



SUMMARY REPORT

STATUS OF TIGERS IN INDIA-2018

Citation: Jhala, Y. V. Qureshi, Q. & Nayak, A. K. (eds). 2019. Status of tigers, co-predators and prey in India 2018. Summary Report. National Tiger Conservation Authority, Government of India, New Delhi & Wildlife Institute of India, Dehradun. TR No./2019/05.

Cover Photo: Sanjay Shukla

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
आषाढ 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



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.

(Prakash Javadekar)

Date: 11.07.2019

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 निर्वाघ्रं छिद्यते वनम् ।
तस्माद्याघ्रो 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 need 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 tigers¹. 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 km²) has now grown to cover 50 tiger reserves (~72,749 km²) 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 India². 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 ExtractCompare⁶ 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.

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 km² (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 km² (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



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 gene pool and can potentially disperse between populations. However, tiger movement between landscapes were likely to be rare events in modern times.

3,81,400 km²

of forests surveyed for tiger signs and prey estimation

522,996 km

foot surveys

26,838

Camera trap locations in 141 sites

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

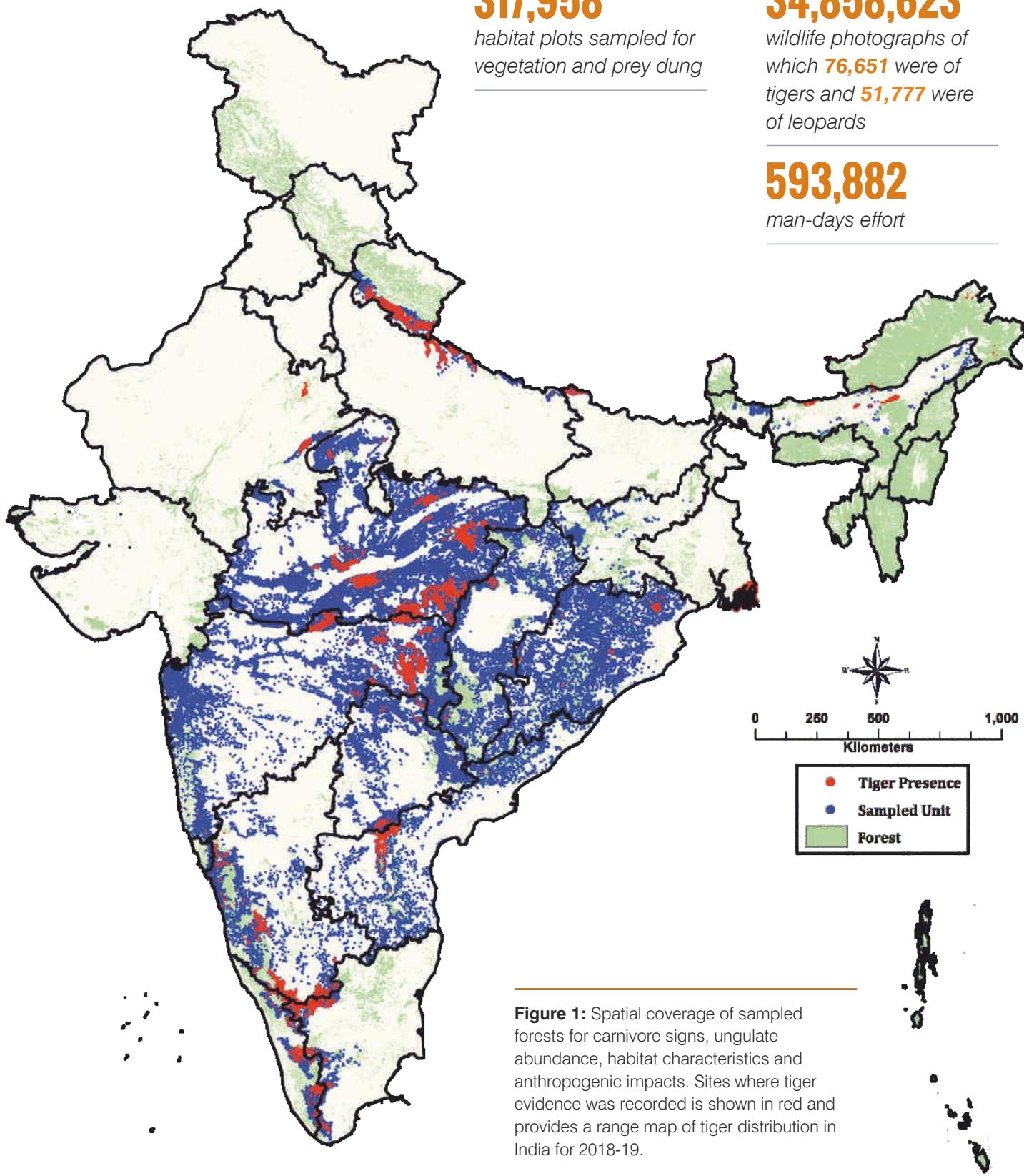


Figure 1: Spatial coverage of sampled forests for carnivore signs, ungulate abundance, habitat characteristics and anthropogenic impacts. Sites where tiger evidence was recorded is shown in red and provides a range map of tiger distribution in India for 2018-19.



Phase I

Frontline staff of State Forest Departments of 21 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 published⁷ 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 40m² 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 26,880 locations spread across 141 sites for mark recapture analysis (Fig. 2). Camera traps were systematically distributed within the sampling area by superimposing 2 km² 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 km² 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 km². If more number of camera traps were available to cover > 200 km², 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 ~100 km².

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

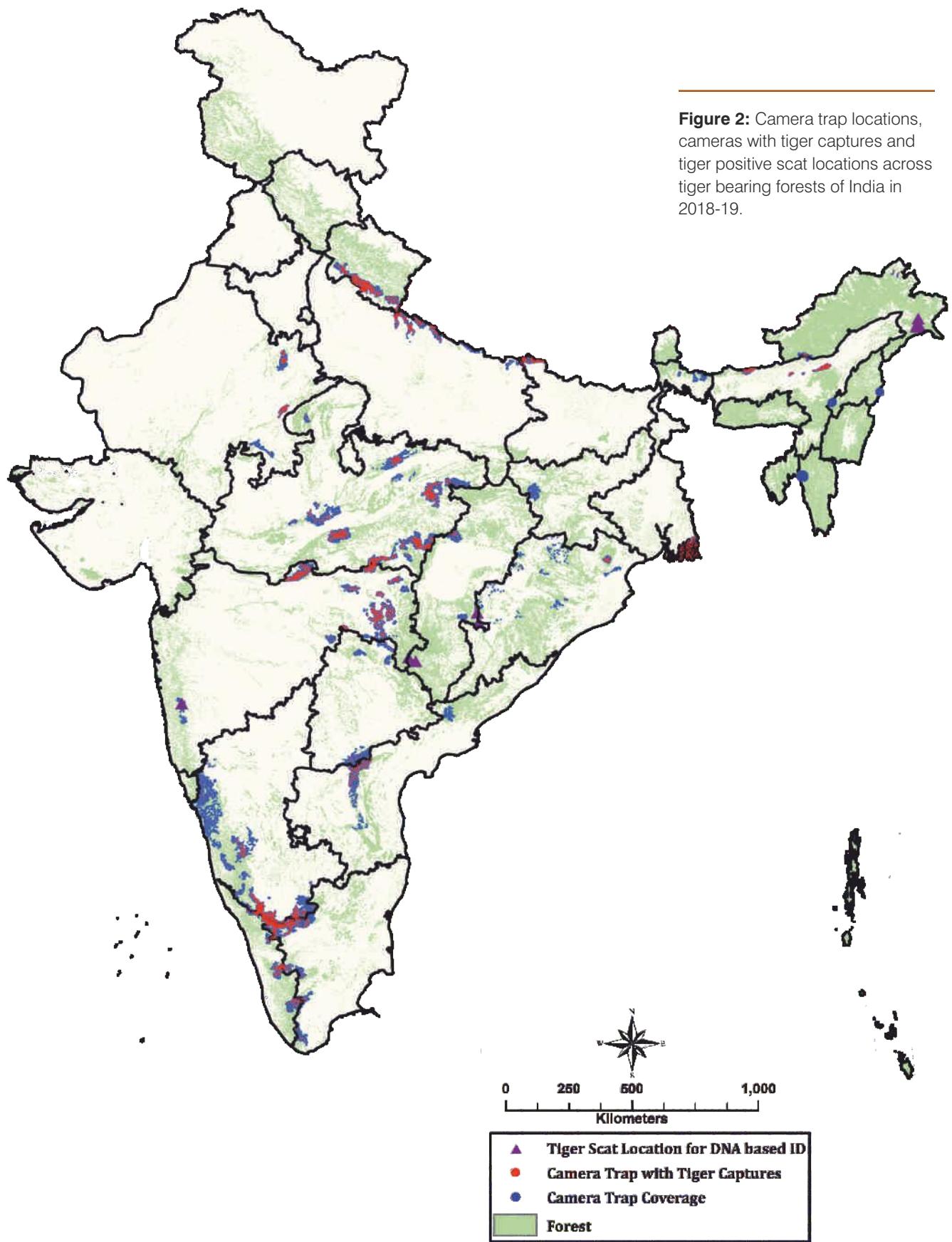
Phase I data was received from 491 Forest Divisions of India and these were processed using M-STRIPES desktop software. Data entry errors, if any, were communicated back to the respective forest divisions for rectification.

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.

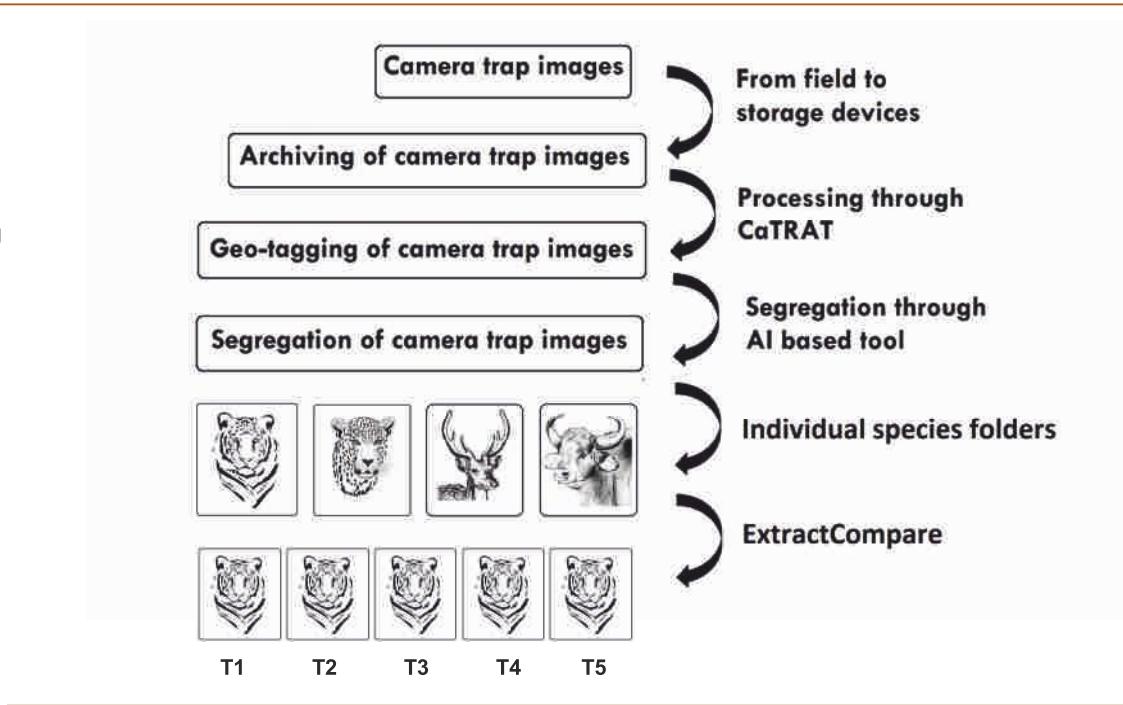




Individual identification of tigers and leopards

Individual identification is carried out using pattern recognition programs ExtractCompare⁶ for tigers and HotSpotter⁸ for leopards. 76,523 tiger photographs and 51,337 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_i) 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 method¹¹. Following extraction, DNA samples were first screened for species identification using a tiger specific cytochrome-b marker¹². 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 MaxEnt¹³. 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.

The fourth cycle of National tiger status assessment of 2018-19 is the most accurate survey conducted. The survey covered 381,400 km² 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 km². 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 km² the country scale since 2014 (88,558 km²). 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%) km². 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

Total tiger population estimated: (2,603 - 3,346)

2,461

Total number of individual tigers camera trapped

2,591

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	10 (8-12)	-	3*	0
West Bengal				
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 (km²) 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

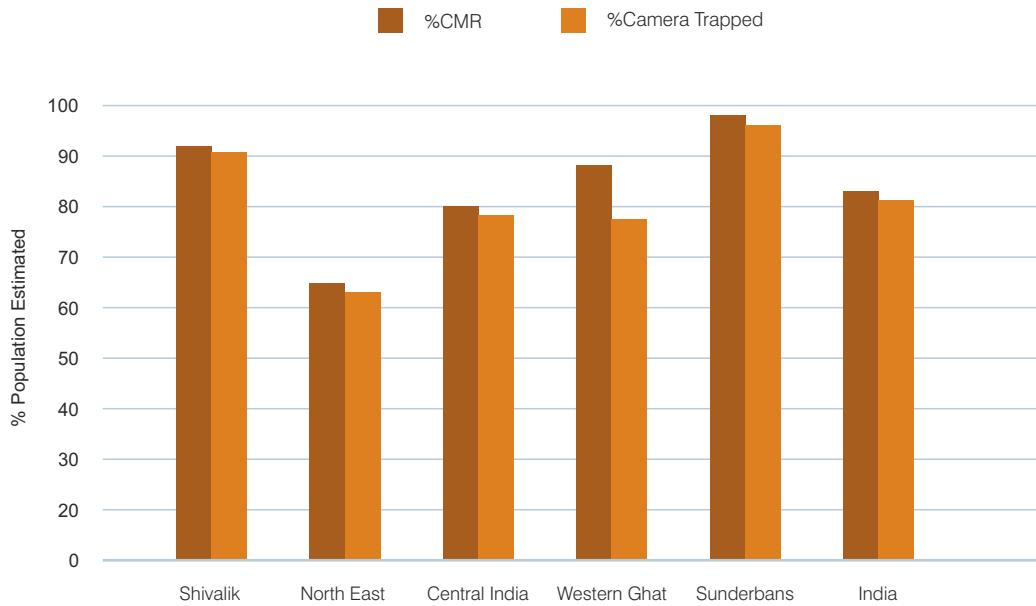
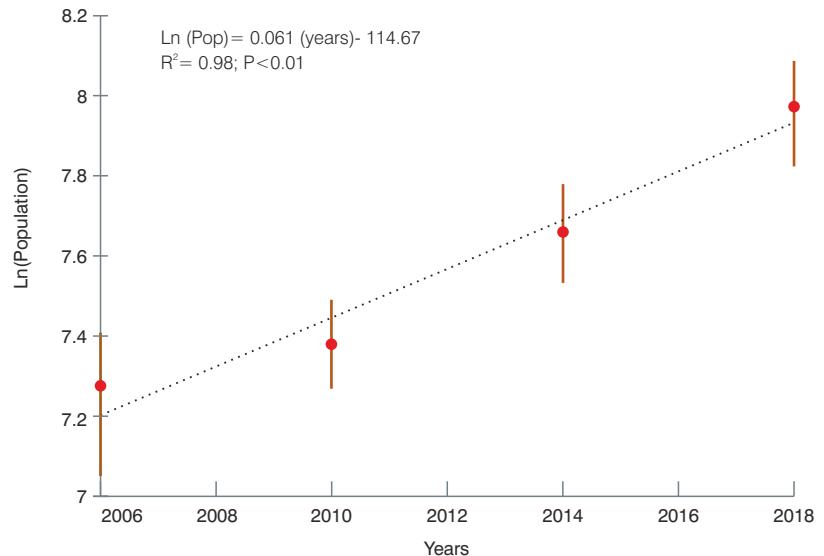


Figure 5:
Proportion of the total tiger population camera trapped and estimated by capture-mark-recapture (CMR).

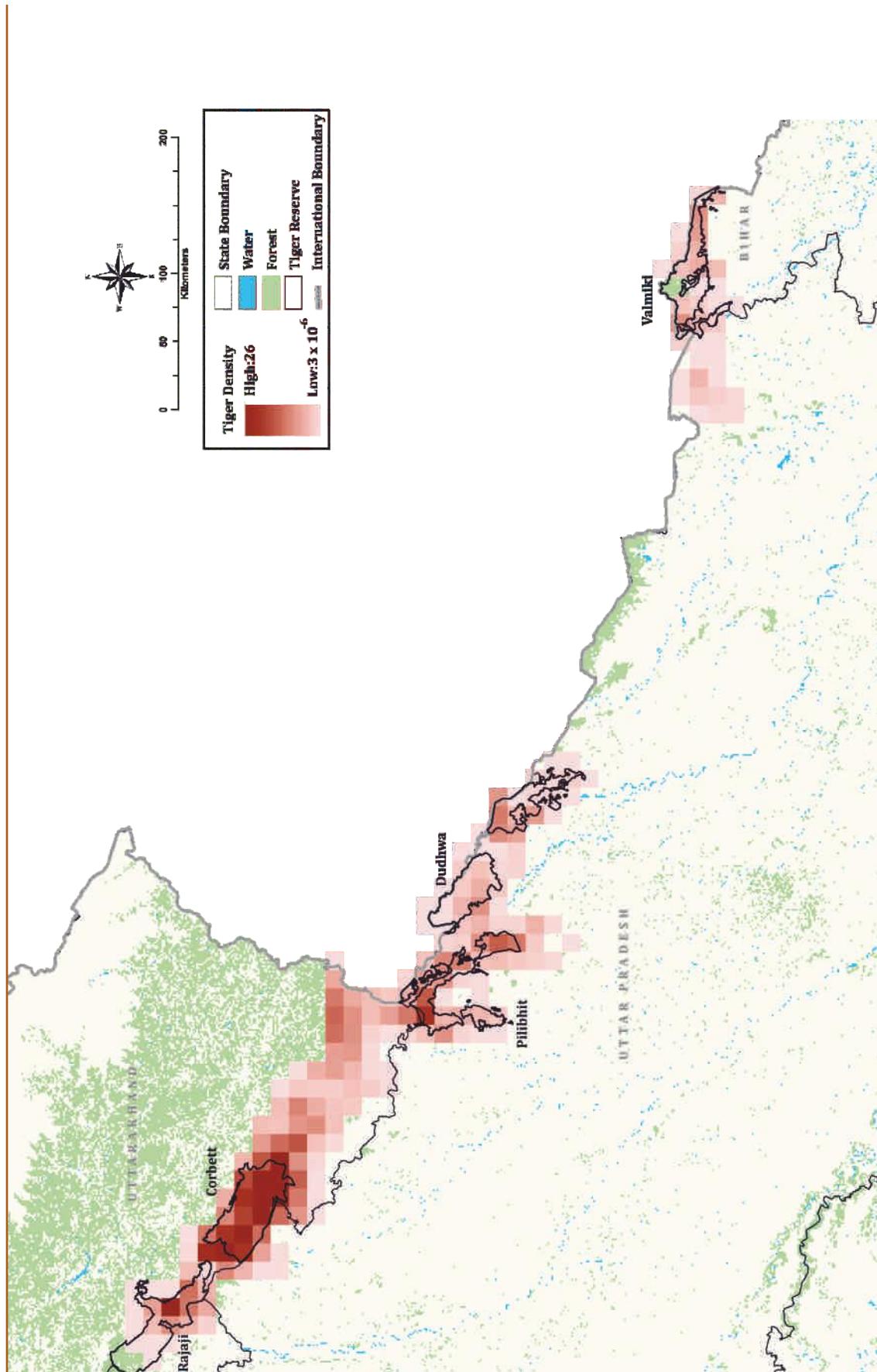
Figure 6: Growth rate of tigers in India estimated by regressing natural log transformed population against years. The slope of the regression gives the instantaneous growth rate ($r=0.06$). Growth rate was computed only from areas that were sampled consistently from 2006 to 2018.





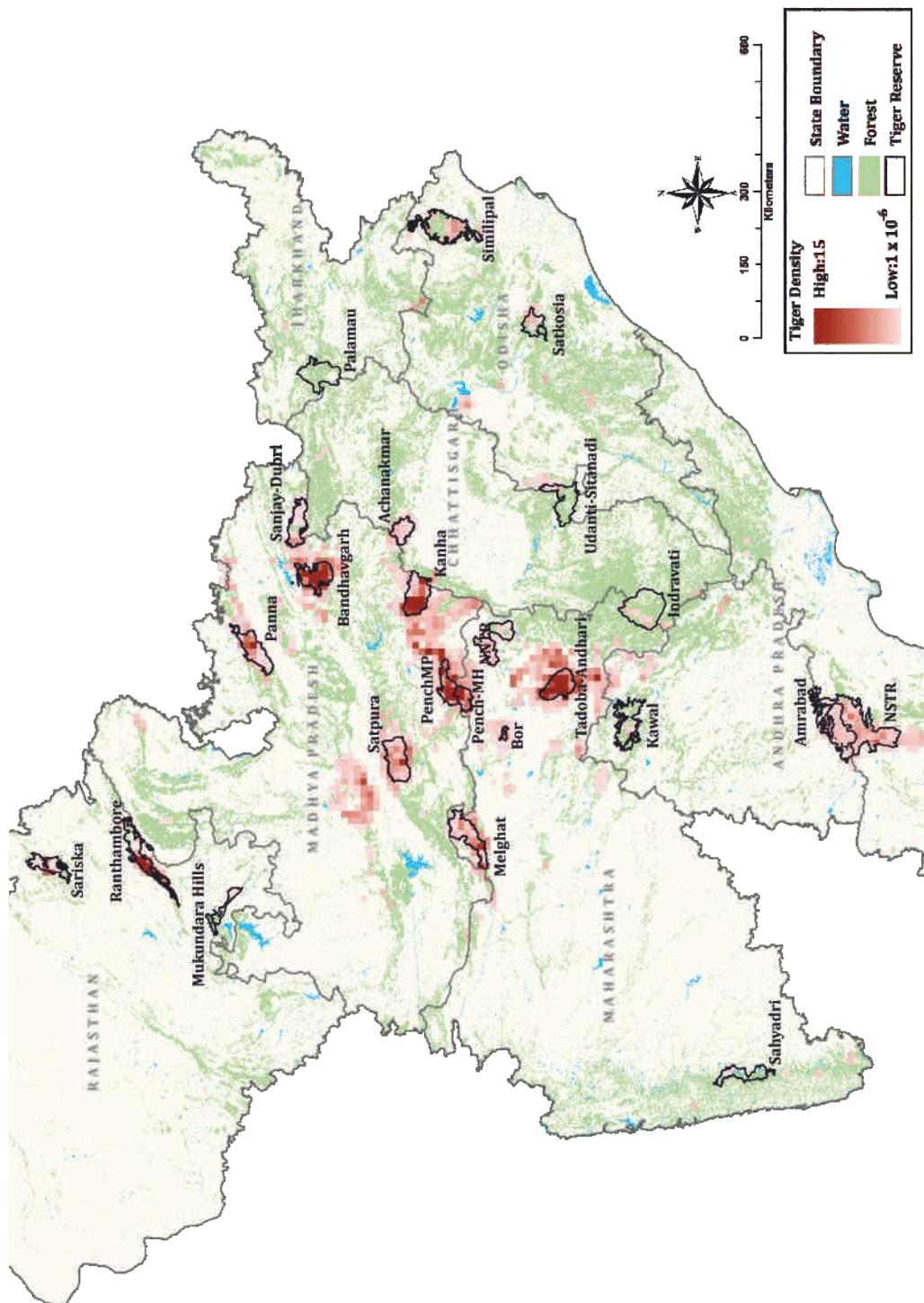
Shivalik Hills and Gangetic Plains Landscape

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

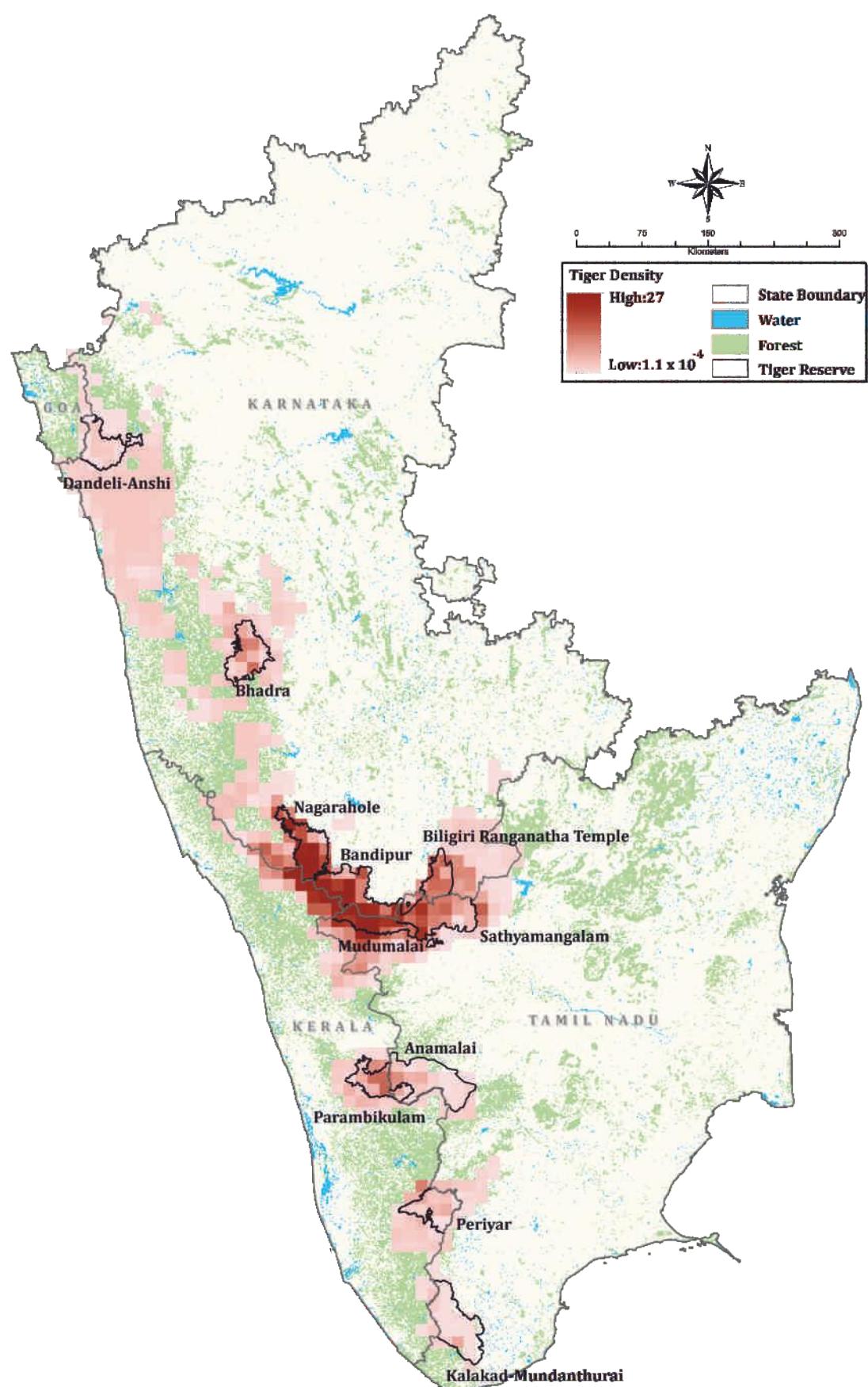
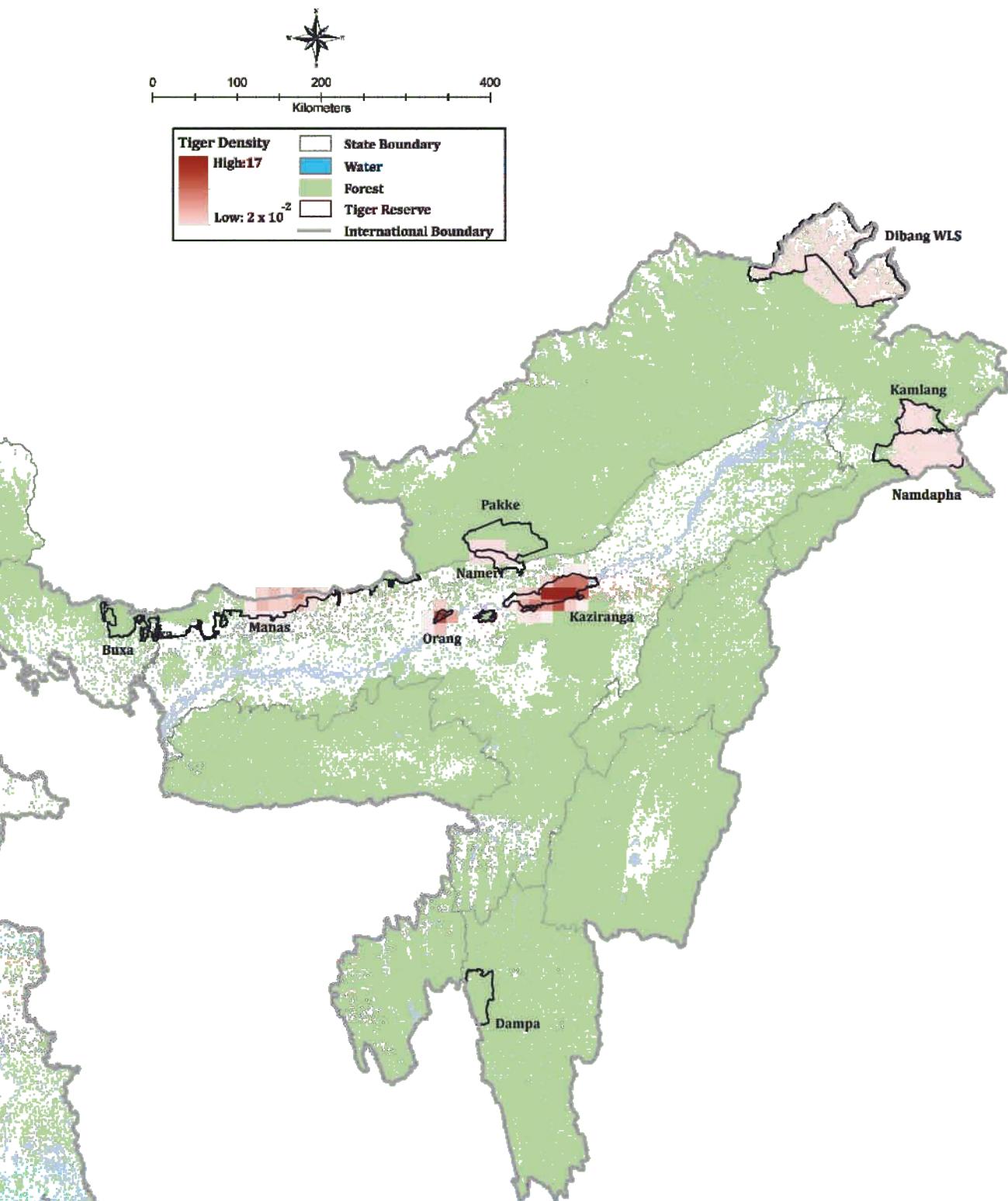


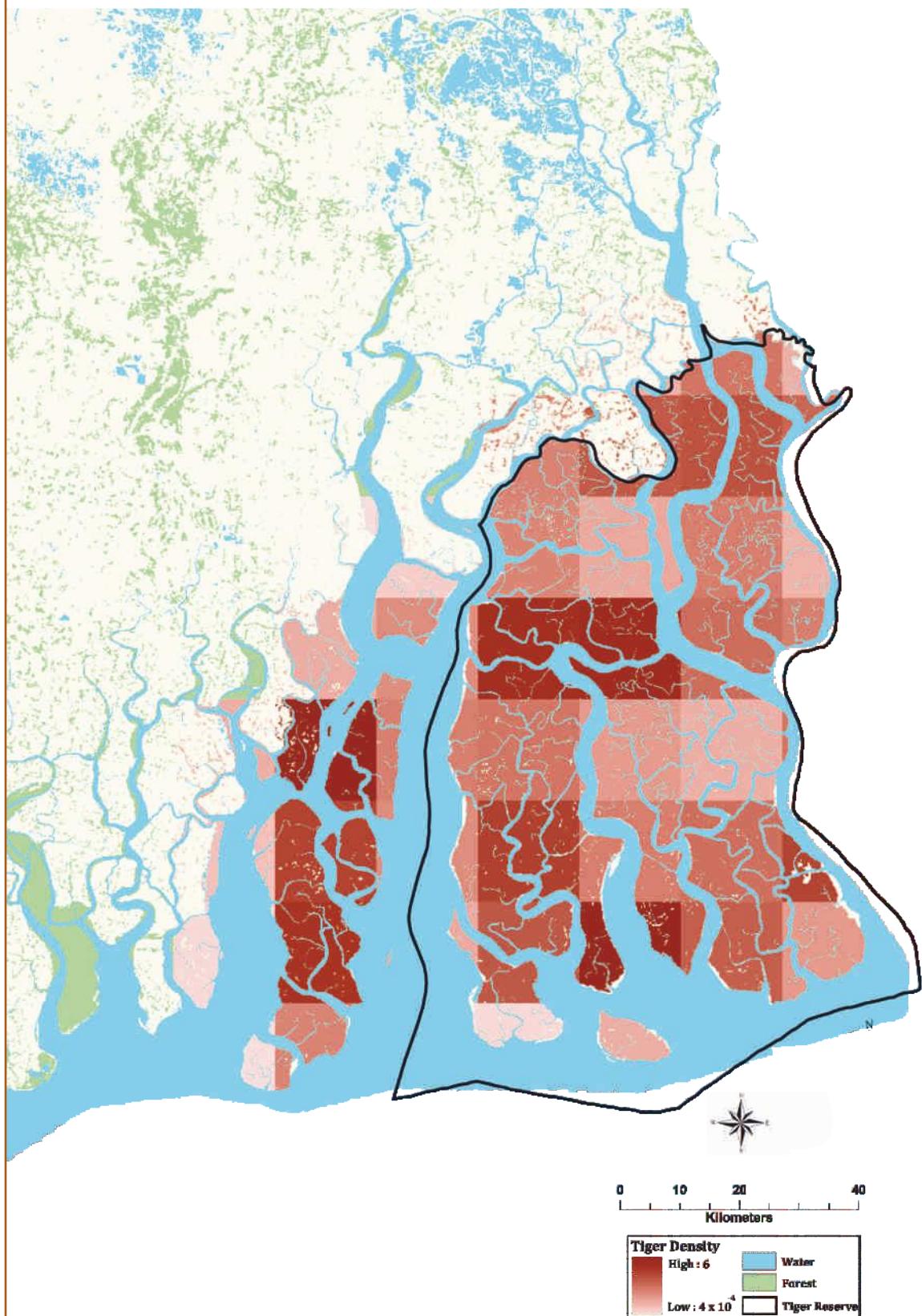
Figure 10: Tiger density map obtained by spatially explicit capture-recapture (SECR) and Maximum Entropy model for the North Eastern Hills and Brahmaputra Flood Plains Landscape

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 km²), 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 Valmiki¹⁴. 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 Simlipal, tigers need to be sourced from the closest source in the same genetic cluster¹⁴. 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

Wildlife Institute of India team:

Dr. V.B. Mathur,
Director;
Dr. G.S. Rawat,
Dean;
Dr. Bitapi Sinha,
Research Coordinator;
Dr. V.P. Uniyal,
Nodal Officer
Externally Aided Projects
Shri P.K. Agarwal,
Deputy Registrar
are acknowledged for their support
and facilitation.
Dr. Gopi G.V.
is acknowledged for providing data.

M-STRIPES Team:

Dr. Rajan Amin &
Kevin Dave for conceptualization.
Shri Ashok Kumar
Ms. Kainat Latafat
Shri Ashish Prasad
Ms. Krishna Mishra
Shri Anup Kumar Pradhan
Ms. Anchal Bhasin
Shri Ninad Mungi
Shri Akshay Jain
Shri Deb Ranjan Laha
Ms. Papori Khatonier

Research Biologists:

Abhilasha Harendra Shrivastava
Adarsh Martandrao Kulkarni
Aishwarya Bhandari
Ajay Chauhan
Anish Kumar
Anjali Mehra
Ankita Sharma
Ashish Kumar Panda
Azam Khan
Bhawana Pant
Chiranjivi Sinha
Devesh Kumar Mishra
Farha Usmani
Gaurav P.J.
Genie Murao
Haritha V Mohanan
Indranil Bhowmick
Indranil Paul
Jyoti Sheoran
Kamakshi Singh Tanwar
Kesha Patel
Maitry Mayurkumar Jani
Manish Ashok Singanjude
Mohammad Mairaj
Monika Saraswat
Mouli Bose
Moulik Sarkar
Nanka Lakra
Nilanjan Basu
Nishant Nandkumar Zajam
Nupur Rautela
Parul Sen
Pooja Choudhary
Prashant Mahajan
Pratik Pramod Pansare
Pritam Kumar Dey
Priyadarshini Mitra
Rameshwar Pandurang Ghade
Ravi Kumar Sharma

Principal Investigators

Dr. Y.V. Jhala and
Prof. Qamar Qureshi

**Faculties involved
all India tiger estimation:**

Dr. Y.V. Jhala,
Prof. Qamar Qureshi &
Dr. Vishnupriya Kolipakam

NTCA-WII Tiger Cell Team:

Dr. Kausik Banerjee,
Shri Ujjwal Kumar,
Ms. Swati Saini,
Ms. Shikha Bisht and
Shri Ayan Sadhu

Extract Compare Team

Dr. Lex Hiby
(program developer)

Ms. Ahana Dutt,
Sh. Muthu Veerappan

Senior Research Biologists

Ms. Manjari Roy,
Shri Sudip Banerjee,
Ms. Neha Awasthi,
Ms. Shweta Singh,
Shri Ritesh Vishwakarma

Riddhi Sondagar
 Sagarika Das
 Samuel George
 Satemmenla Longchar
 Shalu Mesaria
 Soufil Sharifmiya Malek
 Sourabh Pundir
 Sourabh Verma
 Suhas S.N.
 Suman Koley
 Susmita Khan
 Swaroop Rajendra Patankar
 Tehlu Singh
 Thilagavathi M
 Tishya Dasgupta
 Upamanyu Chakraborty
 Vikas Verma
 Vishwapriya, H.M
 Vivekanand Kumar
 Vyshakh A

Volunteers

Arpit Aggarwal
 Garima Bhatt
 Luxmi Hina
 Mohammad Shaan
 Priyanka Kaushik
 Sakshi Tomar
 Salmaan Khan
 Santoshi Negi
 Siddharth Rajmohan
 Sunil Patel
 Supragya Dimri
 Tetseo Vetavolu
 Tiazula Imchen
 William Zanthansanga
 Yash Sharma
 Yukta Singh

Office Assistants:

Shri Gyansah Chhibber,
 Shri Vijay Prakash Baloni

SCIENCE (GIS Firm) team:

Shri Prabir De (Consultant),
 Sh. Arun Kumar (M-STripes
 app developer)

Indraprastha Institute of Information Technology, New Delhi team:

Dr. Saket Anand,
 Sh. Gullal Singh Cheema

University of Petroleum and Energy Studies, Dehradun team:

Sh. Saurabh Shanu
 Sh. Rahul Khot,

**Bombay Natural History
 Society is acknowledged for
 providing data.**

Research Assistants and Interns:

Abhijeet Gurung
 Abhimanyu Bhardwaj
 Abhishek Verma
 Anjali Mishra
 Anuroop Singh
 Aparna Bhagat
 Avinash Yadav
 Ayushi Khanduri
 Deepak Suyal
 Himangshu Borah
 Meera Makwana
 Mukul Rawat
 Naveen Negi
 Neha Yadav
 Patrick Bell
 Pratikshya Mishra
 Samridhi Dixit
 Santanu Sharma
 Siddharth Singh
 Sugandha Gupta
 Sumit Saha
 Swati Singh
 Vaishnavi Gusain
 Vishant Saini
 Yash Dabholkar
 Yuyutshu Bhattacharya

National Tiger Conservation Authority (NTCA) team

Name	Designation
Headquarter	
Dr. Anup Kumar Nayak	ADG (PT) & MS (NTCA)
Dr. Debabrata Swain	ADG (PT) & MS (NTCA)- Retd.
Dr. Amit Mallick	IG
Dr. H.S. Negi	ex-IG
Shri Surender Mehra	DIG
Shri Nishant Verma	DIG
Shri Sanjay Pathak	ex-DIG
Dr. Vaibhav Mathur	AIG
Dr. Rajaram Singh	AIG
Regional Office Eastern Zone	
Shri W. Longvah	IG
Shri D.P. Bankhwal	IG - Retd.
Ms. Agatha Momin	Biologist
Regional Office Central Zone	
Shri Hemant Kamdi	AIG
Shri Anil Dashare	Biologist
Regional Office Southern Zone	
Shri N.S. Murali	IG
Shri P.S. Somasekhar	IG - Retd.
Shri Rajendra Garawad	AIG

**Chief Wildlife
Wardens in the
States involved in
tiger status
estimation 2017-19**

S. No.	States	Name
1	Andhra Pradesh	Shri. N. Prateep Kumar, Shri P. Mallikarjuna Rao, Dr. Mohd Ilyas Rizvi, Shri D. Nalini Mohan
2	Arunachal Pradesh	Dr. R. Kemp, Dr. Rabindra Kumar, Dr. Bipin Behari
3	Assam	Shri Niranjan Vasu, Shri D.P. Bankhwal, Dr. Ranjana Gupta
4	Bihar	Shri Bharat Jyoti, Shri A.K. Pandey
5	Chhattisgarh	Dr. R.K Singh, Shri Kaushlendra Singh, Shri S.C. Agarwal, Shri Rakesh Chaturvedi
6	Goa	Shri Ajay Saxena, Shri Santosh Kumar
7	Jharkhand	Shri Lal Ratnakar Singh, Shri P.K. Verma
8	Karnataka	Shri C. Jayaram, Shri Sanjay Mohan
9	Kerala	Shri A.K. Bhardwaj, Shri P.K. Keshavan, Shri Surendra Kumar
10	Madhya Pradesh	Shri Jitendra Agrawal, Shri Shahbaz Ahmed, Dr. U. Prakasham
11	Maharashtra	Shri A. K. Mishra, Shri N.H. Kakodkar
12	Mizoram	Dr. C.H. Muralidhar Rao
13	Nagaland	Shri Satya Prakash Tripathi
14	Odisha	Shri Siddhanta Das, Dr. Sandeep Tripathi, Dr. Ajay Kumar Mahapatra
15	Rajasthan	Dr. G.V. Reddy, Shri Arindam Tomar
16	Tamil Nadu	Shri P.C. Tyagi, Shri T.P. Raghunath
17	Telangana	Dr. Manoranjan Bhanja, Shri P.K. Jha
18	Uttar Pradesh	Shri S.K. Upadhyay, Shri Pawan Kumar, Shri Sunil Pandey
19	Uttarakhand	Shri D.V.S. Khati, Shri Rajiv Bhartari, Shri Jai Raj, Shri Monish Mullick, Ms. Ranjana Kala
20	West Bengal	Shri Ravi Kant Sinha

**All India tiger
estimation Nodal
Officials in the
States**

S. No.	States	Name
1	Andhra Pradesh	Shri S. Sarvanan, Shri Anand Kumar Jha, Shri K. Gopinatha
2	Arunachal Pradesh	Shri Tana Tapi, Shri C. Loma, Shri T. Riba, Shri Koj Tassar
3	Assam	Dr. Satyendra Singh, Shri Utpal Bora
4	Bihar	Shri S. Chandrasekhar, Shri Hem Kant Roy
5	Chhattisgarh	Dr. S.K. Singh, Shri J.A.C.S Rao
6	Goa	Dr. A. Anil Kumar
7	Jharkhand	Dr. M.P. Singh, Shri Mohan Lal
8	Karnataka	Shri Manoj Kumar, Shri Subhash K. Malkhede
9	Kerala	Shri George P Mathachen, Shri K. Vijayanath, Shri B.N. Anjankumar, Ms. Silpa V Kumar, Shri C.K. Haby, Shri P.K. Vipin Das, Shri M. Unnikrishnan
10	Madhya Pradesh	Shri Alok Kumar
11	Maharashtra	Dr. Rambabu, Shri Sunil Limaye, Shri M.B. Naikwadi, Shri Sachin M. Thakare, Shri G.K. Washisht
12	Mizoram	Sh. Lalthlamuana Pachuau
13	Nagaland	Shri Suman Shivashankar Sivachar W M
14	Odisha	Dr. Jagyandatt Pati, Shri Bhakta Padarbinda Rath, Dr. Nima Charan Palei
15	Tamil Nadu	Dr. Sekhar Kumar Niraj, Shri A. Venkatesh
16	Telangana	Shri Munindra, Shri A. Shankaran
17	Uttar Pradesh	Dr. S.P. Yadav, Shri A.K. Dwivedi, Shri Pawan Kumar Sharma
18	Uttarakhand	Dr. Dhananjai Mohan, Shri Surendra Mehra, Shri Ranajan Mishra
19	West Bengal	Shri N.S. Murali, Shri Nilanjan Mallick, Shri Subhankar Sengupta, Shri Kalyan Rai

Officials who coordinated training in the states

State	Name
Andhra Pradesh	Shri S. Sarvanan, Dr. K. Suryanarayana, Shri P. Ramohan Rao Shri N. Nageswara Rao, HYTICOS, Hyderabad
Arunachal Pradesh	Shri Umesh Kumar
Assam	Shri Sudip Banerjee (WII), Shri Deb Ranjan Laha (WII)
Bihar	Shri Gaurav Ojha, Shri Ambarish Kumar Mall, Dr. Kamlesh Maurya (WWF India), Shri Shariq Shafi (WWF India)
Chhattisgarh	Dr. S.K Singh, Shri A.K Sonwani, Shri M.K Chaudhary, Shri Loknath Patel, Shri S.K Sinha, Shri R.K Rayast, Shri K.L Nirmalkar, Shri T.R Jaiswal, Shri Shyam Singh Dev, Shri Vivek Shukla
Jharkhand	Dr. M.P. Singh, Shri Mohan Lal
Karnataka	Information and Communications Technology (ICT) cell and Tiger cell, Aranya Bhavan, Bengaluru
Kerala	Dr. M. Balasubramanian, Shri M. Ramesh Babu, Dr. Patrick David, Shri R. Rahul, Shri C. Sivakumar, Shri B. Karthik, Shri Vishnu Vijayan, Shri Shiju, Shri Aneesh C.R.
Madhya Pradesh	Dr. Dharmendra Varma - SFRI, Shri Vivek Jain, Shri Subharanjan Sen, Shri Sanjay Shukla, Shri B.S. Annigeri, Shri L. Krishnamoorthy, Shri H.S. Mohanta, Shri M. Pathak, Shri Ravikant Mishra, Shri Rajnish Kumar Singh, Dr. Anjana Rajput - SFRI, Dr. Aniruddha Majumdar - SFRI, Shri Gyan Prakash Shukla
Maharashtra	Shri R.S. Govekar, Shri M.S. Reddy, Shri Mukul Trivedi, Dr. Ben V Clement, Dr. Vinita Vyas, Shri Rishikesh Ranjan, Shri, N.R. Praveen, Shri Amlendu Pathak, Shri Vishal Mali, Shri G.V. Sanap, Shri Kolhankar, Shri Kavitkar, Shri L.N. Patil, Shri P.B. Panchbhai, Shri M. Toro, Shri Y. Bahale, Shri S. Pardikar, Shri M. Khairnar, Shri Tushar Pawar, Shri Kishore Mankar, Shri Manohar Gokhale, Shri M. Motghare, Shri Bobde, Ms. Morkute, Shri V. Khedkar, Shri Azim Mujawar, Ms. Neenu Somarji, Shri R.K. Chavan, Shri B.P. Rathod, Ms. G.S. Nannware, Shri S.S. Bhagawat, Shri G.P. Bobade, Shri G.H. Luche, Shri D.V. Raut, Shri R.H. Kotrange, Shri P.R. Rathod, Shri S.S. Pande, Shri A.H. Gore, Shri G.D. Thombare, Shri K.Y. Talwekar, Shri Amaz Sidam, Shri Mohan Chati, Shri P. Humane, Shri, R. Bhongade, Shri P.N. Naik, Shri P. Sathwane, Shri N.R. Gawande, Shri D.T. Dude, Shri A.R. Deokar, Shri R.R. Sagir, Shri P.E. Patil, Shri C.R. Tambe, Shri S.L. Bilolikar, Shri V.B. Kamble, Shri R.K. Bhawar, Shri K.M. Abharna, Shri S.R. Dumare, Shri R.M. Wakde, Shri P.V. More, Shri S. Thipe, Shri A.K. Mishra, Shri V.K. Bhorade, Shri S.G. Badhekar, Ms. Priyanka Bajaj Tahaliyani, Ms. Pallavi Ghaskadbi (WII), Ms. Lynette Gomes, Shri Rahul Kale, Shri Nilanjan Chatterjee (WII), Shri Zehidul Hussain (WII)
Nagaland	Shri Y M Jami, Ms. K Caroline Angami, Shri Suman Shivashankar Sivachar W M, Shri Jongpong Walling, Shri Kenlumtatei, Shri R. Aaron Yimchunger
Odisha	Shri P. K. Sahoo, Dr. Jagyandatt Pati, Shri Bhakta Padarbinda Rath, Dr. Nimaian Charan Palei
Rajasthan	Shri Y.K. Sahu, Dr. G.S. Bhardwaj, Shri Ghanshyam Prasad Sharma, Shri Mukesh Saini, Shri Hemant Shekhawat, Dr. T. Mohan Raj
Tamil Nadu	Dr. Sekhar Kumar Neeraj, Shri A. Venkatesh, Shri Srinivas R Reddy, Shri V Ganeshan
Telangana	Shri C.P. Vinod Kumar, Shri C. Sarvanan
Uttar Pradesh	Shri V.K. Singh, Dr. Semmaran, Shri Manish Singh, Shri Adarsh Kumar, Shri Kailash Prasad, Shri Samir Kumar, Shri Devendra Chaturvedi, Shri R.K.P. Singh, Shri S.N. Yadav, Shri D.P. Shrivastava, Shri Ashok Kashyap, Shri Ram Baran Yadav, Shri Ashok Chandra, Shri Dilip Shrivastava, Shri Asish Bista (WWF India)
Uttarakhand	Shri Surendra Mehra, Shri Sanatan, Dr. Parag Dakate, Shri Amit Verma, Shri G.S. Karki, Shri Ajay Sharma
West Bengal	Shri Kalyan Rai, Shri Manish Yadav, Shri Durga Kant Jha, Shri Mayukh Ghosh, Shri Ajoy Kumar Das, Shri Deepak M., Shri Kanu Chakraborty, Shri Anindya Guhathakurta
Wildlife Institute of India	Dr. Sutirtha Dutta, Dr. Amit Kumar



Comments by Peers

Dr. Matt Hayward

Associate Professor of Conservation
Twitter: @ConservResearch

School of Environmental and Life Sciences
University of Newcastle, Callaghan, NSW 2308 Australia
Facebook: Conservation Biology @ UoN



Deriving a population estimate for any rare and elusive species is a challenging task, but to do so for dozens of tiger populations across the entire sub-continent of India is immense. The numbers alone are phenomenal – 44,000 field staff, 600,000 person-days, 523,000 km of walked transects, 318,000 habitat surveys, 26,800 camera trap locations across an area of 381,000 km² yielding 35 million photographs of India's wildlife including 76,523 photos of tigers. Yet these efforts would be redundant without using robust methods to analyse them. There has been criticism historically about the methods used in previous tiger censuses, however I believe this is the most robust estimate of tigers possible with detectability and observer error clearly accounted for as well as possible, and I can think of no improvements based on the logistical constraints of our current technological and analytic capabilities. Hence, I am confident that the latest estimate of tigers across India is valid and robust, and represents a clear and impressive increase in population size since the previous estimate.

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

Yours sincerely

Matt

Dr. Chris Carbone

Senior Research Fellow,
Doctoral Programmes Coordinator
Institute of Zoology



Patron: H M The Queen
Vice Patron: HRH The Prince of Wales

During a recent visit to India between June 25th and July 4th, 2019, I was able to take part in discussions and meetings at the Wildlife Institute of India (WII), the National Tiger Conservation Authority (NTCA), and Pench and Kanha National Parks. I was given the opportunity to witness the processes involved in India's effort to assess its tiger populations, which complimented an earlier visit in 2006. I took part in a number of in-depth discussions with a range of people from senior officials to forest beat guards. I commend WII and the Government of India for conducting the all-India tiger surveys. These represent a programme which is unprecedented in scale, rigour and intensity. As far as I am aware, this is the largest centrally coordinated survey of its kind in the world and represents an immense achievement providing invaluable information on the status of not only tigers, but a wide range of coexisting mammals in tiger habitats. The methodology used balances the need to vary survey effort from core tiger habitat to wider marginal areas. This programme combines, GIS analyses and the latest spatially-explicit methodologies in cameratrapping along with wider-scale but lower intensity secondary sign surveys outside of tiger core areas making such a large-scale survey achievable. There have also been impressive improvements since the original survey in 2006 due, in part, to general technological advances (e.g. camera-traps, mobile phones and GPS etc.), but also due to the efforts of WII and partners to develop software tools to automate the data recording and processing, including the use of M-STrIPES (phone app for all types of in field data entry) and data analysis (Extract Compare (tiger ID) and CATRAT (species ID)). These advances are critical to the process as they increase the speed and accuracy of data processing. The current report is immense in scale and intensity covering over 380,000 km² and actually recording ~80% of the total tiger population directly in the photo record of ~ 75,000 tiger photos. I don't doubt that this represents an extremely robust and reliable estimate of the tiger population across the survey area. Tigers are a vital part of India's national heritage and recent reported increases are welcome news! It is essential therefore that tiger core areas and key habitat corridors continue to be maintained and protected against threats of development. In addition, it is important that working conditions of forest guards and other staff, which represent the front-line of India's tiger protection strategy, are reviewed to maintain motivation and effectiveness and to insure the future protection of tigers in the wild.

Dr. Chris Carbone

Dr. Joseph Bump

Associate Professor, University of Minnesota
Director of Graduate Studies
Gullion Endowed Chair in Forest Wildlife Research & Education

UNIVERSITY OF MINNESOTA

Department of Fisheries, Wildlife
and Conservation Biology
College of Food, Agricultural and
Natural Resource Sciences

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

Dr. Joseph K. Bump

Literature cited

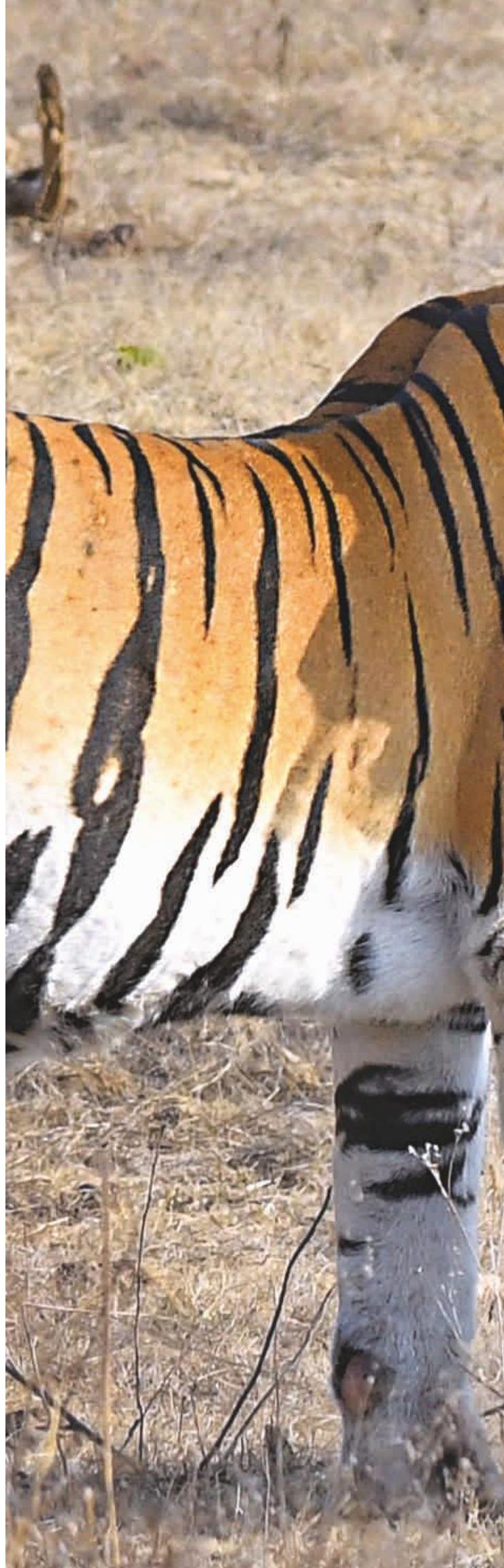
1. Goodrich, J., Lynam, A., Miquelle, D., Wibisono, H., Kawanishi, K., Pattanavibool, A., Htun, S., Tempa, T., Karki, J., Jhala, Y. and Karanth, U. 2015. *Panthera tigris*. The IUCN Red List of Threatened Species 2015: e.T15955A50659951. <http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T15955A50659951.en>.
2. Narain S., Panwar, H.S., Gadgil, M., Thapar, V. and Singh, S. (eds.) 2005. Joining the dots: The report of the tiger task force. Project Tiger, Ministry of Environment and Forests, New Delhi.
3. Jhala, Y.V., Gopal, R. and Qureshi, Q. (eds.) 2008. Status of tigers, co-predators and prey in India. National Tiger Conservation Authority of India and Wildlife Institute of India. TR08/001, Dehradun. Pp 164.
4. Jhala, Y.V., Qureshi, Q., Gopal, R. and Sinha P.R. (eds.) 2011b. Status of tigers, co-predators and prey in India, 2010. National Tiger Conservation Authority, Govt., of India, New Delhi and Wildlife Institute of India, Dehradun. TR 2011/003. Pp 302.
5. Jhala, Y.V., Qureshi, Q. and Gopal, R. (eds.) 2015. Status of tigers, co-predators and prey in India, 2014. National Tiger Conservation Authority, Govt., of India, New Delhi and Wildlife Institute of India, Dehradun. TR 2015/021. Pp 456.
6. Hiby, L., Lovell, P., Patil, N., Kumar, N.S., Gopalaswamy, A.G. and Karanth, K.U. 2009. A tiger cannot change its stripes: using a three-dimensional model to match images of living tigers and tiger skins. *Biology Letters* 5: 383 - 386.
7. Jhala, Y.V., Qureshi, Q. and Gopal, R. 2017. Field Guide: Monitoring tigers, co-predators, prey and their habitats. Fourth ed. Technical Publication of National Tiger Conservation Authority, New Delhi and the Wildlife Institute of India, Dehradun. TR-2017/012.
8. Crall, J.P., Stewart, C.V., Berger-Wolf, T.Y., Rubenstein, D.I., and Sundaresan, S.R. 2013. Hotspotter-pattern species instance recognition. In: 2013 IEEE workshop on Applications of Computer vision, pp 230-237, Curran Associates, Red Hook, NY.
9. Borchers, D.L. and Efford, M.G. 2008. Spatially explicit maximum likelihood methods for capture-recapture studies. *Biometrics* 64: 377-385.
10. Efford, M. 2011. Estimation of population density by spatially explicit capture-recapture analysis of data from area searches. *Ecology* 92: 2202-2207.
11. Boom, R., Sol, C.J.A., Salimans, M.M., Jansen, C.L., Wertheim-Van Dillen, P.M.E. and Noordaa, J.V.D. 1990. Rapid and simple method for purification of nucleic acids. *Journal of Clinical Microbiology* 28: 495-503.
12. Bhagavatula J. and Singh L. 2006. Genotyping faecal samples of Bengal tiger (*Panthera tigris tigris*) for population estimation: a pilot study. *BMC Genetics* 7(1): 48.
13. Phillips, S.J., Anderson, R.P. and Schapire, R.E. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190: 231-259.
14. Kolipakam, V., Singh, S., Pant, B., Qureshi, Q. and Jhala, Y.V. 2019. Genetic structure of tigers (*Panthera tigris tigris*) in India and its implications for conservation. *Global Ecology and Conservation* 20: e00710.





Photo Credits:

Sanjay Shukla
Sudhir Mishra
Moulik Sarkar
Shantanu Sharma
Samrat Godambe







सत्यमेव जयते



भारतीय वन्यजीव संस्थान
Wildlife Institute of India



Forest Department
GOVERNMENT OF UTTARAKHAND



Tamil Nadu Forest Department



Forest and Wildlife Department,
Government of Uttar Pradesh, India



National Tiger Conservation Authority
B-1 Wing, 7th Floor,
Pt Deendayal Antyodaya Bhawan
CGO Complex, Lodhi Road,
New Delhi 110 003, India

Wildlife Institute of India
Chandrabani,
Dehradun - 248001
Uttarakhand, India
www.wii.gov.in