SUMMARY REPORT

STATUS OF TIGERS IN INDIA-2018

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STATUS OF TIGERS IN INDIA-2018

सत्यमेव जयते

प्रधान मंत्री

Prime Minister

MESSAGE

It is heart-warming to learn that National Tiger Conservation Authority (NTCA), Ministry of Environment, Forest and Climate Change, has compiled a report on the fourth cycle of All India Tiger Estimation titled "Status of Tigers Co-predators & Prey in India, 2018."

India has a long standing and successful track record of protecting its tigers. Tiger conservation is a collective responsibility of the Government and the people. Our cultural legacy which encourages compassion and co-existence has played an important role in the conservation of tigers.

The fourth round of the National Tiger status assessment has utilised the latest technology and the best tools for the process. The assessment will reflect the nature and extent of the success of tiger conservation programmes and help in drawing up a futuristic and visionary strategy for the conservation of tigers.

Best wishes to National Tiger Conservation Authority and Wildlife Institute of India for all the painstaking efforts. I wish the fourth cycle of All India Tiger Estimation 2018 all success in its endeavours.

(Narendra Modi)

New Delhi
आषाढ़ 31, शक संवत् 1941
22nd July, 2019

प्रकाश जावडेकर
Prakash Javadekar

मंत्री
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
भारत सरकार
Minister
Ministry of Environment, Forest & Climate Change
Government of India

सत्यमेव जयते

MESSAGE

India has managed to develop without compromising on the conservation of its natural heritage. The latest tiger status assessment, using the best science is proof of our commitment to achieve this holistic approach.

India has the challenging task of ensuring long term survival of tigers if they are to survive in the tiger ranging world, hence, while being a national imperative India also has the responsibility to secure their future across the globe.

India is home to 60% of the global tiger population which is reflective of our conservation initiatives which are thoroughly grounded in science and suitably backed by a legal and financial framework. The fourth cycle of the All India Tiger Estimation has been successfully completed and shows a rise in tiger estimates.

Monitoring tigers to keep a pulse on their numbers is a vital component of evaluating the efficacy of our tiger conservation efforts. I am happy to know that the National Tiger Conservation Authority with technical support of the Wildlife Institute of India has used best available science, which is grounded in fieldcraft to assess the status of our tigers, co-predators, prey and habitats. Being an apex species, safeguarding the tiger will also help India achieve water and climate security.

I compliment the entire team which has work tirelessly in the States and at the Centre to complete the world's largest estimation exercise.

Date: 11.07.2019

(Prakash Javadekar)

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1 INTRODUCTION

In the era of modern development, conserving the tiger is an onerous task. Ensuring the conservation of this top carnivore guarantees the well-being of our forested ecosystems, the biodiversity they represent as well as the water and climate security they provide. Monitoring the status of tigers, along with associated biodiversity of the encompassing ecosystem, is important to assess our success at meeting the commitment of conserving our natural heritage.

This is aptly reflected in the following verse from the Mahabharata:

निर्वनो वध्यते व्याघ्रो निर्व्याघ्रं छिद्यते वनम् ।
तस्माद्व्याघ्रो वनं रक्षेद्वनं व्याघ्रं च पालयेत् ।।

(Tigers cannot survive without forests and similarly forests perish without tigers. Tigers protect the forests that nurture them) (*The Mahabharata Udyoga Parva : 5.29.48*)

Role of tigers as a top predator is vital in regulating and perpetuating ecological processes. In India, tigers inhabit a wide variety of habitats ranging from the high mountains, mangrove swamps, tall grasslands, to dry and moist deciduous forests, as well as evergreen and shola forest systems. Tigers needs large undisturbed tracts of habitat with ample prey to maintain long-term viable populations; thus acting as an umbrella species for a majority of eco-regions in the Indian sub-continent.

In 2010, at the Tiger Summit of St. Petersburg, world leaders committed to doubling tiger numbers by 2022. The tiger population of India is the largest for any country, accounting for >80% of the Global population of 3,159 adult free-ranging tigers[1]. Therefore, the future of tigers as a species, as well as the success of the Global Tiger Recovery Plan at meeting its targets, depends on successful tiger recovery in India. Despite a human population of 1.35 billion and having the fastest growing economy, India has not compromised on its conservation ethos. The Project Tiger, that was initiated in 1973 with nine tiger reserves (~18,278 km^2) has now grown to cover 50 tiger reserves (~72,749 km^2) covering about 2.21% of India's geographical area. Under the ambit of the National Tiger Conservation Authority (NTCA), India has successfully implemented several novel conservation initiatives like voluntary incentivized village relocations, connecting tiger source populations through habitat corridors, amongst others, have borne fruit as evidenced by tiger recovery in the past 16 years.

The National Tiger Conservation Authority (NTCA) in collaboration with the State Forest Departments, Conservation NGO's and coordinated by the Wildlife Institute of India (WII), conducts a National assessment for the "Status of Tigers, Co-predators, Prey and their Habitat" every four years since 2006. The Tiger Task Force appointed by the Hon'ble Prime Minister of India in 2005 mandated a four yearly monitoring of tiger populations across India based on the methodology developed by the Wildlife Institute of India[2]. The first status assessment of 2006 was peer reviewed by International experts and the IUCN.

The information generated by the earlier three cycles of tiger status evaluation exercises [3, 4, 5] resulted in major changes in policy and management of tiger populations. The major outcomes were 1) Tiger Landscape Conservation Plans, 2) designation and creation of inviolate critical core and buffer areas of Tiger Reserves, 3) identification and declaration of new Tiger Reserves, 4) recognition of tiger landscapes and the identification of important habitat corridors, 5) integrating tiger conservation with developmental activities using reliable information in a Geographic Information System, and 6) planning reintroduction and supplementation strategies for tigers in the future so as to prioritize conservation investments and conserve unique gene pools.

India's national tiger assessment is the largest biodiversity survey being carried out anywhere in the world. The fourth cycle of the assessment was undertaken in 2018 and 2019 using the best available science, technology and analytical tools. In this cycle, recording of primary field data digitally through mobile phone application like M-STrIPES (Monitoring System for Tigers - Intensive Protection and Ecological Status), that uses GPS to geotag photo-evidences, and survey information made this exercise more accurate, with smaller margins of human error. Further, it involved the development of innovative technology like automated segregation of camera trap photographs to species using artificial intelligence and neural network models (software CaTRAT - Camera Trap data Repository and Analysis Tool). Program ExtractCompare[6] that fingerprints tigers from their stripe patterns was used to count the number of individual tigers (>1 year old). The unique feature of this cycle of assessment, in keeping up with "Digital India", is the development and use of innovative technological tools in collection and processing of data to reduce human errors.

2 METHODS

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

This method entails estimating spatial covariates of relative abundance of tigers, co-predators, and ungulates, human impact indices, and habitat characteristics across all potential tiger habitat in India, at a fine spatial resolution of a forest beat which is on average about 15 km^2 (Phase I and II). Subsequently an adequate area within each landscape was sampled using camera traps at a high spatial density of one double camera location in 2 km^2 (Phase III). The concept is similar to that of double sampling wherein indices or raw counts of abundance obtained from the entire sample space are calibrated against absolute density obtained from limited samples. The difference between double sampling and SECR approach is that double sampling uses ratio or regression to calibrate indices while tiger population estimation uses spatial information on capture-mark-recapture (that accounts for detection correction) in a joint likelihood with spatial covariates of tiger sign intensity, prey abundance, human disturbance and habitat characteristics. This approach estimates tigers directly within camera trapped areas and extrapolates it to areas with tigers but not camera trapped based on joint distribution of covariates.

Since tigers occur across varied habitats and a large geographical expanse of India, we divided tiger bearing habitats into five major landscapes

- **Shivalik-Gangetic plains**
- **Central India and Eastern Ghats**
- **Western Ghats**
- **North Eastern Hills and Brahmaputra Flood Plains**
- **Sundarbans**

Each landscape was analyzed separately since covariates were likely to differ in their relationship with tiger abundance between landscapes. In addition, landscapes formed logical and biological units wherein tiger populations can share common individuals, a common genepool and can potentially disperse between populations. However, tiger movement between landscapes were likely to be rare events in modern times.

381,400 km²

of forests surveyed for tiger signs and prey estimation

26,838

Camera trap locations in 141 sites

522,996 km

foot surveys

121,337 km²

Covered by Camera Traps

317,958

habitat plots sampled for vegetation and prey dung

34,858,623

*wildlife photographs of which **76,651** were of tigers and **51,777** were of leopards*

593,882

man-days effort

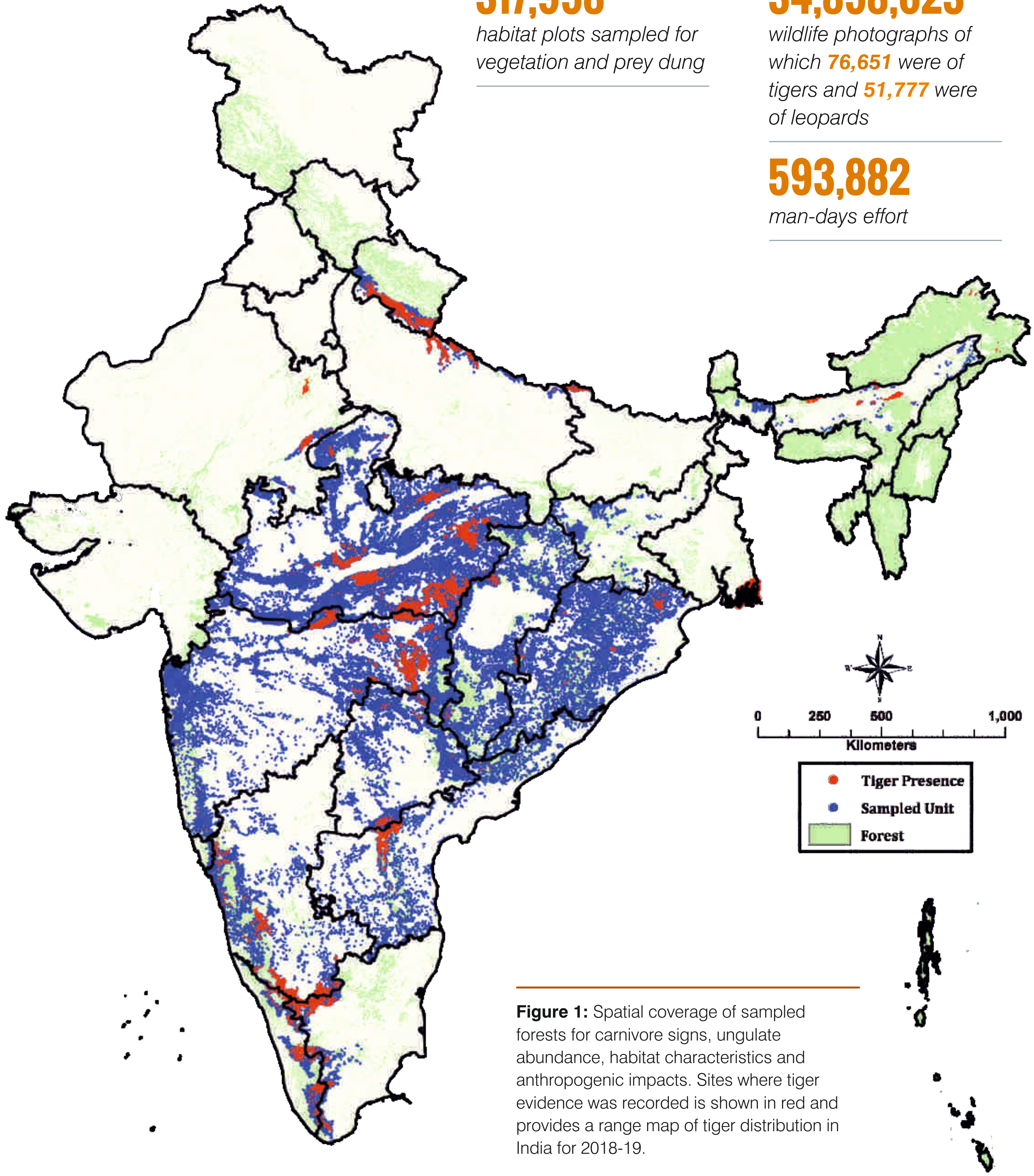


Figure 1: Spatial coverage of sampled forests for carnivore signs, ungulate abundance, habitat characteristics and anthropogenic impacts. Sites where tiger evidence was recorded is shown in red and provides a range map of tiger distribution in India for 2018-19.

Phase I

Frontline staff of State Forest Departments of 20 potential tiger bearing States were trained to collect the Phase I data (Fig. 1) in a digital format on the M-STrIPES mobile application. A field guide in nine regional languages was published[7] and provided to each beat guard.

Data collection on each of the following components was implemented in 2018:

a) Carnivore sign encounters (Form 1: multiple occupancy surveys in a beat)

b) Tiger prey abundance (Form 2: Distance sampling on line transect(s) in a beat)

c) Vegetation (Form 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 identified to species in multiple 40m^2 plots on transects)

For the Sundarbans, the above protocol was modified so as to allow sampling using a boat along river channels (khals). Phase I sampling on the above aspects took a maximum of 10 days for each forest beat with the effort of sampling by two persons.

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. 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 density of road network.

Phase III

Camera trap based Capture-Mark-Recapture: Camera trap surveys are a well-established methodology for abundance/density estimation of carnivores. Development of spatial capture-recapture methods have led to greater clarity in density estimation by integrating the spatial location information of animal photo-captures.

Camera traps were placed at 26,838 locations spread across 141 sites for mark recapture analysis (Fig. 2). Camera traps were systematically distributed within the sampling area by superimposing 2 km^2 grid and deploying at least one pair of cameras (Cuddeback, or Reconyx) within each grid. The cameras are placed in the best possible location to maximize photo-captures of tigers and leopards, identified through extensive search during sign surveys. Each grid was uniquely coded and was set within the 100 km^2 country wide grid that has been fixed since first cycle of National Tiger Status Estimation in 2006 so that subsequent inferences can be compared on the same spatial scale and extent. Sampling was carried out simultaneously in a minimum block of 200 km^2. If more number of camera traps were available to cover $>$ 200 km^2, then sampling was done in larger size blocks. Minimum camera trap location spacing was maintained at around 1 km. Cameras were usually operated between 25 to 35 days at each site, with an average effort of over 500 trap-nights per $\sim$100 km^2.

3 DATA ANALYSIS

Processing of Phase I data in M-STrIPES desktop software:

Phase I data was received from 491 Forest Divisions of India and these were processed using M-STrIPES desktop software. Data entry errors, if any, were communicated back to the respective forest divisions for rectification.

In case of carnivore sign survey data (Form 1), the desktop software was used to prepare input files for modelling occupancy of different species (single season single species format). In case of herbivore density (Form 2), in addition to the occupancy output, the M-STrIPES software outputs ready to use data for program DISTANCE. Similarly, the software also prepares the habitat assessment (Form 3) data on different plant species in a format used for analyzing community structure using abundance/rank ratio [e.g. TWINSPAN, Non-metric multidimensional scaling (NMDS)]. Results of these are not presented in this summary report and are currently under analysis at WII.

Processing of Phase III data:

An image processing software known as CaTRAT (Camera Trap Data Repository and Analysis Tool) was developed, and used for organizing and geo-tagging (tagging individual pictures with the location of the camera trap site) of photo-captures obtained from field. The geo-tagged images were further processed for segregation (Fig. 3). An artificial intelligence (AI) based image processing tool, to automatically segregate the camera trap images into species, was developed in collaboration with Indraprastha Institute of Information Technology, New Delhi. This data was further processed for individual identification of tigers and leopards.

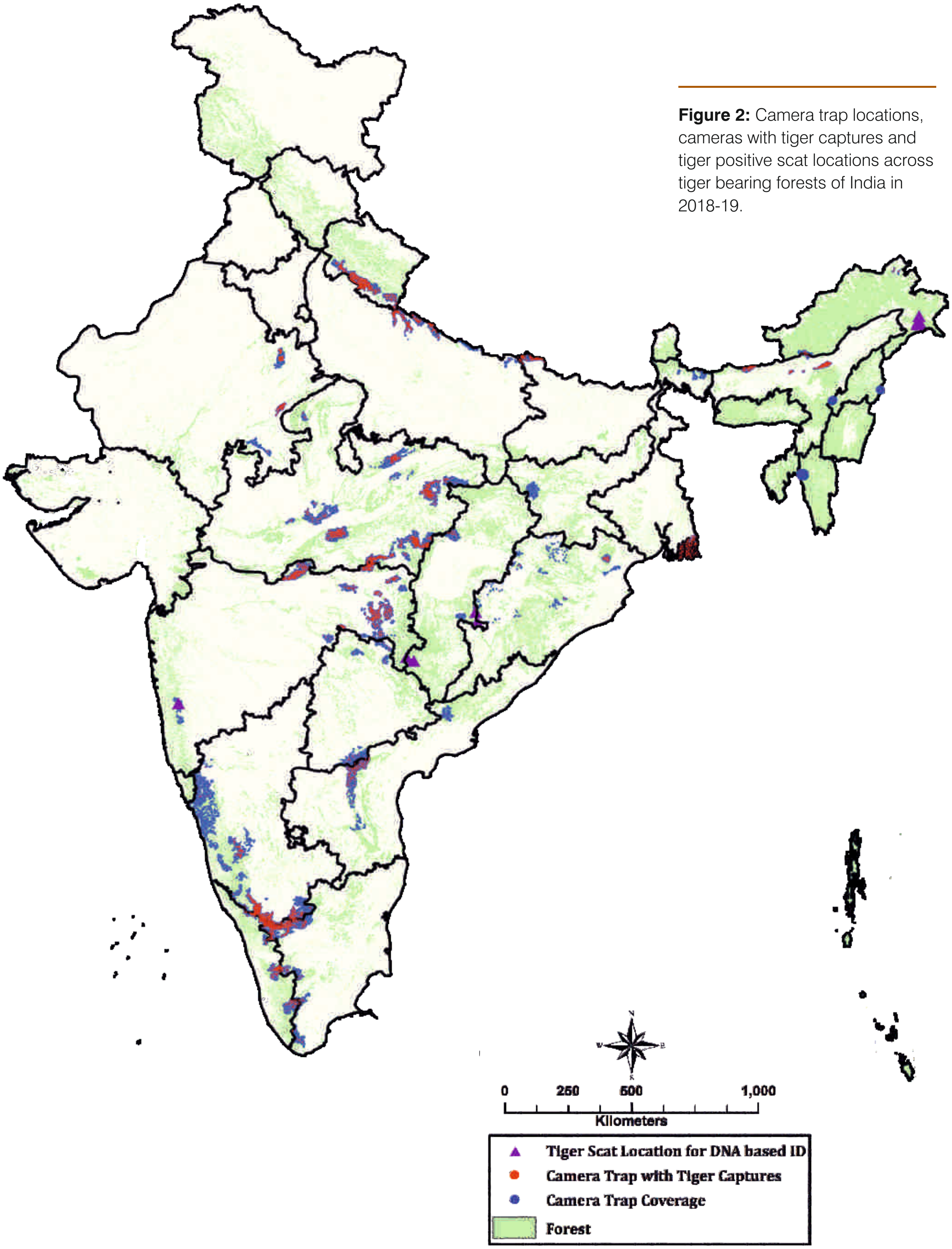
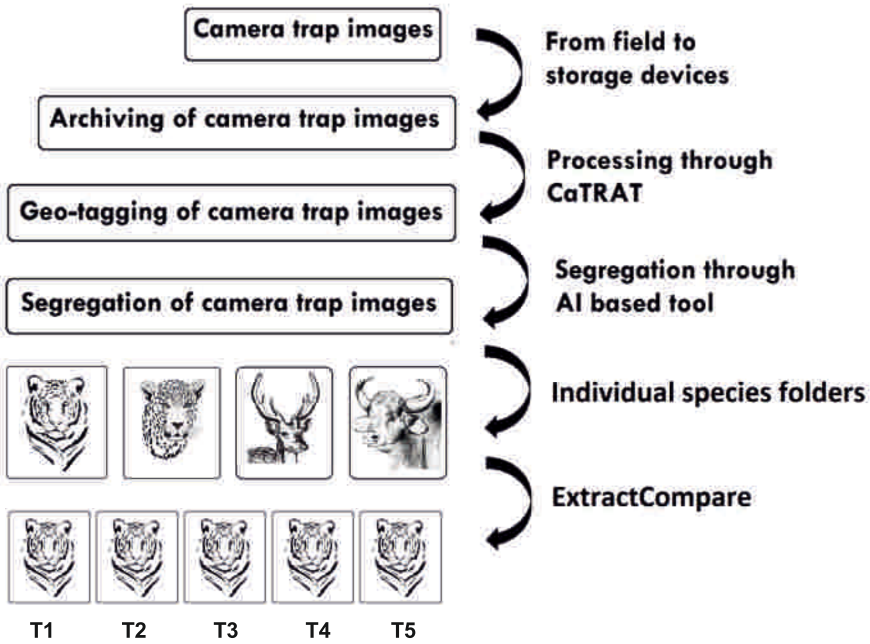


Figure 2: Camera trap locations, cameras with tiger captures and tiger positive scat locations across tiger bearing forests of India in 2018-19.

Individual identification of tigers and leopards

Individual identification is carried out using pattern recognition programs ExtractCompare[6] for tigers and HotSpotter[8] for leopards. 76,651 tiger photographs and 51,777 leopard photographs were obtained from camera traps. A three-dimensional surface model of a tiger is superimposed on a tiger photo to account for pitch and roll related to body posture before extracting the stripe pattern (Fig 4). Using an automated process, pattern recognition software searches through the database of images, to calculate similarity scores between digitized tiger coat patterns to recognize common and unique individuals. Tiger(s) photocaptured in each camera trap site were identified first using this method. Subsequently, tiger photographs of adjoining sites and within each landscape were compared using the National tiger database, so as to remove duplicate tigers, if any, and understand tiger dispersal events. Once individual tigers were identified, a matrix of spatial capture history for each tiger was developed for each site with camera trap IDs, their coordinates and, deployment and operation history of each camera.

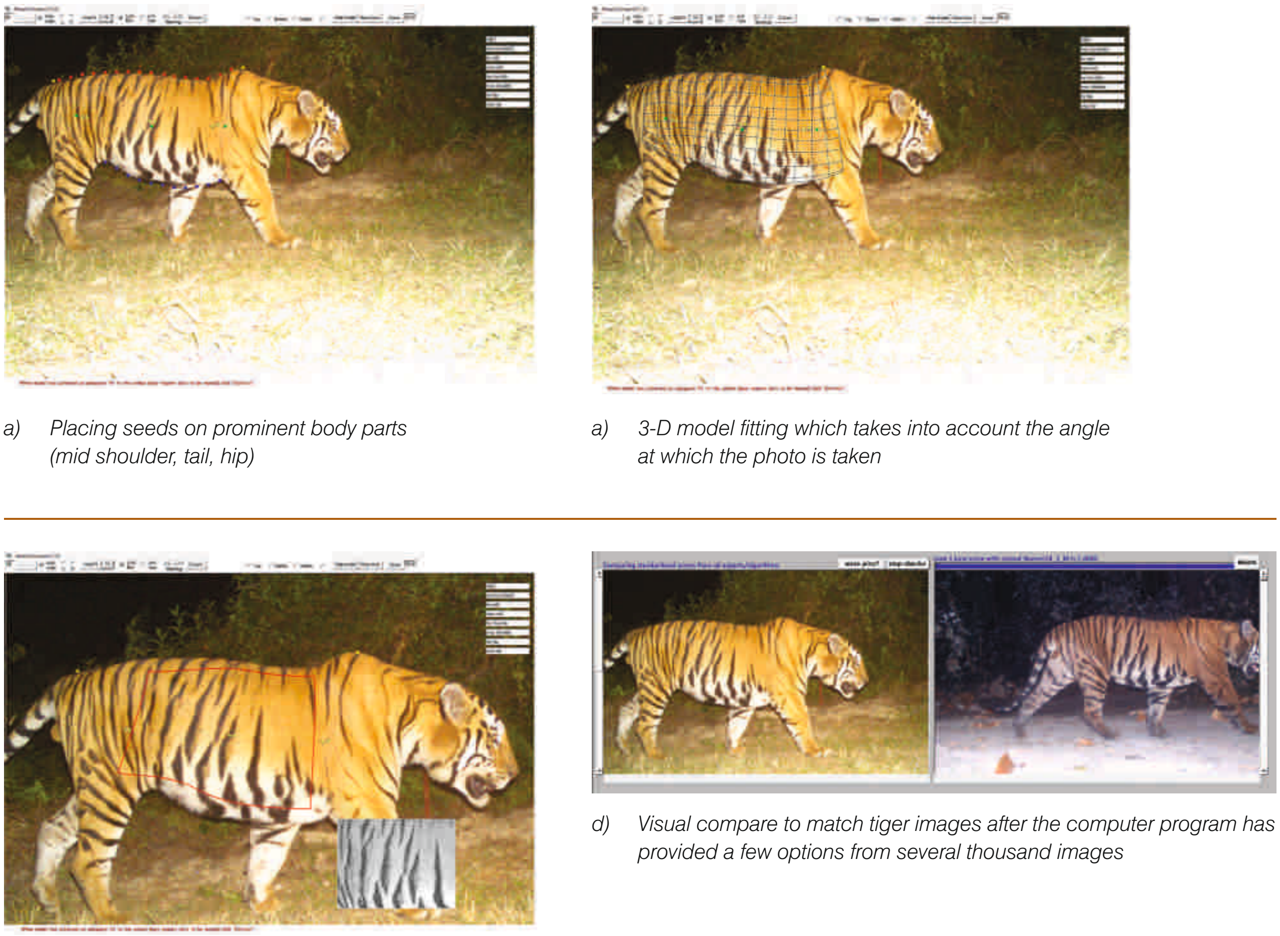
Figure 3: Workflow of species identification from camera trapped images using CATRAT software.



Abundance estimation through Spatially Explicit Capture Recapture (SECR)

We used likelihood based SECR[9,10] to estimate tiger and leopard abundance from camera trap data. The two basic detection parameters in SECR are detection probability (g_0) at the home range centre of the animal and a parameter for spatial movement (σ). We provided a habitat mask with a sufficiently realistic buffer around the camera trap array that excluded non-habitat. In our analysis, density was modelled as a function of covariates. Tiger sign encounter rate, prey encounter or dung densities and human footprint variables obtained from the ground surveys and remotely sensed data were used within SECR as covariates in a joint likelihood framework to model tiger density through package secr in program R. Covariate based abundance models were developed for each landscape to estimate tiger abundance within tiger and leopard occupied forests. Tiger population estimates from camera trapped areas were obtained from SECR, while in areas where tigers were detected but the area was not camera trapped; their numbers were estimated by predicting density surface using the best covariate model (selected based on AIC), for that landscape, in secr.

Figure 4: Process of individual identification of tigers using Extract Compare software.



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

a) *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*

Genetic sampling

At sites where it was not possible to undertake camera trapping due to very low tiger numbers or unfavorable law and order conditions, scat samples of carnivores were collected to estimate minimum number of tigers through genetic analysis. Genomic DNA was extracted from samples using the guanidinium thiocyanate method[11]. Following extraction, DNA samples were first screened for species identification using a tiger specific cytochrome-b marker[12]. Tiger positive samples were confirmed after samples were run along with a positive and negative control. A panel of 11 highly polymorphic microsatellites were used to identify individuals.

Maximum Entropy Models (MaxEnt)

In the north eastern states of Arunachal Pradesh, Mizoram and Nagaland, sampling could not be done with appropriate mark recapture method due to logistic constraints. In these states we used confirmed tiger presence locations from tiger scats (confirmed by DNA profile), and opportunistic camera trap photos to model suitable tiger habitat using program MaxEnt[13]. Minimal tiger density obtained from individually identified tigers within small intensively searched areas was used to provide a crude estimate of tiger numbers in these states.

Peer Participation

The NTCA invited international experts in carnivore ecology and shared with them the advancements done for the 2018-19 tiger status assessment. These experts were shown field data collection protocols and procedures, data generated through M-STrIPES from the field in GIS, camera trap photo repositories, and analytical procedures used. They visited field sites and interacted with Tiger Reserve managers to understand issues related to tiger status assessment, management, and conservation. Their perceptions are appended as Annexure 2 to this summary report.

4 RESULTS

The fourth cycle of National tiger status assessment of 2018-19 is the most accurate survey conducted. The survey covered 381,400 km^2 of forested habitats in 20 tiger occupied states of India. A foot survey of 522,996 km was done for carnivore signs and prey abundance estimation. In these forests, 317,958 habitat plots were sampled for vegetation, human impacts and prey dung. Camera traps were deployed at 26,838 locations. These cameras resulted in 34,858,623 photographs of wildlife of which 76,651 were of tigers and 51,777 were of leopards. The total area sampled by camera traps was 121,337 km^2. The total effort invested in the survey was 593,882 man-days. We believe that this is the world's largest effort invested in any wildlife survey till date, on all of the above criteria.

A total of 2,461 individual tigers (>1 year of age) were photo-captured. The overall tiger population in India was estimated at 2,967 (SE range 2,603 to 3,346) (Table 1, Fig. 7-11). Out of this, 83% were actually camera trapped individual tigers and 87% were accounted for by camera-trap based capture-mark-recapture and remaining 13% estimated through covariate based models (Fig. 5). Tigers were observed to be increasing at a rate of 6% per annum in India when consistently sampled areas were compared from 2006 to 2018 (Fig. 6). Tiger occupancy was found to be stable at 88,985 km^2 the country scale since 2014 (88,558 km^2). Though there were losses and gains at individual landscapes and state scales. The occupancy reported in this report is based on latest forest cover by Forest Survey of India (2017) and therefore cannot be compared with earlier occupied areas which were computed from earlier forest cover data. To make the comparison on the same scale we have recomputed tiger occupied forests for the 2014 cycle on the forest cover of 2017 (Table 2). Reduction in occupied areas was due to a) not finding evidence of tiger presence in sampled forests (20% actual loss), and b) not sampling forests that had tiger presence in 2014 (8 %). New areas that were colonized by tigers in 2018 constituted 25,709 (28%) km^2. This analysis suggests that loss and gain of tiger occupancy was mostly from habitat pockets that support low density populations. Such habitats with low density tigers, though contributing minimally to overall tiger numbers, are crucial links for gene flow and maintaining connectivity between source populations. The loss and gain of tiger occupancy in these marginal areas is a dynamic process and depends on several factors like proximity of a tiger source population, anthropogenic pressures operating in the landscape, associated change in habitat conditions and protection regime. Tiger occupancy has increased in the state of Madhya Pradesh, and Andhra Pradesh. Loss in North East is due to poor sampling. Madhya Pradesh has also registered a substantial increase in their tiger population and along with Karnataka ranks highest in tiger numbers. The poor and continuing decline in tiger status in the states of Chhattisgarh and Odisha is a matter of concern.

2,967	2,461	2,591
Total tiger population estimated: (2,603 - 3,346)	*Total number of individual tigers camera trapped*	*Tiger population estimated through Capture-mark-recapture*

Table 1: Estimated tiger numbers (>1 year of age) in 2018 for landscapes and States compared with estimates for 2006, 2010 and 2014. Numbers in parenthesis are standard error limits.

State	Tiger Population			
	2006	2010	2014	2018
Shivalik Hills and Gangetic Plains Landscape				
Bihar	10 (7-13)	8	28(25-31)	31 (26 - 37)
Uttarakhand	178 (161-195)	227 (199-256)	340 (299-381)	442 (393 - 491)
Uttar Pradesh	109 (91-127)	118 (113-124)	117 (103-131)	173 (148 - 198)
Shivalik-Gangetic	**297 (259-335)**	**353(320-388)**	**485 (427-543}**	**646 (567 - 726)**
Central Indian Landscape and Eastern Ghats				
Andhra Pradesh	95 (84-107)	72 (65-79)	68 (58-78)	48 (40 - 56)#
Telangana	-	-	-	26 (23 - 30)#
Chhattisgarh	26 (23-28}	26 (24-27)	46 (39-53}*	19 (18 - 21)
Jharkhand		10 (6-14)	3*	5
Madhya Pradesh	300 (236-364)	257 {213-301)	308 (264-352)*	526 (441 - 621)
Maharashtra	103 (76-131)	168 (155-183)	190 (163-217)*	312 (270 - 354)
Odisha	45 (37-53)	32 (20-44)	28 (24-32)*	28 (26 - 30)
Rajasthan	32 (30-35)	36 (35-37)	45 (39-51)	69 (62 - 76)
Central India & Eastern Ghats	**601 (486-718)**	**601 (518-685)**	**688 (596-780)**	**1,033 (885- 1,193)**
Western Ghats Landscape				
Goa	-	-	5*	3
Karnataka	290 (241-339)	300 (280-320)	406 (360-452)	524 (475 - 573)
Kerala	46 (39-53)	71 (67-75)	136 (119-150)	190 (166 - 215)
Tamil Nadu	76 (56-95)	163 053-173)	229 (201-253)	264 (227 - 302)
Western Ghats	**402 (336-487)**	**534 (500-568)**	**776 (685-861)**	**981 (871 - 1,093)**
North East Hills and Brahmaputra Plains Landscape				
Arunachal Pradesh	14 (12-18)		28*	29*
Assam	70 (60-80)	143 (113-173)	167 (150-184)	190 (165 - 215)
Mizoram	6 (4-8)	5	3*	0
Nagaland	-	-	-	0
Northern West Bengal	10 (8-12)	-	3*	0
North East Hills, and Brahmaputra	**100 (84-118)**	**148 (118-178)**	**201 (174-212)**	**219 (194 - 244)**
Sundarbans		70 (62-96)	76 (62-96)	88 (86-90)
TOTAL	**1,411 (1,165-1,657)**	**1,706 (1,507-1,896)**	**2,226 (1,945-2,491)**	**2,967 (2,603 - 3,346)**

**: Estimated through Scat DNA*

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

Tigers were not recorded in Buxa, Dampa and Palamau tiger reserves. Reserves had poor tiger status in earlier assessments as well.

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

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

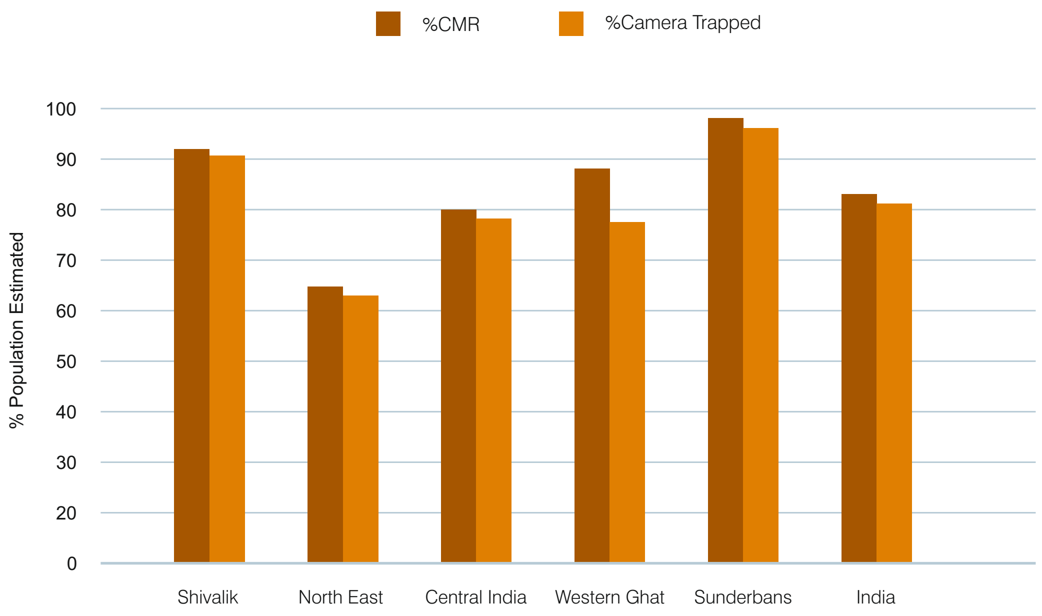
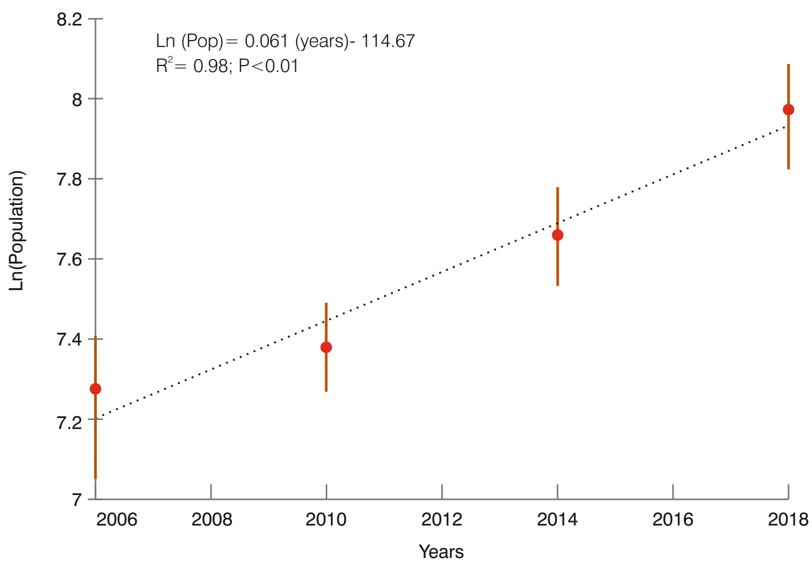


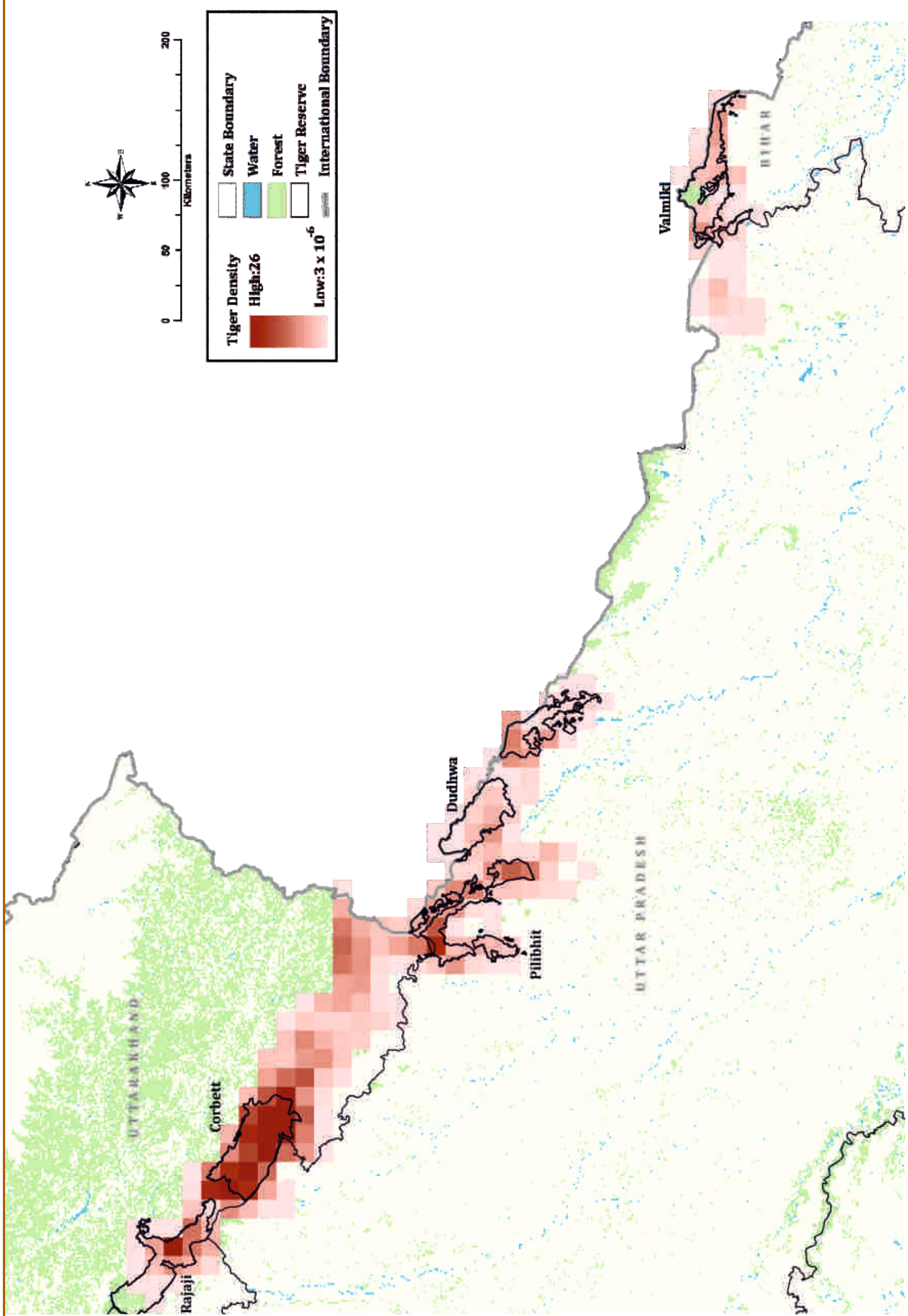
Figure 5: Proportion of the total tiger population camera trapped and estimated by capture-mark-recapture (CMR).

Figure 6: Growth rate of tigers in India estimated by regressing natural log transformed population against years. The slope of the regression gives the instantaneous growth rate (r=0.06). Growth rate was computed only from areas that were sampled consistently from 2006 to 2018.



Shivalik Hills and Gangetic Plains Landscape

Figure 7: Tiger density map obtained by joint likelihood covariate model in spatially explicit capture-recapture (SECR) for the Shivalik Hills and Gangetic Plains Landscape



Central India and Eastern Ghats Landscape

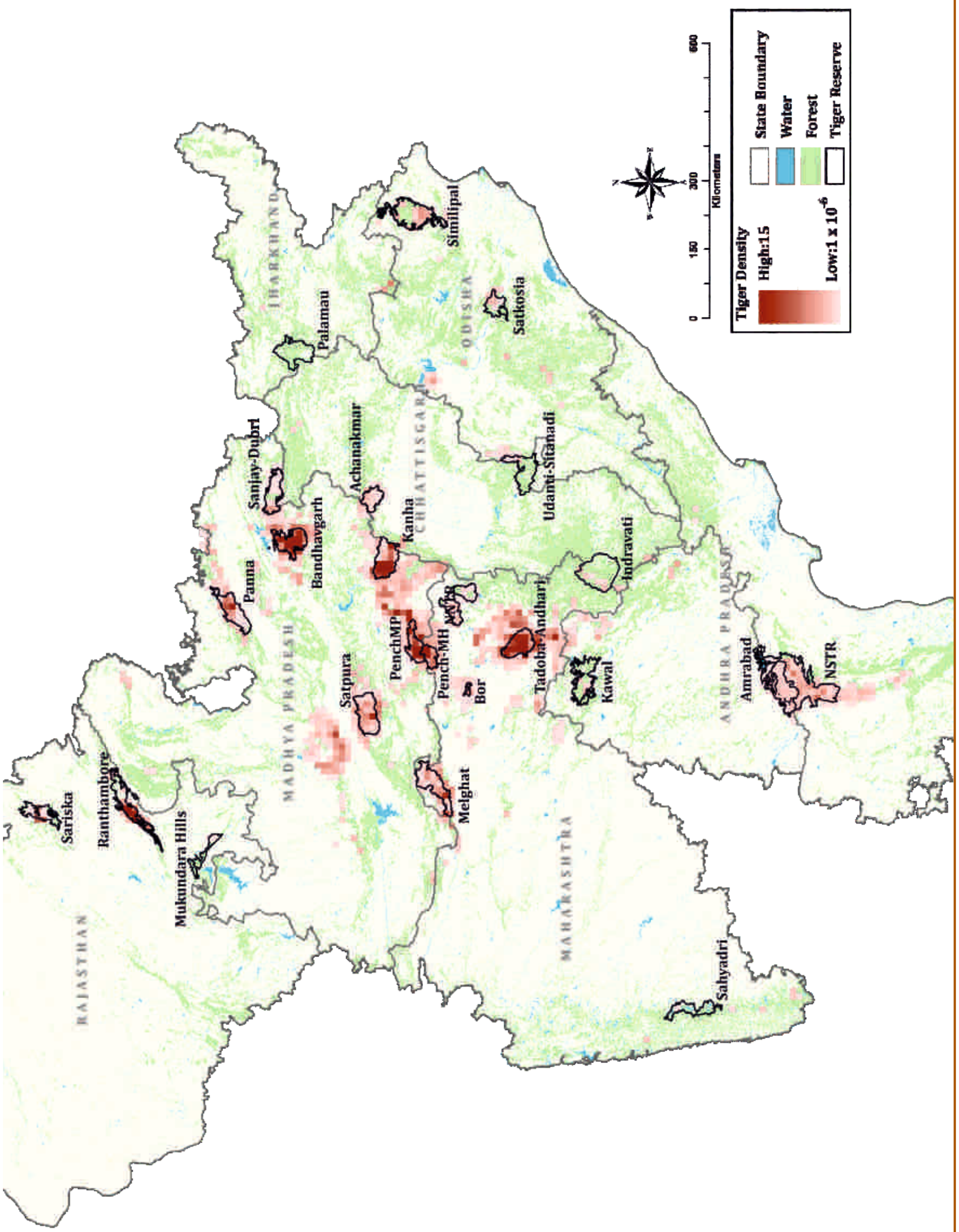
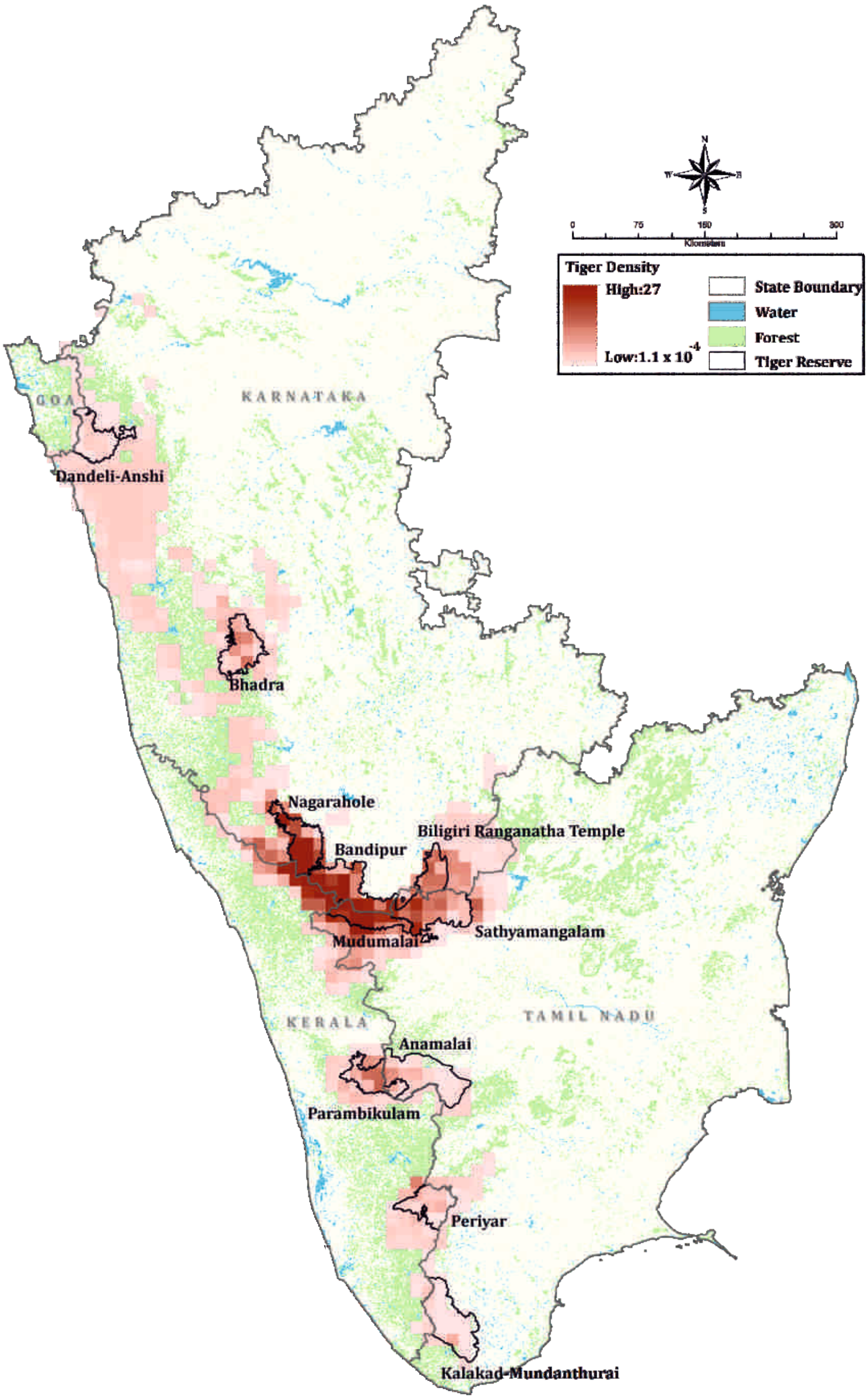


Figure 8: Tiger density map obtained by joint likelihood covariate model in spatially explicit capture-recapture (SECR) for the Central India and Eastern Ghats Landscape

Western Ghats Landscape

Figure 9: Tiger density map obtained by joint likelihood covariate model in spatially explicit capture-recapture (SECR) for the Western Ghats Landscape



North Eastern Hills and Brahmaputra Flood Plains Landscape

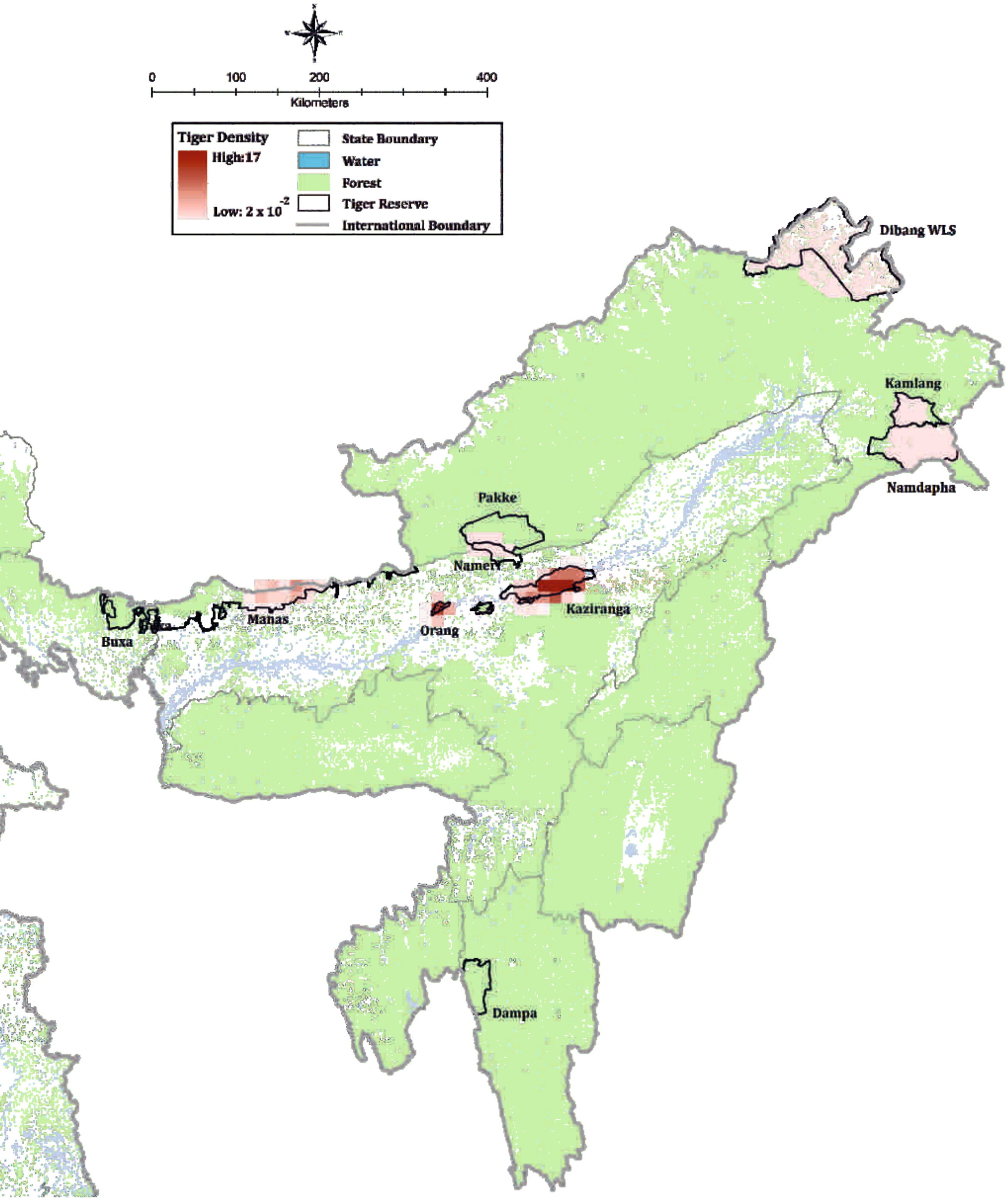
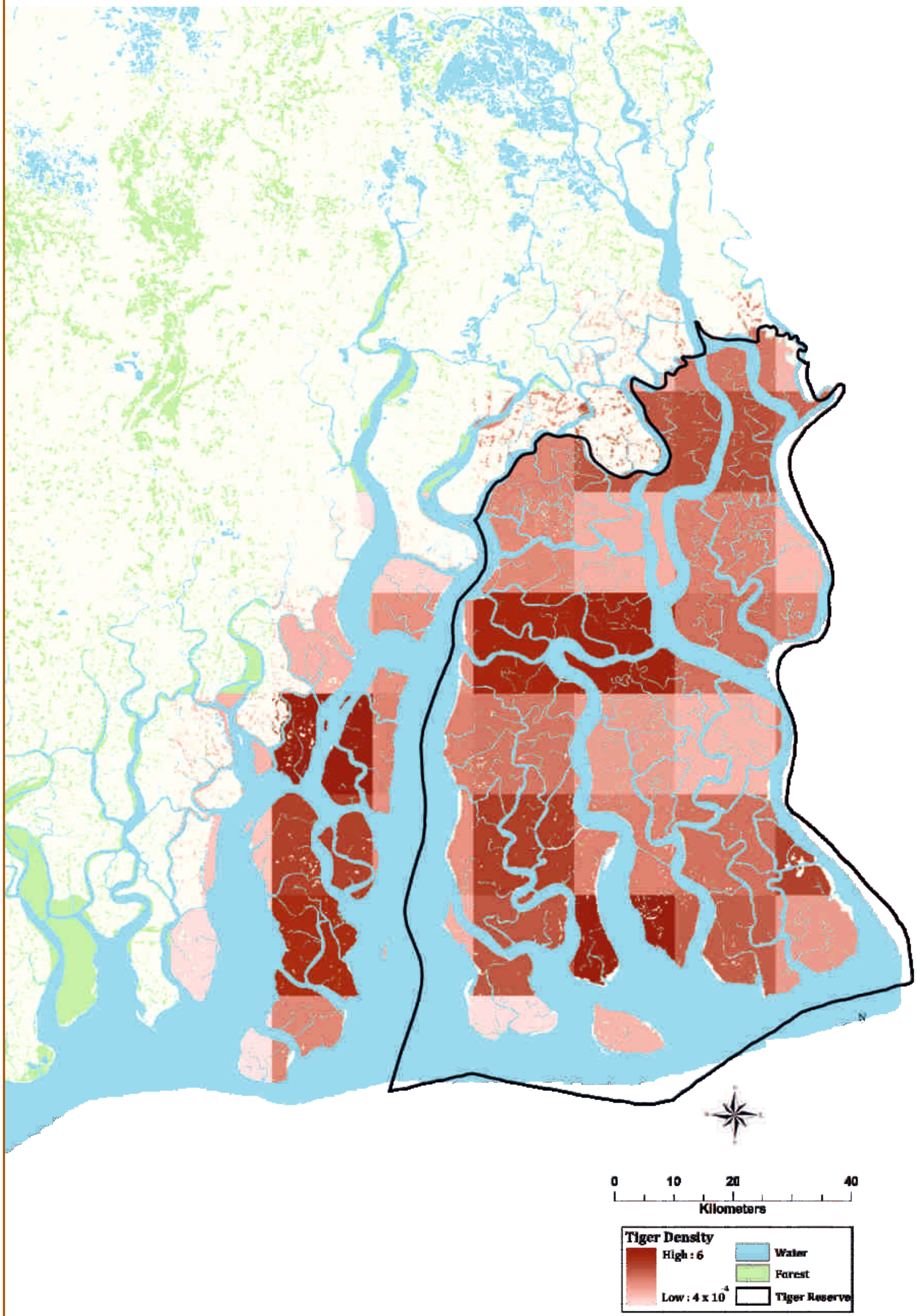


Figure 10: Tiger density map obtained by spatially explicit capture-recapture (SECR) and Maximum Entropy model for the North Eastern Hills and Brahmaputra Flood Plains Landscape

Sundarban Landscape

Figure 11: Spatially explicit capture-mark-recapture tiger density map for the Sundarban Landscape



CONSERVATION IMPLICATIONS

5

In this assessment cycle, a large area was camera trapped (121,337 km^2), where 83% of the tigers were photo-captured hence the major contribution to population estimate (87%) was obtained directly from capture-mark-recapture, and only a small part of the estimate was derived from the SECR covariate-based model. The covariate model has been calibrated from areas having no tigers, to tiger densities exceeding 0.15 tigers km^{-2}, thus covering the full range of tiger densities.

Tiger population in India continues to increase, this rise is observed in areas with substantial and good management inputs, complementing India's conservation efforts. The populations of conservation priority based on genetic distinctiveness, diversity and vulnerability were identified as those of North East Hills, Southern Western Ghats, and tigers of Odisha and Valmiki[14]. Of these, Southern Western Ghats and Valmiki populations have shown improvement, while those of North East Hills and Odisha remain critically vulnerable and need immediate conservation attention. The tiger reserves of Nameri and Pakke have registered declines, while tigers have not been recorded in Buxa, Palamau, and Dampa in this assessment. The poor tiger status in Indravati was related to law and order situation in these areas. In areas where tigers have not been recorded or the population has declined, restoration needs to proceed by improving protection, augmentation of prey, and reintroduction of tigers from appropriate source. For reintroduction of tigers into Palamau, prey augmentation needs to be coupled with restoration of law and order. For tiger reintroduction or supplementation in Palamau and Similipal, tigers need to be sourced from the closest source in the same genetic cluster[14]. Buxa and Dampa can be repopulated through reintroductions from Kaziranga, after prey restoration in Buxa and strengthening protection in Dampa which has a good prey base.

Maintaining the source values of tiger reserve populations through good management, protection and making the core areas inviolate through incentivized voluntary relocation of human habitation has been the most important reason for continued improvement in the status of tigers in India. Ensuring the functionality of habitat corridor connectivity between source populations in India as well as with Nepal, Bhutan, Bangladesh and Myanmar tiger populations is essential for the long-term viability of tiger populations within India and the region. These habitat corridors are often threatened by development of linear infrastructure. Careful spatial planning to avoid traversing critical habitats and their linkages, along with appropriate mitigation through wildlife passage ways will ensure that tigers and biodiversity conservation is not compromised by modern development.

Sustained conservation efforts through continued "political will" have resulted in an increase in tiger numbers. While there is sufficient habitat to accommodate increasing tigers in India, much of this habitat needs conservation investment so as to recover prey populations. Tiger habitat outside Protected Areas are vital for linking source populations but are extensively used by communities; a conservation model that promotes tiger permeability of such habitats while simultaneously securing the livelihoods of local communities is the answer. Managing conflict promptly and providing economic incentives from tigers will foster coexistence in these multiple use forests and ensure the long-term future of tigers in India. India has once again lived up to its' expectations and contributed significantly to the common goal of the Global Tiger Recovery targets.

APPENDIX

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2 APPENDIX

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Deriving a population estimate for any rare and elusive species is a challenging task, but to do so for dozens of tiger populations across the entire sub-continent of India is immense. The numbers alone are phenomenal – 44,000 field staff, 600,000 person-days, 523,000 km of walked transects, 318,000 habitat surveys, 26,800 camera trap locations across an area of 381,000 km^2 yielding 35 million photographs of India's wildlife including 76,523 photos of tigers. Yet these efforts would be redundant without using robust methods to analyse them. There has been criticism historically about the methods used in previous tiger censuses, however I believe this is the most robust estimate of tigers possible with detectability and observer error clearly accounted for as well as possible, and I can think of no improvements based on the logistical constraints of our current technological and analytic capabilities. Hence, I am confident that the latest estimate of tigers across India is valid and robust, and represents a clear and impressive increase in population size since the previous estimate.

India in general, and the project team in particular, should be lauded for their efforts and investment in determining and securing the status of such a globally important and iconic species. This project warrants expansion and should be implemented on a suite of iconic species around the world. I wholeheartedly commend you for your wonderful efforts.

Yours sincerely

Matt

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During a recent visit to India between June 25th and July 4th, 2019, I was able to take part in discussions and meetings at the Wildlife Institute of India (WII), the National Tiger Conservation Authority (NTCA), and Pench and Kanha National Parks. I was given the opportunity to witness the processes involved in India's effort to assess its tiger populations, which complimented an earlier visit in 2006. I took part in a number of in-depth discussions with a range of people from senior officials to forest beat guards. I commend WII and the Government of India for conducting the all-India tiger surveys. These represent a programme which is unprecedented in scale, rigour and intensity. As far as I am aware, this is the largest centrally coordinated survey of its kind in the world and represents an immense achievement providing invaluable information on the status of not only tigers, but a wide range of coexisting mammals in tiger habitats. The methodology used balances the need to vary survey effort from core tiger habitat to wider marginal areas. This programme combines, GIS analyses and the latest spatially-explicit methodologies in cameratrapping along with wider-scale but lower intensity secondary sign surveys outside of tiger core areas making such a large-scale survey achievable. There have also been impressive improvements since the original survey in 2006 due, in part, to general technological advances (e.g. camera-traps, mobile phones and GPS etc.), but also due to the efforts of WII and partners to develop software tools to automate the data recording and processing, including the use of M-STrIPES (phone app for all types of in field data entry) and data analysis (Extract Compare (tiger ID) and CATRAT (species ID)). These advances are critical to the process as they increase the speed and accuracy of data processing. The current report is immense in scale and intensity covering over 380,000 km^2 and actually recording ~80% of the total tiger population directly in the photo record of ~ 75,000 tiger photos. I don't doubt that this represents an extremely robust and reliable estimate of the tiger population across the survey area. Tigers are a vital part of India's national heritage and recent reported increases are welcome news! It is essential therefore that tiger core areas and key habitat corridors continue to be maintained and protected against threats of development. In addition, it is important that working conditions of forest guards and other staff, which represent the front-line of India's tiger protection strategy, are reviewed to maintain motivation and effectiveness and to insure the future protection of tigers in the wild.

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During my June 25th – July 4th visit to India, the Wildlife Institute of India provided an in depth and comprehensive showcase of the methods and process to determine 'Status of Tigers, Co-predators, & Prey in India 2019.' India's effort to estimate its tiger population is unprecedented globally and commendable in scale and scientific sophistication. The methods and process to determine the status of tigers in India in 2018 is scientifically defensible; surveys are aligned with advancements in animal abundance methods and use defensible statistical tools available within the constraints of national-scale assessment and resources. Inclusion of both indices and camera-trap approaches makes pragmatic sense and such joint analyses strengthens the overall assessment. Those responsible for leading tiger estimation in India wholly embrace that the scientific process of peer review and publication in high-quality journals should guide the choice of appropriate methods for monitoring tigers and their prey. Sensitivity analyses would add to the robustness of the process and help address warranted and unwarranted critiques, thereby building confidence in the assessment. The voluntary village relocation program is a major step towards providing tigers needed space, but care should be taken to ensure that villages are truly returned to wildlife habitat and not used for administrative expansion. Investment in the well-being and working conditions of forest guards is an investment in the front line of tiger conservation in India. To the extent that impacts to tiger corridors are minimized the healthy future of tigers is maximized.

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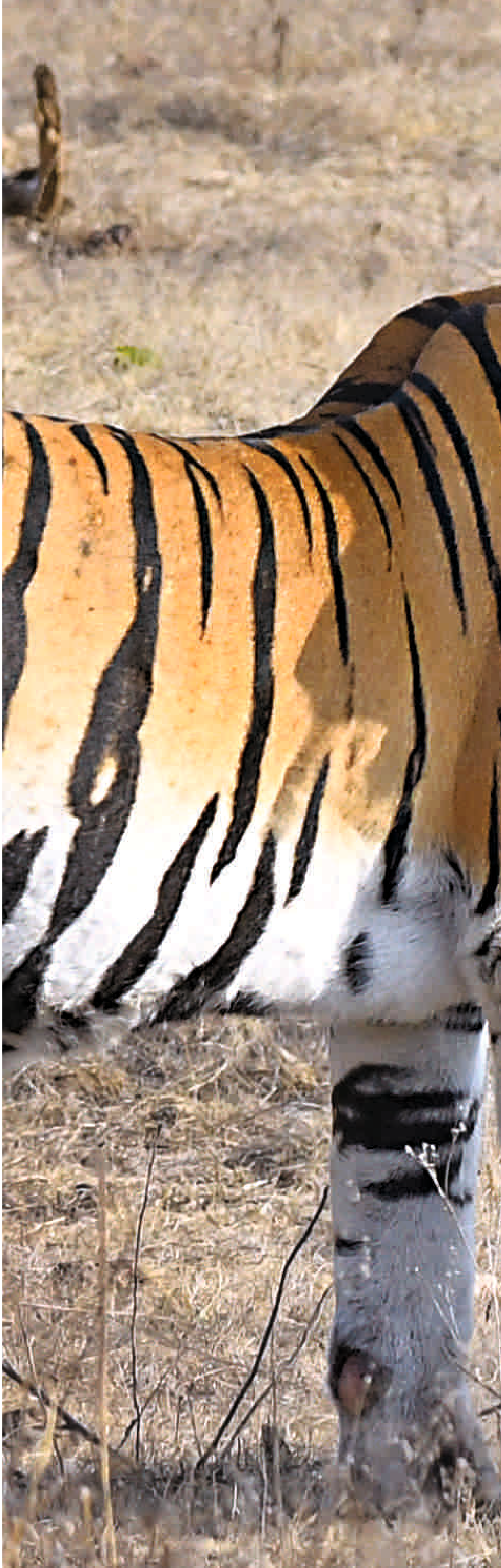

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