the East Kameng district (between 92^0 36' to 93^{0}09' E and 26^{0}54' and 27^0 16' N) of Arunachal Pradesh. Kameng river forms north-western and western boundary of the Tiger Reserve. Pakke tiger reserve comprises of three ranges namely Seijousa, Tippi and Rilo and spans over 1276.95 km^2 area with 861.95 km^2 area demarcated as critical tiger habitat. Papum reserve forest in the east and north-eastern part, and Tenga reserve forest in the north-western part act as buffer to the tiger reserve. Being located at the juncture of oriental and Indo-Malayan realm, this tiger reserve is one of the biodiversity hotspot. A total of 135 camera trap stations were active for 8755 trap nights and yielded 6 individual tigers (Table V.4.1).

Figure V.4.1

Camera Trap layout and tiger presence in Pakke Tiger Reserve, 2022

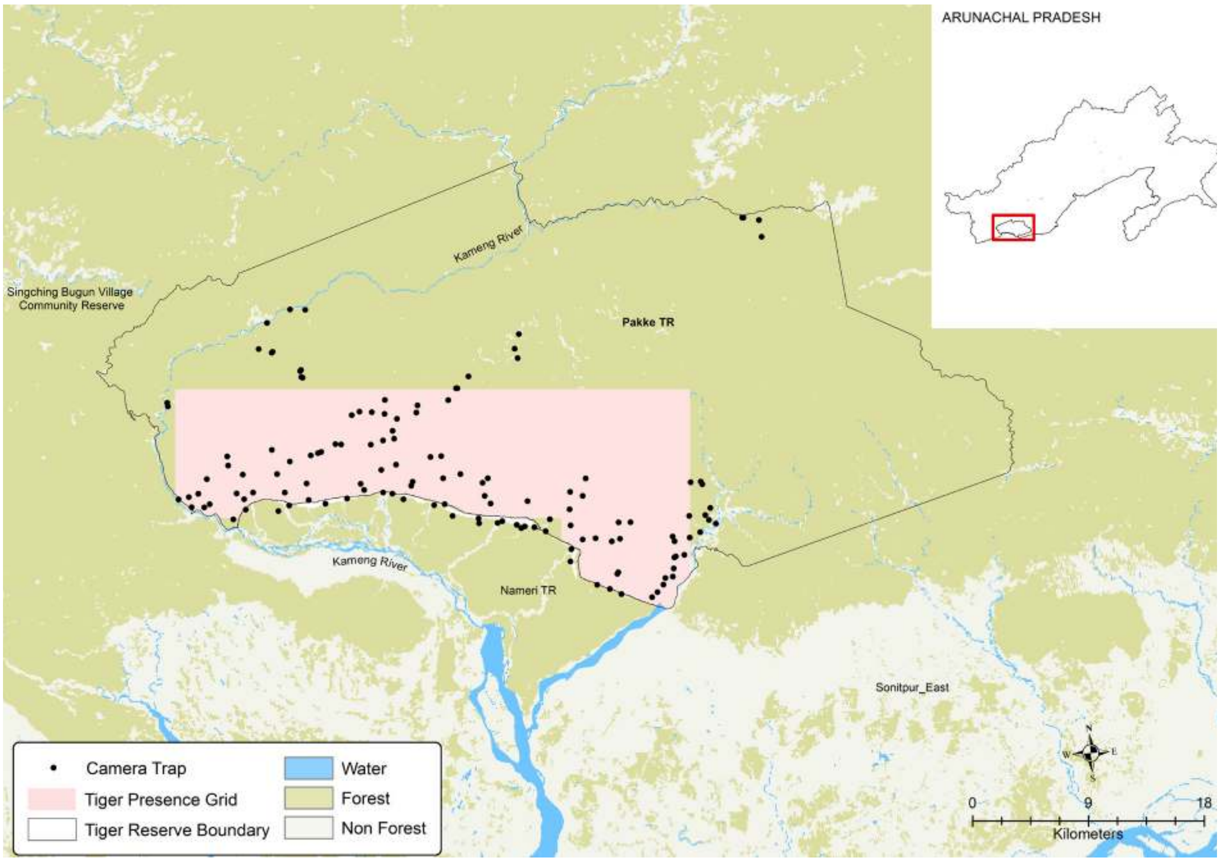

Table V.4.1

Sampling details and number of tiger photo-captured in Pakke Tiger Reserve, 2022.

Parameters	Estimate
Camera points	135
Trap nights (effort)	8755
Number of tiger photos	218
Unique tigers captured	6

Due to the small sample size, the population of tigers could not be modeled. Two out of the six tigers photo-captured in Pakke were also captured in the Nameri Tiger Reserve of Assam. Pakke reportedly has the highest tiger population in Arunachal Pradesh, and together, Nameri and Pakke Tiger Reserves act as a single population block. However, the tiger population of these two tiger reserves has been low and almost constant since the past three cycles and has declined in comparison to 2014 (Jhala *et al.* 2015). Camera trap sampling was mostly concentrated in the southern valley part of the tiger reserve (Figure V.4.1). The reserve is connected with Nameri, which has precarious river connectivity with Kaziranga Tiger Reserve through river islands of Jia Bhoroli or Kameng and Brahmaputra.

NAMDAPHA TIGER RESERVE

Namdapha Wildlife Sanctuary was declared a national park in 1983 and, subsequently, the first Tiger Reserve in Arunachal Pradesh. The tiger reserve is situated in Changlang district (between 27^0 23' to 27^0 39' N and 96^0 15' to 96^0 58' E) of Arunachal Pradesh. An area of 1807.82 km^2 is managed as critical core habitat in this tiger reserve. The terrain of Namdapha is undulating and hilly, with elevation ranges from 200m up to 4571m above the msl (Jhala *et al.* 2020). Geographic complexity with such variation in elevation results in several habitats, from subtropical broad-leaved forests to subtropical pine forests, temperate broad-leaved forests, alpine meadows, and perennial snow (Datta *et al.* 2008). Namdapha harbors a highly diverse species assemblage owing to the geographic location of the tiger reserve at the junction of the Palearctic and Indo-Malayan biogeographic realms. Due to logistics constraint, grid based sampling could not be executed, and sampling was done in blocks. A total of 117 camera trap stations (Figure V.4.2) were operational during the sampling, with an effort of 6690 trap nights (Table V.4.2). No tiger was photo-captured during the sampling exercise in Namdapha. However, an adult tiger was photo-captured during a routine monitoring exercise in the month of February 2023 and added ad libitum.

Figure V.4.2

Camera trap layout and tiger presence in Namdapha Tiger Reserve, 2022

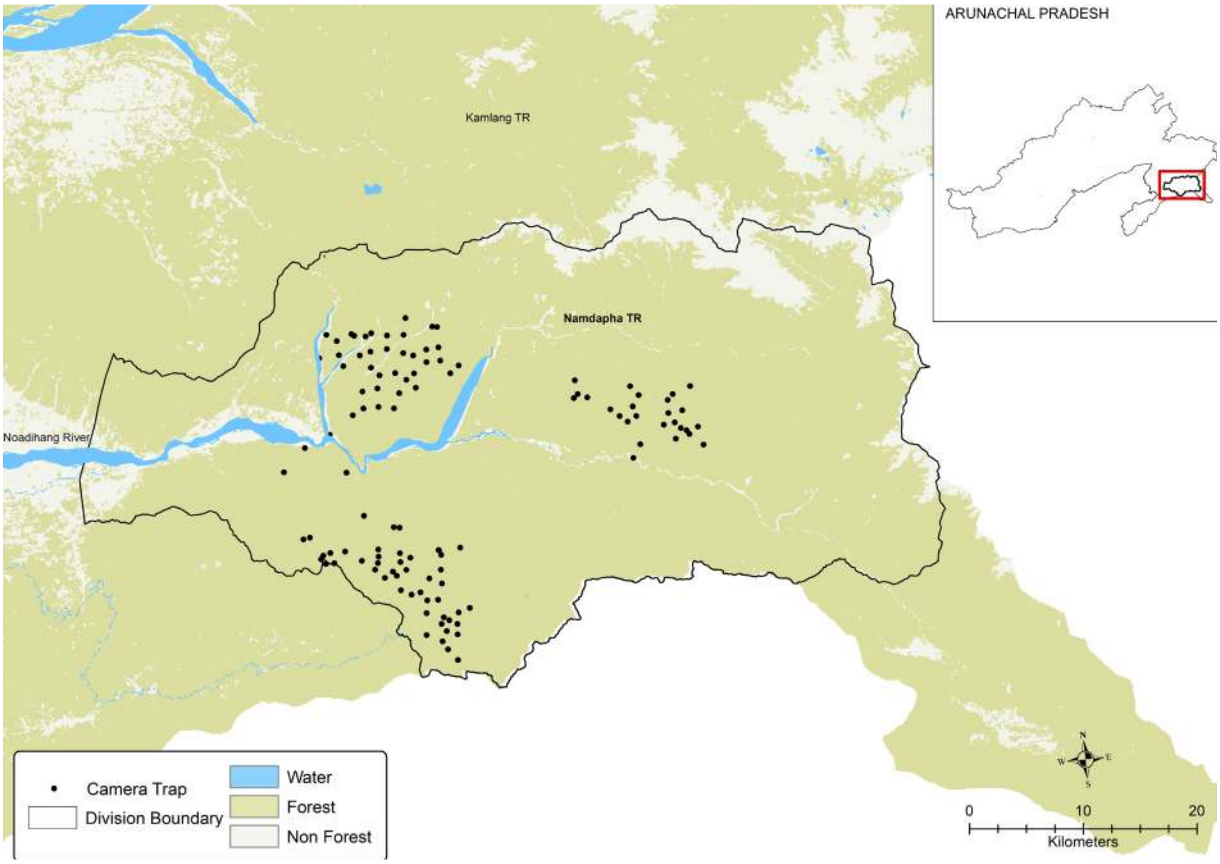

Table V.4.2

Sampling details in Namdapha Tiger Reserve, 2022

Sampling details	Counts
Camera points	117
Trap nights (effort)	6690
Number of tiger photos	0

Tiger presence in Namdapha has consistently been very sparse and low. Tiger occupancy in Namdapha was estimated to be 540 km^2 in 2006. However, tiger occupancy was not estimated in 2010, and tiger presence was confirmed through scat DNA in 2014 and 2018. Despite low abundance of tigers and other associated biota, Namdapha tiger reserve holds utmost importance as the tigers have unique genetic signature (Kolipakam *et al.* 2019). Also, these areas have been entry points of tigers as a species into the Indian sub-continent and part of large contiguous forested tracks extending into Myanmar where another sub-species of tigers P. *t. corbetti* is believed to exist. Since prey densities are also very low, active management through continuous law enforcement monitoring, ungulate population augmentation, tiger reintroduction and participatory conservation with local communities would be helpful to restore or conserve the tiger and biodiversity of this area.

KAMLANG TIGER RESERVE

Kamlang Tiger Reserve issituated in the south-eastern part of the Lohit district (between 27^{0}39’ to 28^{0} N and 96^{0}26’ to 96^{0} 55’E) covers an expanse of 783 km^{2}, with 671 km^{2} designated as core habitat. The reserve derives its name from the Kamlang river, which meanders through the Tiger Reserve and eventually converges with the Lohit river. To the north, Kamlang is demarcated by the Lang River, while its eastern boundary abuts Myanmar’s international border, and its southern extent borders Namdapha Tiger Reserve. The southwestern part of the reserve is separated from Namdapha Tiger Reserve by the majestic Dapha Bhum peak. The reserve’s topography gives rise to diverse habitat types due to variations in elevation gradient. The terrain of Kamlang tiger reserve is extremely rugged, except the narrow floodplains of the river. Sampling was restricted in blocks due to logistic constraints, and a total of 73 camera trap stations were active for 6810 trap nights (Table V.4.3).

Figure V.4.3

Camera trap layout in Kamlang tiger reserve, 2022

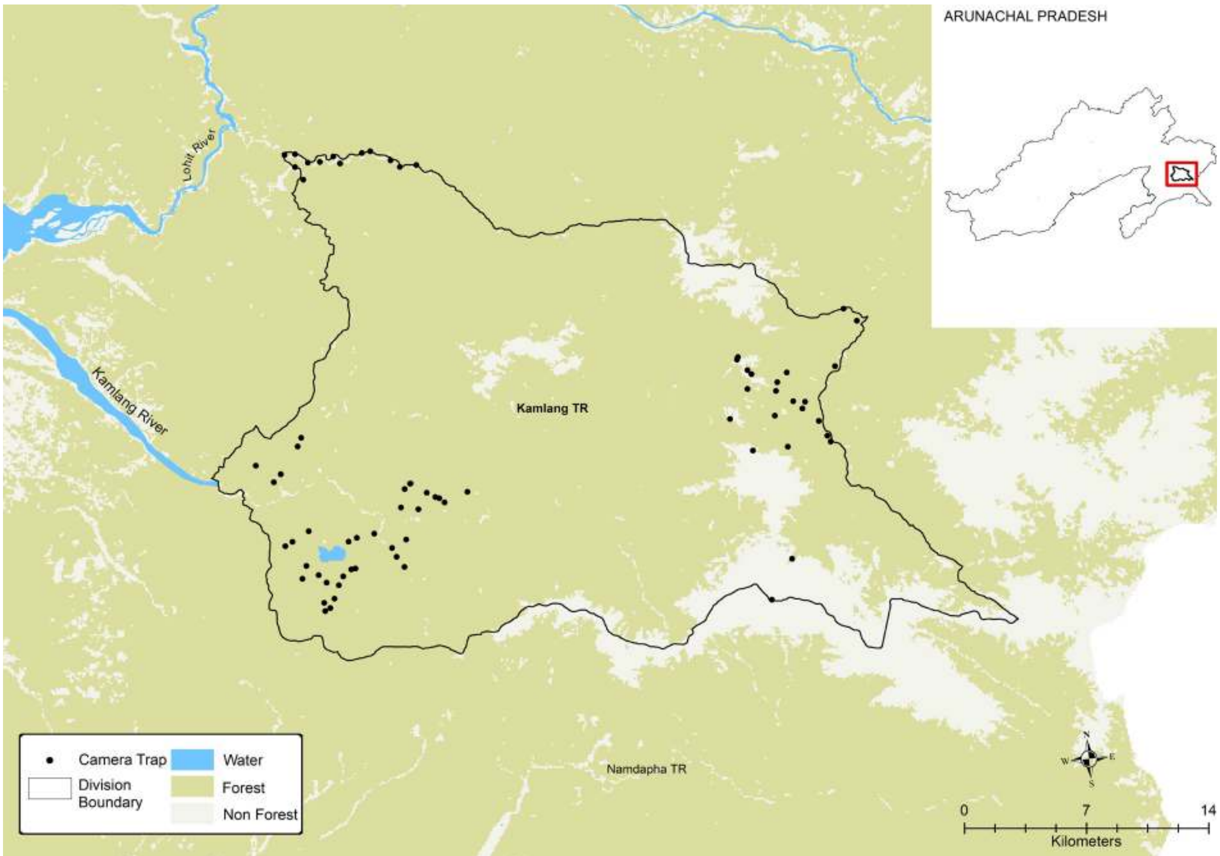

Table V.4.3

Sampling details in Kamlang Tiger Reserve, 2022

Sampling details	Counts
Camera points	73
Trap nights (effort)	6810
Number of tiger photos	0

No tiger was photographed during the camera trapping exercise in 2018 and 2022. However, a during routine monitoring exercise, a tiger was photographed in 2020. Tiger presence in Kamlang was confirmed through scat DNA in 2018. DNA from 21 carnivore scat samples received from Kamlang Tiger Reserve during sampling period of 2021-22 were amplified, but none originated from tigers. Though, abundance of tiger and other mammalian species is extremely low, Kamlang has a continuous stretch of forest and harbors an excellent species assemblage, and acts as a refuge for many critically endangered species.

DIBANG WILDLIFE SANCTUARY

Dibang Wildlife Sanctuary is situated in the Upper Dibang valley district (between $28^{0}38'$ to $29^{0}27'$N and $95^{0}17'$ and 96^{0} 38' E) along the Indo-China international border, and falls under the Dibang-Dihang biosphere reserve. The sanctuary is also an IBA and spans across a 4149 km^2 area (Rahamani *et al*. 2016). It is named after the river Dibang, a major tributary to the Brahmaputra. Numerous rivers, namely Dri, Mathu, Emra, Aanwa, Ahi, Talo, etc., criscross the sanctuary and eventually merges with Dibang river. The topography of the sanctuary is primarily mountainous, with gorges and narrow river flats. Due to logistic constraints, camera trapping was executed in the forested areas alongside major valleys in this sanctuary. A total of 82 camera trap stations were operational for 4158 trap nights and obtained 110 tiger pictures. Two tigers were photographed in this exercise (Table V.4.4).

Figure V.4.4

Camera trap layout and tiger presencein Dibang Wildlife Sanctuary, 2022

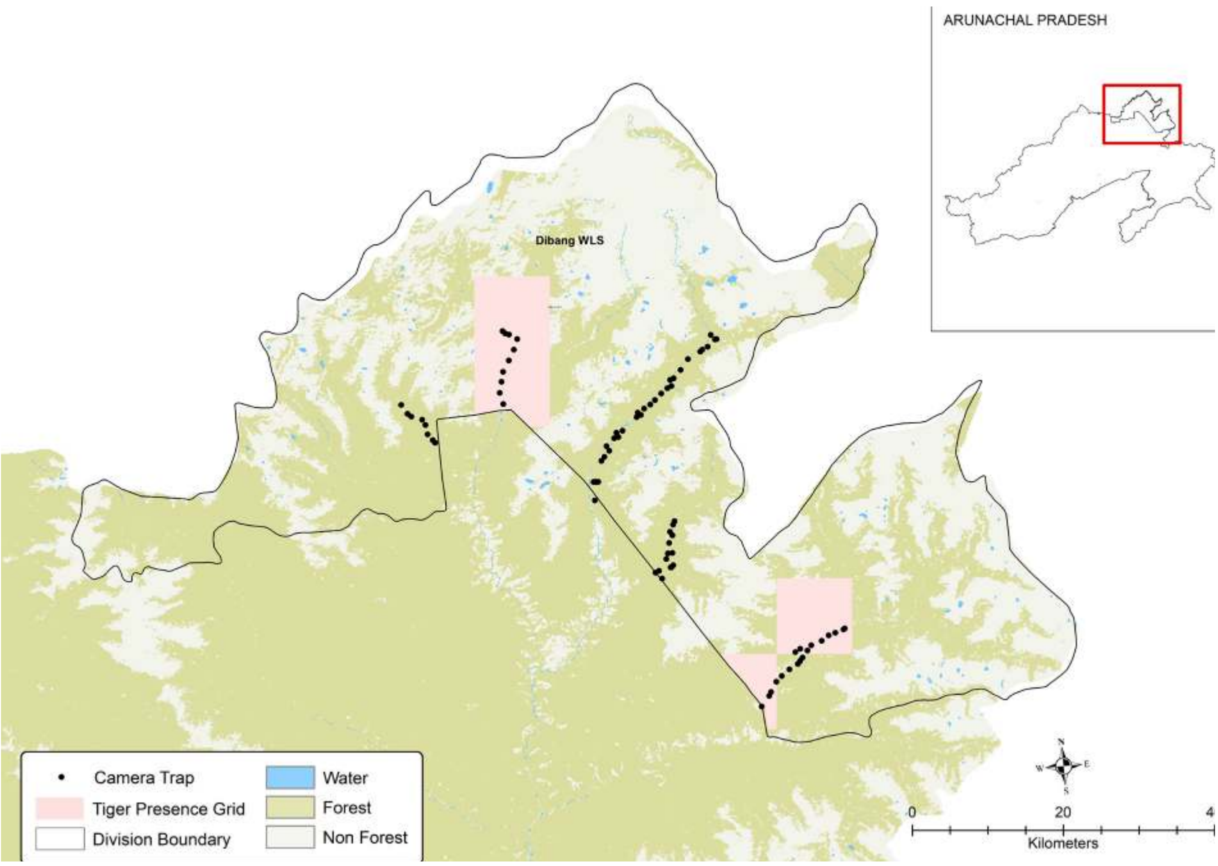

Table V.4.4

Sampling details in Dibang Wildlife Sanctuary, 2022

Sampling Details	Count
Camera points	82
Trap nights (effort)	4158
Number of tiger photos	110
Unique tiger captured	2

First photographic evidence of tiger from this sanctuary was recorded in 2013 (Gopi *et al.* 2014), and number of individual tigers photo-captured in consecutive two tiger estimation cycles viz. 2018 and 2022 are same. However, a study by Adhikarimayum *et al*. 2018 reported 11 tigers in this landscape. Since the sanctuary is located in a strategic position in terms of international relationship with China and border security, numerous developmental activities are being carried out to construct linear infrastructure inside the sanctuary in recent past (NE Now). River Dibang, and its tributaries hold promises for green energies and numerous hydro-electric projects are proposed and planned in this landscape, which are close to the sanctuary. A proposal also has been raised to notify the Sanctuary as Tiger Reserve by concerned authorities. Appropriate mitigation measures should be adopted to ensure biodiversity and tiger conservation in this landscape.

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Assam

KAZIRANGA TIGER RESERVE

Kaziranga Tiger Reserve, located in the southern bank of the river Brahmaputra, is spanned over three districts (26^0 30’ to 26^0 50’ N and 92^0 50’ to 93^0 41’ N) namely Nagaon, Golaghat and Sonitpur of Assam. Due to its enormous natural and cultural history, Kaziranga has been recognized as Natural Heritage Site by UNESCO. This tiger reserve holds the largest population of tigers in the entire landscape and continue to serve as source population. Besides, this tiger reserve is home to the largest population of One horned rhinoceros in world. Major part of Kaziranga falls under alluvial flood plains of Brahmaputra. A total of 230 camera traps were active for 13839 trap nights and yielded 104 individual tigers (Table V.4.5). Detection corrected sex ratio in Kaziranga Tiger Reserve was 2 females per male.

Table V.4.5

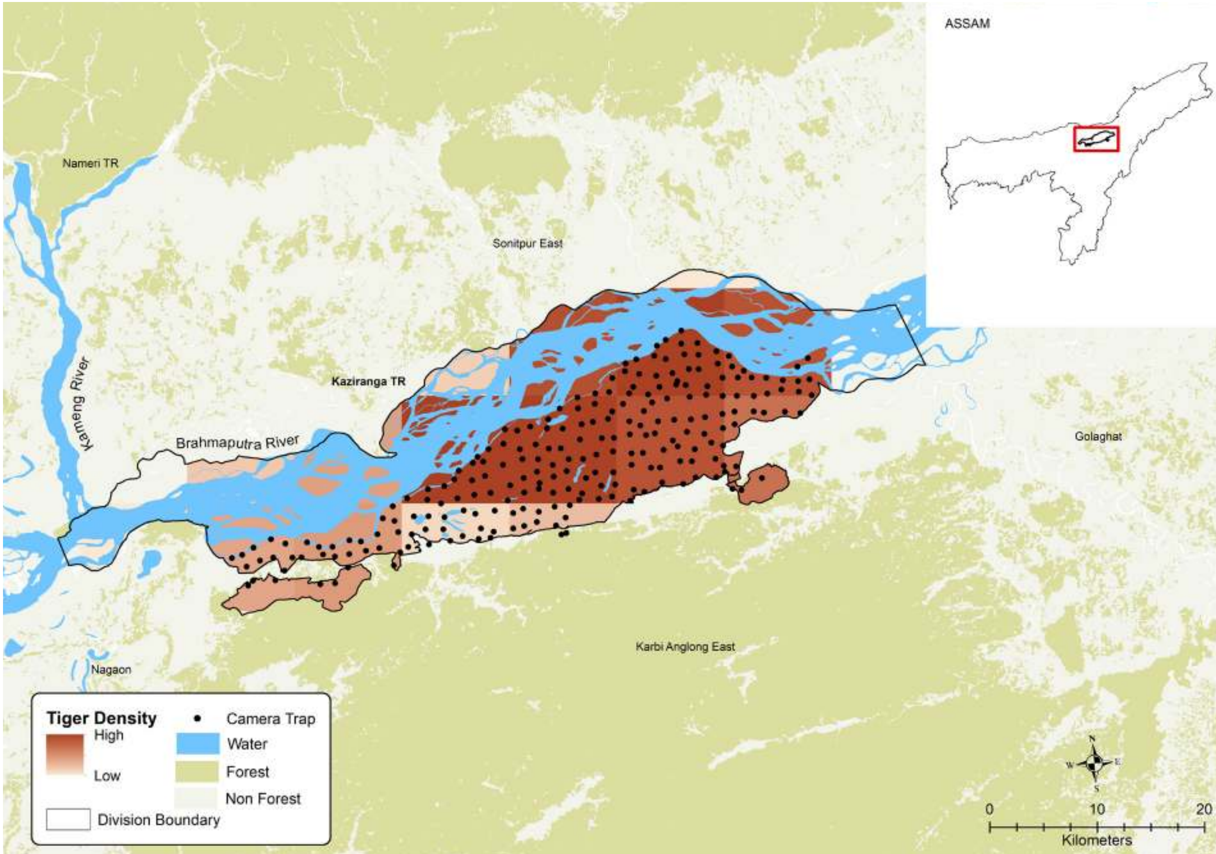
Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Kaziranga Tiger Reserve, 2022

Variables	Estimate
Model space (km^2)	1014
Camera points	230
Trap nights (effort)	13839
Unique tigers captured	104
Model	Pmix (sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	13.44 (1.32)
σ Female (SE) (km)	1.139 (0.02)
σ Male (SE) (km)	2.12 (0.049)
g0 Female (SE)	0.099(0.005)
g0 Male (SE)	0.046 (0.002)
Pmix Female (SE)	0.61(0.05)
Pmix Male (SE)	0.39(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Figure V.4.5

Camera trap layout and spatial tiger density in Kaziranga Tiger Reserve, 2022



Tiger population of Kaziranga is constant as compared to previous cycles (tiger density was estimated 13.06 (1.37) per 100 km^2 in 2018). Kaziranga has one of the highest density of tigers in the world and the only source population in this landscape. Forest patches of Karbi Anglong division act as ecological extension to the reserve. Connectivity of Kaziranga to Nameri-Pakke block in the north through Kameng river, and to larger landscape in south through forested patches of Karbi-Anglong division should be maintained to ensure metapopulation buildup in this landscape. Flood is annual feature and devastating floods occur periodically, thus neighbouring forests of Karbi-Anglong is a crucial refuge for all wildlife, and therefore permanent mitigation measures in the form of animal passages across the major road along the Khasi-Garo hills on southern boundary is urgently required.

MANAS TIGER RESERVE

Manas, named after the river intersecting through the Tiger Reserve, is situated across Bodoland Territorial Area Districts namely, Baksa, Chirang, and Udalguri districts (between $26^{0}35'$ to $26^{0}50'$ N and $90^{0}45'$ to $91^{0}15'$ E) of Assam. This reserve is also a UNESCO World Heritage Site (Natural) and refuge to many critically endangered species like pygmy hog, hispid hare and Bengal florican. The tiger reserve has been thoroughly sampled by camera trap and yielded 57 individual tigers during the sampling (Table V.4.6). Detection corrected sex ratio in Manas Tiger Reserve was 1 female per male.

Figure V.4.6

Camera trap layout and spatial tiger density in Manas Tiger Reserve, 2022

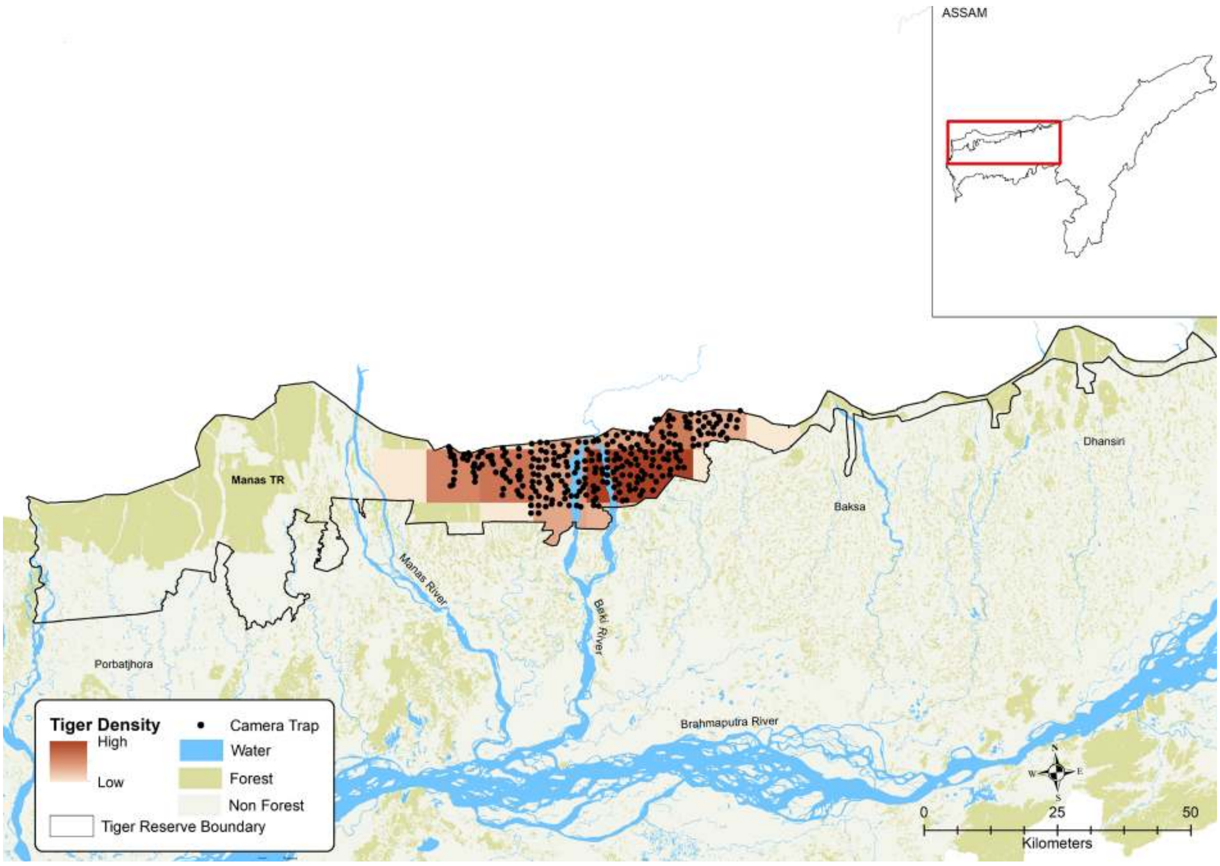


Table V.4.6

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Manas Tiger Reserve, 2022

Variables	Estimate
Model space (km^2)	743
Camera points	267
Trap nights (effort)	10497
Unique tigers captured	57
Model	Pmix (sex)g0(sex)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	7.91 (1.05)
σ Female (SE) (km)	1.988 (0.07)
σ Male (SE) (km)	3.0388 (0.123)
g0 Female (SE)	0.025 (0.002)
g0 Male (SE)	0.015 (0.002)
Pmix Female (SE)	0.57 (0.07)
Pmix Male (SE)	0.43 (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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

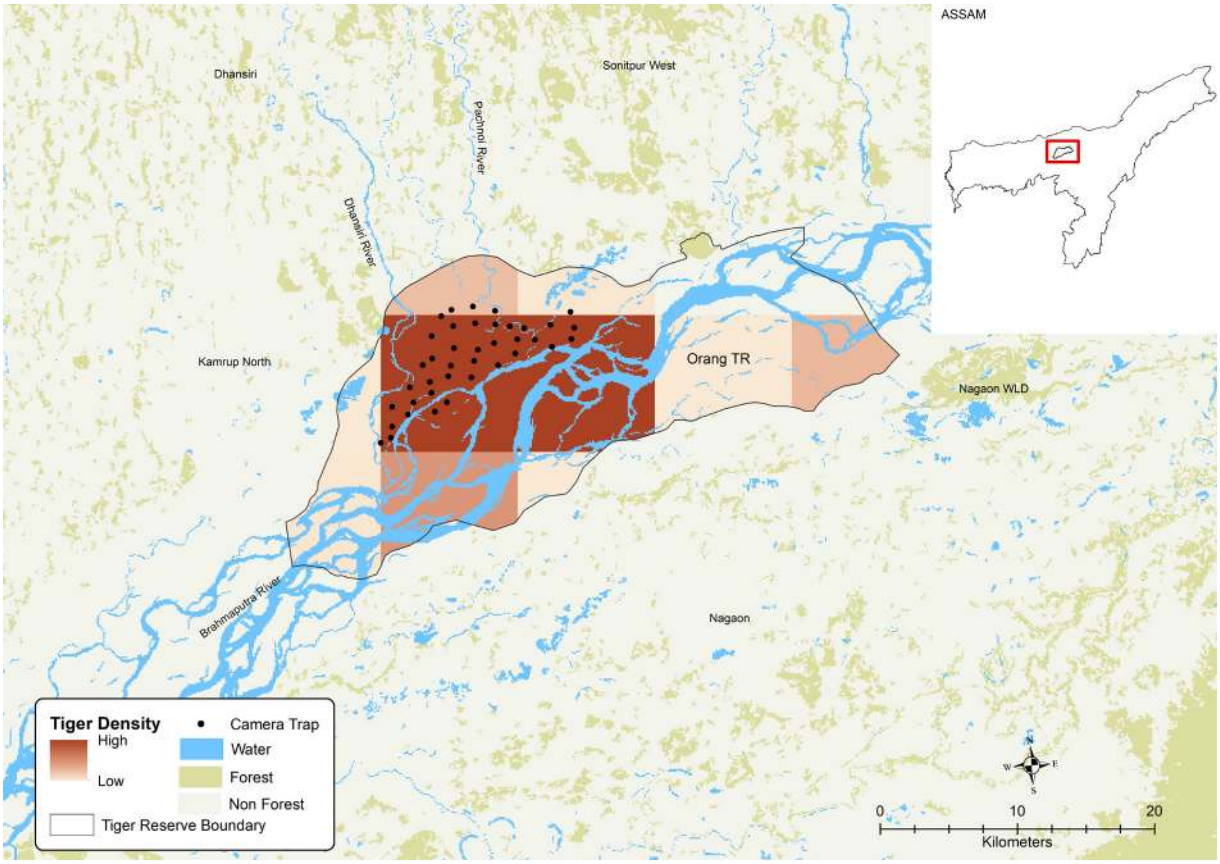
Manas Tiger Reserve has gone through armed conflicts in the past, and these conflicts had severe subsequent effects on conservation efforts as well. One horned rhinoceros was extirpated from this national park and reintroduced in 2008. The tiger population and density of Manas show an increasing trend since 2006 with positive managerial efforts. Together, the entire Manas landscape, including Royal Manas National Park in Bhutan and Buxa Tiger Reserve in West Bengal forms a single population block for the tigers. This contiguous forest patch should be brought under legal protection to maintain genetic connectivity and demographic viability across the landscape. However, the spread of invasive species like *Chromolaena odorata and Mikania micrantha* in the grasslands of Manas Tiger Reserve (Nath *et al.* 2019) is a concern and pose a threat to grassland dependent endangered species like the pygmy hog, eastern swamp deer, Bengal florican, and other associated species. The border road between India-Bhutan-Nepal needs to be carefully aligned to have minimal impact on the wildlife values of the region and appropriately mitigated wherever required.

ORANG TIGER RESERVE

Orang, situated in the Darrang and Sonitpur districts of Assam, represents one of the highest densities of tigers in India and the world. Orang is composed of mainly four different types of vegetation (Champion & Seth 1968) viz., the Eastern Himalaya's moist-deciduous forests, eastern seasonal swamp forest, Khair-Sisso forests and the eastern wet alluvial grasslands (Deka *et al.* 2015). The vegetation of Northern Bank is unique and comprises short and tall grasslands dotted with natural and cultural woodlands and water bodies. A total of 39 camera stations yielded 16 individual tigers with an effort of 1189 trap nights in this tiger reserve (Table V.4.7). The detection corrected sex ratio (female to male) in Orang Tiger Reserve was 5 female per male.

Figure V.4.7

Camera trap layout and spatial tiger density in Orang Tiger Reserve, 2022



Section V.4

Table V.4.7

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Orang Tiger Reserve, 2022

Variables	Estimate
Model space (km^2)	229
Camera points	39
Trap nights (effort)	1189
Unique tigers captured	16
Model	Pmix (sex)g0(.)σ(sex)
$\hat{D}$ SECR (per 100 km^2)	11.34 (2.9)
σ Female (SE) (km)	1.436 (0.09)
σ Male (SE) (km)	3.58 (0.422)
g0 Female (SE)	0.072 (0.009)
g0 Male (SE)	0.072 (0.009)
Pmix Female (SE)	0.84 (0.08)
Pmix Male (SE)	0.16(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,
^g0: Magnitude (intercept) of detection function
Pmix: estimate of proportion of male /female (detection corrected sex ratio)

Orang Tiger Reserve acts as a single forested patch on the northern bank of the Brahmaputra. The entire area was used to be human settlements, and was abandoned in the latter part of 19th Century (Chakdar *et al.* 2019). However, it has one of the highest densities of tigers across the Indian subcontinent. Orang also harbors breeding tigers in the landscape. The tiger density of Orang is almost stable as compared to previous cycles. Dense human habitation and agricultural fields in the north, north-west, and east surround this tiger reserve and needs active management to ensure its survival. The river islands in the southern part act as conduit for tigers and are the only space left for the population to grow and disperse. With recent addition of 201 km^2 as buffer and addition to the core would join this tiger population to the western of Nagaon Wildlife Division (Govt. of Assam, The Assam Gazette 31st August 2022).

NAGAON WILDLIFE DIVISION

This wildlife division is managed as a buffer for Kaziranga and spans across Nagaon and Sonitpur districts ($26^0$28' to $26^0$33' N and $92^0$35' to $92^0$47' E) of Assam. It comprises twin wildlife sanctuaries, namely Laokhowa and Burachhapori. 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 on the northern banks of Brahmaputra River through numerous river islands. There were 16 camera stations, which yielded 1514 trap nights, and five individual tigers were identified (Table V.4.8).

Figure V.4.8

Camera trap layout and tiger presence in Nagaon Wildlife Division, 2022

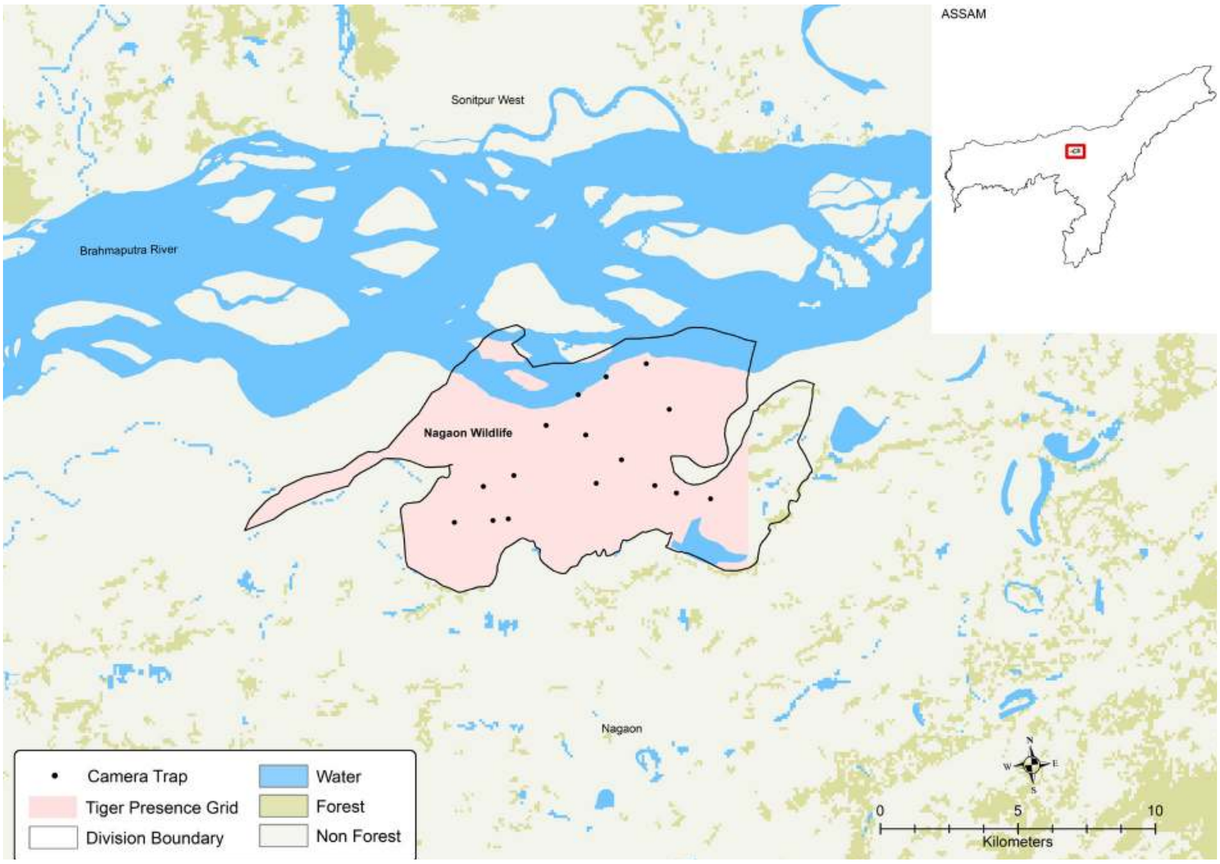


Table V.4.8

Sampling details in Nagaon Wildlife Division, 2022

Sampling Details	Count
Camera points	16
Trap nights (effort)	1514
Number of tiger photos	40
Unique tiger captured	5

This Wildlife Division acts as a stepping stone in the Kaziranga- Orang- Nameri -Pakke population block. The integrity of this wildlife division needs to be protected to maintain movement of animals in this landscape. This division has been camera trapped consecutively since 2018. The tiger population has increased from one tiger to five tigers since 2018. However, this wildlife division faces threat from habitat degradation and immense biotic pressure. Law enforcement monitoring should be implemented in this division to curb biotic pressure and arrest habitat degradation.

NAMERI TIGER RESERVE

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 on the northern bank of the 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 in Arunachal Pradesh. Nameri is crisscrossed by the river Jia Bhoroli and its tributaries: Nameri, Dikorai, Digi, Dinai, Doigrung etc. Jia Bhoroli demarcates the western boundary of the core, and Bordikorai demarcates the eastern boundary. A total of 67 camera trap stations were active for 4100 trap nights, and 3 individual tigers were photo-captured (Table V.4.9). However, two tigers are common with Pakke Tiger Reserve of Arunachal Pradesh.

Figure V.4.9

Camera trap layout and tiger presence in Nameri Tiger Reserve, 2022

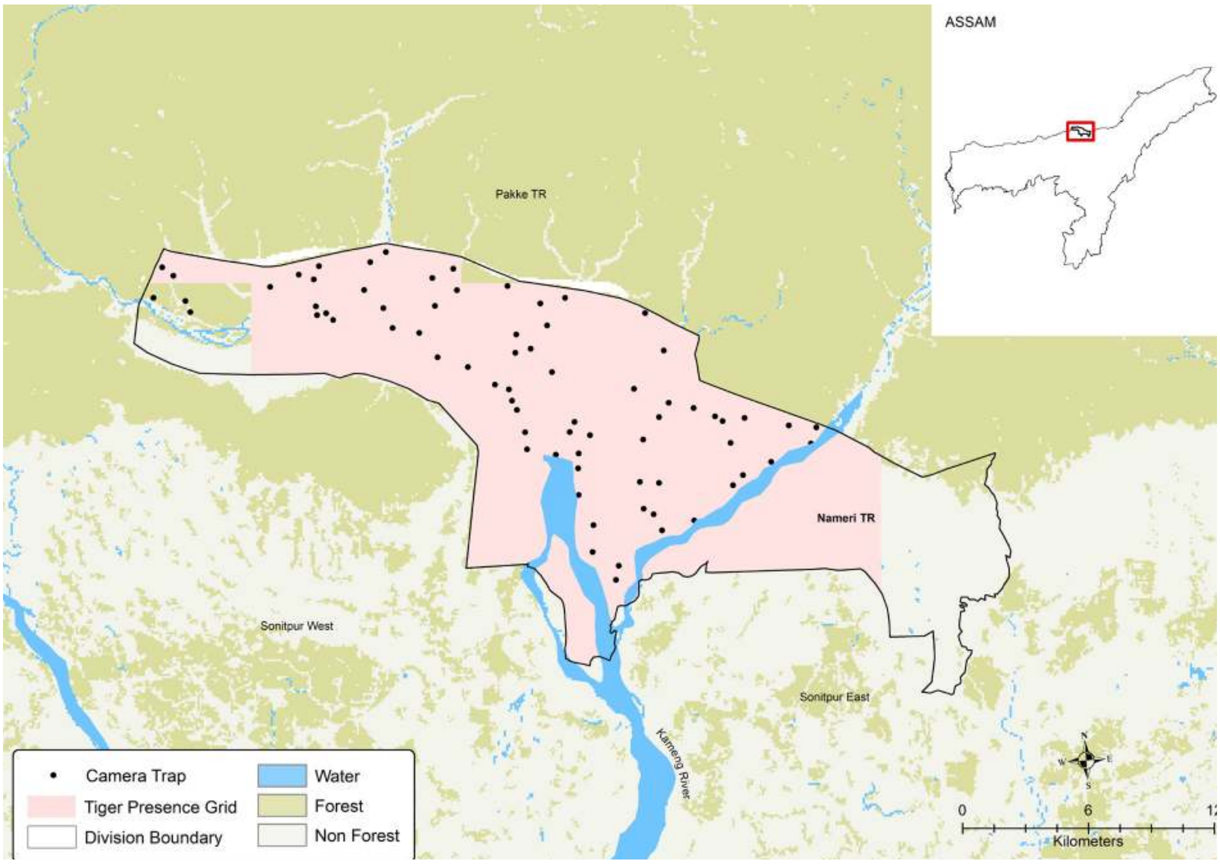
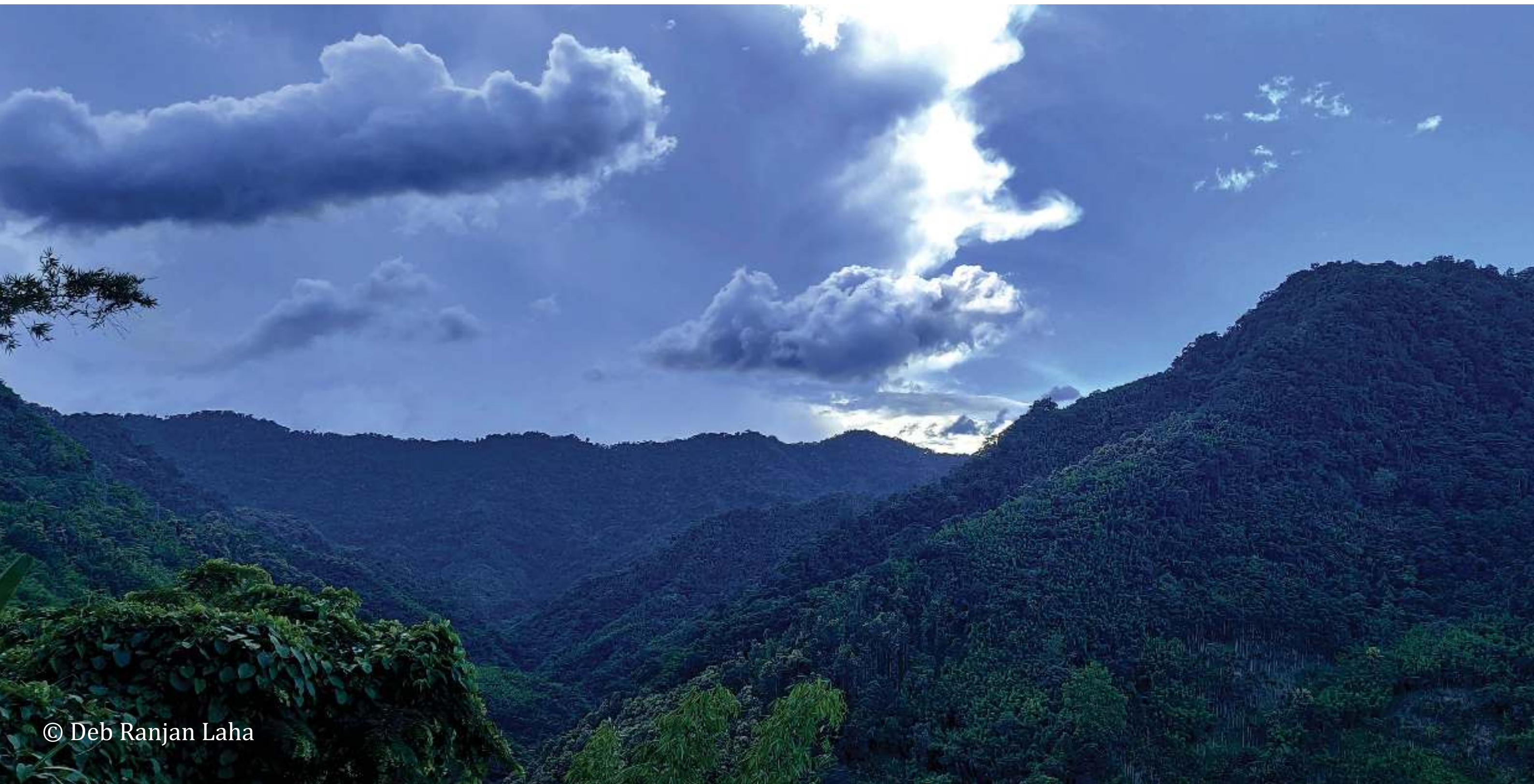


Table V.4.9

Sampling details in Nameri Tiger Reserve, 2022

Sampling Details	Count
Camera points	67
Trap nights (effort)	4100
Number of tiger photos	106
Unique tiger captured	3

Nameri and Pakke act as single population block as both the Tiger Reserves share same tigers. However, tiger population of this block is substantially low and show a decreasing trend since 2010. In terms of ecological integrity of the core habitat, Pakke Tiger Reserve in the north and Jia Bhoroli or Kameng River in the south act as ecological barriers for biotic pressure to the reserve. However, low prey abundance in Nameri is also the reason of low tiger density over the years. Satellite core of this tiger reserve, Sonai-Rupai Wildlife Sanctuary, faces intensive biotic pressure. Adaptive management measure such as prey supplementation or prey augmentation need to done to restore the tiger population. Also, securing riverine corridors though Biswanath could help establish tiger movements from Kaziranga and Orang. There was earlier record of tiger moving from Kaziranga to Nameri through riverine islands and different human land-use areas (Jhala *et al.* 2015). However, poaching is a pervasive threat to this tiger reserve. Recently, skin and body parts of an adult male was seized from Itakhola in Arunachal Pradesh- Assam border, outside buffer areas of Nameri Tiger Reserve (NTCA website). This tiger was photo-captured in Orang Tiger Reserve during this cycle, and later released in Nameri after rescuing it from the vicinity of Guwahati (NE Now).



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West Bengal

BUXA TIGER RESERVE

Buxa Tiger Reserve, situated in Alipurduar district (between 23^0 30' to 23^0 50' N and 89^0 25' to 89^0 55' E), was created as the 15^{th} tiger reserve in the country. An area of 390.58 km^2 is managed as critical core habitat. This tiger reserve is managed by two divisions, namely Buxa East and West. In the north, the reserve is contiguous with Phibsoo Wildlife Sanctuary in Bhutan and with Manas Tiger Reserve in Assam in the east. However, the southern and western boundaries are bordered by human habitation, numerous tea estates, and National Highway 31C. Primary forest type of "Moist tropical forest" (Champion & Seth 1968) and elevation ranges up to 1750 meters above msl. The floodplain and foothills of this tiger reserve is drained by the Jainti, Rydak, Bala, Dima, Gholani and a few other rivers. A total of 162 camera stations were active for 13734 trap nights (Table V.4.10), and a single tiger was photo-captured during the sampling.

Figure V.4.10

Camera trap layout and tiger presence in Buxa Tiger Reserve, 2022

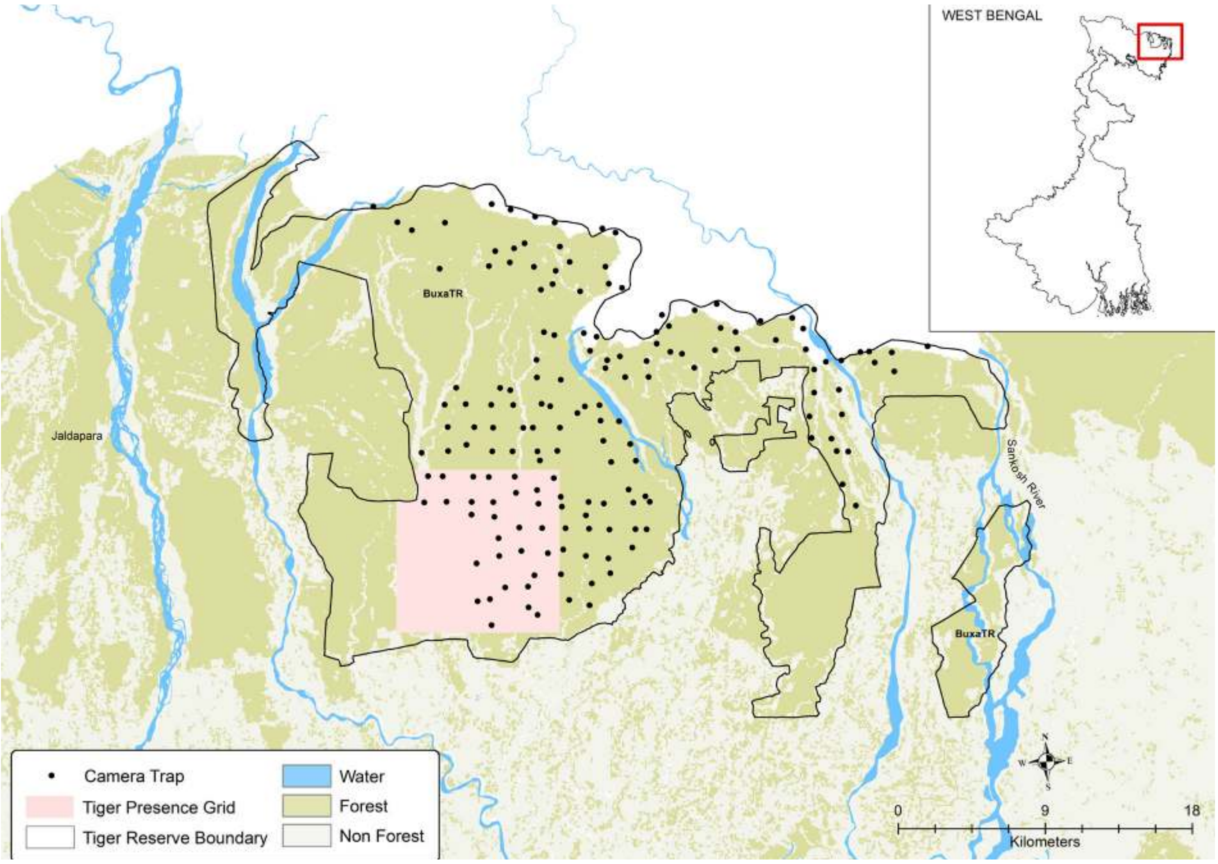


Table V.4.10

Sampling details in Buxa Tiger Reserve, 2022

Sampling Details	Count
Camera points	162
Trap nights (effort)	13734
Number of tiger photos	4
Unique tiger captured	1

The forest of Buxa Tiger Reserve has been historically exploited during the colonial era. Large forested areas were cleared for tea cultivation and agriculture, and the forests were used as hunting grounds. The tiger population of Buxa has been substantially low, and tiger presence was confirmed through scat DNA only in 2014 (Jhala *et al.* 2015). No tigers were reported from Buxa in 2018. However, a tiger was photographed during the camera trapping exercise for the All India Tiger Estimation. Buxa shares a continuous forest patch with the protected area network of North Bengal in the west, Bhutan in the north and the Manas Tiger Reserve of Assam in the east. However, the Tiger Reserve is situated in a mosaic of numerous tea gardens and human habitation. To maintain the ecological integrity of this tiger reserve, private forested lands have to be secured through a legal framework. The invasions of *Chromolaena odorata* and *Mikania micrantha* can be observed in the grasslands and watershed areas. Prey abundance is substantially low in this tiger reserve (Jhala *et al.* 2020). Adaptive management through habitat restoration and prey augmentation should be done in this tiger reserve before relocating the tiger population.

GORUMARA NATIONAL PARK

Earlier managed as a reserve forest since 1895, Gorumara was notified as a wildlife sanctuary in 1949 and later as national park in 1994. Geographically, it is situated in the Eastern Himalaya's sub montane terai belt and located in Malbazaar sub-division of Jalpaiguri district ($26^{0}43'$ to $26^{0}47'$ N and $88^{0}47'$ to $88^{0}52'$ E). This national park is a mixture of floodplains, forests, and grasslands and spans over 79.99 km^2. The terrain of the national park is primarily plain with distinct plateaus. Murti, Indong, and Garati river drains this national park and are tributaries of the Jaldhaka river. This national park is a refuge for a sizeable population of three mega-herbivores, viz. Asiatic elephant, one horned rhinoceros and gaur. A total of 49 camera trap stations were active for 4644 trap nights during the camera trapping exercise and no tiger was photographed (Table V.4.11).

Figure V.4.11

Camera trap layout in Gorumara National Park, 2022

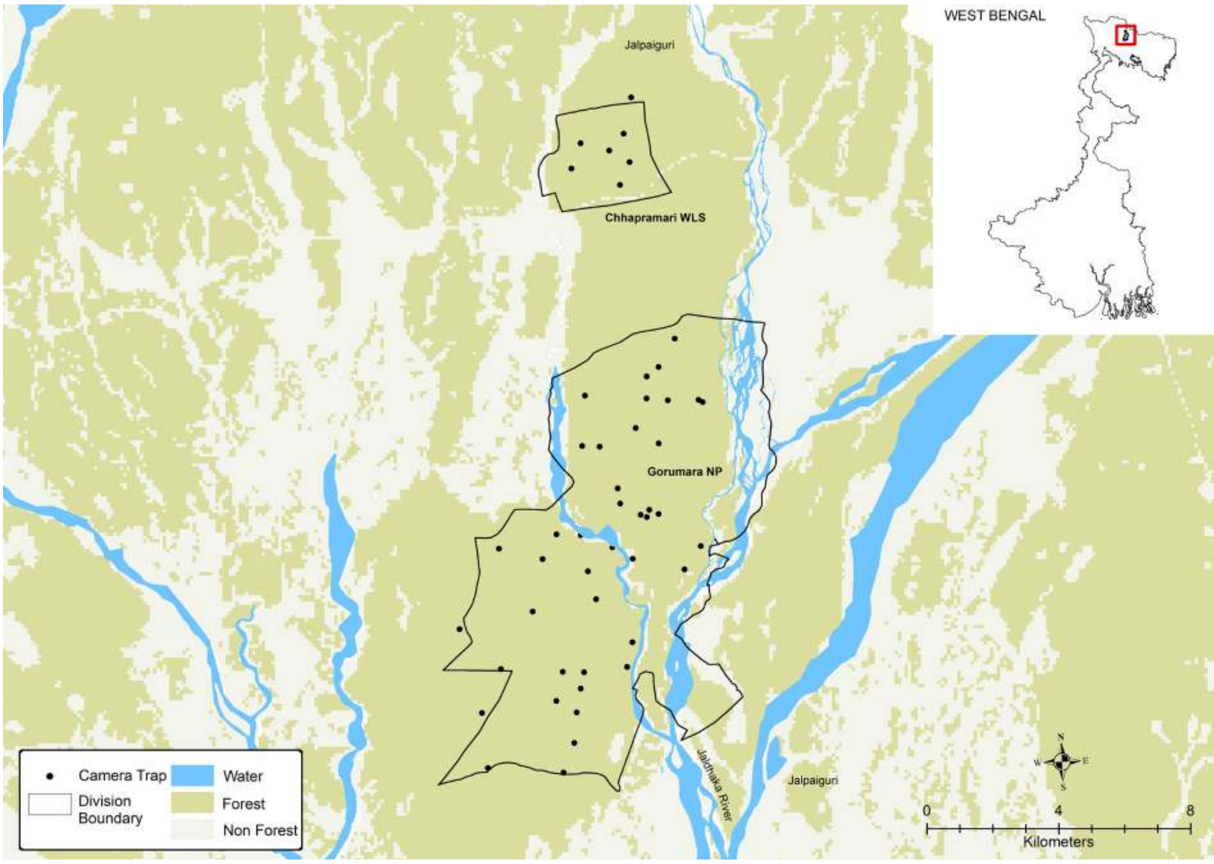


Table V.4.11

Sampling details in Gorumara National Park, 2022

Sampling details	Count
Camera points	49
Trap nights (effort)	4644
Number of tiger photos	0

Gorumara National Park acts as an important conservation area because of assemblage of mega-herbivores and other important biota. However, no tiger was photo-captured during the camera trap exercises in 2018 and 2022. Despite the productive floodplain habitat, this national park experiences numerous biotic pressures as it is situated amidst network of linear infrastructures, human habitation and expanding tourism infrastructures which could be the reason of low abundance of leopard and other carnivores (Jhala *et al.* 2021). A recent study by Mukherjee *et al.* 2019 predicted significant decline of grassland areas, which will pose severe threat to the mega-herbivore population.

JALDAPARA NATIONAL PARK

Jaldapara National Park serves as a habitat for large herbivores such as the Asiatic elephant, one-horned rhinoceros, and gaurs. This is made possible by the fertile floodplains and extensive grasslands found within the park. It is noteworthy that Jaldapara National Park is home to the second-largest population of one-horned rhinoceros in both India and the world, with the Kaziranga Tiger Reserve holding the largest population (Lepcha *et al.* 2022). Situated in the Jalpaiguri district of West Bengal, specifically at coordinates 26°03' to 26°05' N and 88°54' to 88°24' E, this national park also possesses historical, archaeological, and ethnographic significance. The primary drainage system of the park comprises the Torsa River, which is fed by glaciers, the rain-fed Malangi River, and several other rivers (Ghosh *et al.* 2021). These rivers contribute to the creation of alluvial floodplains within the park. In order to conduct the All India Tiger Estimation, camera traps were deployed to survey Jaldapara National Park for two consecutive cycles. A total of 75 camera trap stations were utilized, resulting in 3577 trap nights (Table V.4.12).

Figure V.4.12

Camera trap layout in Jaldapara National Park, 2022

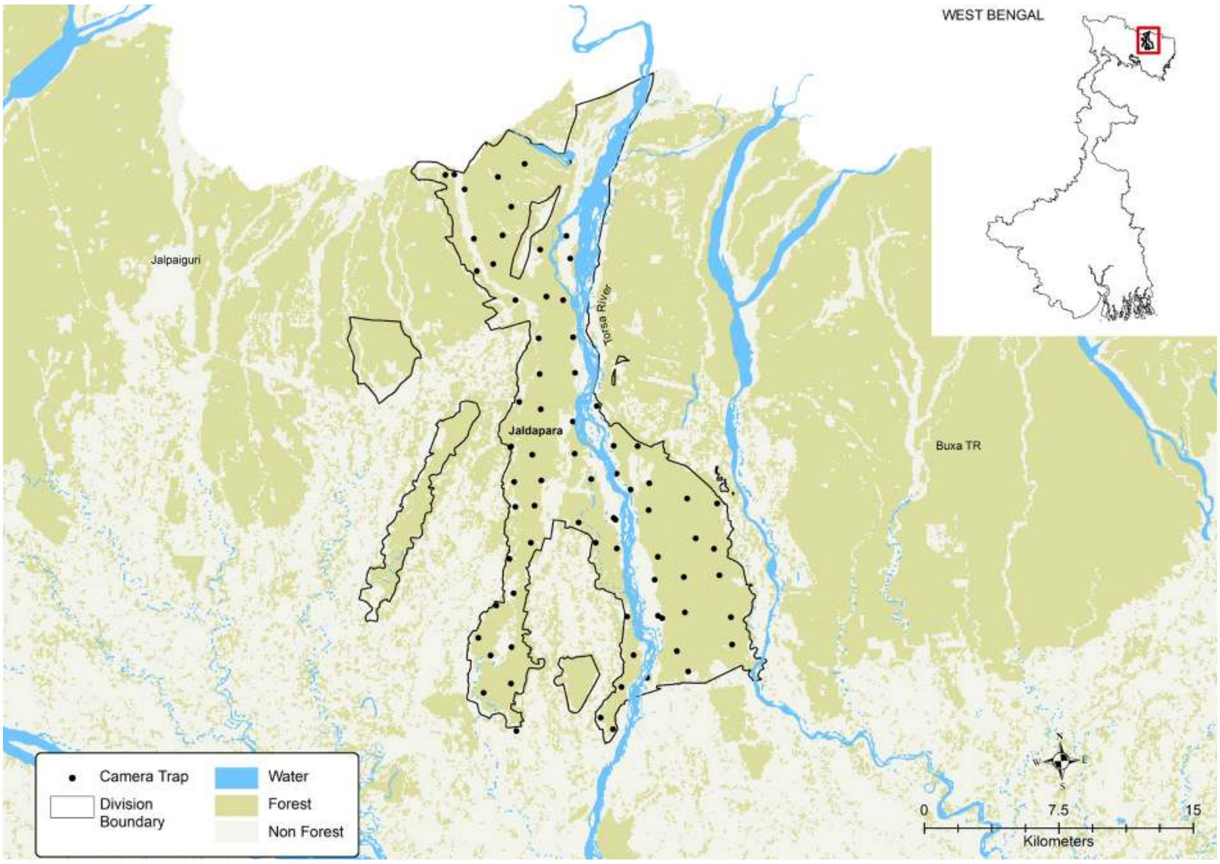
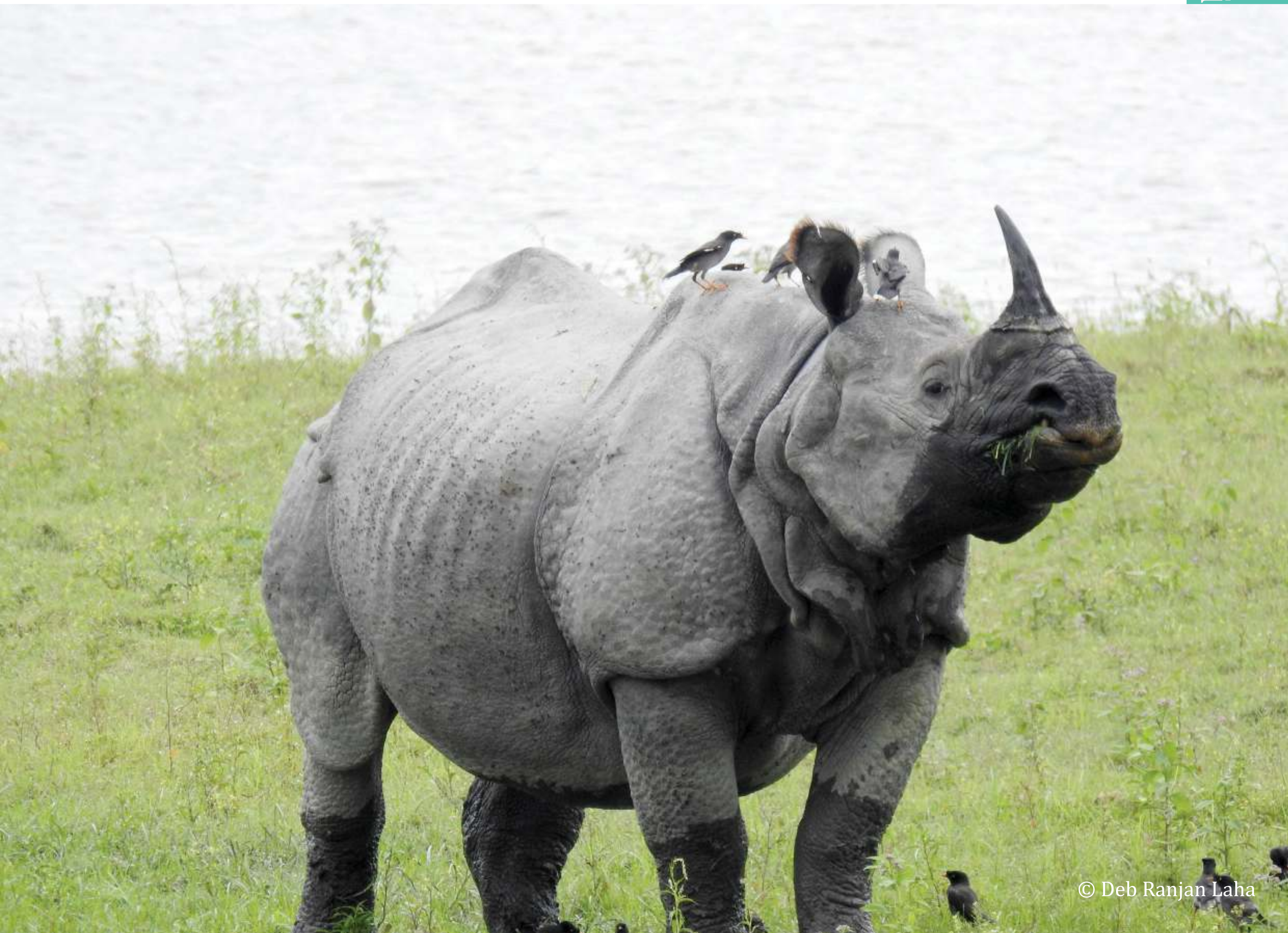


Table V.4.12

Sampling details in Jaldapara National Park, 2022

Sampling details	Count
Camera points	75
Trap nights (effort)	3577
Number of tiger photos	0

No tiger signs have been recorded in Jaldapara National Park since 2018. Instead, the leopard assumes the role of the apex predator within the park, boasting one of the highest leopard densities in the country (Jhala *et al.* 2021). The conservation of mega-herbivores is of utmost importance in this national park. However, that the park is situated amidst dense human settlements, with NH 317 running alongside its western boundary, effectively dividing it into two parts. Furthermore, the indigenous forest dwellers are permitted to collect Non-Timber Forest Products (NTFP) from the park (Lepcha *et al*. 2021). Despite these challenges, there is potential for Jaldapara National Park to become a haven for tigers. This can be achieved by ensuring it remains a contiguous population block with Buxa Tiger Reserve and by reducing anthropogenic and developmental pressures.



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MAHANANDA WILDLIFE SANCTUARY

Mahananda Wildlife Sanctuary is located in the Darjeeling district of West Bengal and falls under the jurisdiction of the Darjeeling wildlife division. Initially managed as a game sanctuary, it was officially designated as a sanctuary in 1959 and spans over an area of 159 km^2. The sanctuary is in close proximity to the Siliguri metropolitan area. The dominant forest type found within the sanctuary is dense mixed forest (Champion & Seth 68). Due to the sanctuary's varying altitudes, it serves as a habitat for a diverse range of endangered and endemic species and forms part of the Greater Khangchendzonga landscape. For the first time, camera traps were deployed in this sanctuary as part of a nationwide tiger estimation effort. During this exercise, a total of 22 camera station were set up, resulting in 1019 trap nights. As indicated in Table V.4.13, one tiger was photo-captured during this period.

Figure V.4.13

Camera trap layout and tiger presence in Mahananda Wildlife Sanctuary, 2022

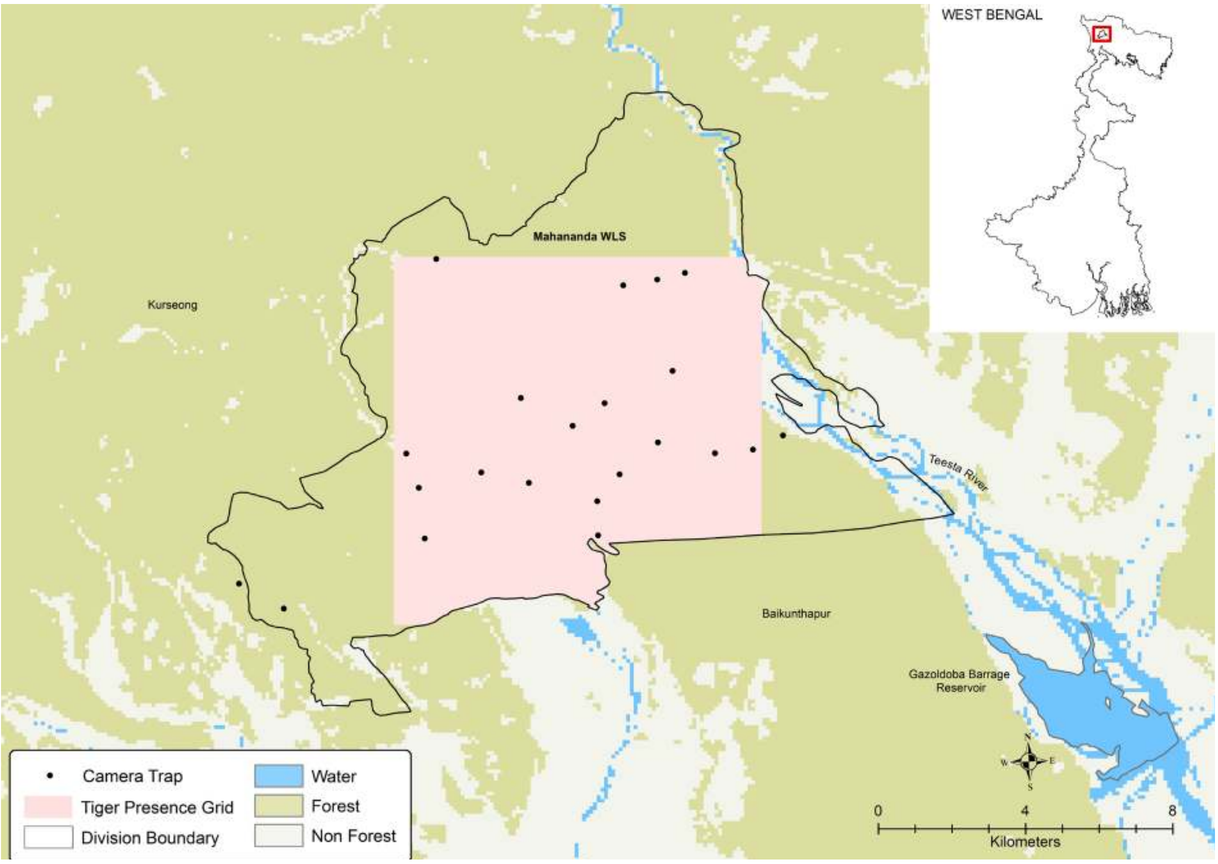

Table V.4.13

Sampling details in Mahananda Wildlife Sanctuary, 2022

Sampling details	Count
Camera points	22
Trap nights (effort)	1019
Number of tiger photos	9
Unique tigers captured	1

During the camera trap exercise conducted in Mahananda Wildlife Sanctuary, a tiger was photographed. However, this tiger was the same individual previously photo-captured in Buxa Tiger Reserve. This finding suggests the existence of a corridor connecting these two landscapes through the protected area network. The presence of a connected habitat corridor is significant for the movement and conservation of tigers in this region.

NEORA VALLEY NATIONAL PARK

Neora Valley National Park is situated in the Kalimpong sub-division of the Darjeeling district. It covers an area of 88 km^2 and falls under the jurisdiction of the Gorumara. Geographically, the park is located in the Eastern Himalayan region of West Bengal and boasts a rich natural heritage. The forest is contiguous with Sikkim in the north, further enhancing its ecological significance. For the first time, the Forest Department conducted camera trapping in this National Park as part of a nationwide tiger estimation exercise. Previous reports have already indicated the presence of tigers in the park, and during the camera trapping exercise, a male tiger was photographed. Due to logistic constraints, sampling in Neora Valley National Park was restricted to blocks. A total of 21 camera stations were strategically placed and remained active for 2550 trap nights within the national park (Table V.4.14).

Figure V.4.14

Camera trap layout and tiger presence in Neora Valley National Park, 2022

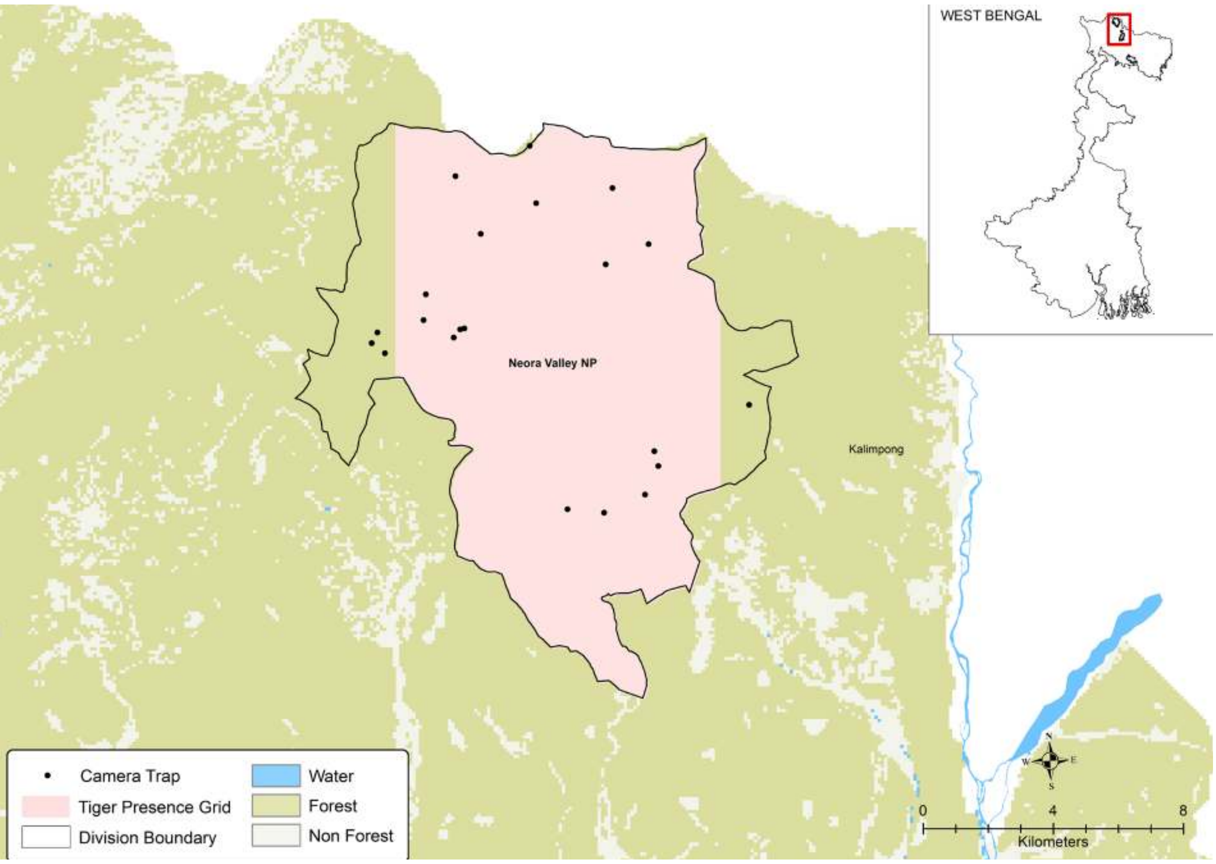

Table V.4.14

Sampling details in Neora Valley National Park, 2022

Sampling details	Count
Camera points	21
Trap nights (effort)	2550
Number of tiger photos	17
Unique tigers captured	1

This national park is a significant conservation area under Greater Khangchendzonga landscape, and is home to high altitude tigers. For better protection of this landscape, law enforcement monitoring, and ungulate supplementation should be implemented.

Mizoram

DAMPA TIGER RESERVE

Dampa Tiger Reserve, located in the Mamit district of Mizoram, situated within the coordinates 23°20' to 23°47'N and 92°15' to 92°30'E. It is the sole tiger reserve in Mizoram and holds significant importance as an Important Bird Area, as recognized by Rahmani *et al.* in 2016. The reserve falls under the Indo-Burma biodiversity hotspot. Dampa Tiger Reserve is traversed by various rivers, including Teirei, Keisalam, Seling, and others. The forest within Dampa primarily consists of moist deciduous vegetation, with wet evergreen forests in the valleys and tropical grasslands at higher elevations. Notably, this tiger reserve is connected to the Chittagong Hill Tracts of Bangladesh through contiguous forest patches. During the camera trapping exercise conducted in the core habitat of the reserve, a total of 43 camera stations were set up, resulting in 1628 trap nights (Table V.4.15). It is important to highlight that this trapping was opportunistic in nature.

Figure V.4.15

Camera trap layout in Dampa Tiger Reserve, 2022.

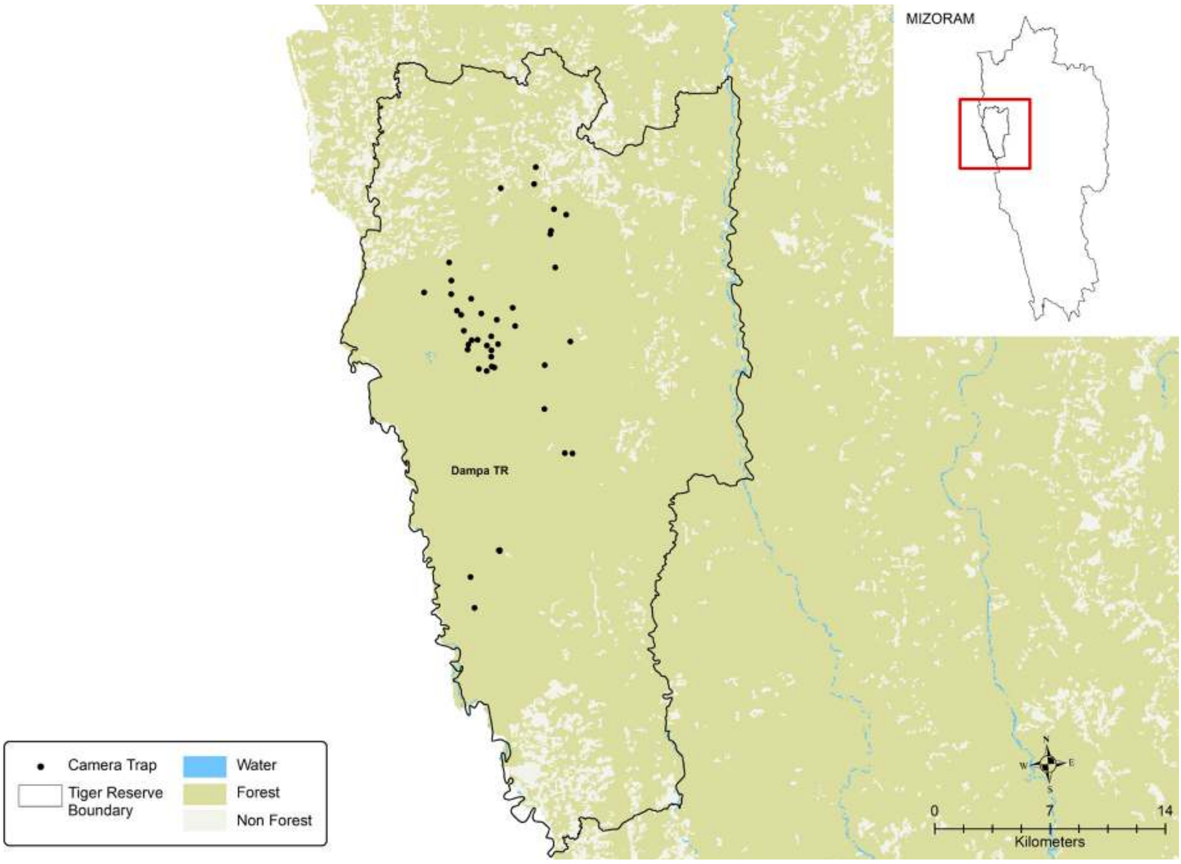

Table V.4.15

Sampling details in Dampa Tiger Reserve, 2022

Sampling details	Count
Camera points	43
Trap nights (effort)	1628
Number of tiger photos	0

Tiger population of Dampa is substantially low, and tiger presence was confirmed through scat DNA in 2014. No tiger was photo captured during 2018 and 2022. However, as per media reports and communication made by the Tiger Reserve staff, a tiger was photo-captured during routine monitoring exercise in 2021 (Times Now). Although abundance of tiger and other biota is low in this reserve, it holds utmost significance in conserving other important carnivore such as clouded leopard. Dampa continues to be a conduit for movement of tigers within North East hills forests. However, implementation of regular law enforcement monitoring and prey augmentation are needed to revive tiger population in this tiger reserve.

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Section VI

Synthesis : Conservation implications

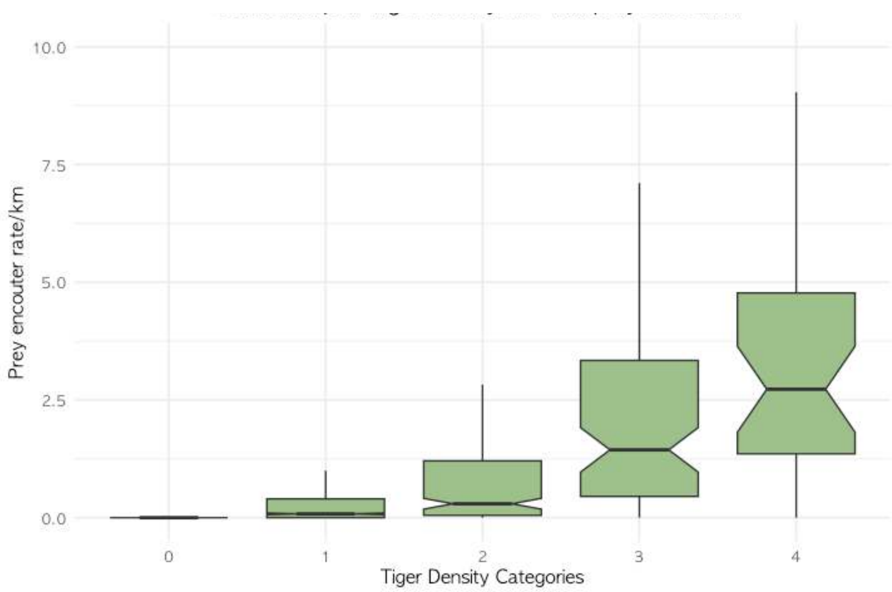
Tigers are a conservation-dependent species. Only after years of conservation efforts have their populations recovered. This recovery has certain commonalities that convey the requirements and prerequisites for the recovery of large carnivores across the world.

PRESENCE AND ABUNDANCE OF WILD UNGULATE PREY

The primary prey for tigers in India consists of large-bodied ungulates like chital, sambar, hog deer, swamp deer, gaur, and wild pigs. Tigers can persist and disperse across habitats that have poor wild prey but can never achieve the high densities that are required for creating source populations, which are important for the long-term persistence of tigers within landscapes (Fig. VI.1).

Figure VI.1

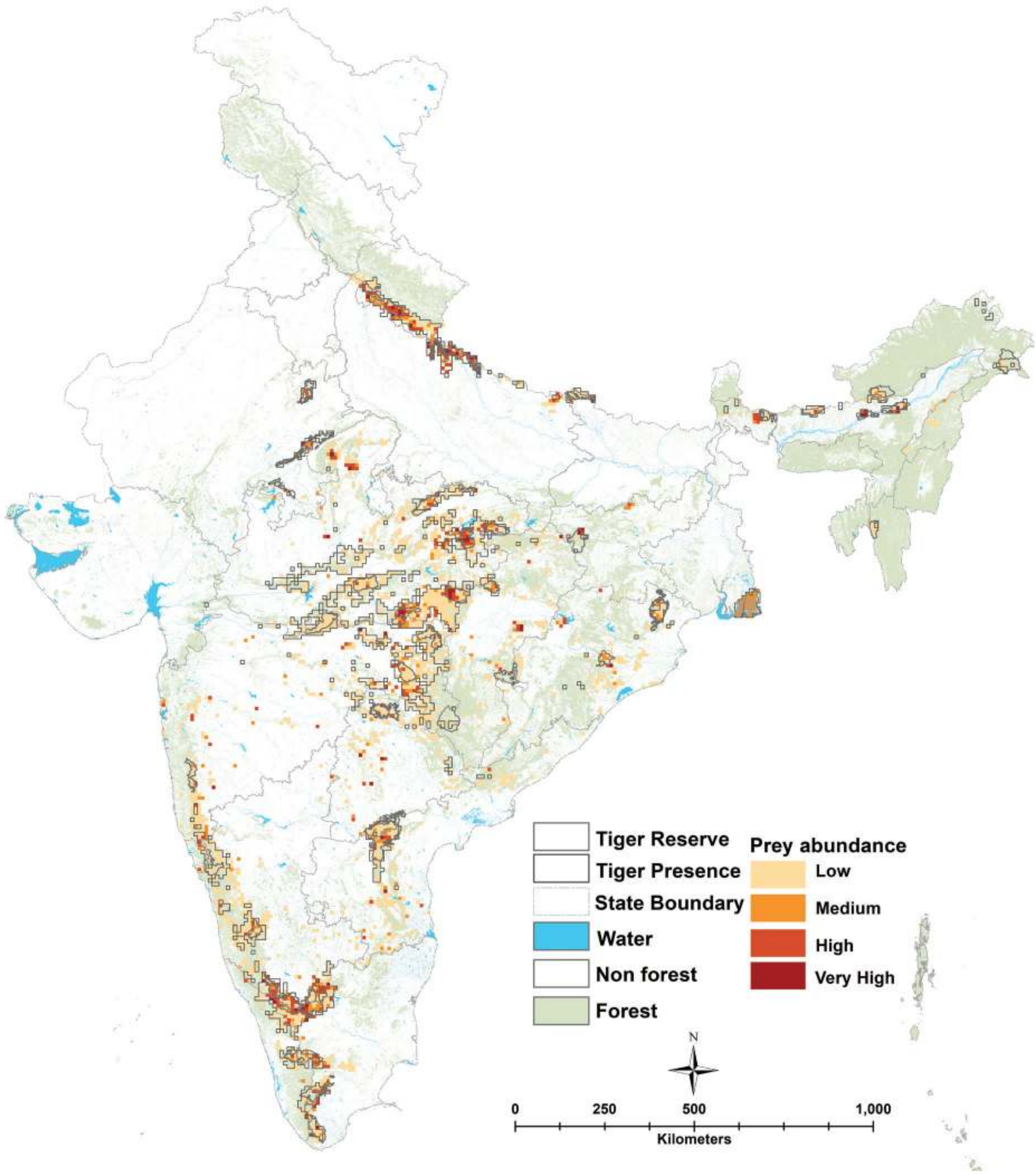
Wild tiger prey (large bodied cervids) encounter rates/km on line transects across different tiger density categories (Tiger density (per 100 km^2) categories: **0** – no tigers, **1** – 0.1- 2.5; **2**- 2.6-6; **3**- 6.1-11; **4**- >11).



At a country scale, Fig. VI.2 depicts the spatial distribution of tiger prey in relation to tiger density. It is clear that the forests of Chhattisgarh, Jharkhand, Odisha, parts of Bihar, southern Uttar Pradesh, and barring some prestigious protected areas in the North East (Kaziranga, Manas, and Orang) the entire region of the North East, is depleted of wild prey. Tigers from these areas have become locally extinct or persist at very low densities, which are not viable in the long term. Prey depletion within these regions is primarily due to people's traditional dependence on bushmeat consumption. Earlier, such practices did not result in local extinctions since human densities were low and wildlife was abundant. Today, the situation is reversed, and since these regions are also some of the poorest regions in India, bushmeat remains a major source of protein for the local communities. If local communities are weaned off bush meat through economic upliftment, education, and a change in lifestyles, then law enforcement is possible and wild prey populations can be restored. Tiger habitat within the protected areas of these above-mentioned regions is still in good condition and covers 30,000 km2. Once prey recovery occurs, this region can accommodate another 900–1,500 tigers, considering a conservative density of 3-5 tigers per 100 km2 (the low-density range of tigers within Indian Protected Areas). Such restoration requires multisectoral

Figure VI.2

Tiger prey distribution and tiger occurrence within India, note the potential tiger habitats that are devoid of tigers and their prey within the states of Chhattisgarh, Jharkhand, Odisha, and the North East.



LEGAL PROTECTION AND HUMAN PRESSURE

Tiger populations across the world are primarily depleted due to poaching, which is fuelled by the illegal demand for their body parts. Though tigers can occur in habitats that are not legally designated as Protected Areas, they achieve high densities (source populations) only within and in close distance to legally protected areas (Fig. VI.3). These high-density populations are the source for recruitment that results in dispersing tigers across the landscape, ensuring gene flow between populations, which is essential for the demographic and genetic viability of the species.

Figure VI.3

Response of tiger density categories from distance to Protected Area (in meter). As the distance increases tiger density decreases. High density source populations are found only within and in the close proximity of Protected Areas.

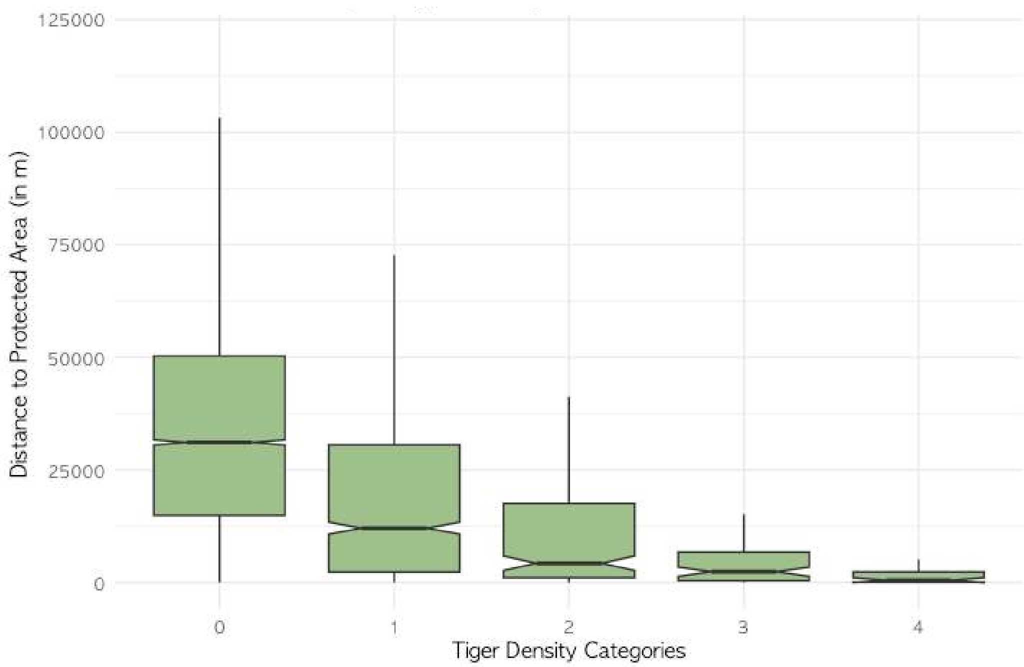
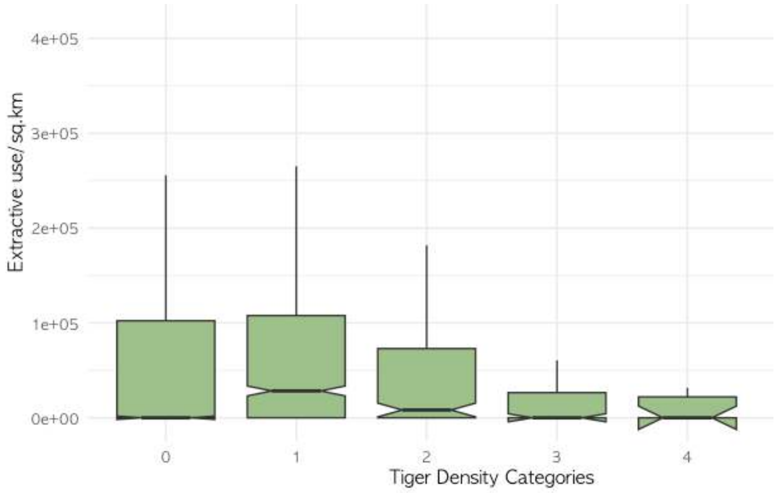


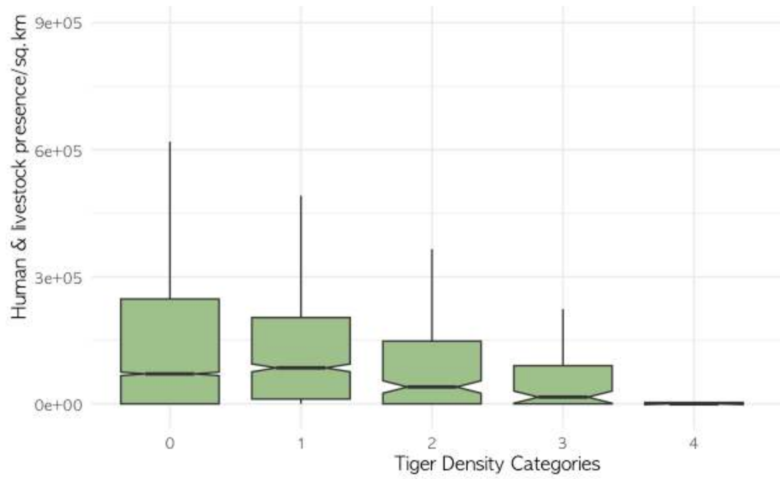
Figure VI.4

Response of tiger density categories to human related impacts a) Extractive uses (wood cutting, lopping and grass extraction) per hectare, b) Presence of humans and livestock in the forest per hectare, c) Urbanization (distance to night lights in m).

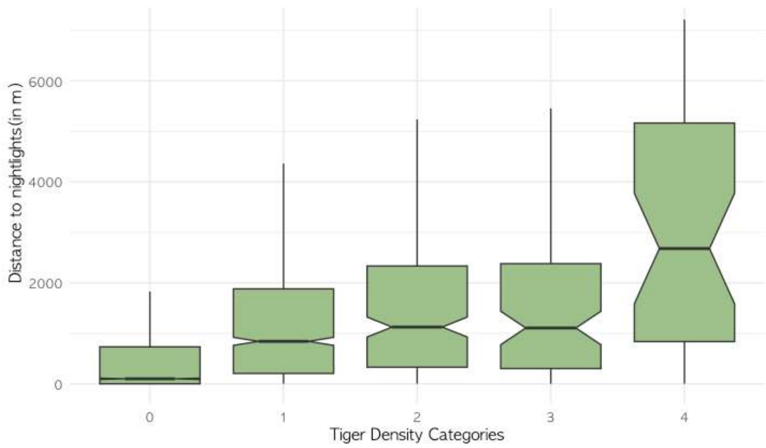
a)



b)



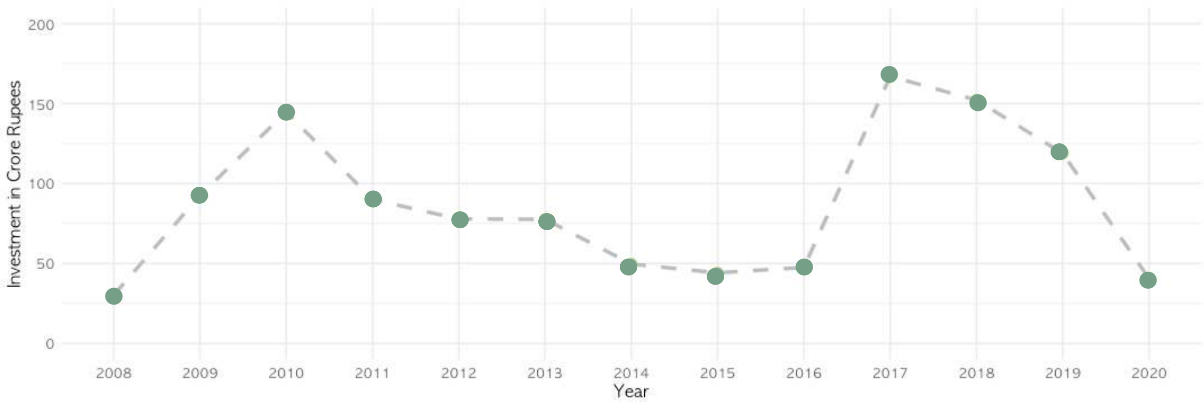
c)



Though tigers occur along with people, extractive uses, livestock and human presence, and urbanization was detrimental to achieving high density tiger populations (Fig. VI.4 a, b &c). From the data (Fig. VI,4), it is clear that land sparing in the form of inviolate core areas of Protected Areas is a very important conservation requirement for large carnivores, especially tigers. The government of India invests substantially in incentivized voluntary village relocation (WPA 2006 amendment) since eviction of people from within Protected areas is illegal (Forest Rights Act 2006). Currently, the Project Tiger scheme of the Central Government provides an incentive of an economic package amounting to 15,00,000 per adult family unit to relocate (Village_Relocation_Order.pdf (ntca.gov.in)). Over the years, the investment in creating inviolate core areas within Tiger Reserves has been substantial (Fig. VI.5). This is a win-win scheme for biodiversity and people since it reduces human impacts within Protected Areas, a major impediment to biodiversity and tiger conservation, while simultaneously providing economic upliftment and better livelihood opportunities to local communities (Jhala *et al.* 2021a). However, funding for this important scheme targeting poor forest dwellers is dwindling over the years, which needs to be increased as it is the most important conservation initiative by any government globally that benefits both people and wildlife.

Figure VI.5

Investment by Project Tiger scheme in incentivized village relocation from within core areas of tiger reserves to create inviolate space for biodiversity.



HABITAT QUALITY, CONNECTIVITY AND GENEFLOW

The degradation of forests, particularly in Territorial divisions, is evident due to widespread human dependence, fragmentation, and the spread of invasive species. It is crucial to invest in restoring these forests to benefit both wildlife and human well-being. While India actively monitors threats to its biodiversity in natural areas, many other important conservation regions, particularly in the Global South and tiger-range countries, lack similar assessments. To effectively monitor changing ecosystems, integrating invasive species assessment into national-scale biodiversity projects is essential.

Although the scale of invasive species invasions may appear daunting, global examples demonstrate the effectiveness of long-term, systematic management in controlling invasive species and restoring native biodiversity. The first step in addressing invasive species is to recognize their presence. To achieve ecological restoration, policies must be designed to translate research findings into conservation actions, taking into account social values and environmental objectives with measurable success indicators. Currently, invasive species management policies and practices suffer from a lack of objectivity, emphasizing the need to adopt adaptive policies and scientific guidelines to enhance management outcomes.

With 1.4 billion people, space for biodiversity conservation comes at a premium in a country like India. The average size of the protected area in India is small (230 km^2). These protected areas are too small to hold the demography and genetic viability of most species, including tigers, for the long term. Therefore, managing them as metapopulations is an essential conservation strategy. With the success of Project Tiger, India has been able to secure the future of its big cats through their successful breeding in the source areas; it is now extremely crucial to ensure that the source populations are connected to other habitat patches to facilitate the dispersal of young adults. This requires habitat linkages in the form of corridors, which pass through human-dominated landscapes. Section IV delineates optimal corridors that can permit dispersal of tigers between source populations; these corridors require attention for the long-term sustenance of the species within India. The forested habitats are under tremendous developmental pressure, leading to fragmentation. A reassessment of the corridors across tiger landscapes shows that the source populations are connected through tenuous, narrow habitat patches that may shrink or be completely lost in the near future unless brought under a conservation agenda. These connectivity areas are under huge anthropogenic pressure, and losing them would restrict tiger dispersal in the landscape, leading to tiger-human conflict and the eventual extinction of tigers.

In the Shivalik landscape, Corbett is connected to Pilibhit and Dudhwa through Nepal and a few weak fragments within India via the Gola River corridor near the township of Haldwani. This corridor is almost lost and requires urgent attention. Suhelwa is completely disjunct from the other protected areas in India and is connected only through habitats in Nepal. Border roads proposed for defence purposes between India, Nepal and Bhutan need to be carefully aligned and mitigated so that they do not become barriers for the genetic exchange of tigers and other wildlife. The tigers of Valmiki were identified as a priority for conservation based on their genetic distinctiveness and vulnerability. The connection of this tiger reserve with Chitwan National Park in Nepal is crucial, as this is what continues to sustain the tigers here. Most of the tiger reserves in this landscape are connected through forest patches in Nepal. Adopting mitigation measures at the bottlenecks in this landscape can secure the long-term dispersal of wild animals in this landscape.

Central India holds the genetically most diverse population in the country. This is due to the extensive connectivity that is present across the landscape. However, the eastern part of the landscape lacks source population and can only be sustained through the source areas from the central area; Achanakmar, Kanha, Pench, NNTR, and Tadoba are some of the largest source population blocks in the world. This block is connected through weak connectivity with other parts of the landscape. Pench-Satpura connectivity is fragile due to coal mines. The western connectivity of Panna is fragmented, leaving its only connection with Ranipur in the north. With future development in mind, connectivity in this landscape remains the most crucial factor, and if mitigations like those done for NH44 can be implemented for all linear developments arising here, only then is the future of tigers in this landscape is secure. Certain important populations are isolated, such as Sariska, Similipal, and Udanti Sitanadi. Tiger reproduces and needs supplementation from genetically closer populations. Similipal has been identified as a population for conservation priority based on its evolutionary potential and genetic distinctiveness. It is important that the historical connectivity is restored and maintained to Bandhavgarh through Palamau, Sanjay-Dubri, and Guru Ghasidas to ensure the survival of this unique lineage.

The Western Ghats are well connected through contiguous forest patches up to the Sahyadri Tiger Reserve; the landscape structure has forests and plantation matrix, where the recent trend of electric fencing of private plantations and other activities is creating barriers to the dispersal of several species, including tigers. It is important to ensure development, both Government and private, to ensure the traditional pathways for elephants and gaurs, as well as for tigers, are protected through mitigation.

In the North-East of the country, the source population of Kaziranga is well connected through the forests of Karbi Anglong, Intanki National Park, and Dampa; however, these forest habitats lack prey, are riddled with snares, and therefore cannot hold tigers for long. In the north, Kaziranga is connected to Nameri and Pakke through the tributaries of the Brahmaputra (the Jia Bhoroli (Kameng) and Dikrong rivers) and also to Kamlang and Namdapha via Dibru-Saikhowa National Park. In this landscape, the North Eastern hill tigers have been prioritized for conservation based on their genetic distinctiveness and diversity. The uniqueness of this population stems from its connectivity to Myanmar, where the tiger population is almost decimated but is a different subspecies, *Panthera tigris corbettii.* However, transboundary connectivity and cooperation are important to maintain the evolutionary distinctiveness of this gene pool.

Investing more in our Protected Areas and allocating funds for wildlife conservation to territorial divisions is a wise decision to enhance protection and conservation efforts. The crucial actions involving habitat and prey recovery, protected inviolate space, connectivity, efforts to reduce poaching and timely resolution of conflicts constitute the essential elements necessary for the ongoing existence of tigers not only in India but also in other regions. Continuous conservation investments are imperative to ensure the well-being of tiger populations. Tigers act as indicators of the health of an intact ecosystem, which in turn provides vital ecosystem services essential for sustaining the planet and human welfare. Therefore, committing resources to tiger conservation serves as a form of insurance, safeguarding the survival of our own species.

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APPENDIX 1

A. National Tiger Conservation Authority (NTCA) Team

NTCA Team Leader: Dr. S.P. Yadav, Member Secretary, NTCA
Nodal Officer: Dr. Amit Mallick, Inspector General of Forest
Shri Rajendra Garawad, Deputy Inspector General of Forest

Head Quarter, New Delhi
1. Ms. Banumathi, G., Assistant Inspector General of Forest
2. Md. Sajid Sultan, Assistant Inspector General of Forest
3. Shri Hemant Singh, Assistant Inspector General of Forest

Regional Office, Bengaluru
1. Shri N.S. Murali, Inspector General of Forest
2. Ms. Harini Venugopal, Assistant Inspector General of Forest

Regional Office, Guwahati
1. Shri W. Longvah, Inspector General of Forest (retd.)
2. Ms. Agatha Momin, Biologist

Regional Office, Nagpur
1. Shri Hemant Bhaskar Kamdi, Assistant Inspector General of Forest
2. Shri Anil Dashare, Biologist

B. Wildlife Institute of India team

Director: Shri Virendra R. Tiwari
Dean: Dr. Ruchi Badola
Project Investigators: Prof. Qamar Qureshi, Dr. Y.V. Jhala, and Dr. Vishnupriya Kolipakam
NTCA-WII Tiger Cell Scientists: Dr. Kausik Banerjee, Dr. Ujjwal Kumar, Dr. Swati Saini, Dr. Shikha Bisht, Dr. Ayan Sadhu

Collaborators: Dr. Lex Hiby (Conservation Research Ltd., UK), Dr. Saket Anand, IIIT ,Delhi

M-STrIPES Team: Shri Anup Pradhan, Shri Ashish Prasad, Shri Deb Ranjan Laha, Ms. Krishna Mishra, Ms. Kainat Latafat, Shri Manish Singanjude, Shri Dhruv Jain, Ms. Rutu J. Prajapati, Shri Nanka Lakra, Ms. Amal Fatima, Shri Yash Dabholkar, Ms. Deeksha N., Ms. Sagarika Das.

Database Archival and Management: Shri G. Muthu Veerappan

Senior Research Biologists: Dr. Bhim Singh, Ms. Genie Murao, Dr. Anindita Bidisha Chatterjee, Ms. Shravana Goswami, Shri Jayanta Kumar Bora, Dr. Sudip Banerjee, Ms. Pooja Choudhary, Shri Keshab Gogoi

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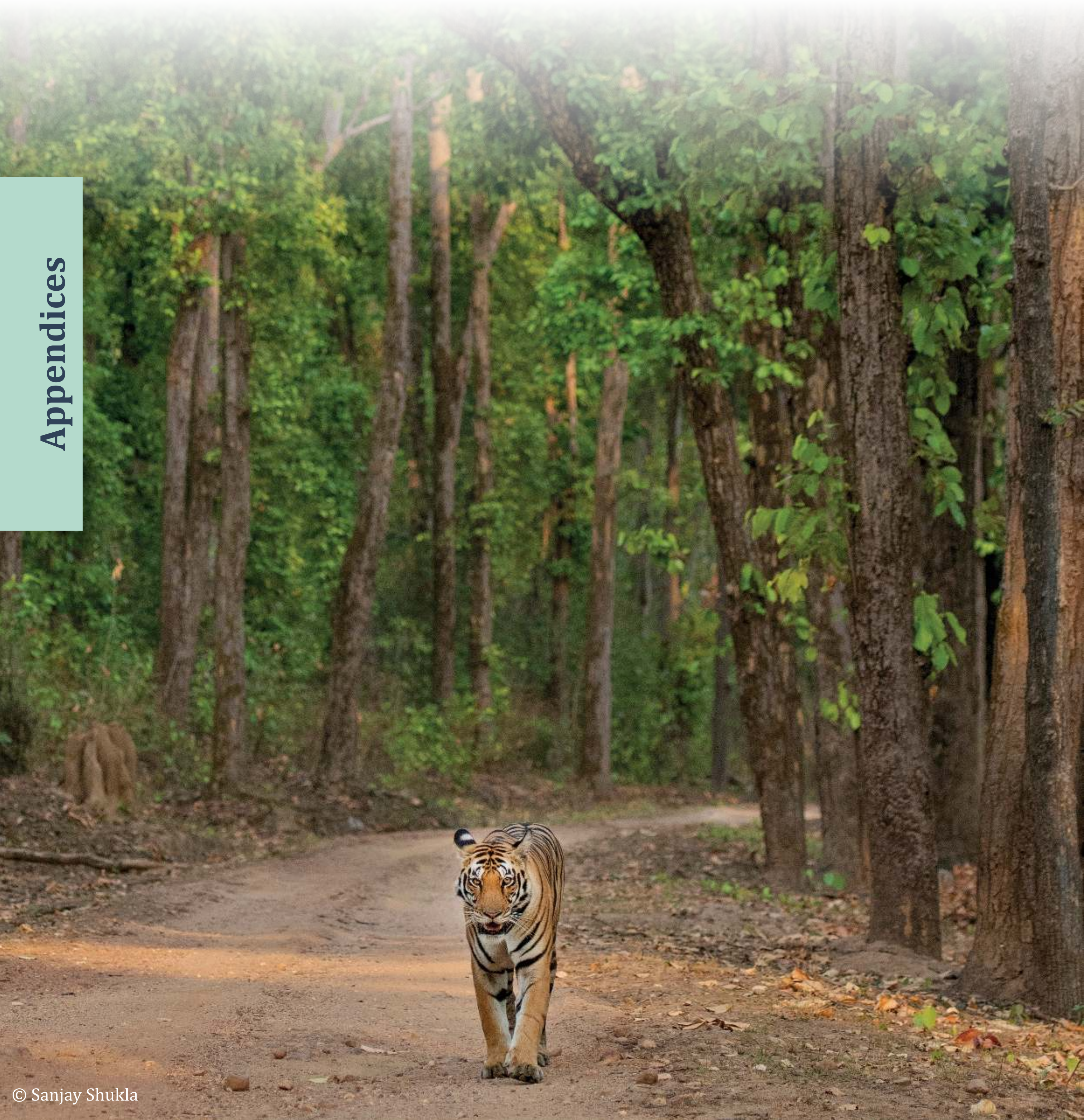

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Research Biologists

Shri Abhilash Nair	Ms. Mahajan Rashmi Deepak
Shri Abhishek Shukla	Ms. Mouli Bose
Shri Aman Deep Rathi	Shri Moulik Sarkar
Ms. Ananya Ajay	Ms. Mridula
Ms. Ananya Dutta	Ms. Nupur Rautela
Ms. Ananya Sengupta	Shri Omkar Nar
Shri Anshuman Gogoi	Ms. Parul Sen
Shri Arif Ahmad	Ms. Pooja Latwal
Ms. Aritra Roy	Shri Prayas Auddy
Shri Ayan Khanra	Shri Rajrajeshwar Thakar
Ms. Deepali Chatrath	Shri Richard S Sangma
Shri Devvrat Singh	Ms. Ritu Bisht
Ms. Drashti Gosai	Shri Rohan Desai
Ms. Farah Naz	Ms. Sayali Aspat
Shri Gaurav Anil Shinde	Shri Shahzada Iqbal
Ms. Gausiya Kelawala	Shri Shivam Tiwari
Ms. Gayatri Bakhale	Ms. Shristi Joshi
Ms. Geetanjali	Ms. Shriya Milind Auradkar
Ms. Harshini Jhala	Shri Sourav Das
Shri Himanshu Kumar	Ms. Stuti Anjaria
Ms. Juri Roy	Shri Sultan
Ms. Kalpana Roy	Ms. Sumandrita Banerjee
Ms. Kamakshi Singh Tanwar	Ms. Susmita Nilesh Patil
Shri Kathan Bandyopadhyay	Ms. Udita Garbyal
Shri Kaushik Mohan Koli	Ms. Umang Kaur Josan
Ms. Kesha Patel	Ms. Vaishnavi Gusain
Ms. Maitreyee Vishwas Bhave	Ms. Vedanshi Maheshwari
Shri Mayur Markhad	Shri Vishnuvardhan
Ms. Meghavi Purohit	Ms. Yashi Singh
Shri Mohit Kumar Patra	
Ms. Satemmenla Longchar	

Technical Assistants

Shri Abhishek Petwal	Shri Pratik Majumder
Shri Akash Rana	Shri Pratik Pansare
Shri Ankan Halder	Ms. Preeti Parihar
Shri Anurag Nashirabadkar	Ms. Richa Joshi
Ms. Archana Negi	Ms. Ritupriya Debnath
Ms. Arti Adhikari	Shri Rohit Kumar
Ms. Arukshata Thakur	Shri Rudrajyoti Barman
Shri Ashish Joseph	Shri Rushikesh Kadam
Ms. Ashwini Mamgain	Ms. Saana Benurwar
Shri C. Jebin Bristo	Ms. Shankhamala Ghosh
Ms. Chaiti Tripura	Ms. Sheela Kanswal
Shri Gorati Arun Kumar	Shri Shiladitya Acharjee
Shri Hritik Dhami	Ms. Shrawani Wankhade
Shri K. M. Sooraj Murali	Ms. Shreya Yadav
Ms. Kiran Rawat	Shri Shubham Kumar Maletha
Shri Lakshman Bhajarang	Ms. Shweta Singh
Shri Lalitkumar Patil	Ms. Sneha Madhwal
Shri Manas Shukla	Ms. Sonali Aswal
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Ms. Neha Tolia	Ms. Swati Chandola
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Shri Nishant Saraswat	Ms. Swati Singh
Shri Nishi Nath Halder	Shri Tryambak Dasgupta
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Shri Piyush Tripathi	Ms. Vartika Negi
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Ms. Prateeksha Nath	Ms. Yati Gairola
Ms. Rashi Nautiyal	Shri Nitesh Goswami
Shri Dixit Verma	Shri Yashaswi Garg
Shri Abhinav K.S. Yadav	

Interns and volunteers

Shri Abhay Thakur	Ms. Sneha Mane
Shri Akshay Jain	Shri Pankaj Ojha
Ms. Geeta	Shri Parth Kathad
Shri Harshal Waghmare	Ms. Pinky Yadav
Shri Himanshu Matta	Shri Pranav Thapa
Shri Inderjeet Singh	Ms. Prateeksha Nath
Ms. Kavita Bisht	Ms. Preeti Parihar
Ms. Madhu Panwar	Ms. Preeti Tripathi
Ms. Mahima Gagar	Ms. Riddhi Sondagar
Ms. Monibhadra Roy	Shri Roheel Taunk
Ms. Moupika Gosh	Shri Saurav Panday
Ms. Nivedita Sharma	Shri Yajurved
Ms. Nivedita Singh	Ms. Abhilasha Srivastava
Ms. Farah Usmani	Shri Shantanu Sharma
Ms. Bhawana Pant	Shri Shantanu Ishwar Nagpure
Ms. Manisha Bhatt	Ms. Riddhi

Design: Shri Paritosh Bharti, Ms. Swasti Joshi

Extract Compare Team: Ms. Monika Saraswat, Ms. Genie Murao, Dr. Anindita Bidisha Chatterjee, Ms. Rutu J. Prajapati

Finance: Shri Surendra Singh Yadav

Scientific Administrative Assistant: Shri Harsh Deep Sethi, Ms. Pallavi Sharma

Office Support Staff: Shri Devendra Singh, Shri Shambhu Kimothi, Shri Dhyan Singh

IT support : IT, RS & GIS Cell Team

Program developers

Shri Prabir De (SCIENCE, Dehradun) and	Kaiinos Geospatial Technology Pvt. Ltd., Hyderabad

C. Chief Wildlife Wardens in the States Involved in the Tiger Status Estimation 2022-23

S. No.	States	Name
1	Andhra Pradesh	Shri N. Prateep Kumar, Shri Y. Madhusudhan Reddy
2	Arunachal Pradesh	Shri G Kumar, Shri R.K Singh, Shri N. Tam
3	Assam	Shri M.K. Yadava
4	Bihar	Shri Prabhat Gupta
5	Chhattisgarh	Shri P.V. Narsingh Rao, Shri Sudhir Agarwal
6	Goa	Shri Santosh Kumar, Shri Saurabh Kumar
7	Jharkhand	Shri P.K. Verma, Shri Sanjay Kumar Srivastva, Shri Ashish Rawat, Shri Shashikar Samanta
8	Karnataka	Shri Sanjay Mohan, Shri Vijaykumar Gogi, Shri Rajiv Ranjan
9	Kerala	Shri Surendra Kumar, Shri Devendra Kumar Verma, Shri Bennichan Thomas, Shri Ganga Singh
10	Madhya Pradesh	Shri Alok Kumar, Shri J.S. Chouhan
11	Maharashtra	Shri Mahip Gupta, Shri Sunil Limaye
12	Mizoram	Shri R. S. Sinha, Shri Ritu Raj Singh
13	Nagaland	Shri Ved Pal Singh, Shri Satya Prakash Tripathi
14	Odisha	Shri S. K. Popli, Shri Shashi Paul
15	Rajasthan	Shri Arindam Tomar, Shri M.L Meena
16	Tamil Nadu	Dr. Shekhar Kumar Niraj,Shri Thiru. Shri K.K. Kaushal, ShriThiru. Syed Muzammil Abbas, Shri I. Anwardeen, Shri Thiru. Srinivas R. Reddy, Shri Thiru. Akash Deep Baruah, Shri Yogesh Singh
17	Telangana	Ms R Sobha, Shri Swargam Srinivas, Shri Rakesh Mohan Dobriyal
18	Uttar Pradesh	Shri S. Singh, Shri K.P. Dubey
19	Uttarakhand	Shri J.S. Suhag, Dr. P.M. Dhakate, Dr. Samir Sinha
20	West Bengal	Shri V.K. Yadav, Shri Debal Ray

D. All India tiger estimation Nodal Officials of the States

S. No.	States	Name
1	Andhra Pradesh	Shri D.A. Kiran, Ms T. Nagamaneswari
2	Arunachal Pradesh	Shri Millo Tasser
3	Assam	Dr. Satyendra Singh
4	Bihar	Shri Surender Singh
5	Chhattisgarh	Shri T. Ashish Kumar Bhatt
6	Goa	Shri Jabestin A.
7	Jharkhand	Shri Kumar Ashutosh
8	Karnataka	Shri Kumar Pushkar, Shri Subhash Malkhede
9	Kerala	Shri P.P. Pramod, Shri K. Vijayananthan, Shri K.V Uthaman, Shri P Muhammed Shabab
10	Madhya Pradesh	Dr. H.S. Negi, Shri Subharanjan Sen, Shri Rajnish Kumar Singh
11	Maharashtra	Shri B.S. Hooda
12	Mizoram	Shri Pu Laltlanhlua Zathang
13	Odisha	Dr. J.D. Pati
14	Rajasthan	Shri Sharda Pratap Singh, Shri Nandlal Prajapat
15	Tamil Nadu	Shri Thiru. K.K. Kaushal, Shri Thiru. D.Venkatesh, Shri Tmt. C.H. Padma, Shri Thiru. Akash Deep Baruah.
16	Telangana	Dr. D. Samhita, Shri B. Srinivas, Shri C.P. Vinod Kumar
17	Uttar Pradesh	Shri Sanjay Kumar Pathak
18	Uttarakhand	Shri Ranjan K. Mishra
19	West Bengal	Shri Piar Chand, Shri Rajesh Kumar

E. Official and Biologist Who Coordinated Sampling exercise in the State 2022

S. No.	States	Name
1	Andhra Pradesh	Shri Srinivasa Reddy, Shri Alan Chong Teron, Shri Vigneesh Appavu G, Shri Vineet Kumar Nanyal, Shri Ravindra Dhama, Shri P. Venkata Sandeep Reddy, Shri C.Chaitanya Kumar Reddy, Shri Y.V.Narashimha Rao, Shri G.Satish
2	Arunachal	Shri Tapek Riba, Shri T. Pali, Shri Aduk Paron, Ms Chesta Singh, Shri Suraj Singh, Shri Harshraj Dhinkar Wathore, Shri Kime Rambia, Shri Taluk Rime, Shri Tage Mili, Shri Kenjum Membron, Shri Tajum Yomcha, Shri Chandan Ri, Shri Mayurkumar Hamubhai Variya, Shri Aditya Das, Shri Son Yowa Hade, Shri Tukum Macha, Shri Mayuk Lamgu, Shri Rubu Tado,Shri Token Rime, Shri Kelsang Dechen, Shri Deokon Chiri, Shri Julu Brah, Shri Dongro Natung, Shri Hage Tare, Shri Kame Rigom, Shri Paramod Singh Meyan, Shri Dyaba Mipi, Shri Midu Molo, Shri Dilip Molo, Shri Sagar Sonar, Shri Ema Mili, Shri Anjitey Mikhu
3	Assam	Shri P. Sivakumar, Shri Jatindra Sarma, Dr. Vaibhav C. Mathur Shri Pankaj Sharma, Shri Ramesh Kumar Gogoi, Shri Pradipta Baruah, Shri Piraisoodan B, Shri Dibakar Das, Shri Chiranjeev Jain, Shri Arun Vignesh, Shri Rabindra Sarma, Shri Pallav Kumar Deka, Shri Jayanta Deka, Shri Kanak Baishya, Shri Khagesh Pegu, Shri Chiranjeev Jain, Shri Sheshidhar Reddy, Shri Nayanj Jyoti Rajbangshi, Shri Champak Deka, Shri Khanindra Kalita Shri Nayanjyoti Rajbanshi, Shri Chakrapani Ray, Shri Rajib, Shri Jesimuddin Ahmed, Shri Bidyut Bikas Borah, Shri Bibhuthi Ranjan Gogoi, Shri Bibit Dehingia, Shri Debajit Saikia, Dr. Pranjal Gogoi, Shri Sonam Kr. Gupta, Shri Arup Kalita, Shri Jatindra Mohan Das, Shri Pradib Dev Goswami, Shri Soumitra Das, Shri Manjit Sonowal, Shri Bibhuti Majumdar, Shri Debashish Buragohain, Shri Babul Brahma, Shri Krishna Hanse, Shri Pankaj Bora, Shri Pushpadhar Burgohain, Shri Dibyajyoti Deori, Shri Nayanjyoti Borah, Shri Shahnawaj Hussain, ShriAbhinav Baruah, Shri Bastav Borkatoky, Shri Raj Pallav Neog Shri Karmeshwar Boro, Shri D Rongpi, Shri Roji Barman, Shri Basiram Brahma, Shri Rajendra Nath, , Shri Girish Kalita, Shri Deep Kalita, Shri Amrit Doley, Shri Jyotishman Deka, Shri Uddipta Kalita, Shri Sajid Choudhury, Shri Himangshu Sarma, Shri Papul Rabha, Shri Dipankar Deka, Shri Nayan Pathok, Mrs Papori Kachari Shri Bichitra Narayan Sarma, Shri Satyajit Deka,
4	Bihar	Shri Surendra Singh, Shri Hemakant Roy, Dr Nesamani K.,Shri Neeraj Narayan, Shri Ambrish Kumar Mall, Shri Pradyumn Gaurav, Shri Manish Verma, Shri Amita Raj, Shri Sourabh Verma, Shri Arif Ahmad, Dr. Kamlesh K Maurya (WWF India), Shri Soham Sachin Pattekar (WWF India).

S. No.	States	Name
5	Chhattisgarh	Shri S.Jegadeeshan,Shri S.P.Paikra,Mrs. Praneetha Paul, Shri Ganveer Dhammshil, ShriSatyadeo Sharma, Shri Varun Jain, Mrs. Priyanka Tripathi
6	Goa	Shri Jebestin A., Sh Anand Jhadhav, Shri Prem Kumar, Shri Aniket Gaonkar
7	Jharkhand	Sri Kumar Ashutosh, Shri Kumar Ashish, Shri Prajesh kant jena, Shri Manish Kumar Bakshi, Shri Ravindra Kumar
8	Karnataka	Shri Biswajit Mishra, Shri Ramesh Kumar, P., Shri Mahesh Kumar, Shri Harshakumar Chikkanaragund., Shri Prabakaran, S., Shri Santhosh Kumar, G., Ms Deep Contractor, Shri Maria Christu Raja, D., ShriT. Heeralal, Shri S. S. Lingaraja, Shri Vijay Salimath, ShriYatish Kumar D., Shri Manoj Kumar, Shri Upendra Pratap Singh, Shri Manjunath.R.Chavan, Shri P. Shankar, Shri S. Venkatesan, Shri B N N Murthy, Shri Prakash S. Netalkar, Dr.Malathi Priya, Dr. Hanumanthappa K T, Shri Sandip Hindurao Suryawanshi, Shri Chandrashekar Naik K, Shri N. H Jagannatha, Shri G P Harsha Bhanu, Shri Sumitkumar Subhashrao Patil, Shri Dinesh Kumar Y K, Shri Prabhakar Priyadarshi, Shri Arsalan, Shri Shivshankar .E, Shri Devaraju V, Shri Prashant Shankhinamath, Shri Prashanth, P.K.M., Dr.Ajjaiah G.R., Shri Ganapathi K, Shri Vasanth Reddy K V, Shri S. G. Hegde, Shri Gopal, Shri Nandish, L, Dr. Santhosh Kumar G. Shri N E Kranthi, Shri Nilesh Shinde, Shri Yashpal Kshirsagar, Ms Dipika Bajpai, Shri Balakrishna S, Shri Basavaraj Kn, Ms Anupama H, Ms Vaanathi M M, Ms Sareena Sikkalagar, Shri Chandranna A, Ms Kajol Ajit Patil, Shri A T Poovaiah, Shri M Sivaram Babu, Shri Sharanabasappa, Shri Ruthren P, Shri Ashish Reddy Mv, Shri Dinesh Kumar Yk, Ms Seema P A, Shri Ravishankar C, Ms Kamala, Dr V Karikalan, Shri Kapileshwara Mahadevappa Gamanagatti, Shri Mohan Kumar D, Shri G U Shankar, Shri Im Nagaraj, Shri Ramesh Kumar, P., Shri Kanteppa, Shri T. Bhaskar, Shri Kanteppa, Shri P R Manjunath, Umar Badshan Kurgund, Shri S Y Bilagi, Charan G S, Ashwathappa T, Sahan Kumar TM, Shri Prakash A D, Shri Chandrashekar Patil, Shri Suresh Teli, Mallinath Kusanal, Mallinath Kusanal (incharge), Shivarudrappa Kabadagi, Shri BV Chauvan, Shri Manjunath G Naik, Shri Sharan Kumar, Kavya Chaturvedi, Kavya Chaturvedi, Shri Ashok R Bhat, Smt Himavathi Bhat, Shri SM Vali, Shri Ragu D, Shri Ragu D, Shri Ashok B Alaguru, Shri Sumith Kumar Subhashrao Patil, Shri Ravikumar, Shri Paramesh K, Shri Ankaraju M N, Shri Nagendra Prasad, Ms Bhagyalaxmi MC, Ms R Vanitha, Shri Prabhakar Priyadashi, Shri Sandeep Hindurao Suryavanshi, Shri Ramesh BR, Shri Chetan Mangala Gasti, Shri K N Manjunath, Shri K S Chengappa, Ms Ratnaprabha T A, Shri Saurabkumar, Shri B Y Yalager, Shri Suresh CN, Shri Srinivas N Yaradoni, Basvaraj Dange, Dr. Shivakumar Gajare, Sunil Kumar Chauvan, Md. Fayazudin, Shri Md. Asad, Shri Sathish, (CONT.)

S. No.	States	Name
	Karnataka	Shri Gopal, DS Dayanand, Shri Moshin, Shri Nehru, Ms Roshani, Kumari Kajol Ajith Patil, Shri VP Karyappa, Shri N Subramanya rao, Shri VP Karyappa, Subramanya, Rangaswamy KN, Anusha P, Shri BS Shashidar, Shri Shankaregouda, Shri RD Putnalli, Same on Charge, Shri Suresh, Shri K G Prakash, Shri Shridhar R, Shri Gopya Naik, Shri CY Shivamurthy, Shri Praveen Kumar Basrur, Shri K V Subramanya, Shri Ganesh V Thadagani, Ms Sunita Mallikarjun Nimbargi, Shri Muddanna, Smt Roshni AJ, Shri Lohhith BR, Sri. M. N. Naveen, Sri. G. Ravindra, Sri. K. Paramesh, Sri. K.S. Chengappa, Ms Rathnaprabha T.A., Shri Sandeep Surya Vanshi, Shri Mahadevaiah, M., Kavya Chaturvedi, Shivananda S Todkar, Amarakshar. V.M, Mahadev S P, Sathish A.V, Gopal K P, Shri Amarakshar, V.M., Shri Shaikh Abdul Aleem Siddiqui, Ms Niveditha, T.P., Shri Vinay, L., Shri Imran Patel, Kumari. Jeevitha, B., Kumari. Varidhi Krishna.
9	Kerala	Shri Ganga Singh,Shri Pramod P.P.,Shri Sanjayankumar, Shri R. S. Arun, Shri K. R. Anoop, Shri K. Vijayananthan, Mrs. K.S. Deepa, Shri P Muhammed Shabab, Shri Pramod P.P., ShriR.Sujith, Shri K.V Harikrishnan, Shri Abdul Assis,Shri P. K. Jayakumar Sharma, Shri Ayush Kumar Kori Shri Sunil Sahadevan,Shri A. Shanavas, Shri K. I. Pradeep Kumar, Shri Anil Antony, Shri Varun Dalia, Shri Ramesh Bishnoi Shri Vinod Kumar M G, Shri Subhash K.B, Shri N. Rajesh, Shri C.V. Rajan Shri Sambudha Majumder, Shri Ravikumar Meena Mrs. R. Lekshmi, Shri T. Aswin Kumar, Shri P. Praveen,Shri Kurra Srinivas, Shri Surjith M.K,Shri Manoj K, Shri P. Biju, Shri P. Karthick, Shri Abdul Latheef C,Mrs. A. Shajna,Shri K.J. Martin Lowel,ShriPatil Suyog Subhash Rao ,Shri K. V. Harikrishnan,Shri S. V. Vinod,Shri Jayachandran G,Shri Santhosh Kumar V,ShriR.Sujith, Shri Prabhu P.M, ShriAni J R,Shri I. S. Suresh Babu, Shri Manu Sathyan,Shri Sanil,Dr. M. Balasubramanian, Shri Vishnu Vijayan,Shri M. Ramesh Babu, Shri Anoop V,Shri Vishnu O,Shri Rahul C.M, Shri Rahul R
10	Madhya Pradesh	Dr. H.S. Negi, Shri Subharanjan Sen, Dr. B.S. Annigeri, Shri L. Krishnamoorthy, Shri Uttam Sharma, Sh.S. K. Singh,Shri Y. P. Singh, Shri Ashok Mishra,Shri Rajiv Kumar Mishra, Shri Brijendra Jha, Shri Amit kumar Dubey, Shri Dev A prasad J., Shri Ripudaman Bhadoriya, Shri Ravindra Mani Tripathi, Shri Lovit Bharti, Shri Adhar Gupta, Vijay Kumar Sunda, Shri Rajnish Kumar Singh, Dr. Anirudh Majumder, Shri Amitabh Agnihotri, Shri Gyan Prakash Shukla, Shri Tejas Karmarkar, Shri Sumit Saha, Ms Sangeeta Kevat, Shri Jitendra Awase, Shri Uttam Singh Sastiya, Shri Amit Khanna, Shri Rajendra Singh Chauhan, Shri Madhav Uike, Shri Rajendra Singh Solanki, Shri Suresh Kusre, Shri Virendra Kumar, Shri Rajesh Ninama, Shri Ambika Prasad Maravi, Shri Shiv Kumar Kokadia, Shri Inder Singh Bare, Shri Rameshwar Uike, Shri Rameshwar Udake, Shri Upendra Dubey (WWF India), Shri Sandip Choksey (WWF India), Shri Rahul Talegaonkar (WWF India), Shri D.P. Srivastava (SFRI)
11	Maharashtra	Dr. Clement Ben, Shri B. S. Hooda, Mrs. Sreelakshmi A.,Dr. Ravikiran Govekar, Mrs. Sreelakshmi A., Shri Nanabhau Sitaram Ladkat, Shri Samadhan Chavan, Dr. Jitendra S. Ramgaokar, Miss. Jayoti Banerjee, Shri Jayaram Gowda,Shri R. S. Ramanujam ,Shri S. Yuvraj ,Shri Prabhunath Shukla,Shri Atul Deokar, Shri Kiran Patil, Shri Pramod Panchbai, Shri Thengadi, Shri Uttam Shankar Sawant, Shri Vishal Mali, Shri G. Guruprasad, Shri Kushagra Pathak, Shri Nandkishor Kale, Shri Navalkishore Reddy, Shri Sumant S. Solanke, Mrs. Divya Bharti M., Shri N Jaykumaran, Madhumitha S., Shri Manoj N. Khairnar, Shri A.W. Nimje, Shri Kulraj Singh, Miss. Punam Pate,Shri Pawan Jeph, Shri Suresh Salunkhe, Shri Ganesh Patole, Shri Tushar Dhamdhere, Shri Abhijit Waykos, Shri Bapu Chagan Yele ,Shri Mahesh Chagan Khore , (CONT.)

S. No.	States	Name
	Maharashtra	Shri Mahadev, Shri R.R. Kulkarni, Shri Kamlesh Patil ,Shri Indrajeet n. Nikam ,Shri Ravindra. B. Kondawar, Shrishupal Pawar, Shri Sandip Kumbhar, Shri Balkrushna Hasabnis, Shri Nandkumar Nalawade, Shri Dnyaneshwar Rakshe, Shri Sandip Jopale, Sau. Miss.Swati Vijay Maheshkar, Shri Baurao Krishnarao Tupe, Sau. Yogita V. Atram (Madavi), Shri Ghanshyam Raghunath Naigamkar, Shri Santosh Ramdas Thipe, Shri Kiran Wasudeo Dhankute, Shri Ravindra Haridas Chowdhari, Shri Satish Kisan Shende, Miss. Shubhangi Ravindra Krishnapurkar, Shri Pradip Laxman Chawhan, Shri Rundan SadaShriv Katkar,Shri Arunkumar Ramlakhan Gound, Shri Yogesh V. Tapas, Shri Vivek Yewatkar, Shri Abhay Chandel, Shri Shantanu Sharma, Miss. Abhilasha Shrivastav, Shri Akash Patil, Miss. Prajakta Hushangabadkar, Shri Sachin Nikesar, Shri Sahbaz Sheikh, Shri Pawan Uttamrao Tikhile,Shri Sunil Kamdi, Shri Akash Sarda, Shri Gajanan Dhadse, Shri P. E. Patil, Suman Koley, Zehidul Hussain, Shaheer Khan, A. Krishnan, Jaideep Patil, Advaita Ravindran
12	Mizoram	Shri C. Lalbiaka,Shri Lalnunzira, Shri Andrew Lalthlamuana, Shri James Thanmawia, Shri Zoliansanga
13	Nagaland	Shri T. Aochuba, Dr. Sentitula, Shri Suman Sivasankar Sivachar W. M., Shri Rajesh Kumar, Dr. Prabhat Kumar, Shri Tokaho Kinimi, Svil Ltu, Shri Limaba, Shri Sashilemla, Shri Ailong Phom, Shri Temjenmongba, Shri Shilu, Shri Moakumdang, Shri Imkongmar, Shri P. Bendangmongba, Shri Chubanunsang, Shri Nahwang, Lansothung Lotha, Shri Wopansao, Shri Bokato, Shri Aaron Yimchunger, Shri Imnawapang
14	Odisha	Shri M. Yogajayanand, Shri Aksshay Kumar Patnayaik, ShriT.Ashok Kumar, Dr. Jagyandatt Pati, Dr. Prakash Chand Gogineni, Dr. Smrat Gowda D.S.,Shri Sudhanshu Sekhar Khora, Shri Sai Kiran D.N., Shri Saroj Kumar Panda, Shri Samir Kuamr Satpathy, Ms. Anshu Pragyan Das, Shri Bimal Prasanna Acharya, Bidya Sagar, Shri Pradeep Kumar Dey, Shri Nikesh Kumar Mahapatra, Shri Samresh Kumar Biswal, Shri Bhakta P. Rath, Dr. Nimai Charan Palei, Shri Harshvardhan Singh Rathore, Shri Gatikrishna Behera, Shri Pankaj Kumar Das
15	Rajasthan	Shri Sedu Ram Yadav, Shri R. N. Meena, Shri T. C. Verma, Shri R. K. Khairwa, Shri Mahendra Kumar Sharma, Shri Bijo Joy, Shri Alok Gupta, Shri Sudarshan Sharma, Shri Sangram Singh Katiyar, Shri Sanjeev Kumar Sharma, Shri D. P. Jagawat, Shri Manas Singh, Shri Arun Kumar D, Shri Maria Shine, Shri Arvind Kumar Jha, Dr. Ramanad Bhakar, Shri Vinod Rai, Shri Kishore Singh, Shri Bheru Singh Rathore, Shri kishan Singh Ranawat, Shri Devendra Kumar Purohit Shri jayanti lal Garasiya, Shri Tarun Kumar Mehra, Shri Anurag Bhatnagar, Shri Hari Mohan Meena, Md. Mairaj, Shri N.Gokulakkannan, Shri Devendra Singh, Shri Rajrajeshwar Thaker, Shri Prayas Auddy, Shri Kaushik Koli, Ms. Deepali Chatrath, Shri Mohit Kumar Patra, Ms. Stuti Anjaria, Ms. Aritra Roy, Ms. Gayatri Bakhale, Ms. Sumandrita Banerjee, Shri Abhishek Petwal, Shri Devrat Singh, Shri Pankaj Ojha, Shri Omkar Nar, Shri Rohan Desai, Shri Gaurav Shinde, Ms. Oindrila Paul, Ms. Preeti Tripathy (CONT.)

S. No.	States	Name
16	Tamil Nadu	ShriS. Ramasubramanian, Shri Thiru. D. Venkatesh, Shri Nihar Ranjan, Shri S.Ramasubramaniyan, Shri Thiru.Deepak S.Bilgi, Dr.N.Senthil Kumar, ShriR.Padmawathe,Shri A.S.Marimuthu, Shri S.Arokiaraj Xavier, Shri M.G. Ganeshan, Dr. P.K.Dileep, Shri S.N.Tejesvi, ShriTmt. C.H. Padma, Shri Tmt. C. Vidhya, Shri Selvi.S. Senbagapriya, Dr.Bhosale Sachin Tukaram, ShriThiru.L. C. S. Srikanth, ShriThiru. P. Arunkumar, Shri R. Kirubashankkar, Shri Devendra Kumar Meena, ShriKulal Yogesh Vilas, Shri S.Anand, Dr.H.Dileep Kumar, Mrs.C.Vidhya, Dr.J.R.Samartha, Dr.Gurusamay Dubbala, Shri A.Anbu, ShriD. Rameswaran, ShriN.Sridharan,Shri Ashok Kumar, Shri M.llayaraja, Shri K.Ganesh Ram, Shri M. Dhayananthan, Shri L. Sivakumar, Shri N. Manojkumar, Shri N.Rajendran, Shri Kanthan, ShriN. Mariyappan, Shri S. Murali, Shri R. Ramesh, ShriC. Sivakumar, ShriK. Suresh, ShriP. Ganeshpandiayan, ShriDr. V. Saravanan, ShriC. Sivakumar, ShriS. Sivakumar, ShriD. Dinesh, ShriS. Sathish, ShriM. Ramalingam, ShriC. Sakthivel,Shri J. Peter Prem Chakravarthi, Shri N.Sridhran, Shri Karthik Thamizharasu, Shri K. Anvar, Dr. K.Mahesh Kumar, Shri C.Sakthivel, ShriG.Karthikeyan, Shri J. Yogesh, Shri M. Palanisamy, Dr. P. Santhosh Kumar, Dr. A. Samson, ShriThiru.M.Parthiban, ShriThiru.D.Keerthivasan, Miss.Thiru.S.Meenakshi Sundaram, Miss. Tmt.R.Nagalakshmi, ShriThiru.R.Muniyandi, ShriThiru.M.Murugan, Mrs.S.Agnes Jeya Packiavathi ShriP.Yogeswaran, Shri J. Dalson Mani, Shri Tmt. S. Buvaneswari, Shri P. Gunalan.
17	Telangana	Shri B. Srinivas, IFS, Sri M. J. Akbar, Ms Sunitha Bhagavath, Smt N. Kshitija, P.V. Raja Rao, Shri D. Bheema, Shri C.P. Vinod Kumar, G. Ramalingam, Sri G. Kista Goud, Sri Sivala Rambabu, Sri D. Venkateshwar Reddy, Sri A. Venkateshwarlu, Sri S. Satyanarayana,Sri P. Ramakrishna, Shivani Dogra, Sri VikasMeena, Sri S Shantharam, Sri PetlaRajashekar, Shri JoguYellam, Sri S. Mahaboob, Sri Narsimha, Sri M. Ravi Kanth, Sri Md. Saleem,
18	Uttarakhand	Shri Rahul, Shri Naresh Kumar, Dr. Dheeraj Pandey, Dr. Saket Badola, Shri Siddhant Umaria, Mrs Kalyani, Shri Neeraj Sharma, Shri Digant Nayak, Shri Sher Singh, Shri Bhuvan Chand Upreti, Shri Rajendra Kumar BishtShri Neeraj Sharma, Shri Prakash Chandra Arya, Shri Kishan Chand, Ramakant Tiwadi, Shri Brij Bharti Sharma, Shri LR Nag, Shri Amit Goswami, Shri Harish Negi, Mrs Shalini Joshi, Shri Lalit Mohan Arya, Mrs. Prema Tiwadi, Shri Shiv Shankar Giri, Shri Neeraj Negi, Shri Ashu Saini, Shri Sanjay Pandey, Dr. I.P. Bopanna (WWF India), Dr. Meeraj Anwar (WWF India), Shri Devrishi Chattopadhyay (WWF India), Shri Devrat Panwar (WWF India), Shri Siddhant Umaria (WWF India), Shri Yash Kumar Agarwal (WWF India), (CONT.)

S. No.	States	Name
	Uttarakhand	Shri Ankur Patra (WWF India), Shri Arpan Gupta (WWF India), Shri Jagjivan Dhami (WWF India), Shri Puran Singh (WWF India), Shri Paramdeep Singh (WWF India),Shri Sajal Singh (WWF India), Shri Shrestha Singh (WWF India), Miss Ankita Chand (WWF India), Miss Riya Adak (WWF India), Sher Singh (WWF), Bhuwan Chand Upreti (WWF), Rajender Kumar Bist (WWF).
19	Uttar Pradesh	Shri Sanjay Kumar Pathak ,Shri Kailash Prakash, ShriSameer Kumar, Shri Sundresha, Shri Akashdeep Bhadwan, Shri Naveen Khandelwal, Shri Sitanshu Pandey, ShriSatyapal Singh, ShriGirdhari Lal, ShriSobran Lal, ShriShivbabu Saroj , ShriVimlesh Kumar, ShriRam ji, ShriShatrohan lal, ShriChandrabhal Singh, ShriRamkumar, ShriSurendar Kumar, ShriWazir hasan, ShriArun Mohan, ShriPramod Kumar Srivastav, ShriRadheysyam, ShriMobeen Arif, ShriApoorv Gupta, ShriG P Rana, ShriRambharan Yadav, ShriAngad Prasad Singh, ShriMayank Pandey, ShriMohit singh, ShriLiladhar, Shri Radheyshyam, ShriRamphool Yadav, ShriAmit Gangwar, ShriRakesh Kumar, ShriChandprakash, ShriVijay Pal, ShriDulare , ShriAjay Kumar, ShriUday Pratap Singh, ShriManoj Kumar, ShriKrishan Kumar Pal, ShriDharmenda Dhaka, ShriRamkant Pandey, Dr. Mudit Gupta, ShriAshish Bista, ShriRohit Ravi(WWF India), ShriDabeer Hasan(WWF India), Shri Naresh Lodhi(WWF India), Shri Kandhai Lal(WWF India), Shri Anil Kumar Srivastav (WWF India), Shri Devendar Kumar (WWF India), ShriPremchand(WWF India), Shri Ramlakhan (WWF India),Shri Mukesh Kumar(WWF India) ,Shri Rahul Kumar(WWF India) ,Shri Ravi Saxena(WWF India) ,Shri Mohd. Shahid (WWF India).
20	West Bengal	Shri Rajendra Jakher, Shri Buddha Raj Sewa, Shri Tapas Das, Shri Ajay Kumar Das, Shri Apurba Sen, Shri Milan Kanti Mandal, Shri Deepak M., Shri Parveen Kaswan, Shri S. Jones Justin, Shri Harish, Shri Soumen Mondal, Shri Nabi Kanth Jha, Shri Pallab Mukherjee, Shri Ranjan Talukdar, Shri Gebu Lepcha, Shri Novojit De, Shri D. Roy, Shri Partha Sarathi Pramanik,Shri Partha Pratim Tripathi, Shri Amalendu Maji, Shri Arnab Das, Shri Arnab Choudhary, Shri Sujit Kr Barma, Shri Narendranath Dutta,Shri Anurag Chowdhury, Shri Chinmoy Barman, Shri Samiran Mukherjee, Shri Avik Das, Shri Syeed Saeef ur Rahman, Shri Biswajit Das, Shri Nur Islam, ShriAnkan Nandi, ShriRaj Kumar Saha ,Shri Biplab Ghosh, ShriSubhayu Saha,Shri Ashim Kumar Dandapat, Shri Monojit Chakraborty, Shri Debasish Mondal, Shri Amitesh Satpathy, Shri Soham Mitra, Shri Subhayu Saha, Shri Prabhat Kr Barman, Shri Promit Lal, Shri Mayukh Ghose, Shri Debojyoty Ghosh, Shri Shekhar Sarkar, Shri Orvill Nazarearth, Ms Shikha Jasrotia.

APPENDIX 2

Across the country, five major workshops were held, while an additional 70 workshops were conducted online. Moreover, 35 training sessions took place in various states. States have further conducted workshops in their Protected Areas and divisions.

List of Training of Trainers Workshops

Date of Workshop	Venue of the Workshop	Participating States	Approximate number of personnel trained
August 06 - 08, 2021	Mudumalai Tiger Reserve, Tamil Nadu	Andhra Pradesh, Goa, Karnataka, Kerala, Tamil Nadu, Telangana	112
August 12 - 14, 2021	Ranthambore Tiger Reserve, Rajasthan	Chhattisgarh, Madhya Pradesh, Maharashtra, Odisha, Rajasthan	105
August 25 -27, 2021	Rajaji Tiger Reserve, Uttarakhand	Bihar, Uttar Pradesh, Uttarakhand, Jharkhand	80
September 02 - 04, 2021	Manas Tiger Reserve, Assam	West Bengal (North), Assam, Mizoram, Meghalaya, Nagaland, Arunachal Pradesh	96
November 02 - 04, 2021	Sundarbans Tiger Reserve, West Bengal	Staff of Sundarbans of India and Bhitarkanika NP (Odisha)	62

APPENDIX 3

Contribution is based on work done for field sampling, data analysis supervision, and writing up; The WII team names are in no particular order; the data presented belongs to the NTCA, WII, and State Forest Departments according to the respective MoU's;

LIST OF CONTRIBUTORS

Shivalik Hills and Gangetic Plains Landscape

NTCA TEAM

Satya P. Yadav, Amit Mallick, Rajendra Garawad, Hemant Singh

WII TEAM

Qamar Qureshi, Y.VJhala, Vishnupriya Kolipakam, Shikha Bisht, Ujjwal Kumar, Swati Saini, Anindita Bidisha Chatterjee, Anup Kumar Pradhan, Ashish Prasad, Sudip Banerjee, Kainat Latafat, Monika Saraswat, G.Muthu Veerappan, Vaishnavi Gusain, Dhruv Jain, Pooja Choudhary, Abhishek Shukla, Ananya Ajay, Ananya Dutta, Anshuman Gogoi, Ayan Khanra,Devvrat Singh, Gayatri Bakhale, Geetanjali, Juri Roy, Kaushik Koli, Nanka Lakra, Mouli Bose, Mridula, Nupur Rautela, Omkar Nar, Prayas Auddy, Rajrajeshwar Thakar, Richard Sangma, Ritu Bisht, Sagarika das, Shivam Tiwari, Stuti Anjaria, Vedanshi Maheshwari, Sumandrita Banerjee, Yashi Singh, Abishek Petwal, Anurag Nashirabadkar, Archana Negi, Ashwini Mamgain, Hrithik Dhami, Gaurav Naithani, Md. Shaan, Mukesh Kumar, Neetu Bathla, Neha Toila, Nibedita Basu, Nishant Saraswat, Rashmi Mahajan, Rohit Kumar, Srishti Joshi, Shankhmala Ghosh, Shiladitya Acharjee, Sonika Phogat, Sonali Aswal, Swati Chandola, Swati Kukreti, Swati Singh, Upasana Thakur, Geeta, Neelam Negi, Pranav Thapa, Prateeksha Nath, Harshdeep Sethi, Suraj Chauhan, Surbhi Koli

Central India & Eastern Ghats Landscape

NTCA TEAM

Satya P. Yadav, Amit Mallick, Rajendra Garawad, Hemant Kamdi, Anil Kumar Dashahre

WII TEAM

Qamar Qureshi, Y.V.Jhala, Vishnupriya Kolipakam, Ujjwal Kumar, Rutu Prajapati, Krishna Mishra, Ashish Prasad, Manish A. Singanjude, Ayan Sadhu, Anup Kumar Pradhan, Ninad Mungi, Shravana Goswami, Jayanta Kumar Bora, Swati Saini, Bhim Singh, Kainat Latafat, Monika Saraswat, G. Muthu Veerappan, Keshab Gogoi, Deb Ranjan Laha, Nanka Lakra, Genie Murao, Anindita Bidisha Chatterjee, Omkar Nar, Abhishek Shukla, Richard S. Sangma, Ayan Khanra, Anshuman Gogoi, Sumandrita Banerjee, Dhruv Jain, Vaishnavi Gusain, Gaurav Anil Shinde, Rohan Desai, Drashti Gosai, Roheel Taunk, Susmita Panggam, Parth Kathad, Susmita Patil, Ritu Bisht, Rajrajeshwar Thakar, Devvrat Singh, Kaushik Mohan Koli, Juri Roy, Sneha Madhwal, Kamkshi Tanwar, Amandeep Rathi, Arif Ahmad, Mohd. Akram, Gitanjali Vashisht, Yash Dabholkar, Inderjeet Singh, Shahzada Iqbal, Shantanu Nagpure, Mahima Gagar, Umang Kaur Josan, Sonali Aswal, Pooja Sharma, Rudrajyoti Barman, Ashish Joseph, Lakshman Bhajarang, Monal Jadhav, Vedanshi Maheshwari, Mukesh Kumar, Abhay Thakur, Upasna Thakur, Swati Kukreti, Geeta Negi, Preeti Parihar, Hrithik Dhami, Tryambak Dasgupta, Abhishek Petwal, Stuti Anjaria, Gayatri Bakhale, Aritra Roy, Mohit Kumar Patra, Pankaj

Ojha, Yashi Singh, Shaikh Obair Aqueel Ahmad, Sonika Phogat, Prayas Auddy, Nivedita Sharma, Sheela Kanswal, Shriya Auradkar, Amal Fathima, Subhalakshmi Muduli, Meghavi Purohit, Ananya Dutta, Pinky Yadav, Gaurav Naithani, Shiladitya Acharjee, Neetu Bathla, Mridula, Harshdeep Sethi, Niharika Virdi, Prateeksha Nath, Swati Chandola, Piyush Kumar, Parul Sen, Nupur Rautela, Moulik Sarkar,Akshay Jain, Kesha Patel, Sultan, Harshini Jhala, Pooja Chaudhary, Kathan Bandypadhyaya, Deepali Chatrath, Oindrila Paul, Preeti Tripathy, Rashi Nautiyal, Nitesh Goswami, Dixit Verma, Yashaswi Garg, Abhinav K.S. Yadav

Western Ghats landscape

NTCA TEAM

Satya P. Yadav, Amit Mallick, N S Murali, Rajendra Garawad, Harini Venugopal

WII TEAM

Qamar Qureshi, Y.V.Jhala, Vishnupriya Kolipakam, Ayan Sadhu, Genie Murao, Kausik Banerjee, Prayas Auddy, Ananya Dutta, Deepali Chatrath, Kainat Latafat, Kamakshi Singh Tanwar, Sonika Phogat, Dhruv Jain, Vaishnavi Gusain, Ashish Prasad, G. Muthu Veerappan, Monika Saraswat, Manish Singanjude, Nanka Lakra, Pooja Choudhary, Rajrajeshwar Thakar, Gayatri Bakhale, Aritra Roy, Kaushik Mohan Koli, Stuti Anjaria, Abhishek Petwal, Abhishek Shukla, Sumandrita Banerjee, Vedanshi Maheshwari, Pratik Pansare, Suranjita Roy, Akash Rana, Sheela Kanswal, Anurag Nashirabadkar, Omkar Nar, Ayan Khanra, Umang Kaur Josan, Piyush Tripathi, Mukesh Kumar, Gaurav Anil Shinde, Maitreyee Vishwas Bhave, Mohit Kumar Patra, Mridula, Pankaj Ojha, Shaikh Obair Aqueel Ahmad, Harshal Waghmare, Mouli Bose, Monibhadra Roy, Nivedita Singh, Neetu Bathla, Neelam Negi, Nishi Nath Halder, Shweta Singh, Tryambak Dasgupta, Manas Shukla, Anshuman Gogoi, Riddhi Sondagar, Susmita Patil, Yashi Singh, Richard Sangma, Rohan Desai, Shivam Tiwari, Juri Roy, C. Jebin Bristo, Hritik Dhami, K. M. Sooraj Murali, Manoranjan Parida, Md. Akram, Prateeksha Nath, Pratik Majumder, Shiladitya Acharjee, Sonika Phogat, Subhalaxmi, Suraj Chauhan, Sushree Subhangi Sahu, Swadhin Kumar Jena, Swati Singh, Kalpana Roy, Amal Fathima, Ananya Ajay, Harshdeep Sethi, Shreya Yadav, Gorati Arun Kumar, Rushikesh Marotrao Kadam, Saurabh Pandey, Swati Chandola, Swati Kukreti, Ms Ritu Bisht, Udita Garbyal, Upasna Thakur, Chaiti Tripura, Neha Kumari, Pinky Yadav, Moupika Gosh, Tapasya Thapa, Madhu Parwar.

North Eastern Hills and Brahmaputra Flood Plains Landscape

NTCA TEAM

Satya P. Yadav, W. Longvah, Rajendra Garawad

WII TEAM

Qamar Qureshi, Yadvendradev V. Jhala, Vishnupriya Kolipakam, Deb Ranjan Laha, Shikha Bisht, Ujjwal Kumar, Swati Saini, Ashish Prasad, G. Muthu Veerappan, Monika Saraswat, Anindita Bidisha Chatterjee, Genie Murao, Rutu Prajapati, Kainat Latafat, Pooja Chaudhary, Bhim Singh, Abhishek Petwal, Rajrajeshwar Thakar, Juri Roy, Shankhamala Ghosh, Nanka Lakra, Nishant Saraswat, Vedanshi Maheshwari, Omkar Nar, Pratik Pansare, Dhruv Jain, Vaishnavi Gusain, Udita Garbyal, Sneha Madhwal, Sajeer P., Ritu Bisht, Susmita Panggam, Anurag Nashirabadkar, Yash Dabholkar, Richard S. Sangma, Ananya Pandey, Rohit Kumar, Mridula, Amal Fathima, Shiladitya Acharjee, Rudrajyoti Barman, Yashi Singh, Shivam Tiwari, Farah Usmani, Gausiya Kelawala, Ananya Sengupta, Farah Naz, Vishnuvardhan, Shrishti Joshi, Pooja Latwal, Susmita Nilesh Patil, Sonika Phogat, Deeksha N., Neha Kumari, Surbhi Koli, Ankita Rawat, Mohammed Shaan, Gaurav Naithani, Sagarika Das, Mouli Bose.

Sundarbans

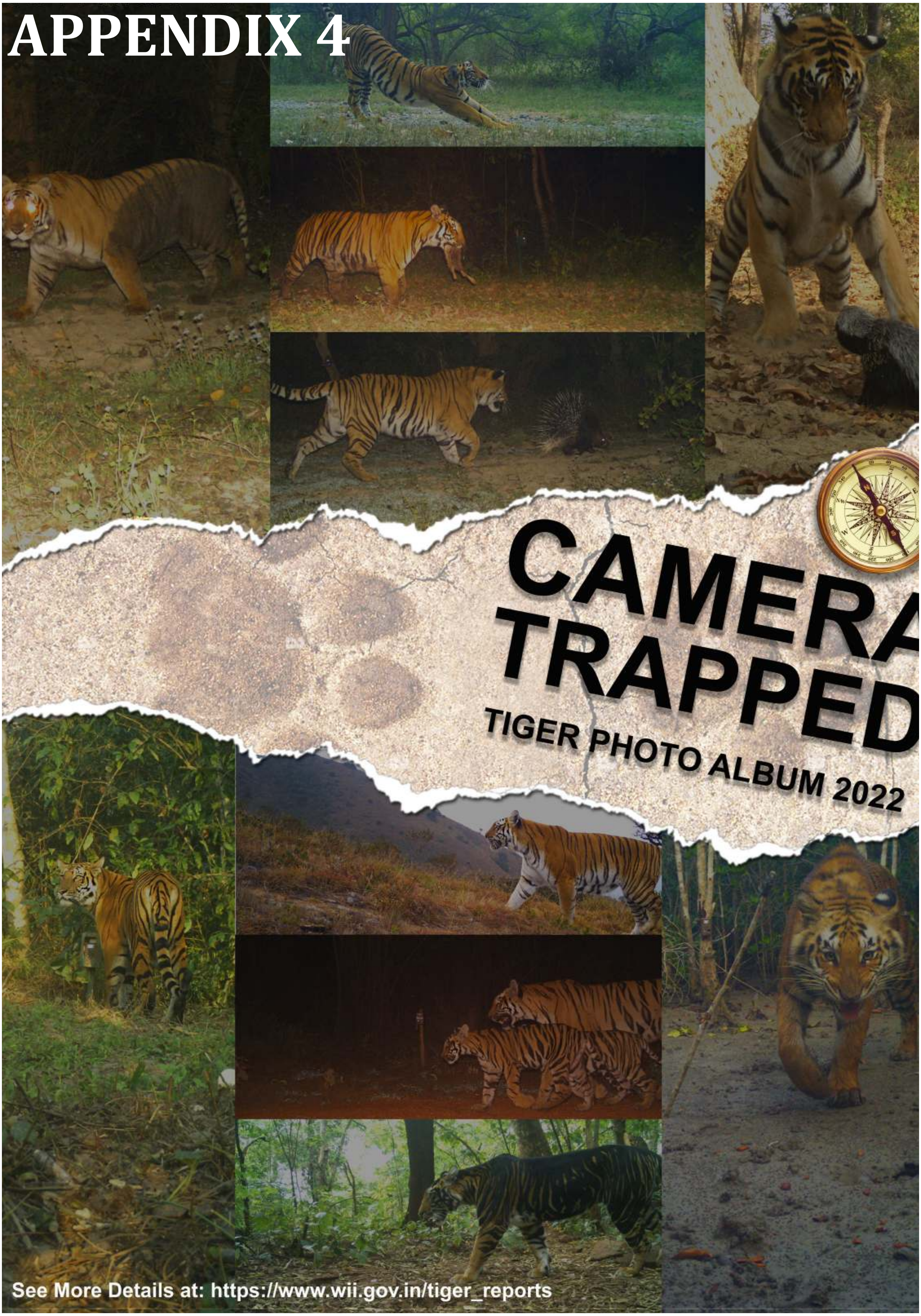
NTCA TEAM

Satya P. Yadav, W. Longvah, Amit Mallick, Ms. Agatha Momin

WII TEAM

Qamar Qureshi, Yadvendradev V. Jhala, Vishnupriya Kolipakam, Deb Ranjan Laha, Ujjwal Kumar, Ayan Sadhu, Swati Saini, Rajrajeshwar Thakar, Abhishek Petwal, Juri Roy, Ayan Khanra, Kalpana Roy, Vaishnavi Gusain, Sajeer P., Dhruv Jain, Sheela Kanswal, Upsana Thakur, Mouli Bose.

APPENDIX 4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Status of

Tigers

Co-predators & Prey in India

National Tiger Conservation Authority
B-1 Wing, 7th Floor,Pt Deendayal
Antyodaya Bhawan, CGO Complex,
Lodhi Road, New Delhi 110 003, India
https://ntca.gov.in/

Wildlife Institute of India
Chandrabani, Dehradun - 248001
Uttarakhand, India
www.wii.gov.in