2008

STATUS OF TIGERS, CO-PREDATORS AND PREY IN INDIA

राष्ट्रीय व्याघ्र संरक्षण प्राधिकरण
National Tiger Conservation Authority

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Y.V.Jhala, R.Gopal, Q.Qureshi (eds.) (2008). Status of the Tigers, Co-predators, and Prey in India. National Tiger Conservation Authority, Govt. of India, New Delhi, and Wildlife Institute of India, Dehradun. TR 08/001 pp-151

STATUS OF TIGERS, CO-PREDATORS AND PREY IN INDIA

National Tiger Conservation Authority
Ministry of Environment & Forests

and

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

2008

Contents

PREFACE

For designing, implementing, and evaluating the success of any conservation program for an endangered species, it is imperative to monitor the status, distribution, and trends in the populations of the target species. The monitoring program should be transparent in its approach, and holistic, addressing an array of parameters related to the survival of the species by using the blend of the best available science and technology. In case of the tiger our National animal, the only form of country wide monitoring was based on the pugmark system which depended on identifying individual tigers by experts. The system generated a total count of tigers in the states and in the country, but gave no indication of spatial occupancy, population extent and limits, connectivity between populations, habitat and prey conditions which constitute the crucial elements for the continued survival of the tiger in a landscape. Realizing the shortfalls of the pugmark monitoring system in keeping pace with modern conservation biology needs for a monitoring scheme, the Project Tiger Directorate commenced a project in collaboration with the Wildlife Institute of India and the Forest Department of Madhya Pradesh in 2003 to evolve a monitoring program for "Tigers, Co-predators, Prey and their Habitat" in the Satpura-Maikal Landscape. This pilot project evolved field friendly data collection protocols in consultation with field managers and scientists. The monitoring program uses remote sensing, geographic information system, and global positioning system technology in combination with high resolution spatial data and field data, based on sign surveys, camera trapping, and distance sampling, to effectively monitor tiger and prey populations. After the Sariska crisis, the Tiger Task Force recommended the implementation of this monitoring scheme for all tiger occupied landscapes. The Project Tiger Directorate (currently the National Tiger Conservation Authority) synergized this mammoth task by liaisoning with the State Forest Departments to generate the required field data in appropriate formats and the Wildlife Institute of India to impart training in field data collection, and for estimating tiger and prey densities for the Nation wide monitoring program.

Dr. Prodipto Ghosh, Secretary (retd.), Ministry of Environment and Forests took personal interest in ensuring the success of the program in the true sprit of an independent scientific endeavor. We thank Ms. Meena Gupta, Secretary Ministry of

Environment and Forests for her support. This exercise was facilitated by Shri R. P. S. Katwal, Additional DG (WL) (Retd.) and by Shri Vinod Rishi, in his capacity as Additional DG (WL) (Retd.); we acknowledge their support.

Shri P. R. Sinha, Director and Dr. V. B. Mathur, Dean, Wildlife Institute of India provided the conditions for fostering the working environment essential for completing this task. We acknowledge their contribution with gratitude. Dr. K Sankar, helped coordinate the logistics and recruitment of researchers at the Wildlife Institute of India. Faculty members of the Wildlife Institute of India are acknowledged for assisting in various field training workshops (Appendix 1.1). We thank Dr. S.A. Hussain and Dr. V.P. Uniyal, Hostel Wardens of WII for accommodating our large team of researchers at odd hours and short notices. Chief Wildlife Wardens and participating forest officials are acknowledged for successful implementation of the Phase I field data collection and compilation. Shri K. Nayak, Field Director Kanha Tiger Reserve is acknowledged in particular for galvanizing field managers and conducting training. The enthusiasm and sincerity of the frontline staff in collecting field data which is the backbone of this monitoring program is acknowledged. Estimating absolute densities of tigers and prey with the needed accuracy and precision is by no means an easy task, the research team (Appendix 1.1) of the Wildlife Institute of India accomplished this within the stipulated timeframe by sincere and untiring efforts. Dr. Andrew Royle is acknowledged for his assistance in occupancy modeling of tigers. We are grateful to the comments, critiques, and suggestions by the National, International peers (Appendix 1.2), and others who communicated with us in helping improve this monitoring program. We thank Dr. Nita Shah for editing the landscape part of this report and Ms. Bitapi Sinha for assistance in publication. We acknowledge Nilanjana Roy, Babita, Parabita Basu, Vivek Badoni, Vinay Sharma, Virendra Sharma, Manoj Aggarwal, and Rajesh Thapa for assistance in preparing this report. We thank translators for transcribing field guide into different regional languages. We thank our families, Nita, Rajeshwari, Harshini and Dhananjay for their understanding and support during the course of this project. J. Vattakaven is acknowledged for photo credits of the cover.

------- The Authors

EXECUTIVE SUMMARY

1- This report evaluates the current status of tigers, co-predators and their prey in India. It is the outcome of a country-wide effort to scientifically determine the occupancy, population limits, habitat condition and connectivity, so as to guide conservation planning for ensuring the survival of free ranging tigers. The study shifts the focus from tiger number and protected area oriented conservation practices to landscape level holistic conservation strategies.

2- A three phase approach was used to sample all forested habitats in tiger states. A double sampling approach was used to first estimate occupancy and relative abundance of tigers, co-predators, and prey through sign and encounter rates in all forested areas. A team of researchers then sampled a subset of these areas using robust statistical approaches like mark-recapture and distance sampling to estimate absolute densities of tigers and their prey. Covariate information was generated using remotely sensed data and attribute data using Geographic Information System. Indices (tiger signs, prey relative abundance indices, habitat characteristics) were then calibrated against absolute densities and the relationships used for extrapolation of tiger densities within a landscape. Tiger numbers were obtained for contiguous patches of occupied forests by using average densities for that population block. Numbers and densities are reported as adult tigers with a standard error range.

3- Tiger occupied forests in India have been classified into 6 landscape complexes; namely (a) Shivalik-Gangetic Plains, (b) Central Indian Landscape Complex (c) Eastern Ghats, (d) Western Ghats, (e) North-Eastern Hills and Bhramaputra Plains, and (f) Sunderbans. Tiger populations within these landscape complexes are likely to share a common gene pool, since tiger habitats within these landscape complexes were contiguous during the recent past. Each landscape complex consists of landscape units that still have contiguous tiger habitat and contain one to many breeding populations of tigers (source populations). Within each landscape unit there exists a potential to manage some of the tiger populations as a meta-populations. This enhances the conservation potential of each of the single populations and probability of their long-term persistence.

4- Occupancy of a forest patch by tigers was negatively correlated with human disturbance indices and positively correlated with prey availability, forest patch and core sizes. For establishing and maintaining high density source populations of tigers it is essential to set aside inviolate areas devoid of human presence within each landscape. These source populations should be connected through multiple use forests (buffers and corridors) where human land uses conducive to maintaining low density tiger occupancy are permitted and fostered by providing appropriate incentives to local communities.

5- The Shivalik-Gangetic plain landscape complex is composed of two landscape units; (a) Kalesar to Kishenpur and (b) Dudhwa to Valmiki. The landscape complex had about 20,800 km^2 of potential tiger habitat on the Indian side. The Dudhwa-Valmiki landscape is now connected only via Nepal forests, and needs to be managed through International cooperation with Nepal. Currently the tiger occupies 5080 km^2 of forested habitats with an estimated population size of 297 (259 to 335) in six separate populations. The most important tiger population within this landscape is Corbett having tiger presence in 1,524 km^2 with an estimated population of 164 (151-178). The landscape is characterized by having the ability of sustaining high density tiger populations e.g. Corbett 19.6 tigers per 100 km^2, Dudhwa, Kishenpur and Katarniaghat tiger density ranging between 4.5 to 6.5 tigers per 100 km^2. Thus, with good management and protection tiger reserves in this landscape can serve an important role for tiger conservation. Reserves and landscapes that need fostering to achieve their inherent potential are Rajaji (along with Shivalik, and Haridwar Forest Divisions) and Valmiki Tiger Reserve.

6- Within the forest area of the Central Indian Landscape tiger presence is currently reported from 47,122 km^2 (11.6 % of forests) with an estimated tiger population of 451 (347 to 564) distributed in 17 populations The Central Indian landscape complex consists of eleven separate landscapes out of which four have potential to sustain meta-populations of tigers. These are (a) Kanha-Pench landscape of about 16,000 km^2 with tiger occupancy of 3880 km^2 with an estimated population of 121 tigers (b) Satpura-Melghat landscape of 12,700 km^2 with a tiger occupancy in 3331 km^2 and a population estimate of 69 tigers (c) Sanjay-Palamau landscape of 13,700km^2 and (d) Navegaon-Indravati

landscape of 34,000 km². Five other landscapes with single source populations which could potentially persist due to their reasonable large size and potential for high density tiger population are (a) Bandhavgarh with tiger occupancy in 1575 km² and a population estimate of 47 tigers (b) Panna with tiger occupancy in 974 km² and a population estimate of 24 tigers (c) Ranthamore-Kuno-Palpur with tiger occupancy in 3506 km² and a population estimate of 36 tigers (d) Tadoba with tiger occupancy in 775 km² and a population estimate of 34 tigers (e) Simlipal with tiger occupancy in 2297 km² and a population estimate of 20 tigers. Areas that need major inputs for achieving their conservation objectives and potential are Simlipal landscape, Palamau – Sanjay landscape, and Indravati landscape (which could not be assessed due to insurgency). The above landscapes are large, contiguous forest patches with legal conservation status and therefore can potentially sustain viable tiger populations. Large part of area with low sign intensity in Western Maharashtra was not used for analysis due to non map able information.

7- The Eastern Ghat landscape complex currently has about 15,000 km² of potential tiger habitat. Tigers occupy 7,772 km² of forested habitats with an estimated population size of 53 (49 to 57) in a single contiguous forest block constituted by the Srisailam-Nagarjuna Sagar Tiger Reserve and adjoining forests in the districts of Kurnool, Parakasam, Chuddapah, Mahbubnagar and Guntur. This landscape is capable of supporting higher densities of tigers than currently reported. Major problems in achieving this potential is insurgency, biotic pressures, and subsistence level poaching of tiger prey.

8- Currently tigers occupy 21,435 km² of forests within the Western Ghat Landscape comprising 21% of the forested area. The current potential tiger habitat in the landscape complex is about 51,000 km². The population estimate for this landscape was 366 (297-434) tigers. The Western Ghat landscape complex consists of three landscape units; (a) Forested area from the district of Pune to Palghat in Kerala, and eastwards upto Dharmapuri in Tamil Nadu. This landscape has good potential for long term tiger survival due to its large extent of over 34,000 km² of contiguous forest, with several source populations of tigers that likely exist as a meta-population (b) Forest areas South of Palghat upto Kodaikanal having some connectivity with the Periyar landscape

(c) the Periyar-Kalakad landscape unit of about 10,000 km² area. The single largest population of tigers in India is within this landscape comprising the landscape of Nagarhole-Madumalai-Bandipur-Waynad encompassing the states of Karnataka, Tamil-Nadu and Kerala having a tiger occupancy in 10,800 km² and an estimated tiger population of about 280 tigers. This population serves as a fine example of managing inter-state tiger reserves for establishing populations that have a good chance of long term persistence as well as provides a source to repopulate neighboring forests.

9- North-Eastern hills and Bhramaputra plains currently reported tiger occupancy in 4230 km² of forests. This landscape was sampled in an expedition mode based on supervised knowledge and not as per the Phase I protocol, thus this occupancy is likely to be an under estimate. North East Hills and Brahmaputra Flood Plains Landscape is also composed of two landscape units; (a) The largest single landscape unit of about 136,000 km² extending from Pakke Tiger Reserve to Namdapha Tiger Reserve in the East, and towards Dampa Tiger Reserve in the South. Kaziranga constituting a major source population of tigers, is connected through the Karbi Anglong hills. The landscape continues West upto Balphakram National Park, (b) The second landscape complex consists of Manas Tiger Reserve, in Assam, along with Buxa Tiger Reserve, Gorumara and Singhalila forests of West Bengal. The landscape is fragmented on the Indian side but has forest contiguity through Bhutan, and currently has about 7,200 km² of good tiger habitat. The single most important tiger population in this landscape was that of Kaziranga that formed a part of a forest patch of 136,000 km² , tiger occupancy of Kaziranga was only 766 km² but due to its potential for sustaining a high density population and forest contiguity through the Karbi Anglong hills it serves as a major source for dispersing tigers.

10- The Sunderbans landscape complex is the smallest isolated landscape that likely has a single population of tigers with a tiger occupancy in 1586 km². Population number assessment for Sunderbans is ongoing as a separate exercise as the uniqueness of the habitat requires a different approach such as using radio-telemetry for estimating tiger numbers. The Sunderbans tiger population needs to be managed through International cooperation with the Government of Bangladesh.

11- State wise summery of tiger occupancy and estimated population is provided in table ES.1.

12- The above assessment has shown that though the tiger has lost much ground due to direct poaching, loss of quality habitat, and loss of its prey there is still hope. Individual tiger populations that have high probability of long term persistence by themselves are only a few: Nagarhole-Madumalai-Bandipur-Waynad population, Corbett population, Kanha population, and possibly Sunderban and Kaziranga-Karbi Anglong populations. Tiger populations that exist and can persist in a meta population framework are Rajaji-Corbett, Dudhva-Katarniaghat-Kishenpur (along with Bardia and Shuklaphanta in Nepal), Satpura-Melghat, Pench-Kanha, Bhadra-Kudremukh, Parambikulum-Indira Gandhi, and KMTR-Preiyar. The landscapes that have potential but are currently in need of conservation inputs are Sirsailam Nagarjun Sagar, Simlipal, Ranthambore-Kuno Palpur, Indravati–Northern Andhra Pradesh, and Bandhavgarh-Sanjay-Palamau. To ensure the long term survival of tigers in India it is imperative to offer strict protection to established source populations and manage areas with restorative inputs by involving local communities in buffer and corridor areas by providing them with a direct stake in conservation. Tigers are a conservation dependent species requiring large contiguous forests with fair interspersion of undisturbed breeding areas. This leaves little choice other than to evolve strategies by mainstreaming conservation priorities in regional development policy and planning for managing Priority areas identified in the landscape complexes. Such an approach would ensure that breeding tiger populations have a possibility to share genetic material and exist in a meta-population framework, thereby enhancing the possibility of their survival.

Table ES.1 : Forest occupancy of Tigers, Co-Predators, Prey and population estimates of tigers.

State	Tiger km²	Leopard km²	Dhole km²	Sloth Bear km²	Chital km²	Sambar km²	Wild Pig km²	Nilgai km²	Tiger Numbers		
									No.	Lower limit	Upper limit
Shivalik-Gangetic Plain Landscape Complex											
Uttarakhand	1901	3683	-	853	2161	2756	3214	422	178	161	195
Uttar Pradesh	2766	2936	190	3130	5537	2641	7761	8375	109	91	127
Bihar	510	552	323	532	576	321	570	494	10	7	13
Shivalik-Gangetic	**5177**	**7171**	**513**	**4515**	**8274**	**5718**	**11545**	**9291**	**297**	**259**	**335**
Central Indian Landscape Complex and Eastern Ghats Landscape Complex											
Andhra Pradesh	14126	37609	41093	54673	37814	33159	58336	26526	95	84	107
Chattisgarh	3609	14939	3794	20951	18540	7604	25058	9250	26	23	28
Madhya Pradesh	15614	34736	28508	40959	41509	33551	599033	41704	300	236	364
Maharashtra	4273	4982	4352	6557	5970	5730	7370	4754	103	76	131
Orissa	9144	25516	8215	43236	6040	6112	21525	711	45	37	53
Rajasthan	356	-	-	-	-	-	-	-	32	30	35
Jharkhand**	1488	131	-	2640	721	721	6226	1108	**Not Assessed**		
Central Indian	**48610**	**131**	**85962**	**2640**	**721**	**721**	**6226**	**1108**	**601**	**486**	**718**
Western Ghats Landscape Complex											
Karnataka	18715	20506	15862	20749	42349	43412	21999	-	290	241	339
Kerala	6168	8363	10801	6904	2931	10469	8809	-	46	39	53
Tamil Nadu	9211	14484	19658	13224	13567	15909	19768	2505	76	56	95
Western Ghats	**34094**	**43353**	**46321**	**40877**	**58847**	**69790**	**50576**	**2505**	**402**	**336**	**487**
North East Hills and Brahmaputra Flood Plains											
Assam*	1164	1500	285	380	-	270	2047	-	70	60	80
Arunachal Pradesh*	1685	670	675	199	-	353	412	-	14	12	18
Mizoram*	785	2324	776	479	-	1700	1489	-	6	4	8
Northern West Bengal *	596	1135	301	-	280	309	491	-	10	8	12
North East Hills, and Brahmaputra	**4230**	**5629**	**2037**	**1058**	**280**	**2632**	**4439**	-	**100**	**84**	**118**
Sunderbans	**1586**	-	-	-	**1184**	-	**1591**	-	**Not Assessed**		
Total Tiger Population									**1411**	**1165**	**1657**

* Population estimates are based on possible density of tiger occupied landscape in the area, not assessed by double sampling.

** Data was not amenable to population estimation of tiger. However, available information about the landscape indicates low densities of tiger in the area ranging from 0.5 to 1.5 per 100 km².

1. Introduction

The present report is the final outcome of the All India Tiger Monitoring exercise undertaken on the direction of the Ministry of Environment and Forests by the Wildlife Institute of India in association with National Tiger Conservation Authority, MoEF, Government of India, and the State Forest Departments. Tiger is not only a flag bearer of conservation but also an umbrella species for majority of eco-regions in the Indian subcontinent. Its role as a top predator is vital in regulating and perpetuating ecological processes and systems (Terborgh J. 1991, Sunquist et al. 1999). The tiger needs large undisturbed landscapes with ample prey to raise young and to maintain long term genetic and demographic viability (Seidensticker and McDougal 1993, Karanth and Sunquist 1995, Carbone et al. 1999).

Unlike Africa, Latin America or South-East Asia, the forest boundaries in India appear to have stabilized while forest quality continues to deteriorate due to resource extraction (Ghimere 1979, Gunatilake & Chakravarty 2000, Lele et al. 2000). In the past 50 years, humans have changed these ecosystems largely to meet growing demands for food, fresh water, timber, fiber, and fuel (Millennium Ecosystem Assessment, 2005) more rapidly and extensively than in any comparable period of time in human history. Meeting the challenges of increasing demand for land by an ever growing population, in the absence of holistic landscape conservation planning has severely compromised the conservation of tigers and its ecosystem. If we intend to conserve tigers in their natural habitats, we need innovative approaches to land use planning that maintain connectivity between tiger source populations in a meta-population frame work.

Currently tigers occur largely in the forest areas of 17 States in India. Goa, Nagaland, Meghalaya, and Haryana, have reports of occasional tiger occurrence. The distribution of tigers and their density in these forests vary on account of several ecological and anthropogenic factors like forest cover, terrain, natural prey availability, presence of undisturbed habitat and the quality of managerial efforts taken towards protection.

Broadly, the country can be divided into six tiger occupied landscape complexes:

1. Shivaliks and the Gangetic Plain
2. Central Indian Landscape
3. Eastern Ghats
4. Western Ghats
5. North-East Hills and Brahamputra Plains and
6. Sunderbans

The Protected Areas in India are analogous to small islands in a vast sea of ecologically unsustainable land uses of varying degrees. Tiger reserves and some protected areas serve as source populations of tigers while intervening forested areas act as corridors. Thus the "tiger bearing forests" need to be fostered with protection as well as restorative inputs to ensure their source and corridor value for demographic and genetic viability of tiger populations. This becomes extremely crucial at the national level for evolving a road map to prevent the extinction of the tiger.

This report attempts to take stock of what we have and where. These are essential steps towards assigning priorities and identifying crucial links. The tools used include assessment of tiger occurrence, remotely sensed data and attribute data, analysed using GIS and multivariate statistical models. It provides spatial data on tiger distribution at the beat level and its associated landscape characterization at 100 km^2 grids; which is a precursor for land use planning incorporating conservation concerns and priorities.

The current monitoring system for tigers, co-predators, prey and their habitat transcends beyond estimating mere numbers. It is a holistic approach which uses the tiger as an umbrella species to monitor some of the major components of forest systems where the tiger occurs in India. The data and inferences generated by the system would not only serve as a monitoring tool but also as an information base for decision making for land use planning. It provides an opportunity to incorporate conservation objectives supported with a sound database, on equal footing with economic, sociological, and other values in policy and decision making for the benefit of the society. After the Sariska debacle, this system with a few modifications was recommended as a monitoring tool for the entire country by the Tiger Task Force.

India harbors a reasonably large proportion of the World's tiger population. This is attributed to a good forest cover (678,333 km², 20.64%), reasonable number (613) of good protected areas with a wide coverage, 28 established tiger reserves and 10 proposed tiger reserves.

The only form of tiger population monitoring undertaken in the country is a total count (census) of the country-wide tiger population every four years and within tiger reserves every one to two years. The census is based on intensive monitoring of tigers within areas, identifying individual tigers by visual inspection of the pugmark tracings/plaster casts, mapping tiger distribution at the local scale and inferring total numbers from the above information (Choudhury 1970, Panwar 1979, Sawarkar 1987 and Singh 1999). This methodology has come under severe criticism (Karanth et al, 2003). The major limitations of the above technique are that 1. it relies on subjective (expert knowledge) identification of tigers based on their pugmarks; 2. the pugmarks of a tiger are likely to vary with substrate, tracings/casts and the tiger's gait; 3. it is not possible to obtain pugmarks of tigers from all tiger occupied landscapes, and 4. the method attempts a total count of all tigers (Karanth et al, 2003). An alternative proposed by tiger biologists is to use individually identified tigers by camera traps in a capture-recapture statistical framework to estimate tiger densities (Karanth 1995 and 1998, Karanth and Nichols 1998, 2000 and 2002, Karanth et al 2004, Per Wegge et al 2004 and Pollock et al 1990). The method has been useful in determining tiger densities in small areas, within tiger reserves having high to medium density tiger populations. The method has a high potential for monitoring source population and smaller sample areas within tiger occupied landscapes. However, due to the technical nature of the method, high cost, security issues of the equipment and low performance in low density tiger populations this method has its limitations for a country-wide application for monitoring tigers (Carbone et al 2001, Karanth 1995 and 1998, Karanth and Nichols 1998, 2000 and 2002,Karanth et al 2004 and Kawanishi and Sunquist 2004). The other two potential methods that can be used in smaller sample areas for monitoring source tiger populations are the individual identification of tigers from digital images of their pugmarks (Sharma et al, 2005) and tiger DNA profiles obtained from scats and other non-invasive techniques (Broquet and Petit 2004, Prugh et al 2005

and Xu et al 2005). Here, we use an alternative method based on a four-stage approach:

Methods

Phase I: Spatial mapping and monitoring of tigers, prey and habitat

For estimating the distribution, extent and relative abundances of tigers, other carnivores, and ungulates data were collected in simple formats on carnivore signs and ungulate sightings in forested areas of the region within each forest beat. Data were also recorded on indices of human disturbance and habitat parameters. Over 88,000 copies of the field guide (Jhala, Qureshi & Gopal 2005) for data collection were printed in nine regional languages and given to beat guards of all beats. Six regional workshops were conducted to train officials for field data collection. The trained forest officials in turn trained field staff by subsequent workshops. These constituted the Phase I data and were collected by the State Forest Department between November 2005 to March 2006. A total effort of 491,648 man days was expended to sample 460,920 km of carnivore sign survey walks and 184,368 km of transect walks. This probably constitutes an unpresidented effort for any wildlife survey conducted in the world.

This stage consists of mapping
(a) tiger presence and relative abundance (*Karanth and Nichols 2002*);
(b) tiger prey presence and relative abundance and
(c) habitat quality and anthropogenic pressures at a high spatial resolution of 15-20km^2.

We consider a forest beat (an administrative unit, 15-20 sq km in average size, delineated primarily on natural boundaries) as the unit for sampling. Since each beat is allocated to a beat guard for patrolling and protection, the boundaries of a beat are well recognised by forest staff. The sampling was systematically distributed in all beats of potential tiger occupied forests (tiger reserves, revenue and reserve forests).

Thus, in effect, the entire landscape where tigers are likely to occur is sampled (beats are not stratified or randomly sampled, but all beats were sampled as large humanpower was available for sampling). In forest areas, where beat boundaries are not delineated (< 20 per cent of tiger occupied forests in the country) such as the

northeast 15-20 sq km sampling units were identified on the basis of natural boundaries (ridges, drainage, etc). The detailed methodological approach for sampling carnivore signs, ungulate encounter rates, pellet/dung counts, habitat and anthropogenic pressures are presented in the 'Field Guide' (*Jhala, Qureshi and Gopal 2005*). The target data were extremely easy to collect did not require high level of technical skills or equipment. It is crucial that the forest department staff is primarily responsible for the data collection due to the sheer magnitude of the task involved. Furthermore, the involvement of the forest department staff instills ownership and accountability of this agency which is primarily responsible for the protection and management of wildlife resources. The forest department staff was trained in the data collection protocol.

The spatial data generated was scientifically robust, amenable for statistical analysis and inference. Since several replicate surveys were taken in each beat, we were able to model tiger occupancy, detection probability of tiger signs, and relative sign density at a high spatial resolution (stratified on the basis of ecological characteristics, range or a superimposed grid of varying scale) using the approach of MacKenzie *et al* (2002), Royale and Nicholes (2003) and Royle (2004). Since the data was analysed in a GIS domain, several spatial and attribute data like human density, livestock density, road network, topographical features, forest type and cover, meteorological data, poaching pressures and landscape characteristics was used as covariates to model tiger occupancy and relative abundance in a landscape and individual forest patches. Time series analysis of the data at a larger spatial resolution is likely to have sufficient precision for monitoring spatial occupancy of tigers in association with changes in tiger prey, habitat quality and anthropogenic pressures. We have tried to address the issue of reporting inflated numbers by laying emphasis on animal signs instead of numbers. Furthermore, the resolution of the data generated will be reduced to four-five categories (high, medium, low and absent). Several corroborating variables like prey encounter rates, pellet group counts and habitat condition will help in ensuring quality data; discrepancies in reporting were relatively easy to pinpoint. There was an audit mechanism in place to scrutinise the data collection, compilation and analysis. National and international experts acted as observers while officers in-charge ensured adherence to the prescribed protocol and transparency of protocol implementation. The system, once institutionalised and implemented, will not only serve to monitor tiger populations

but will also monitor the status of other biodiversity resources of all tiger occupied landscapes, truly exemplifying the role of the tiger as a flagship. It will serve as an effective tool for decision makers, managers and conservationists alike and will help guide and plan land use policy at a landscape level.

Phase II: Spatial and attribute data

The spatial and aspatial data that are likely to influence tiger occupancy of a landscape will be used for modeling in a GIS domain. The vegetation map, terrain model, night light satellite data, drainage, transportation network, forest cover, climate data, Normalised Difference Vegetation Index, livestock abundance, human density, socio-economic parameters, etc were used for modeling habitat condition and tiger occupancy. Beat-wise vegetation sampling was done to generate broad vegetation map. IRS (LISS3 and AWiFS), LANDSAT and AVHRR satellite data was used. Part of this component was done in collaboration with Forest Survey of India and Survey of India. This modeling helped in determining current spatial distribution of tigers, potential habitats, threats to crucial linkages between occupied landscapes and conservation planning.

Digitized beat maps of Madhya-Pradesh, Andhra-Pradesh, Karnataka, and Tamil Nadu were used to spatially link the Phase I data in a Geographic Information System. In the absence of digitized beat maps, hand held Global Positioning System units were used in the remaining states for determining the beat locations. These were mapped and Phase I data of these states attached to these coordinates in a GIS.

Phase III: Estimating the population of tigers and its prey

Phase 3 of the methodology answers the question of how many tigers and ungulates are there. Teams of researchers were deployed in each landscape complex for estimating tiger density and ungulate densities within stratified sampling units. We used the double sampling approach of Pollock et al (2002) by sampling the entire landscape for occupancy and relative abundance related indices along with other covariates (human disturbance and habitat quality – Phase I & II data) and a sub sample for estimating absolute density. Indices were then calibrated against known absolute densities for extrapolation in that landscape (Conn et al. 2004, Pollock et al 2002, Skalski and Robson, 1992, Williams et al 2002).

Tiger numbers

We stratified each landscape into tiger sign abundance classes of high, medium, low and no tiger sign at the beat and larger spatial resolution (100 km^2). In each of these strata, within a landscape we estimated actual tiger density in 5 to 13 replicates of sufficient size (100-200 km^2). We primarily depended on remote camera traps to identify individual tigers based on stripe patterns, population estimates based on mark-recapture framework were done using CAPTURE, CARE 2 and Density 4 (Carbone et al 2001, Chao & Yang 2003, Efford 2007, Karanth 1995 and 1998, Karanth and Nichols 1998, 2000 and 2002, Karanth et al 2004, Pollock et al 1990, Per Wegge et al 2004 and Rextad & Burnham 1991). These densities were then extrapolated for the areas under various density classes within the landscape to arrive at a tiger population estimate. We do realise that these population estimates have high variances, but since these estimates are not be used for monitoring trends (which is proposed to be done through the site occupancy and relative abundance data), they should suffice the need for converting a relevant ecological index to a more comprehensible concept of numbers. The tiger population reported by us throughout the report are tigers above 1.5 years of age. We did not consider captures of cubs and juveniles for population and density estimation as this age group is under represented in camera trap studies.

Tiger prey

Phase I of the protocol would be reporting encounter rates on line transects (*Buckland* et al *1993*); these would suffice for monitoring trends in ungulate population and site-specific occupancies as the same transects would be sampled during subsequent surveys. To convert encounter rates to density, an estimate of the effective strip width of these transects would be essential. The effective strip width of a transect primarily depends on the visibility (vegetation and terrain type), ability to detect ungulates by different observers and animal behaviour (*Buckland* et al *1993*). We modeled effective strip widths in different vegetation types of a landscape using double sampling technique (Pollock et al 2002), wherein a team of researchers sampled the beat transects in each habitat type using distance sampling technique (Buckland et al. 1993). Pellet group counts on transects would serve as an index to the presence and relative abundance of ungulates.

The entire process from conceptualization to implementation (Phase I to Phase III) was transparent and open to scrutiny by independent National and International

Peers. A public debate was invited over email by the Tiger Task Force on the methodology which was also critiqued by International peers selected by the IUCN and the MoEF (Appendix 1.2). Independent National and International observers participated in field data collection and compilation. This process of review greatly refined the methodology and data collection procedure.

Phase IV: Intensive monitoring of source populations

We propose that source populations of tigers (tigers in tiger reserves and protected areas) in each tiger landscape complex be monitored intensively. We propose the following methodology for this monitoring:

Photo registration of tigers: Pictures of individual tigers obtained by camera traps or by regular cameras should be maintained in the form of a photo identity album. Records should be kept on the location, condition (breeding status, injury, etc) and associated tigers whenever a tiger is sighted. This will provide crude data on ranging patterns, demography and mortality.

Tiger pugmark and other signs: Regular monitoring of tiger signs (pugmark tracings, plaster casts, etc) should be undertaken in every beat at a weekly interval with monthly compilation of data. With experience and exposure to the resident tigers and their pugmarks, the forest staff may be able to identify individual tigers from their track set characteristics (Panwar 1979, Smith et al 1999 and Sharma 2001). Sign surveys and individual tiger monitoring should become a regular task for every guard as was the practice some years ago and is currently practised in some tiger reserves. The monthly data should be mapped and maintained to analyse trends.

Monitoring by telemetry in select areas: Use modern technology of VHF, GPS and satellite telemetry to study and monitor aspects of demography, metapopulation dynamics (dispersal, ranging patterns), mortality, predation ecology and behaviour. In all source populations, tiger abundance and density should be estimated using camera traps, digital images of pugmarks and/or DNA profile from non-invasive methods biannually.

It was not possible to conduct a beat wise survey in all the forests of the North Eastern Hills Landscape and in the Sundarban Landscape. For the North Eastern Hills surveys were conducted in expedition mode based on supervised knowledge of tiger presence. This approach permitted us to use the data for mapping tiger

occupancy but it was not possible to extrapolate tiger densities for the landscape from this data.

Since Sunderbans is a unique and hostile tiger habitat we have evolved a separate protocol for evaluating tiger, prey, and habitat status for the Sunderban landscape (Appendix 1.3). Population estimates and detailed status report would be provided later as per the protocol. Herein we provide data on tiger distribution and occupancy of this landscape.

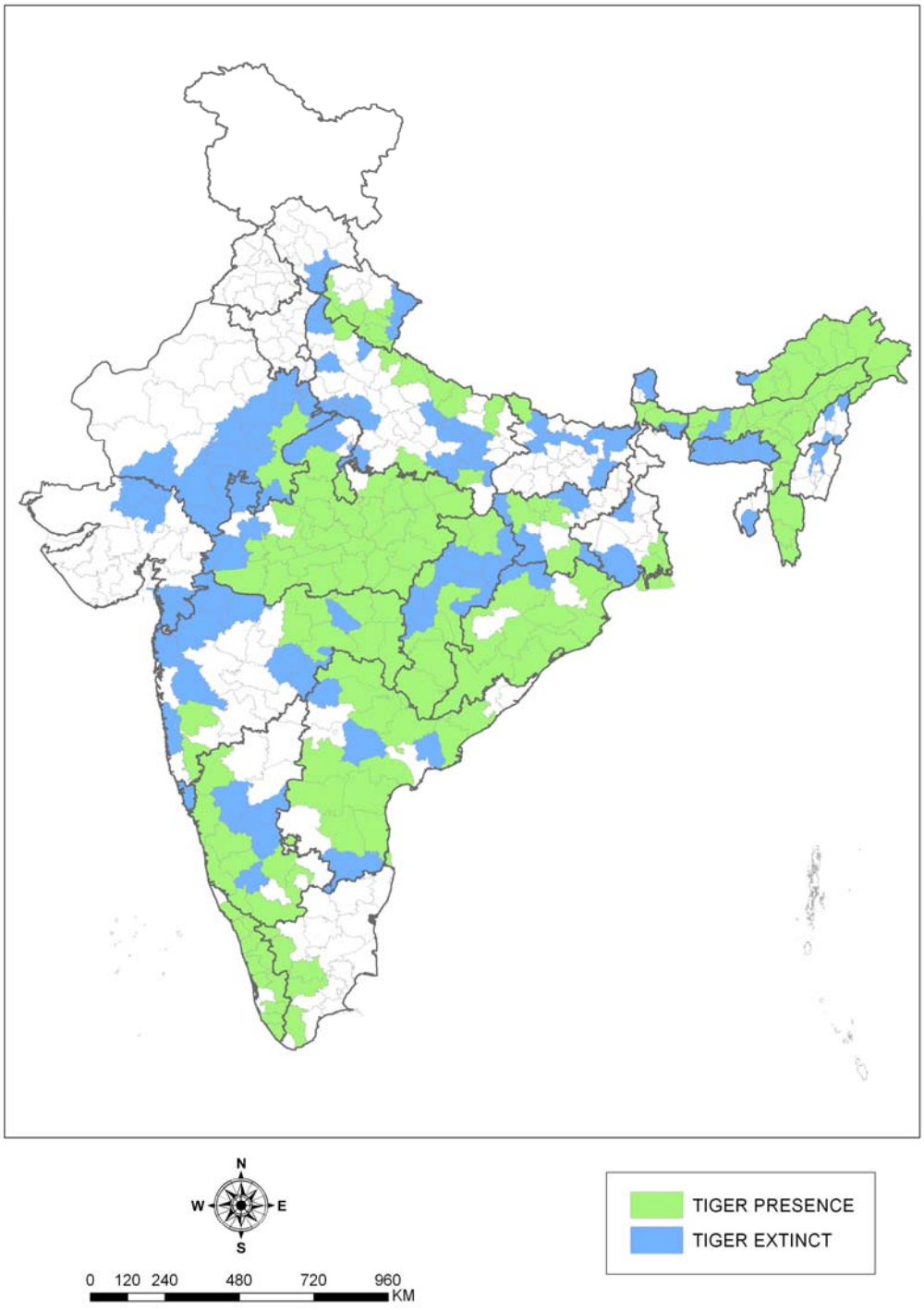
Modeling Tiger Occupancy and Densities

The historical tiger distribution map was constructed for the past 150 years (before the commencement of Project Tiger) through a literature survey. A total of 140 records where mention of the tiger could be attributed to a geographical location (Appendix 1.4) were used for developing this map (Figure 1.1). Geographical locations mentioned in the literature were mapped to current districts in a GIS with a link to the referenced report.

Data was compiled on tiger presence reported at the tehsil level for the past 5-6 years (1999-2004) through a questionnaire addressed to the Chief Wildlife Wardens of all tiger-states by the Project Tiger Directorate. Though several states had data on tiger numbers in some tehsils (especially in protected areas), only the reported presence of tiger(s) in the past six years were used to score a tehsil as "occupied by tigers" or not. Since tigers were unlikely to live outside of forests, forest cover map was superimposed on the tehsils occupied by tigers, and non forested areas were eliminated from further analysis. The tiger occupied tehsils were further divided into three groups, tehsils that had reported tigers (a) only for 1 year, (b) for 2-3 years and (c) for more than 3 years between 1999-2004.

To compare the historical tiger distribution with the current tiger distribution, the information on current tiger distribution at the tehsil resolution was converted to the coarser scale of districts. The districts in which tigers have become locally extinct were marked (Figure 1.1). Tigers seem to have been preferentially exterminated from the Western and Northern population limits. The Western districts have dry thorn/deciduous forests with low productivity, while the Gangetic Plains have been heavily exploited for intensive agriculture.

Figure 1.1 Districts with tiger occupied forests and districts where tigers have become locally extinct within the past 100 years



Relationships between verified tiger occupied forested beats, unoccupied beats and Phase-I data, and Phase-II data were developed to understand the underlying factors that make a habitat patch suitable for tigers. Several factors like prey encounter rates, wildlife dung index, canopy cover, anthropogenic disturbance indices life signs of lopping wood cutting, grass cutting, livestock trails, people seen on transects and livestock dung were significantly different between areas occupied by tigers and unoccupied forests. Phase –II information like distance from roads, forest patch size, distance from night lights, and core area size attributes were significantly different between tiger occupied forests and unoccupied patches. This information was then used in a logistic regression framework to validate reported tiger occupancy. Grids with deviations were highlighted for further field verification.

Tiger densities (tigers >1.5 years) obtained from camera traps were used to develop predictive models for tiger density estimation in tiger occupied forests. Principle component analysis was used to extract parsimonious, independent information from Phase-I and II data. Tiger densities (as dependent variable) were modeled using Multiple Linear Regression with the Principle Component scores as the independent variables. The principle components that significantly contributed to explaining variation in tiger densities were primarily those containing information on tiger sign indices, prey indices, anthropogenic disturbances and wilderness values.

Tiger occupied landscapes and habitat potential

Entire India was divided into six landscape complexes (Figure 1.2) based on current tiger occupancy and potential for connectivity. A landscape complex is largely a unit comprised of several ecological landscapes, which are or were interconnected in the recent past and have a potential for exchanging genetic material between tiger populations inhabiting the complex. The six landscape complexes were (1) Shivaliks and the Gangetic Plain, (2) Central Indian Highlands, (3) Eastern Ghats, (4) Western Ghats and (5) Brahmaputra Flood Plains and North Eastern Hills and (6) the Sundarbans (Figure 1.2).

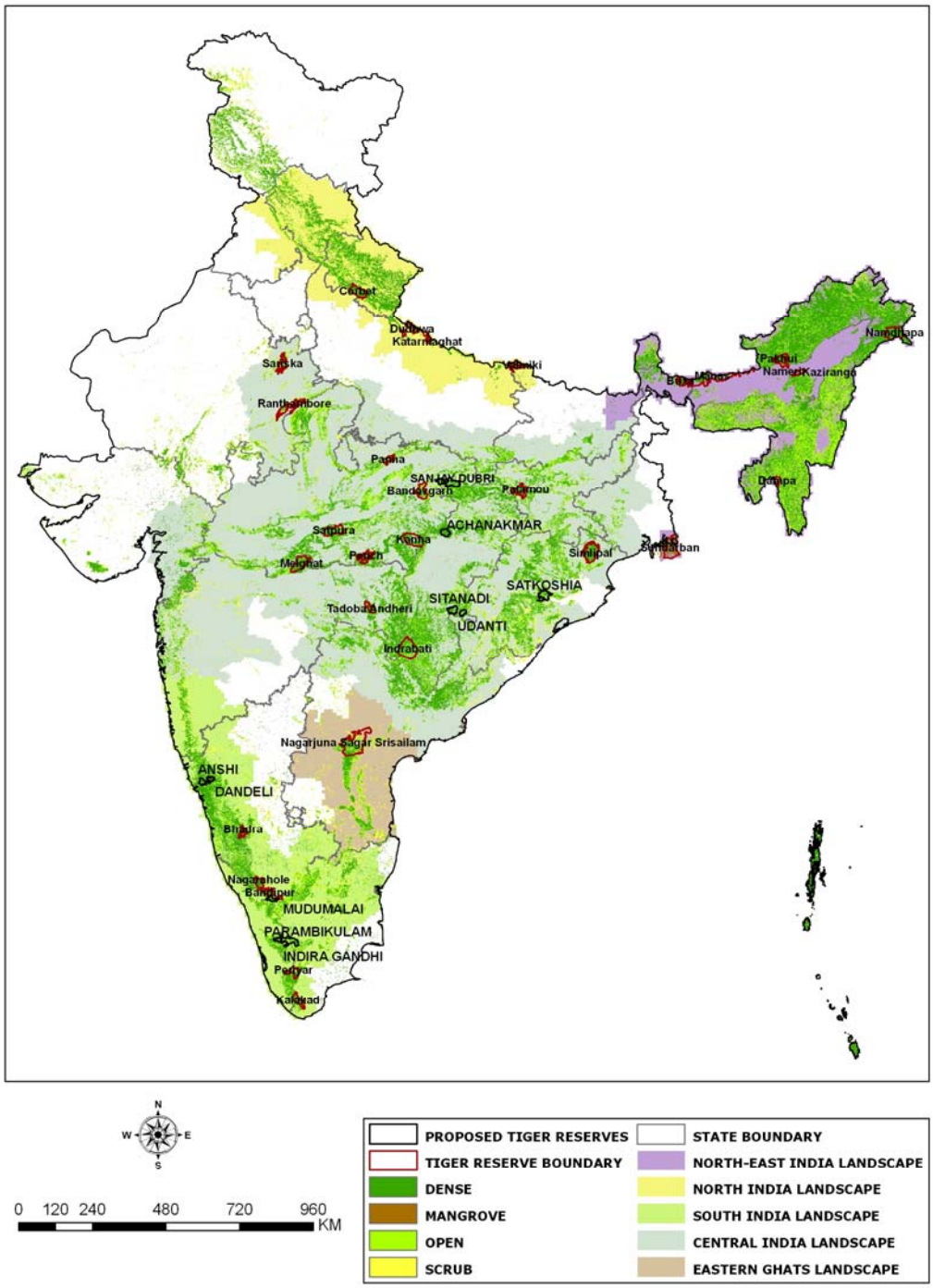
The overall spatial occupancy of tigers in a forest patch is based on the premise that small tiger population can persists for long periods given sufficient prey and adequate protection (Karanth & Stith 1999, Mishra et al. 1987, Panwar 1987, Wikramanayake et al. 1999). A 10km x 10km grid was then superimposed on all

forested habitats. Data from each grid on 22 different variables (Appendix 1.5) were extracted of which 14 were found to be significantly contributing to the tiger occupancy model. Occupancy of 10 km x 10 km forest patches by tigers was modeled, using variables defining landscape characteristics (patch size, core size, shape and connectivity of forests), climatological data and variables depicting human influences within each landscape complex (Appendix 1.6). The binary logistic model was used to model the potential of tiger habitat within each landscape complex. The model fit was tested using Receiver Operator Characteristic (ROC) Curves. The area under ROC curves ranged between 98 to 99 percent for all landscape models indicating a good fit.

The concept of the conservation potential of a landscape was adopted from Opdam et al. 2003, Wikramanayake et al. 1999, Chundawat et al. 1999, Dinerstein et al. 1999, Johnsingh et al. 2004, Narain et al. 2005, and Smith et al. 1998. Demographic viability and population persistence information from Kenney et al. 1995, Karanth and Stith 1999, Sunquist et al. 1999, Seidensticker et al. 1999, Smith et al. 1999, Wikramanayake et al. 1999, Smirnov 1999, Miquelle et al 1999 a & b, Rabinowitz 1999, Kumar & Wright 1999, and Carbone & Gittleman 2002, were used.

The probability of tiger occupancy in forested areas of each landscape complex (based on the logistic model) was used to map habitat suitability for tigers. The variables that explained probability of tiger occupancy were level of forest fragmentation, size of forested patch, prey presence, and anthropogenic pressures.

Figure 1.2 Tiger occupied landscapes, Potential Tiger habitat and Tiger Reserves



Shivalik-Gangetic Flood Plains

Principal Investigators
Qamar Qureshi, Rajesh Gopal, Y.V. Jhala

Research Team
Agni Mitra, Aishwarya Maheshwari, Ajay Singh Nagpure, Ashem Rahul Singh, Ashis K. Gharai, Dr. Amit Kotia, Dr. Durg Singh Rajpurohit, Dr. Hem Singh Gehlot, Dr. Kamal Singh Negi, Janmejay Sethy, John C.E., Jyoti Singh, Jyotirmay Jena, Kunwar Sain, Manish Bhardwaj, Mohit Badyal, Navonil Das, Parobita Basu, Peer Muzamil Shams, Prudhvi Raj G. and Rajni Sharma.

2. Shivaliks – Gangetic Flood Plain

Also referred to as the Terai Arc Landscape, this landscape complex stretches from a little west of the Yamuna River through southern Nepal to forests of Bhutan in the east. It stretches across five Indian states with Valmiki Tiger Reserve in Bihar marking its eastern boundary within India. Since key connectivities of this landscape are in Nepal and Bhutan, an effective conservation strategy will be possible only with trans-boundary co-operation.

The Shivalik hills, the adjoining bhabar areas and terai plains are in the form of narrow strips running parallel to the main Himalayas, and there is a continuum of forests and wildlife populations across these zones. The Shivaliks, which run along the base of the Himalaya, are an uplifted ridge system formed from the debris brought down from the main Himalaya. The coarse material brought down by the Himalayan rivers is deposited along the foothills to form a pebbly-bouldery layer referred to as the *bhabar*, while the finer sediments or clay are carried further to form the *terai*. The bhabar is characterized by low water table, as the deposits are bouldery and porous, and all but the major rivers and streams disappear into the ground on emerging from the hills. The streams reappear along the terai, which has fine alluvial soil resulting in high water table. Altitude within the Shivaliks ranges from 750 to 1400 m. The bhabar zone exhibits an undulating topography with an altitude ranging between 300 and 400 m. Terai is relatively flat with a surface gradient, which is slightly higher near Shivaliks (Johnsingh et. al 2004).

According to the recent classification proposed by Wikramanayake et al. (1999, 2002) that takes into consideration both biogeography and conservation values, the landscape corresponds to three ecoregions – (i) Upper Gangetic Plains moist deciduous forest, (ii) Terai-Duar savanna and grasslands and (iii) Himalayan sub-tropical broadleaf forest. Of these, the Terai-Duar savanna is listed among the 200 globally important areas, due to its intact large mammal assemblage, even though it scores low on plant species richness and endemism.

The vegetation in the area comprises of a mosaic of dry and moist deciduous forests, scrub savannah and productive alluvial grasslands, which harbour a rich fauna including several endemic and globally endangered species. Prominent among such species are tiger, Asian elephant, one-horned rhinoceros and swamp deer. Other

endemic and obligate species found in this Landscape are hog deer (*Axis porcinus*), hispid hare (*Caprolagus hispidus*), Bengal florican (Houbaropsis bengalensis) and swamp francolin (*Francolinus gularis*). Many of these species, surviving in small populations, have their last home in this Landscape (Johnsingh et al. 2004).

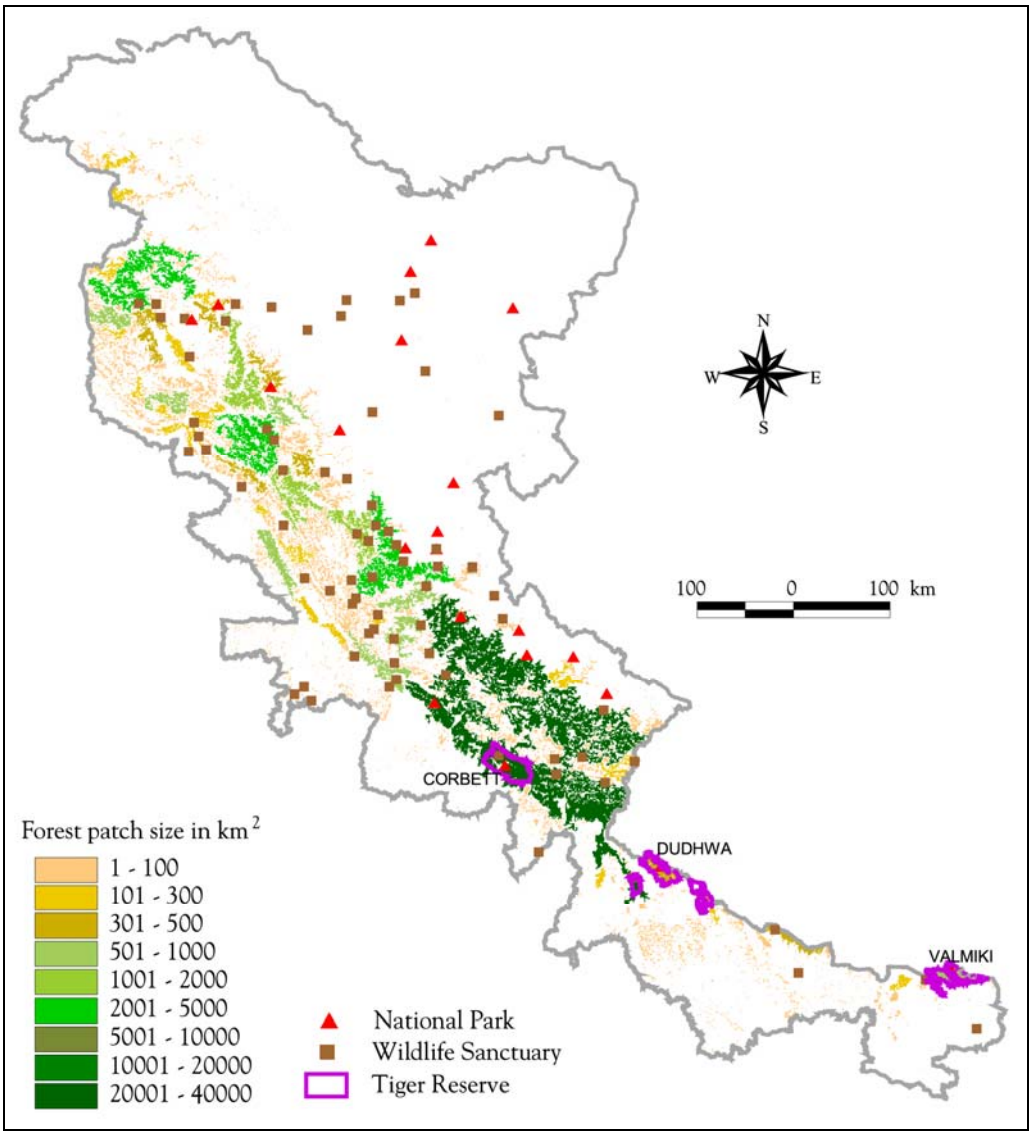
For tigers, the landscape holds some promise as the tiger inhabited forests in the region are still somewhat connected (Figure 2.1). If key corridors can be maintained and a few more restored, the landscape has the potential to become one of the strongholds for tigers.

Total geographic area : 422675 km^2.
Political units in India : Parts of Jammu & Kashmir, Punjab, Haryana, Himachal Pradesh, Uttranchal, Uttar Pradesh and Bihar.
Average population density : 239 km^{-2} (Figure 9)
Total protected area : 4492 km^2 (7.1% of the total land area)
Total forested area : 93094 km^2.
Major biogeographic zones: 1. Himalaya (West Himalaya (2B)), 2. Semi Arid Punjab Plains (4A) and 3. Gangetic Plains (Upper Gangetic Plains (7A) & Lower Gangetic Plains(7B))

Table 2.1 Landscape characteristics of the Shivaliks and the Gangetic Plain

Parameters	**Value**
Number of forest patches	5660
Forest patch density per 1000 km^2	3.5
Mean forest patch area (km^2)	11.48
Mean forest perimeter to area ratio	33.8
Total forest core area (km^2)	3337
Number of disjunct forest core areas	233
Mean forest core area (km^2)	0.59
Median forest core area (km^2)	9
Total forest core area in forest patches >1000 km^2	2796

Figure 2.1 Distribution of Protected Areas and various size of forest patches in the Shivalik – Gangetic Plain landscape complex.



Tiger Status:

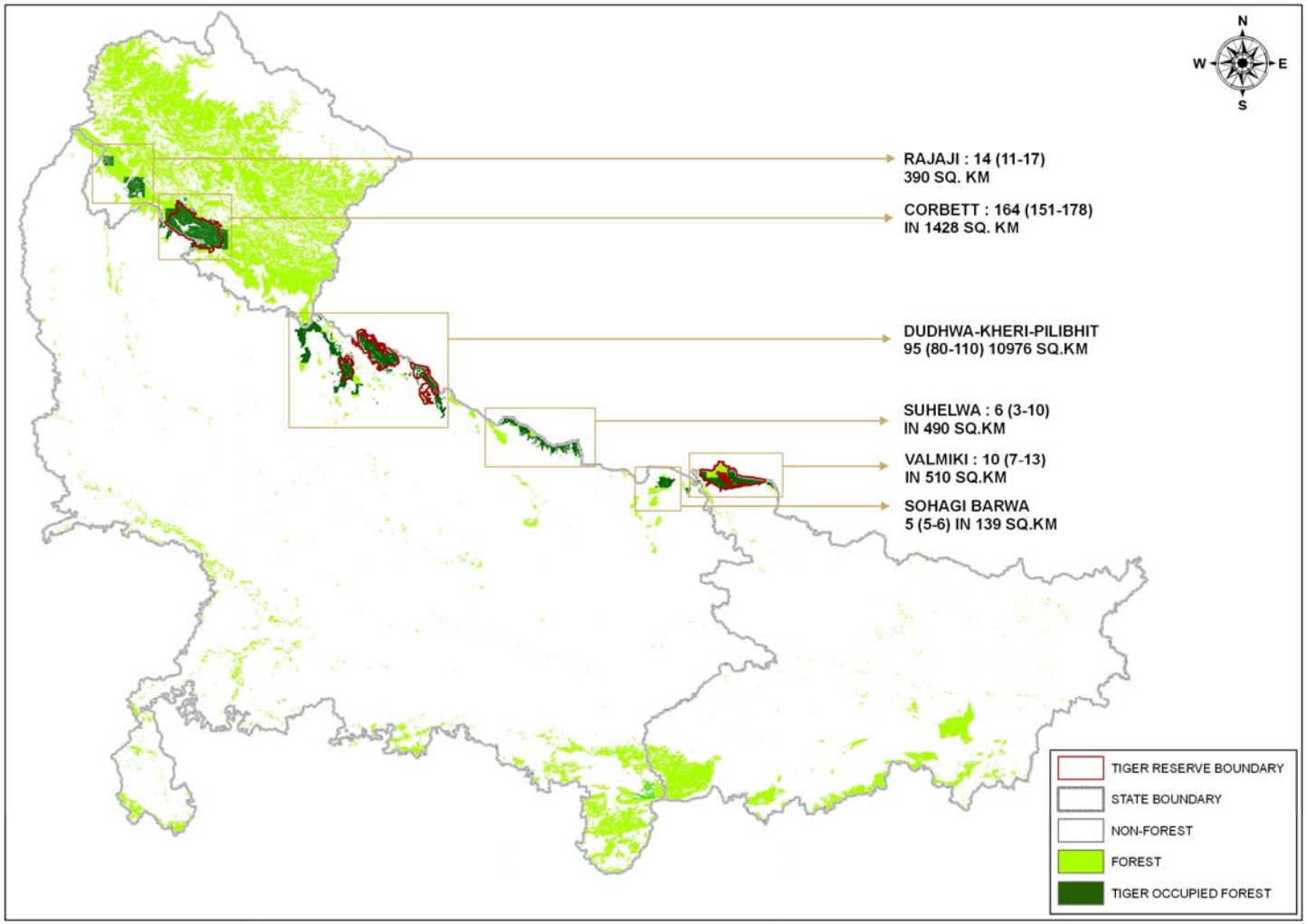
The tiger has become locally extinct in 29% of the districts of this landscape where it was historically recorded. Currently the tiger occupies 5080 km^2 of forested habitats with an estimated population size of 297 (259 to 335) in six separate populations (Figure 2.2).

Tiger habitat in this landscape exists in two contiguous 'relatively' large patches (Figure 2.1), which consist of :

(a) Kalesar in Haryana to Kishanpur in Uttar Pradesh covering areas of Rajaji National Park and Corbett Tiger Reserve (21,500 km^2). This landscape unit is most promising for long term tiger conservation in this landscape complex.

(b) Dudhwa Tiger Reserve and Sohagi Barwa in Uttar Pradesh and Valmiki Tiger Reserve in Bihar (2600 km^2) are connected through the Shivalik forests (Churia hills) of Nepal. These forests in Nepal have protected areas like Sukla Phanta, Bardia, and Chitwan National Parks. This landcape unit has high tiger conservation potential through transboundary conservation efforts and International cooperation and commitment. The tiger habitats within India by themselves have limited long term value, unless managed as a holistic landscape including connectivities and source populations in Nepal.

Figure 2.2 **Tiger occupied forests, individual populations, their extent and habitat linkages within the Shivalik-Gangatic Flood plain landscape**



Landscape Occupancy of Co-predators and prey in Shivalik-Gangetic Flood Plains

Leopard occupancy was detected in 7,171 km^2 (Figure 2.3), Wild Dog occupancy was detected in 513 km^2 (Figure 2.4), Sloth bear occupancy was detected in 4,515 km^2 (Figure 2.5), Chital occupancy was detected in 8,274 km^2 (Figure 2.6), Sambar occupancy was detected in 5,718 km^2 (Figure 2.7), Wild Pig occupancy was detected in 11,545 km^2 (Figure 2.8), Nilgai occupancy was detected in 9,291 km^2 (Figure 2.9) and Elephant occupancy was detected in 579 km^2.

Figure 2.3 **Leopard occupied forests, individual populations, their extents and habitat connectivity in Shivalik Gangetic Lanscape Complex**

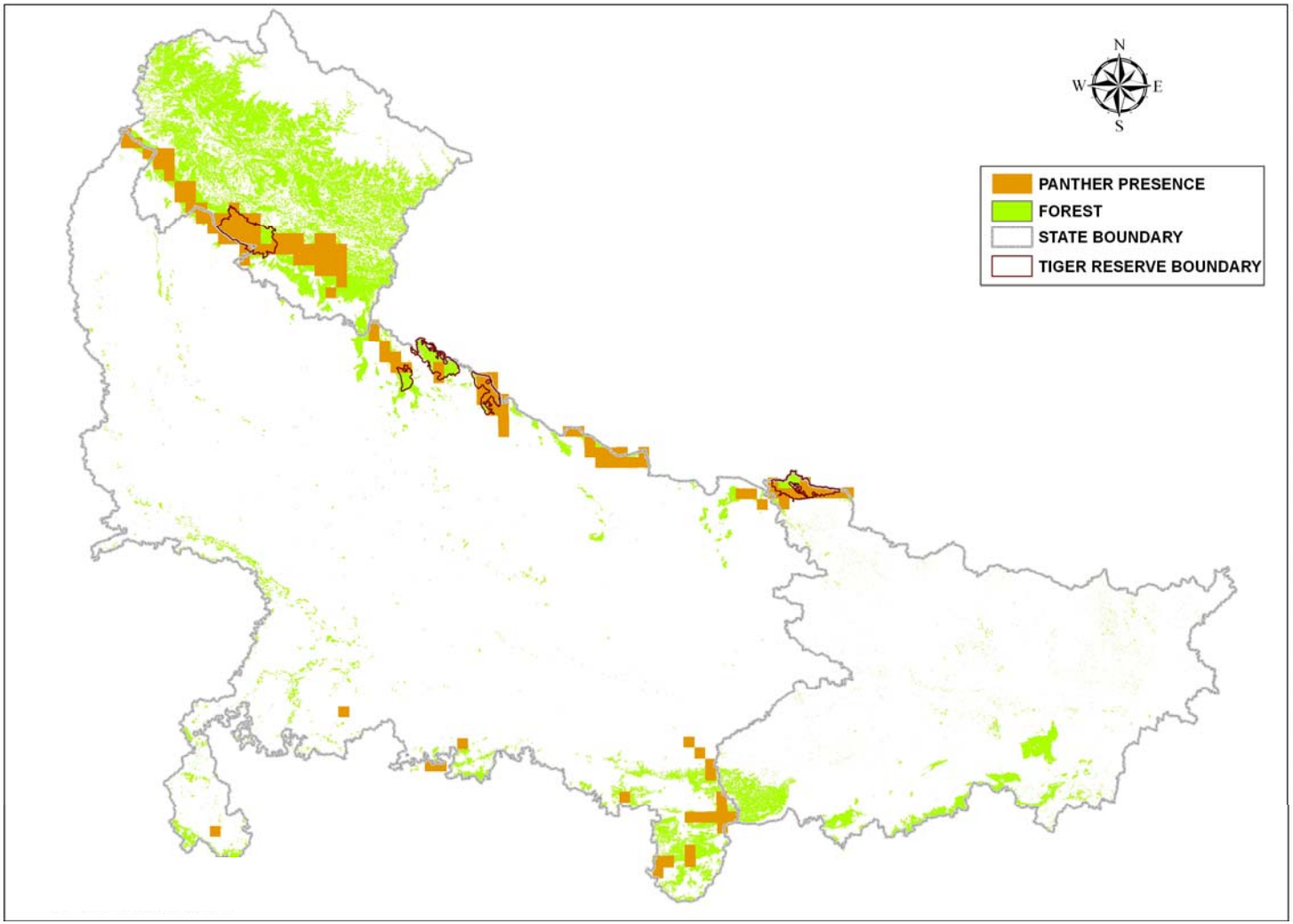


Figure 2.4 **Wild Dog occupied forest, individual populations, their extents and habitat connectivity in Shivalik Gangetic Lanscape Complex**

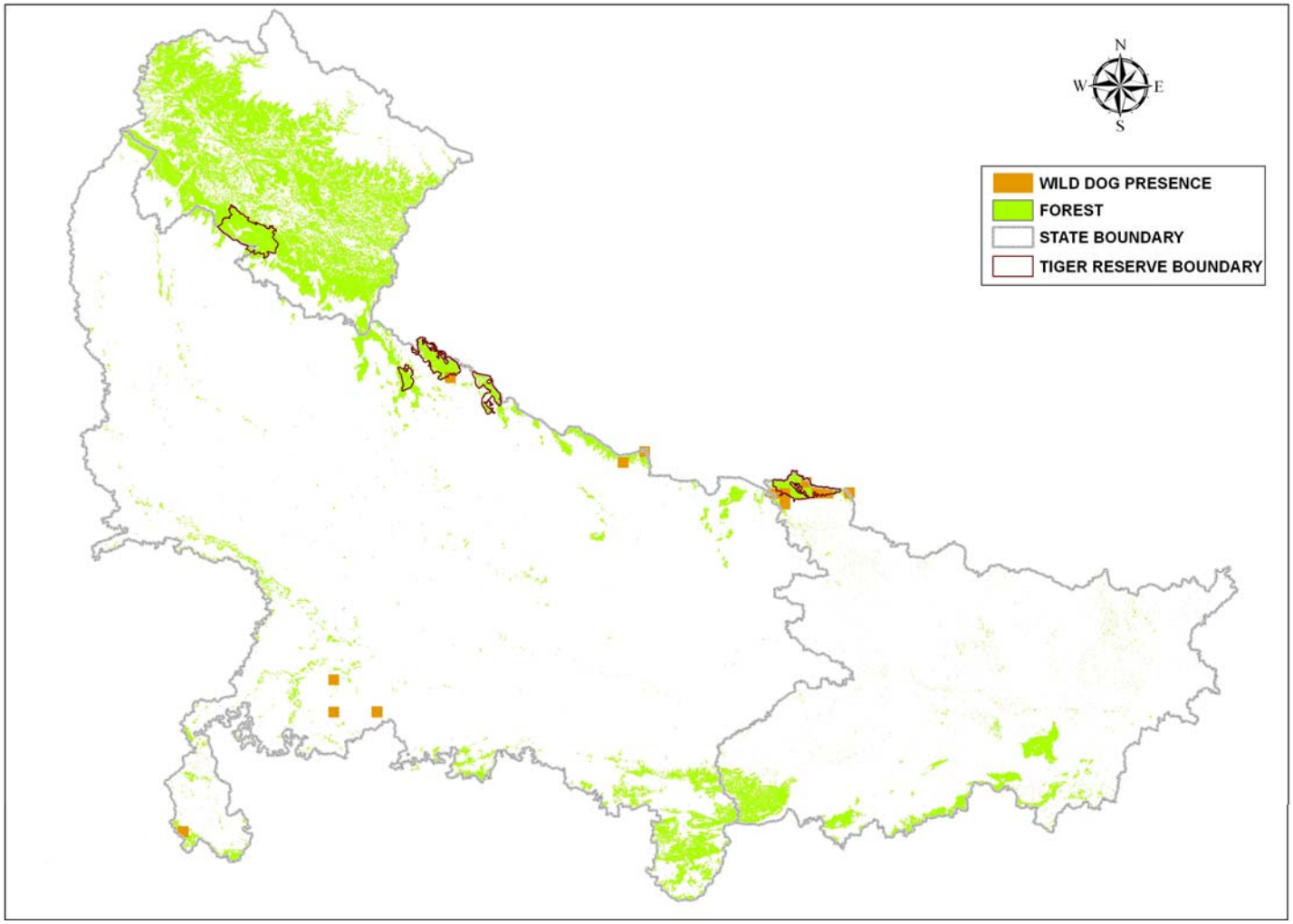


Figure 2.5 **Sloth Bear occupied forest, individual populations, their extents and habitat connectivity in Shivalik Gangetic Lanscape Complex**

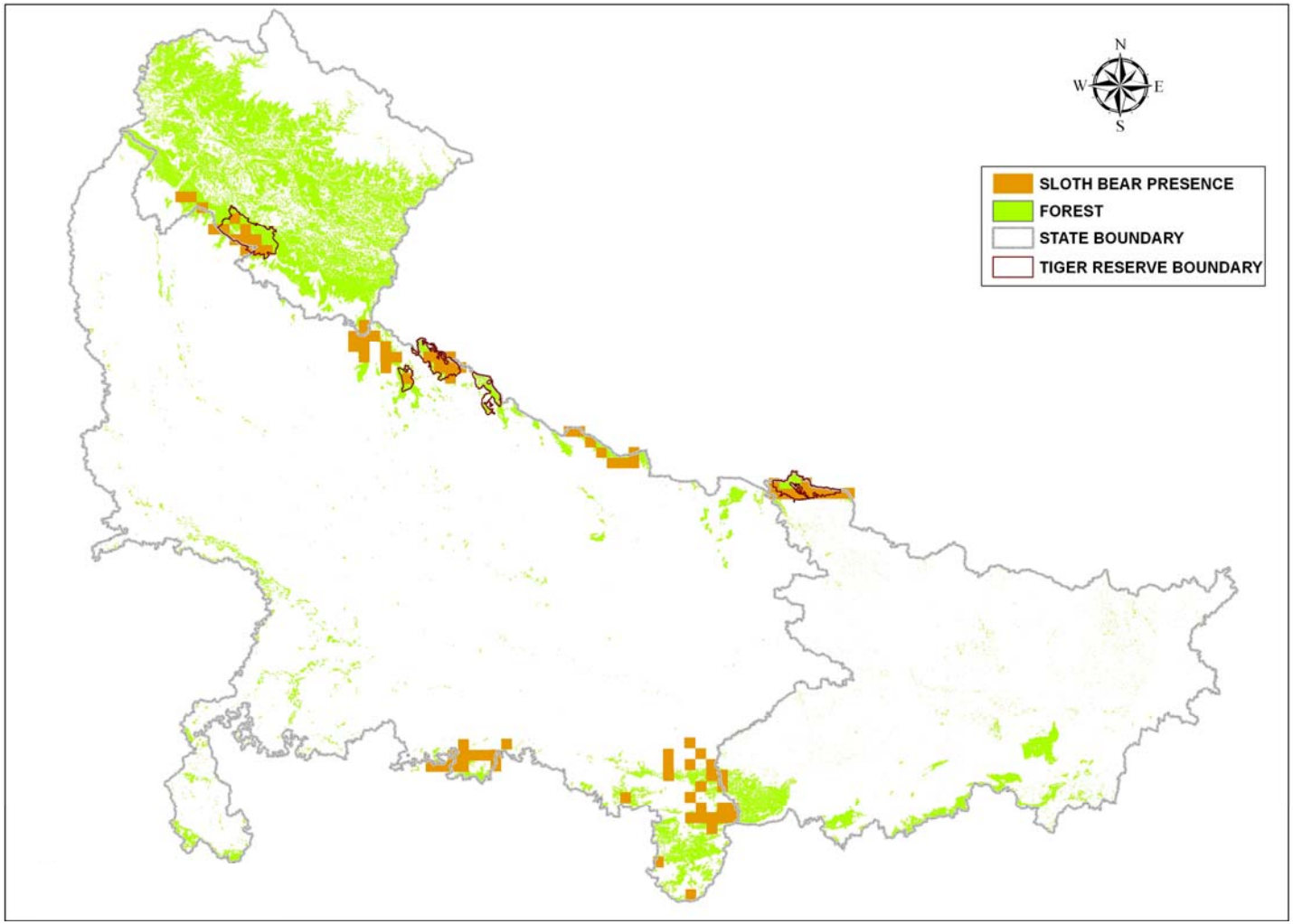


Figure 2.6 **Chital occupied forest, individual populations, their extents and habitat connectivity in Shivalik Gangetic Lanscape Complex**

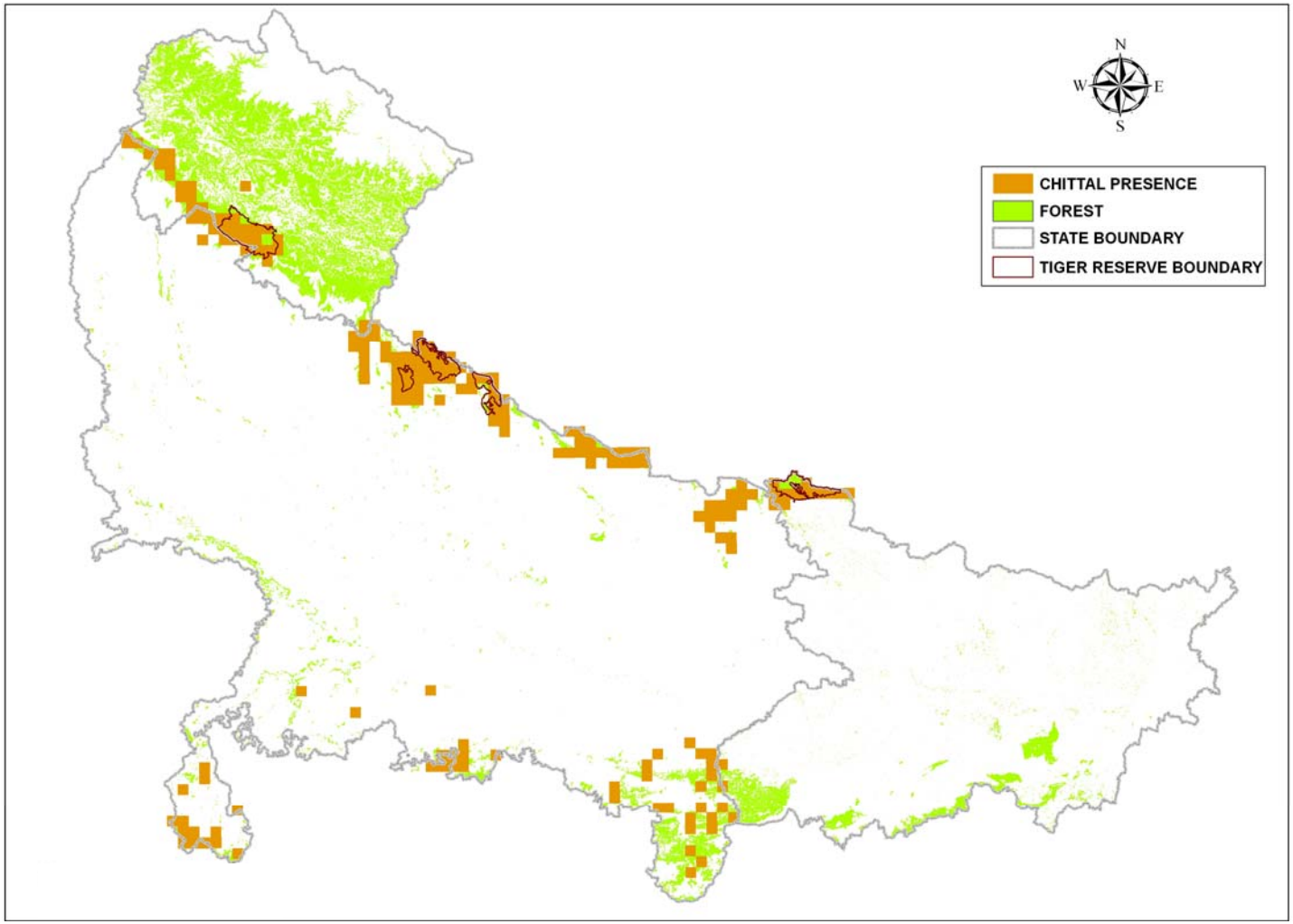


Figure 2.7 **Sambar occupied forest, individual populations, their extents and habitat connectivity in Shivalik Gangetic Lanscape Complex**

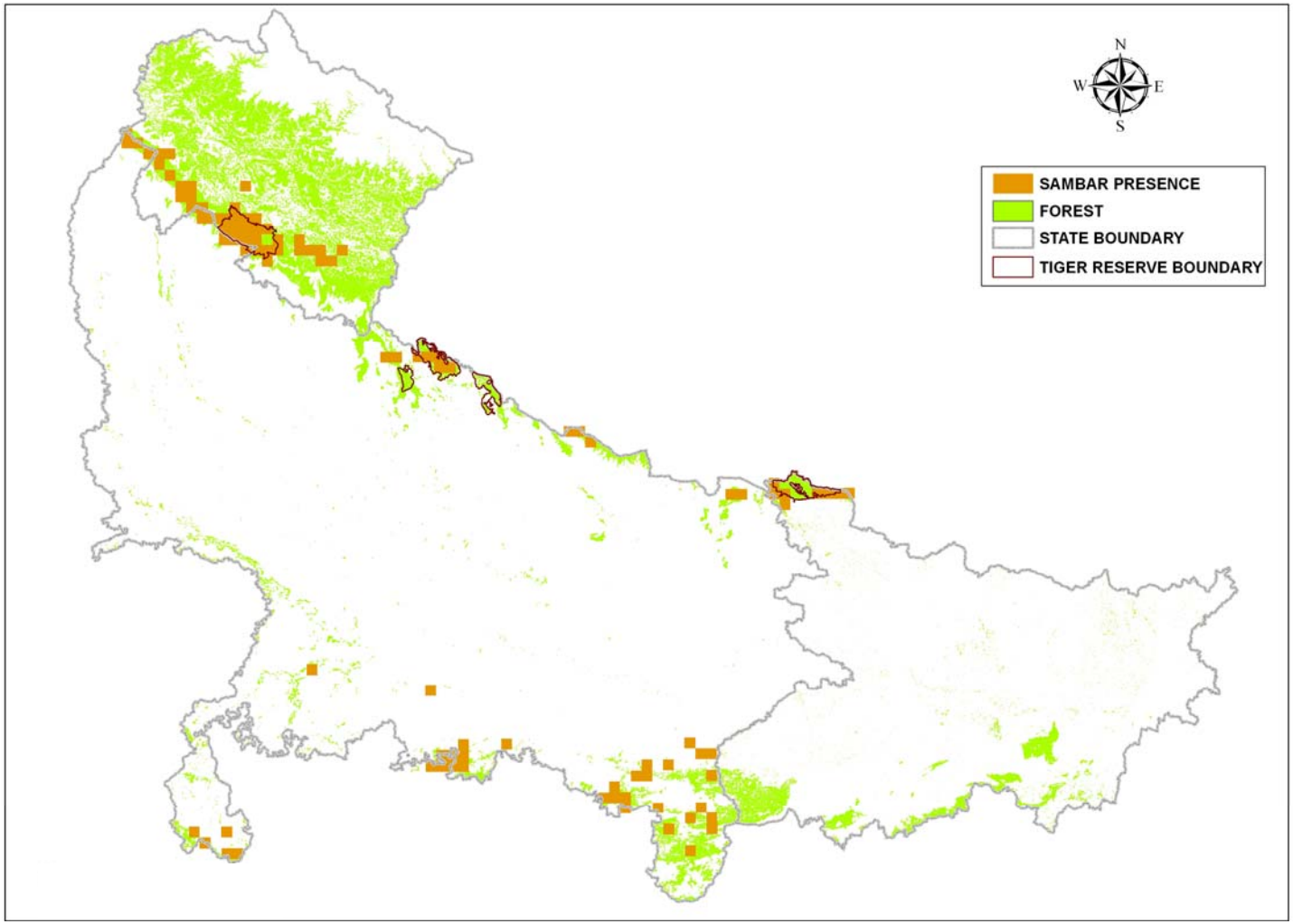


Figure 2.8 **Wild Pig occupied forest, individual populations, their extents and habitat connectivity in Shivalik Gangetic Lanscape Complex**

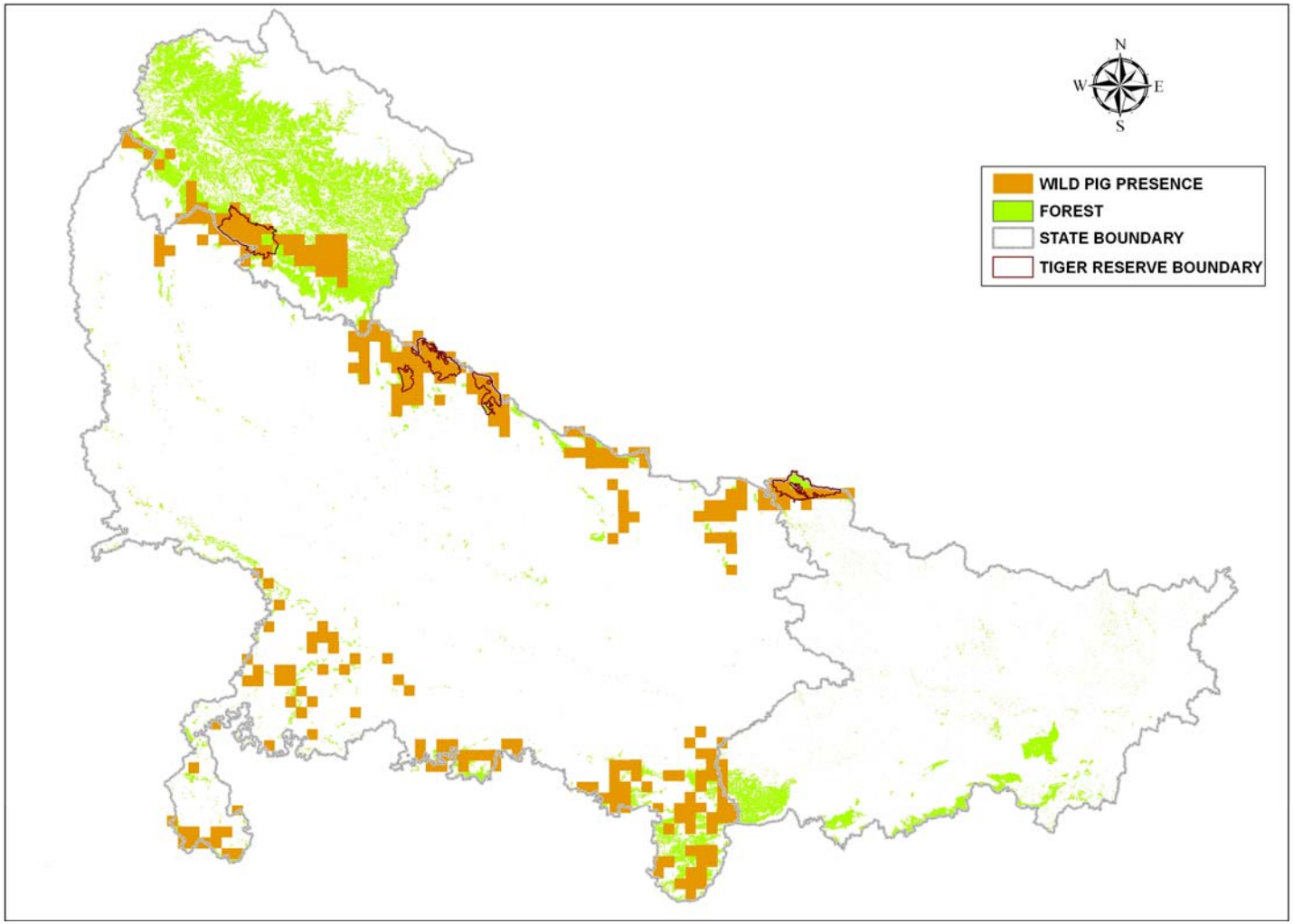
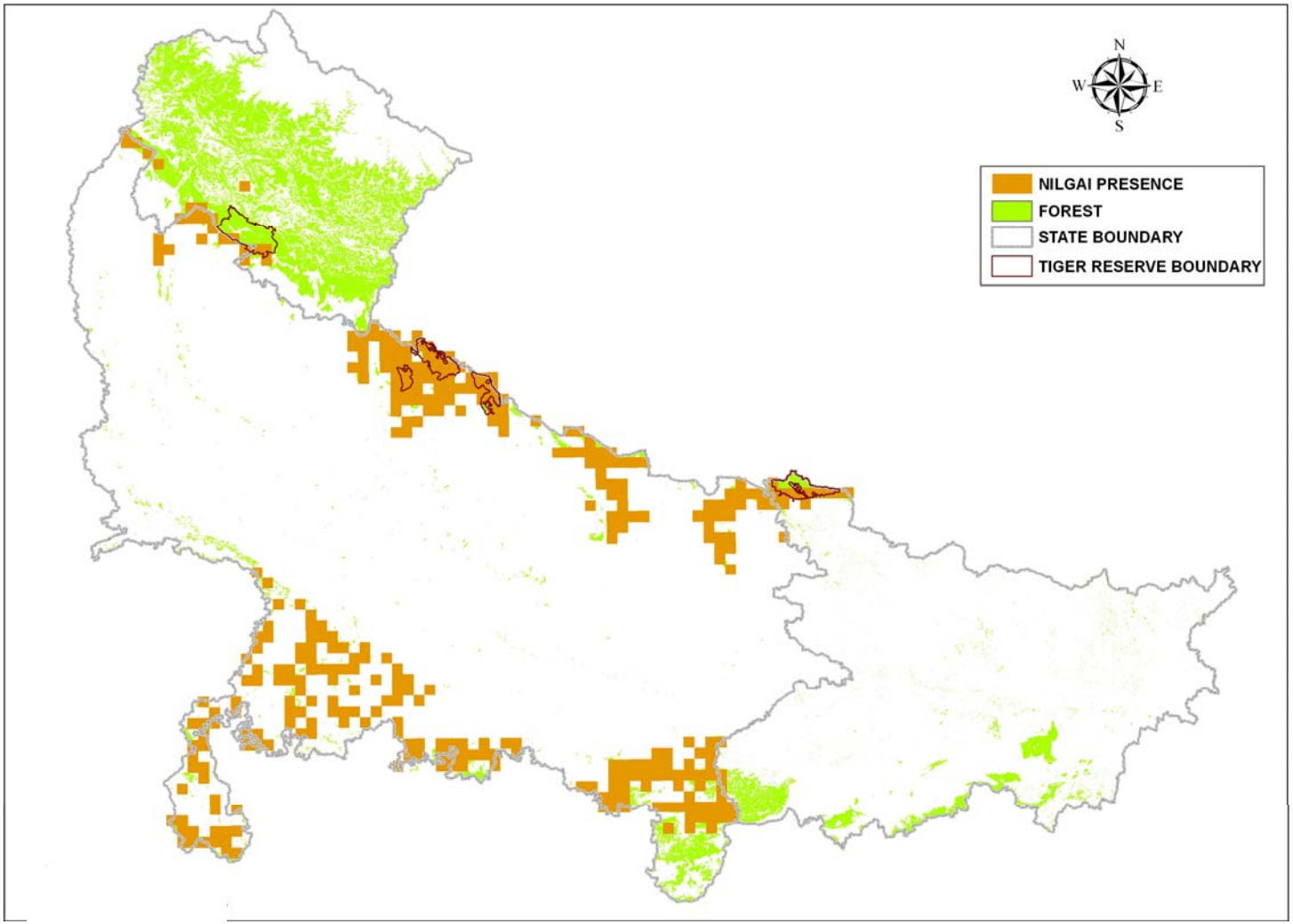


Figure 2.9 **Nilgai occupied forest, individual populations, their extents and habitat connectivity in Shivalik Gangetic Lanscape Complex**



UTTARAKHAND

The forest cover of Uttarakhand is 24,536 km² , comprising 46% of the geographic area of the State. Forests of Tiger Conservation Priority I &II were 13,000 km² in Uttrakhand. Currently tigers occupy 1901 km² of these forests having tiger population of 178 (161 to 195). Leopard occupancy 3,583 Km², Bear occupancy (sloth and black bear) was 953 km².

Amongst prey species occupancy of Sambar was 2,756 km², Chital 2,161 Km², Wild pig 3,214 Km², and Nilgai 422 Km²,

Uttarakhand has a single major population of tigers constituted by the Corbett Tiger Reserve and its surrounding forests of Lansdowne, Kashipur, West part of Haldwani, North western Nainital and lower elevation area of Ranikhet comprising a occupied area of 1500 km².

Another smaller population (14, 11 to 17) is recorded in Rajaji National Park covering an occupied area of 390 km². Sporadic occurrences of tigers are reported in the forests of Tehri upto an elevation of 3000m.

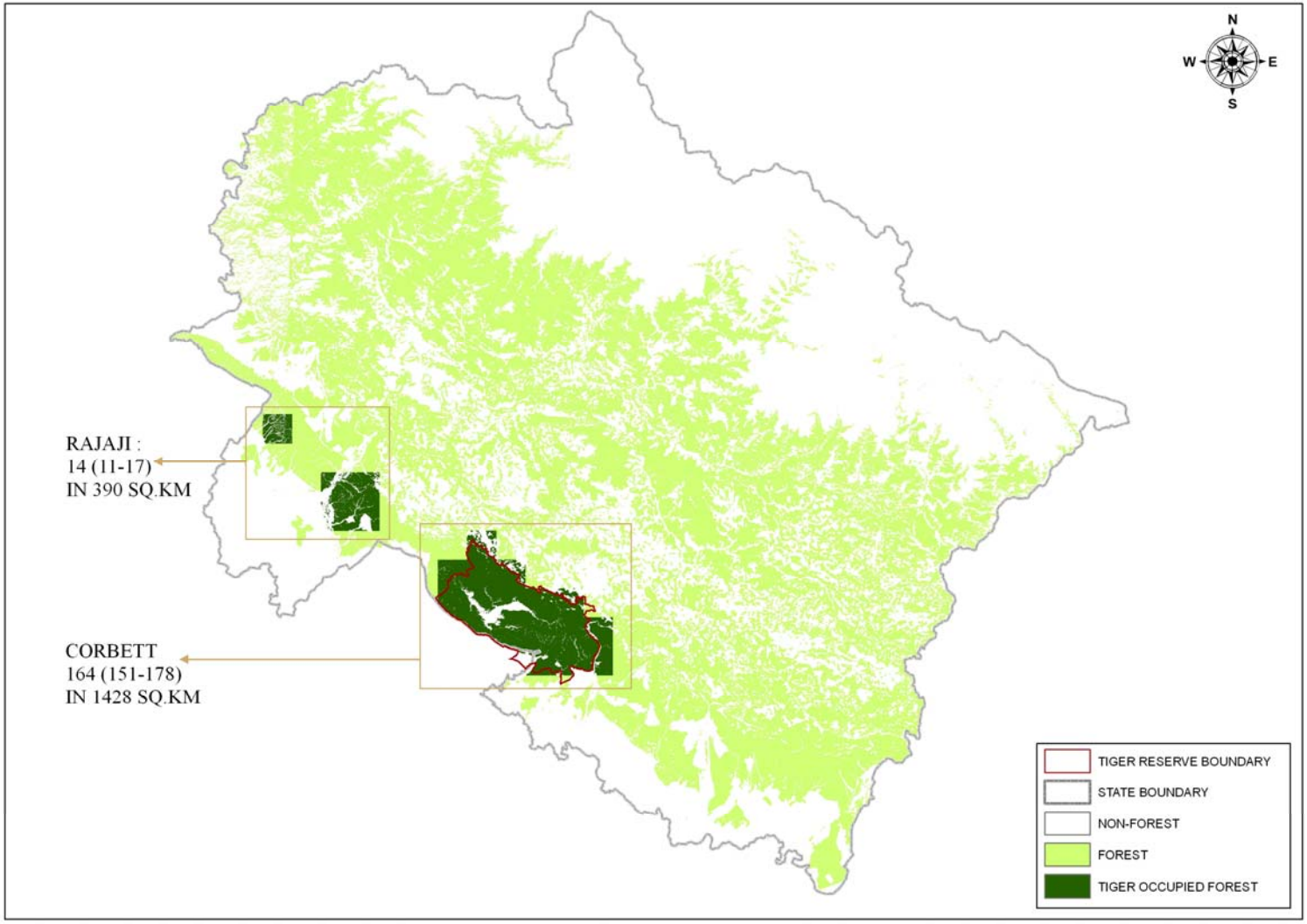
Conservation Recommendations

(1) The source population of Corbett Tiger Reserve having a tiger occupancy in 1,524 km² with an estimated population of 164 (151-178) tigers sustains all reported tiger presence throughout the state and North western forests of Uttar Pradesh. It is currently the only demographically viable population in Northwestern India and responsible for maintaining genetic connectivity throughout the Northwestern tiger populations of the Terai Arc landscape. Since this population of tigers has the best chances of long term survival, it is essential to create an inviolate space of over a 1000 km² as the core area of Corbett Tiger Reserve. The well being and source value of this core can only be achieved by active management of the buffers in Landsdowne, Haldwani, Ramnagar, Terai East West and Central forest divisions. These buffers not only ensure and enhance the source value of the core, but along with Haridwar forests provide habitat corridors for dispersing tigers to maintain demographic viability of Rajaji population and genetic linkages with the Pilibhit population.

(2) The smaller tiger population of Rajaji National Park having an occupancy of 390 km² with an estimated population of 14 (11-17) tigers is sustained by dispersing tigers from Cobett Tiger Reserve. Through, with recent management interventions of translocating resident Gujjar families from Chilla and Dhaulkhand these areas have the potential of sustaining small breeding populations of tigers. If such small breeding populations in mini cores are fostered in Rajaji by good management practices and protection there is a possibility of repopulating the Shivalik Forest Division (UP) with dispersing tigers from Rajaji. Forest contiguity exists from Corbett to Kalesar in Haryana and onwards in Southern Himachal Pradesh. Dispersing tigers occasionally traverse this intervening forests. Breeding tiger populations in Rajaji are essential to ensure tiger occupancy of these forests.

(3) For enhancing tiger dispersal from Corbett towards the west the following linkages in the corridors are bottle necks for tiger movement and need conservation management inputs. : a) Landsdowne: though there is sufficient cover but the area has low tiger prey densities due to human pressure, b) Ganga – Chilla Motichur: due to the development of the townships of Haridwar and Rishikesh, development along the the highway connecting the two townships and the dependency of the increasing human population on forest resources is responsible for making the area impermeable to wildlife. c) Yamuna River corridor- is crucial for maintaining connectivity with Kalesar. Major issues in this corridor are colonies of laborers setteled along Yamuna river for boulder mining. Towards the East tiger dispersal would be facilitated by management of the a) Boar river b) Nehal-Bhakra,d) Gola River, e) Kilpur-Khatima-Surai corridors. All of the above river corridors have intense bolder mining activity and associated settlements of labor colonies making them barriers to wildlife movements.

Figure 2.10 Tiger occupied forest, individual populations, their extents and habitat connectivity in Uttarakhand



UTTAR PRADESH

The forest cover of Uttar Pradesh is 14424 Km^2 constituting 6% of the land area. Of this forested habitat 3175 Km^2 constitutes Potential Tiger habitat of Priority I and II. Tigers were found to occupy 2766 km^2 of forests with an estimated population of 109 (91-127) in Uttar Pradesh. Leopards occupancy was reported to be 1889 km^2, while Sloth bears occupied 1446 km^2 and Dhole 109 km^2 of forested habitats in Uttar Pradesh.

Within Uttar Pradesh tigers are distributed in one major population and three smaller populations. Sporadic occupancy is reported in Sonbhadra Forests. The major population is constituted by Dudhwa Tiger Reserve comprising of Dudhwa National Park, Kishenpur Wildlife Sanctuary, Katarniaghat Wildlife Sanctuary and forests of Pilibhit, North and South Kheri forest divisions. The forested area with tiger occupancy constituted by this population is 1,916 km^2. This population is connected across the Nepal border via the forests of Pilibhit (Lagga-Bagga) to Sukla Phanta of Nepal and Katarniaghat is connected across the border to Bardia National Park in Nepal.

The smaller population in the West is in Bijnor forests covering an area in UP of 221 km^2, maintained by dispersing tigers from the Corbett Tiger Reserve. The two smaller Eastern populations are in Suhelwa Wildlife Sanctuary with a tiger occupancy of 490 km^2 and Sohagibarwa Wildlife Sanctuary having a tiger occupancy in 139 km^2 in two separate blocks. Suhelwa is connected with the forests of Mahadevpuri in Nepal (Figure 2.3).

Conservation Recommendation

1) Dudhwa Tiger population forms three distinct units comprising of Katarniaghat, Dudhwa, and Kishenpur-Pilibhit that have intervening land between them under private ownership. The estimated tiger numbers in this population were 95 (80-110) having an occupancy of 1833 km^2. Currently the land use matrix is primarily sugarcane and rice farming, and is not totally tiger hostile. No legal government owned corridor exists to connect these 3 units. For long term conservation of tigers in this population it is essential to procure and develop a government owned corridor system that could potentially be restored along water courses and remaining swamp lands by careful mapping and planning. The state needs to work in partnership with private land owners, so as to ensure that the intervening land use pattern remains tiger friendly. This could be achieved by economic incentives

and subsides. To minimize backlash and hostilities towards tiger conservation the local communities needs to be compensated promptly at market rates for wild damage.

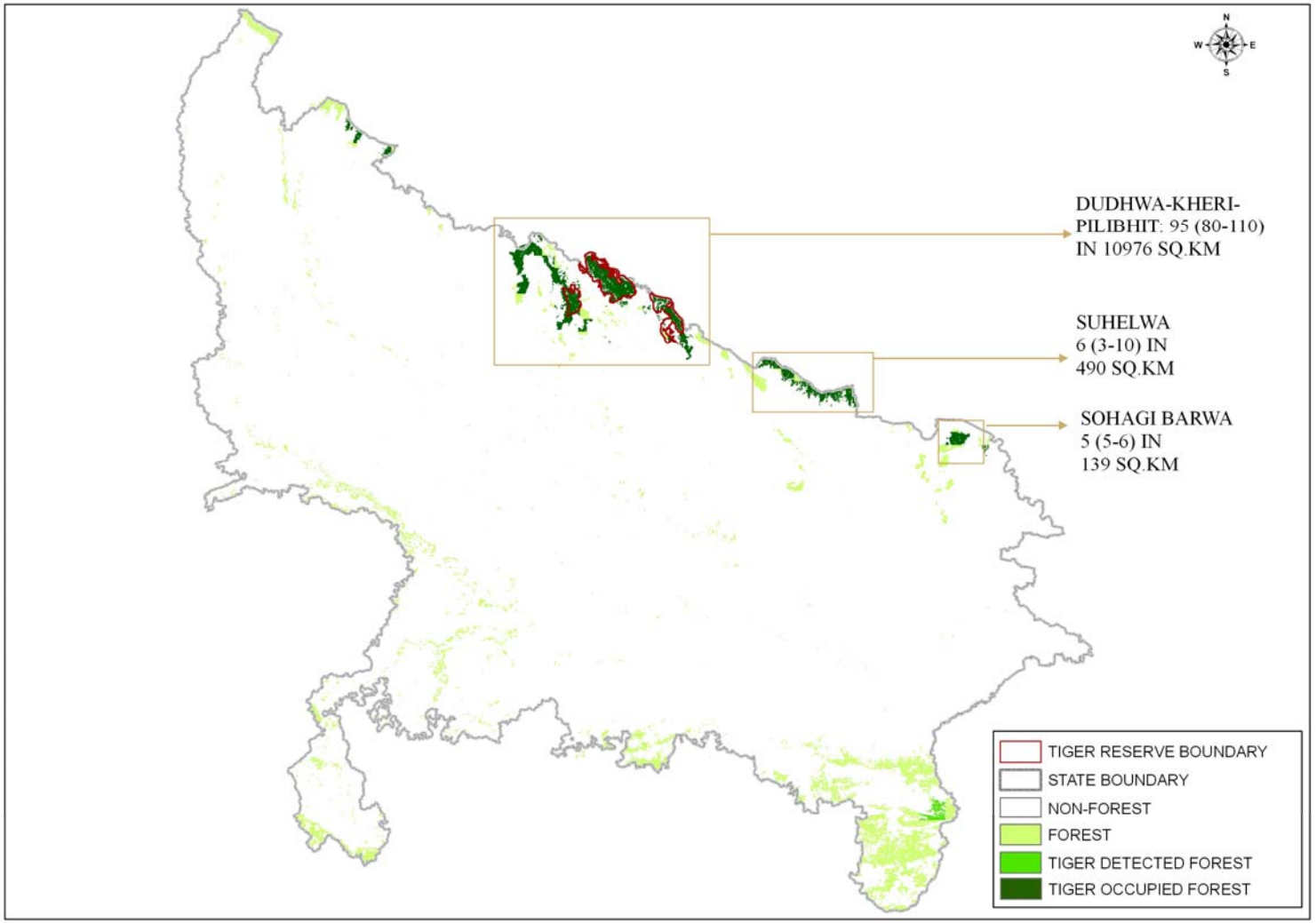
2) The Dudhwa population forms a part of the meta-population composed of Shukluphanta and Bardia as the other source populations in Nepal. This meta-population structure needs to be maintained through trans-boundary connectivity's ensured through international cooperation for the long term survival of tigers in Nepal (Suklaphanta and Bardia) and Dudhwa. Dudhwa- Pilibhit population has high conservation value since it represents the only tiger population having the ecological and behavioral adaptations of the tiger unique to the Terai habitat.

3) The Bijnor tiger occupancy can only be maintained as long as its connectivity with the Corbett Source remains intact.

4) The Suhelwa population is isolated on the Indian side with tiger occupancy in 475 km^2 and an estimated population of 6 (3-10) tigers. It potentially has connectivity via the Shivalik hills (Mahadevpuri-Lamahi Dovan corridor) of Nepal with Chitwan National Park and Valmiki Tiger Reserve, in Bihar. Sohagibarwa has precarious stepping stone connectivity with Valmiki Tiger reserve and long term tiger persistence in this population is doubtful due to its small size and poor linkages. Tigers are likely to survive here as long as Valmiki and Chitwan sources produce substantial dispersing individuals. The estimated population is based on signage and index data reported during phase I. In the case of this population supervised knowledge of the field situation suggests that the estimate is on the higher side.

5) Sporadic tiger occurrences in the Sonbhadra forests of south eastern UP suggest a potential linkage with tiger occupied forests of Madhya Pradesh, Jharkhand and Chattisgarh. Forests of Sonbhadra are connected with forests of these three states.

Figure 2.11 Tiger occupied forest, individual populations, their extents and habitat connectivity in Uttar Pradesh



BIHAR

The State of Bihar has a forest cover of 5,842 km², comprising 6 % of the geographical area of the State. Tiger Conservation Priority I & II forests constituted 800 km². Tiger occupancy was reported to be 510 km² with an estimated tiger population of 10 (7-13) tigers. Leopard presence was reported from 551 km², Sloth bear presence in 534 km², Dhole presence in 323 km² of forests. Amongst prey species chital occupied 576 km², sambar 321km², nilgai 494 km², and wild pig 570 km² of forested habitats

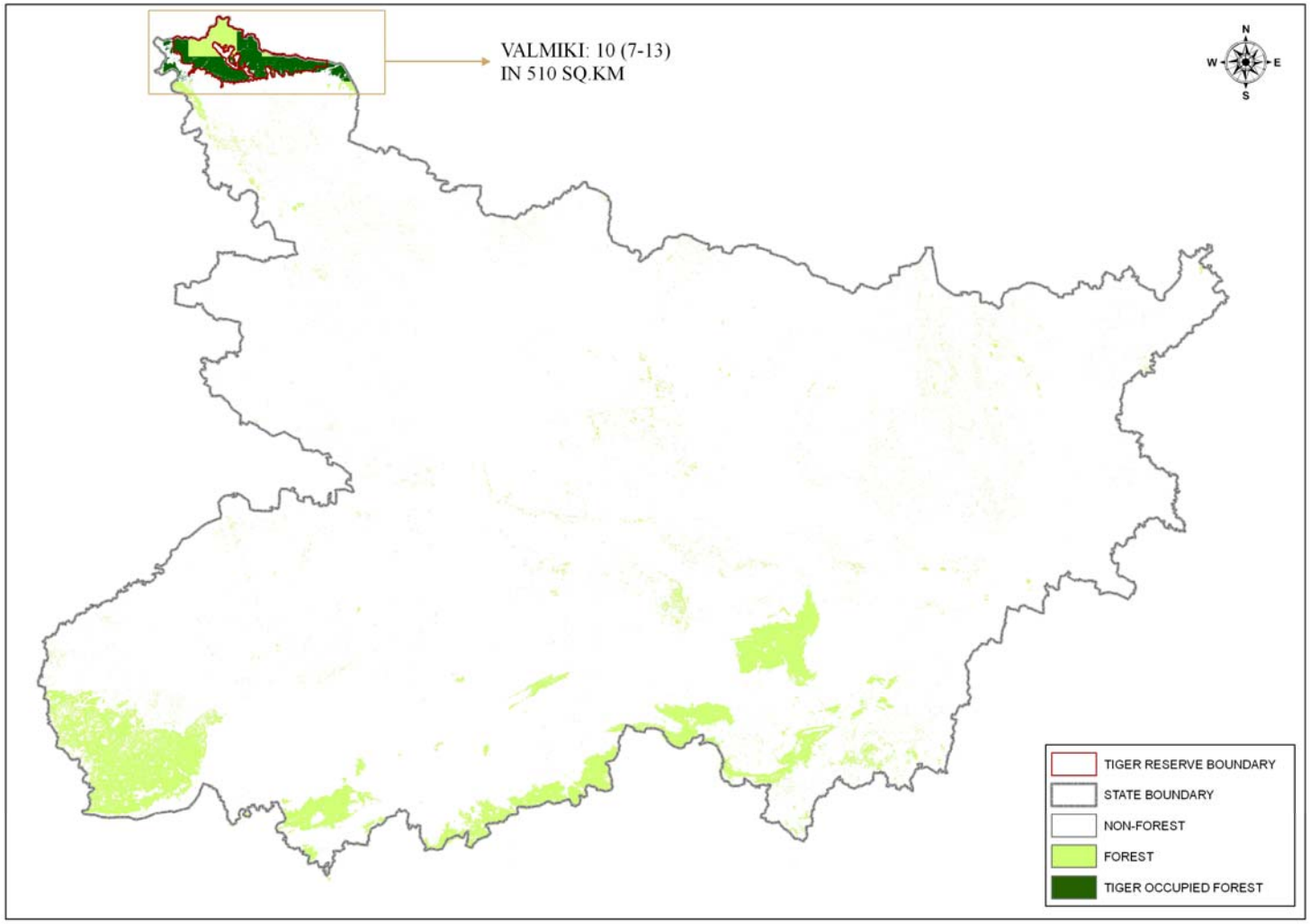
Tiger population in the state of Bihar occurs as single population in Valmiki Tiger Reserve. This population has a tiger occupancy of 510 km² within India and is contiguous with Chitwan National Park in Nepal.

Conservation Recommendations

The Valmiki population is contiguous with the Chitwan tiger population. For long term persistane of this population the connectivity with Chitwan is critical. Towards the south west this population is connected with the eastern block of Sohagibarwa, UP. This connectivity is essential for tiger persistence in Sohagibarwa. The value of Valmiki can be enhanced by protection form commercial and subsistence poaching of tiger and its prey. Reduction of human dependencies on the forest would enhance prey populations and in turn benefit tigers.

Southern forests of Bihar within the sanctuaries Kaimur and those bordering Jharkhand (Gautam Buddha, Koderma) have connectivity's with Palamau Tiger Reserve and can potentially have tiger occupancy through dispersing tigers if Palamau source population is improved.

Figure 2.12 Tiger occupied forest, individual populations, their extents and habitat connectivity in Bihar



Central Indian Landscape

And

Eastern Ghats

Principal Investigators

Y.V. Jhala, Rajesh Gopal and Qamar Qureshi

Research Team Central India

Agni Mitra, Ajay Singh Nagpure, Aniruddha Majumdar, Ashis K. Gharai, Ashish K. Bais, Chandrima Home, Dr. Amit Kotia, Dr. Durg Singh Rajpurohit, Dr. Jimmy Borah, Dr. Kamal Singh Negi, Dr. Karabi Deka, Dr. Sumit Dookia, Harshad Mangave, Indrani Sasmal, J. Peter Prem Chakravarthi, Janmeyjay Sethy, Jayasooryan K.K., John C.E., Joseph Vettakaven, Jyoti Singh, Jyotirmay Jena, Kuladeep Roy, Kunwar Sain, Manish Bhardwaj, Mohit Badyal, Peer Muzamil Shams, Prudhvi Raj G., Purnima Manar, R.K. Jagadish, Rajeev Pillai, Rajendra Prasad Gupta, Raju Lal Gurjar, Rashid H. Raja, Reenima Hazarika, Rishi Kumar Sharma, Satyaranjan Behera, Shilpi Gupta, Shubham Dutta, Sirish Kyatham, T. Ramesh, Tana Mewada, Tripti Negi, Uday Kumar Das, Umesh kumar Tiwari, Vibhav Srivastava, Vidyadhar Atkore, Vishal V. Patil.

Research Team Eastern Ghats

Aishwarya Maheswari, J. Peter Prem Chakravarthi, Janmejay Sethy, Jaysooryan K.K., Jyotirmay Jena, Prudhvi Raj G., Satyaranjan Behera, Umeshkumar Tiwari.

3 Central Indian Landscape

Whilst much of the central Indian forests have been greatly disturbed by anthropogenic development, the zone does contain some of India's finest forests, particularly in undivided Madhya Pradesh. The majority of the forests are of a deciduous nature, but there are regions of greater diversity in the hill ranges. Relict populations of buffalo and swamp deer suggest, a much wider distribution of these species in the past. Even though the zone has some of the largest wilderness areas of India, there are growing signs of forest and environmental degradation. The Deccan highlands form the principal catchment for many of Central and Southern India's main river systems (Narmada, Tapti, Mahanadi and Godavari) loss of forest cover is already discernable in increased frequency of drought, floods, erosion and reservoir siltation. Thus there is a need for greater conservation inputs for wildlife, forest resource and water catchment purposes (Rodgers & Panwar 1988).

Central India is principally the zone of deciduous forests. The northern part of the zone has forests dominated by stunted Sal, Anogesius, Acacia and miscellaneous species. Part of the landscape is moist with good sal forests having an interspesion of miscellaneous species. The southern half of the landscape has a drier forest association. The central part of the landscape consists of teak and miscellaneous species. Few natural grasslands which were confined to river valleys are now lost to agriculture. Some areas are maintained in the successional stage of anthropogenic grasslands (e.g. old village sites or wastelands) by fire, tree cutting and livestock pressure.

Most wildlife species are widespread through the whole zone, e.g. chital (*Axis axis*), sambar (*Cervus unicolor*), nilgai, chowsingha (*Tetraceros quadricornis*). However, some species are more frequent than others, while a few species are restricted to moister areas, e.g. barking deer (*Muntiacus muntjak*) and gaur (*Bos gaurus*). Some species are restricted to drier, open areas, - e.g. blackbuck (*Antelope cervicapra*) and chinkara (*Gazella gazella*), but still have a wide distribution. Species which have small relict population include elephant, the wild buffalo and the hard ground swamp deer. The gharial (*Gavialis gangeticus*) is restricted to a few rivers flowing into the Ganges and Mahanadi Rivers. The carnivore include tiger, leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*) and dhole (*Cuon alpinus*). However their ranges are increasingly fragmented as natural forest areas decrease in size (Rodgers and Panwar 1988). The better protected areas do provide example of the levels of density and diversity that mature wildlife communities can attain, but these are few in number.

Most of the tiger reserves in the landscape still have connectivity, with the potential of sustaining meta-populations. With protection of corridors, restorative ecology, and rejuvenation of prey outside protected areas the region has one of the best potential for long term tiger conservation (Figure 3.1).

Total geographic area : 1170220 km^2

Political units : Madhya Pradesh, Uttar Pradesh, Bihar, Jharkhand, Chhatisgarh, Orissa, Andhra Pradesh, Maharashtra and Rajasthan.

Average population density : 142.5 km^{-2}

Total protected area : 25739.4 km^2 (4.1% of the total Land Area)

Total forested area : 406580 km^2

Major biogeographic zones : 1. Semi Arid (Punjab Plains (4A) & Gujarat Rajputana (4B)), 2. Western Ghats (Malabar Plains (5A) & Western Ghat Mountains (5B)), 3. Deccan Peninsula (Central Highlands (6A), Chotta-Nagpur (6B), Eastern Highlands (6C), Central Plateau (6D) & Deccan South (6E), 4. Gangetic Plains (Upper Gangetic Plains (7A) & Lower Gangetic Plains (7B)) & 5. Coasts (East Coast (8A) & West Coast (8B)

Table 3.1: Landscape Characteristics of the Central Indian Landscape Complex

Parameters	Value
Number of forest patches	19405
Forest patch density per 1000 km^2	9.4
Mean forest patch area (km^2)	13.6
Mean forest perimeter to area ratio	34.2
Total forest core aera (km^2)	30272
Number of disjunct forest core areas	1013
Mean forest core area (km^2)	1.04
Median forest core area (km^2)	9
Total forest core area in forest patches >1000 km^2	28313

Tiger Habitat status:

Districts from which tigers have become locally extinct within the recent historical past from the Central Indian Landscape was 30%. Forested area where tiger is currently reported was 48,610 km^2 (11.6 % of forests) with an estimated population of 548 (437 to 661) (Figure 3.2) in 17 populations. Potential habitat for tiger occupancy in the landscape complex was 156,548 km^2 (38.5% of forests).

Within Central Indian landscape complex potential meta-populations of tigers exist in four landscape units (Figure 3.2).

1) Kanha-Pench Landscape : This is one of the best landscapes (16,000 km^2) that exists today with two, source populations of tigers connected as a potential meta-population. The weakest connectivity for this landscape exists at the forested border of Seoni and Wara Seoni tehsils, which needs to be managed with restorative inputs on a priority basis. This would ensure the linkage between the source populations and foster metapopulation existence.

2) Satpura-Melghat landscape : Though tiger densities in this landscape are medium to low (even in source populations), the landscape features (12,700 km^2) are condusive for long term persistence of a meta-population. To boost up the conservation value of this landscape it may be pertinent to increase protection and prey populations. The weakest link in this landscape is in Itarsi tehsil which needs protection and restoration.

3) Sanjay-Palamau landscape : The landscape is characterized by low tiger and prey population, with high biotic pressure. Target areas of concern are forests in Pratapur, Pal and Samri tehsils (13,700 km^2). These need to be protected and their habitat values enhanced to sustain prey and tiger populations. The Bandhavgarh Tiger Reserve can potentially be an important source for this landscape. Currently no contiguous forest patch exists between Bandhavgarh and Sanjay-Palamau landscape units. However, several small forest patches exist which could serve as "stepping stones" for the spill over population of tigers from Bandhavgarh. These forest patches (Priority II) need to be protected and enhanced in the tehsils of Beohari, Jaisinghnagar and Sohagpur to increase the conservation value of this landscape.

4) Navegaon-Indravati landscape : This is one of the largest intact forested landcape (34,000 km^2) in Central India. However, its current conservation value for tigers is poor due to authoropogenic pressures, insurgency and low prey populations. There is a paucity of any major source population of tigers. There is a potential for connectivity with Tadoba Tiger Reserve and Kanha-Pench landscape through "stepping stone" forest patches. Target forests to connect these source populations are in the tehsils of Gond, Pipri, and Sirpur for Tadoba, and Dongargarh, Sulekasa, and Deori in the case of Kanha-Pench landscape. If the former connectivity is restored through the forest patches of Dongargarh, Sulekasa and Deori two large landscapes of (34,000 and 16,000 km^2) area would be connected. This has the potentiall to exist as a meta population, as one of the best tiger conservation areas in the world.

5) Isolated Tiger Populations : Many small to medium size habitat blocks exist in Central India that support isolated tiger populations. Some of these populations have the potential to be connected to larger tiger bearing landscapes or to each other.

(a) Bandhavgarh Tiger Reserve: The forest block that includes Bandhavgarh is about 2000 km^2. It has fragmented forest patches towards its North West which has potential for some connectivity with Sanjay-Palamau landscape. To the south, there is potential for connectivity through more degraded patchy forests with the Kanha-Pench landscape.

(b) Panna : The forest patch that includes Panna is 3500 km^2. Panna has lost all potential for connectivity with other tiger landscapes but due to its size, if properly protected and managed can sustain a sizeble tiger population.

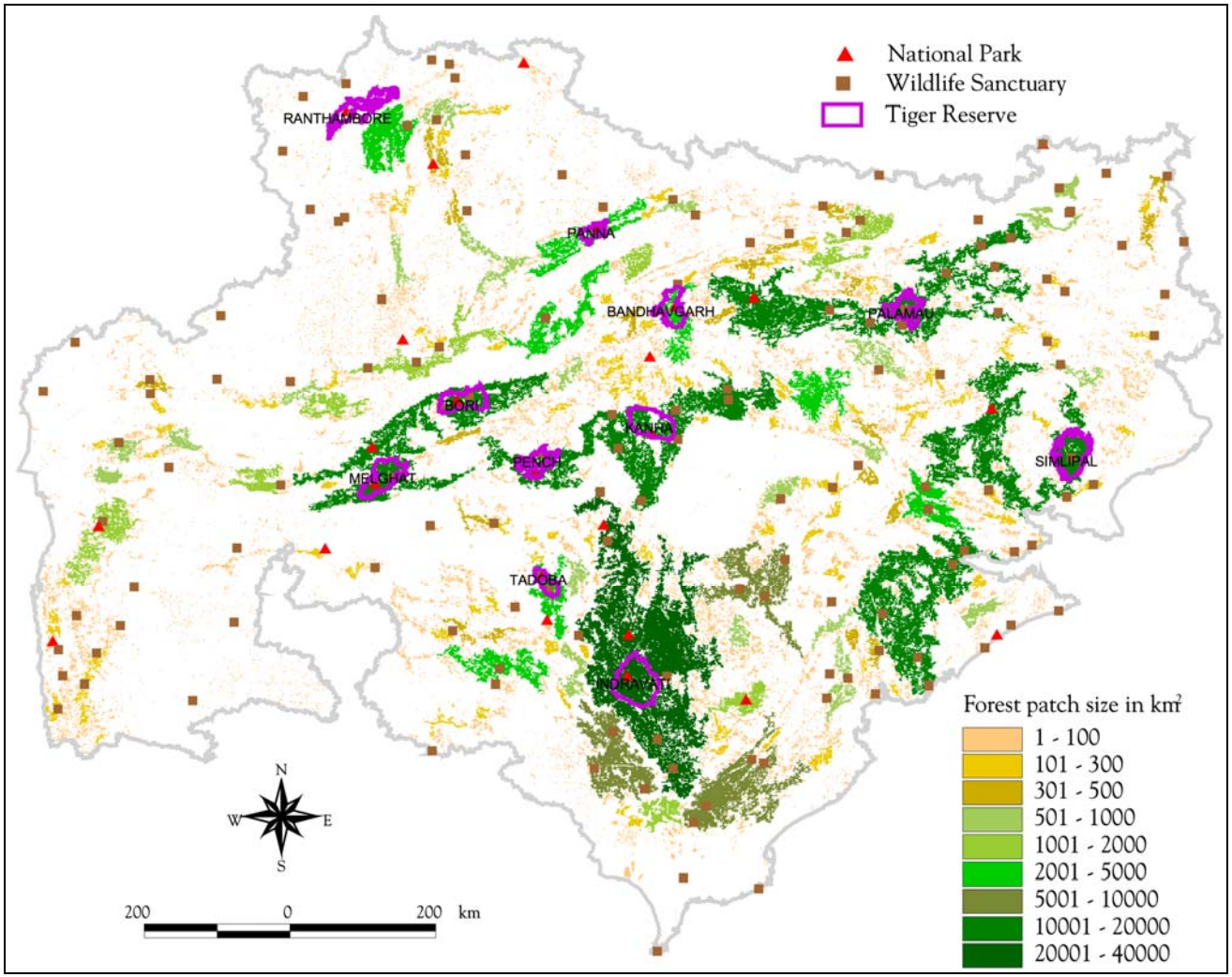
(c) Ranthambore–Kuno–Palpur–Madhav : Though Ranthambore forest patch (300 km^2) is physically disjunct, it has the potential to be a source for Kuno-Palpur landscape (4000 km^2). The connectivities through forest patches is poor, but the landscape is sparsely populated with ravinous terrain which is condusive for movement of dispersing tigers. The possibility of tigers dispersing into Madhav-Shivpuri (650 km^2 forest patch) via stepping stone forest patches also exist.

(d) Tadoba Tiger Reserve : This is included in a forest patch of 2000 km^2, and has the potential to become an important source population for the Navegaon-Indravati landscape. It has the potential for sharing genetic material with Kanha-Pench landscape through restorative management of intervining areas ranging between 5-20 km^2 in size.

(e) Simlipal Tiger Reserve : It is a part of a forested patch of 3800 km^2. The potential for connectivity with another tiger occupied landscape is poor. However, due to its large size Simlipal has the potential to sustain a sizable tiger population.

(f) Saranda National Park : The forest patch that includes the Saranda National Park is about 7400 km^2. This forest has the potential for connectivities towards the South with forested districts of Sundargarh, Sambalpur, Denkenal, Puri, Phulbani and Ganjam, covering an area of about 15,000 km^2.

Figure 3.1 Distribution of Protected Areas and various size of forest patches in the Central Indian Landcspe



4. Eastern Ghats Landscape Complex

Eastern Ghats are a long chain of broken hills and elevated plateaus, running along the Indian east coast and passing through the states of Orissa, Andhra Pradesh and Tamil Nadu (with more than 50% of it being in Andhra Pradesh). The region has a regime of climate that favours luxurious growth of vegetation and forest. This zone has important biological values including viable elephant, gaur and other mammalian populations, as well as a wide diversity of plant communities, with a mixture of subtropical and tropical evergreen elements. Considering contiguiety of tiger habitats and forests we have considered the Northern parts of the Eastern Ghats i.e. the Godavari valley as a part of the Central Indian Landscape. Herein we report the status of central and southern Andhra Pradesh.

The Eastern Ghats are endowed with a lot of diversity as it harbours various types of coastal ecosystem such as, estuaries, mangroves, lagoons and coral reefs. They extend over a length of several hundred kilometres between the rivers Mahanadi and Vaigai along the East Coast (after Rodgers and Panwar 1988).

The forests of Eastern Ghats mainly include tropical dry and moist deciduous types with few patches of semi-evergreens existing in association with high lands. Floristic surveys carried out at district and zonal levels reported nearly 2000 species of flowering plants in the region.

Although the historic continuity of Eastern Ghat forests with those in Central India along the Chota Nagpur Plateau is now almost lost, there are still large enough forest areas within this landscape (Figure 4.1). Nagarjunasagar Srisailam Tiger Reserve, the largest Tiger Reserve in India, adds to its conservation value. However, this habitat is presently plagued by extremist problems, which makes implementation of conservation measures difficult.

Total geographic area : 120764 km^2
Political units : Andhra Pradesh only.
Average population density : 65.1 km^{-2} (Figure 21)
Total protected area : 3385.2 km^2 (2.8% of the total Land Area)
Total forested area : 2416.4 km^2
Major biogeographic zones : 1. Deccan Peninsula (Central Plateau (6D) & Deccan South (6E)) and 2. Coasts—East Coast (8B)

Figure 4.1 Distribution of Protected Areas and various size of forest patches in the Eastern Ghats landscape complex

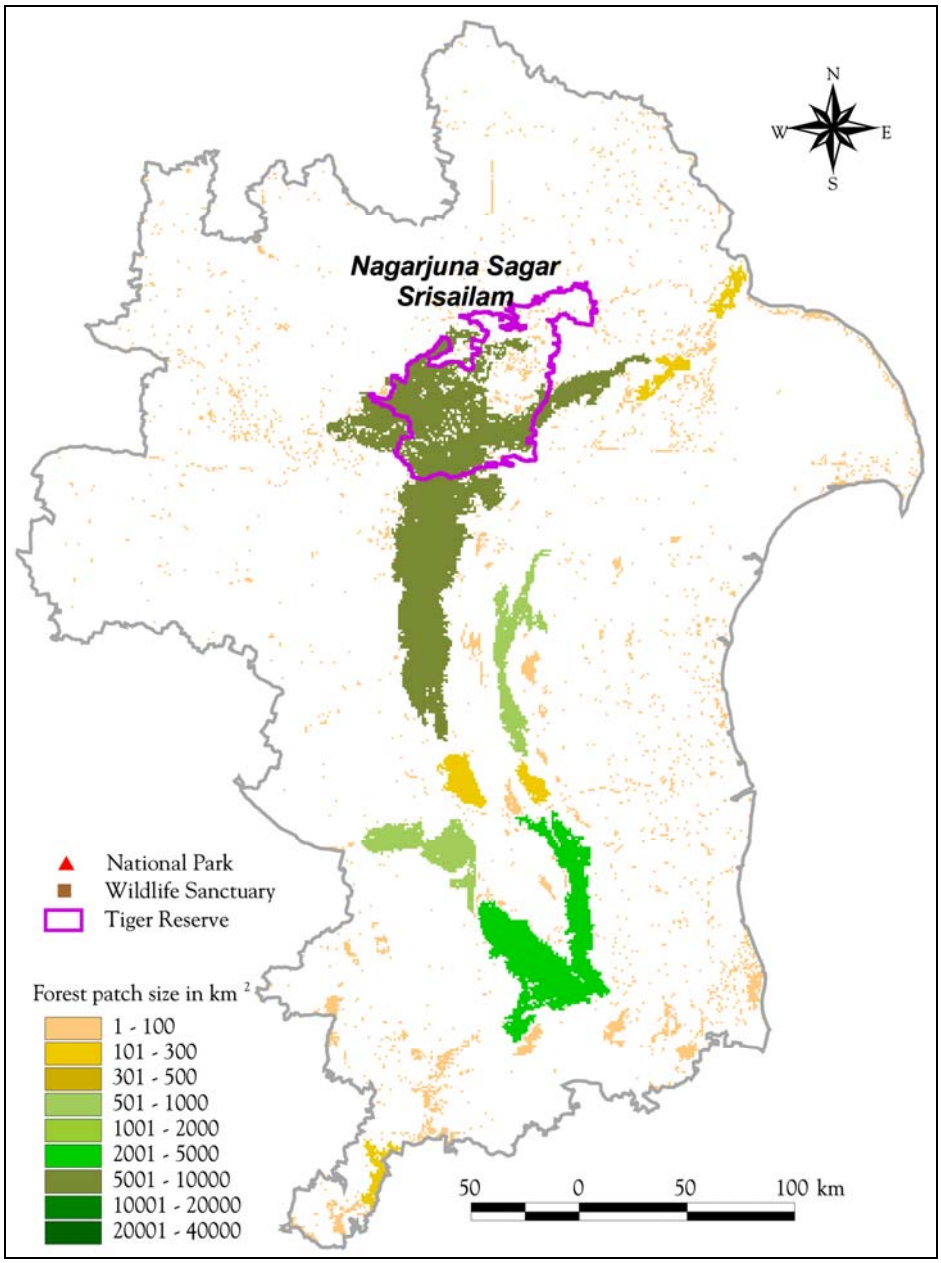


Table 4.1: Landscape Characteristics of the Eastern Ghats Landscape Complex

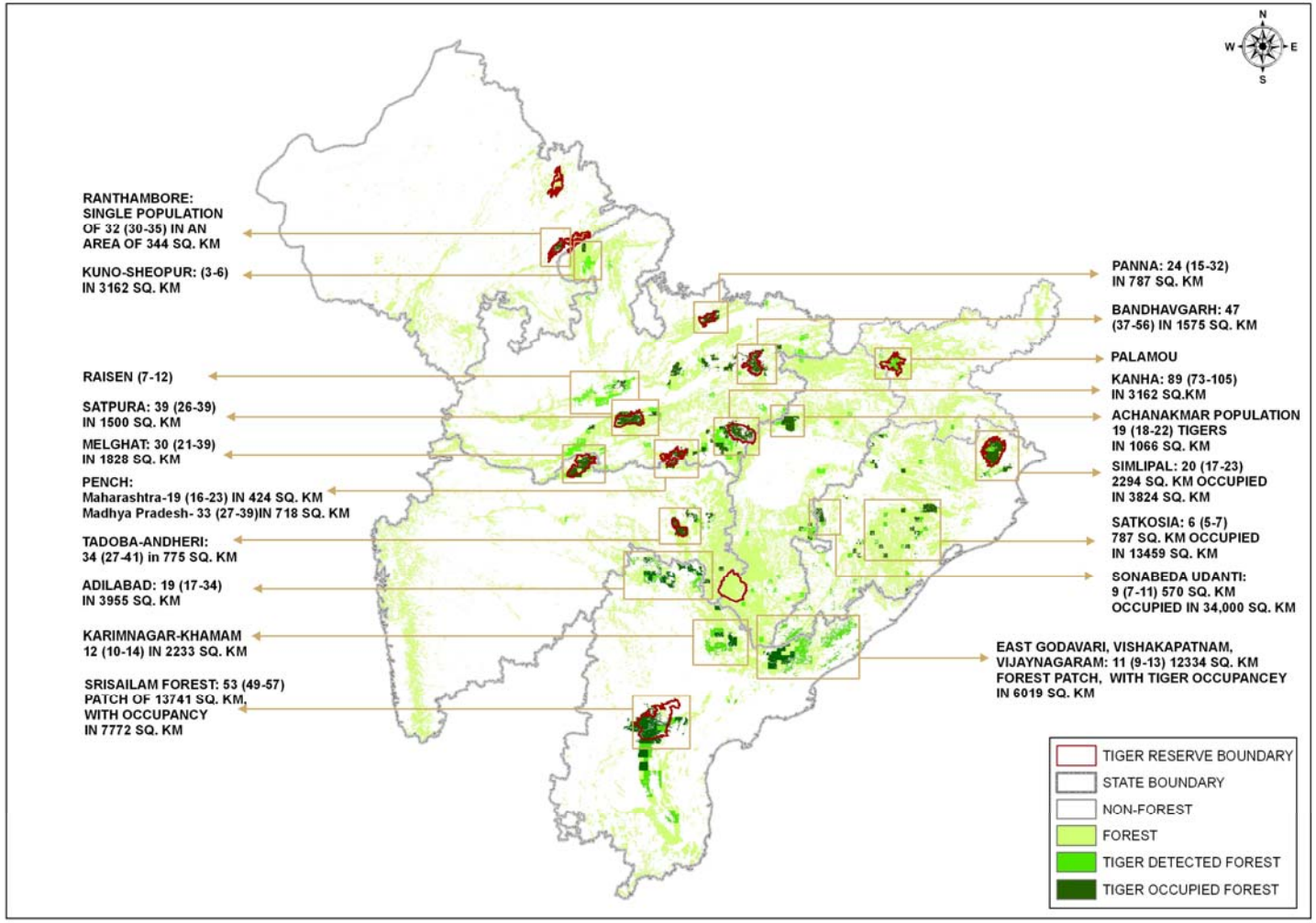
Parameters	Value
Number of forest patches	2062.0
Forest patch density per 1000 km²	8.6
Mean forest patch area (km²)	7.6
Mean perimeter to area ratio	36.1
Total forest core area (km²)	4371.0
Number of disjunct forest core areas	33.0
Mean forest core area (km²)	1.15
Median forest core area (km²)	10.5
Total forest core area in forest patches >1000 km²	3853

Tiger Habitat status:

Currently the tiger occupies 7,772 km² of forested habitats with an estimated population size of 53 (49 to 57) in a single population (Figure 4.2). Potential habitat for tiger occupancy in the landscape complex: 15837 km² (58.6% of forest).

The Eastern Ghat landscape complex consists primarily of three separate forest (Figure 24) blocks. 6000 km² area of Nagarjunasagar Tiger Reserve-Gundla Brahmeshwara poposed National Park, 3000 km² block of forest comprising of Srivenkateshwara National Park and 700 km² forest patch in the tehsils of Kanigiri, Baduel, Udayagiri and Giddalur. The Nagarjunasagar forest block has the best potential for tiger conservation in this landscape followed by the Tirupati forest block. However the 3 forested blocks are isolated with low probability of sharing tiger gene pools through "stepping stone" forest patches. The Tirupati forest patch likely had good connectivity with the Western Ghat landscape during the recent past. Currently, only small forest patches dot the interveining landscape between the Eastern and Western ghats, which are unlikely to act as corridors for tiger movement

Figure 3.2 **Tiger occupied forests, individual populations, their extents and habitat connectivity in Central Indian Landscape and Eastern Ghats Landscape Complex**



Landscape occupancy of Co-predators and prey in Central India and Eastern Ghats Landscape

Leopard distribution in the Central Indian Landscape is more contiguous in comparison to tigers and forms 9 occupied blocks of forested habitat with some intervening scattered presence. Total occupancy of leopards in central India and Eastern Ghats was 117,7782 km^2 (Figure 3.3), In Central India Madhya Pradesh likely has the largest population of Dhole. In Central India and Eastern Ghats Dhole distribution seems to be made up of 7 distinct populations and several scattered occurrences. The total forested area occupied was 85,962 km^2 . (Figure 3.4), Sloth bear distribution is reasonably contiguous forming 11 different blocks in Central India. They occupy about 166,376 km^2 of forested habitat. (Figure 3.5), Chital was distributed in 109,873 km^2 of forested habitat. (Figure 3.6), Sambar was distributed in 861,56 km^2 of forested habitat. (Figure 3.7), Wild Pig was distributed in 711,322 km^2 of forested habitat. (Figure 3.8) and Nilgai was distributed in 82,945 km^2 of forested habitat. (Figure 3.9)

Figure 3.3 **Leopard occupied forests, individual populations, their extents and habitat connectivity in Central Indian Landscape and Eastern Ghats Landscape Complex**

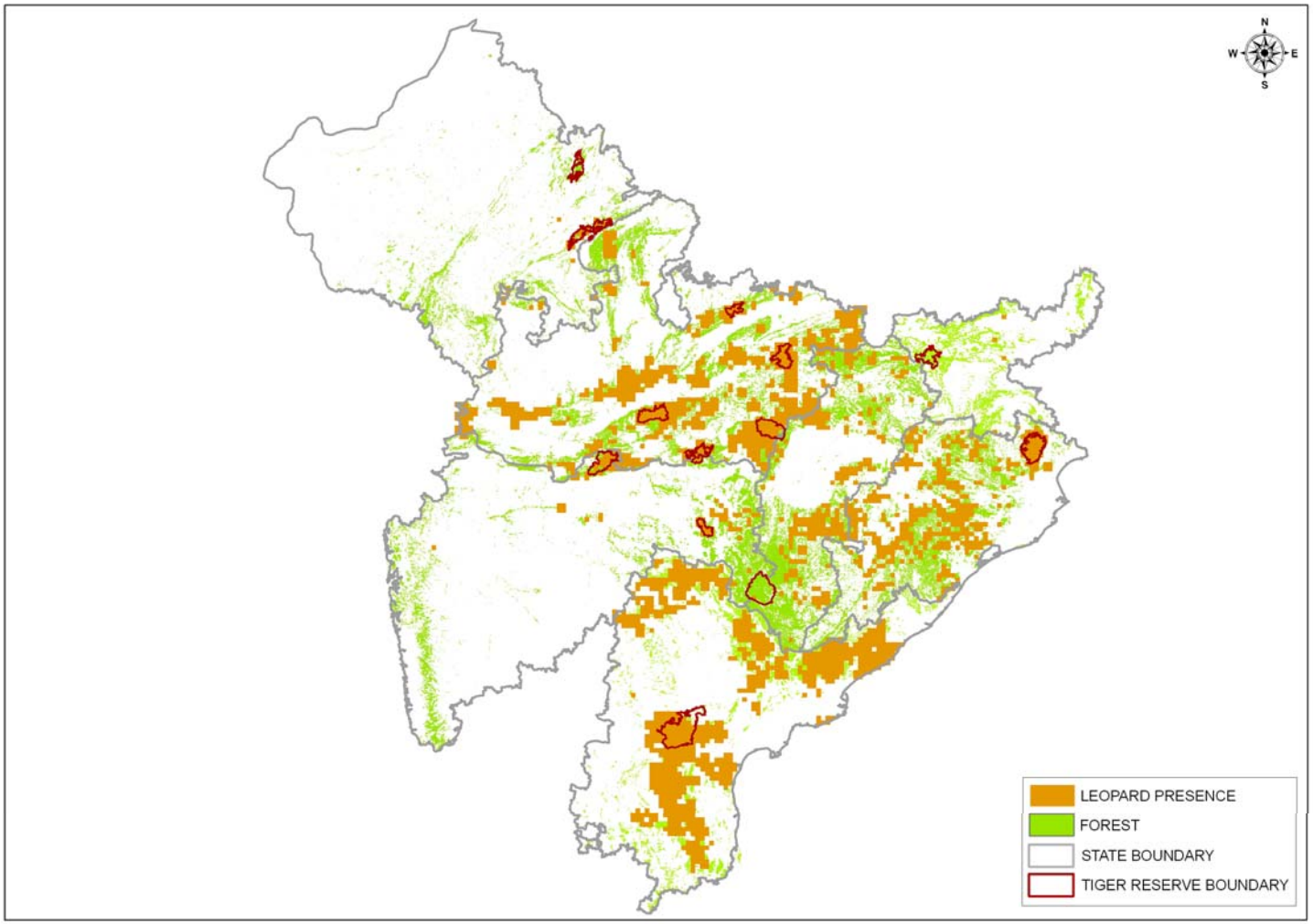


Figure 3.4 **Wild Dog occupied forests, individual populations, their extents and habitat connectivity in Central Indian Landscape and Eastern Ghats Landscape Complex**

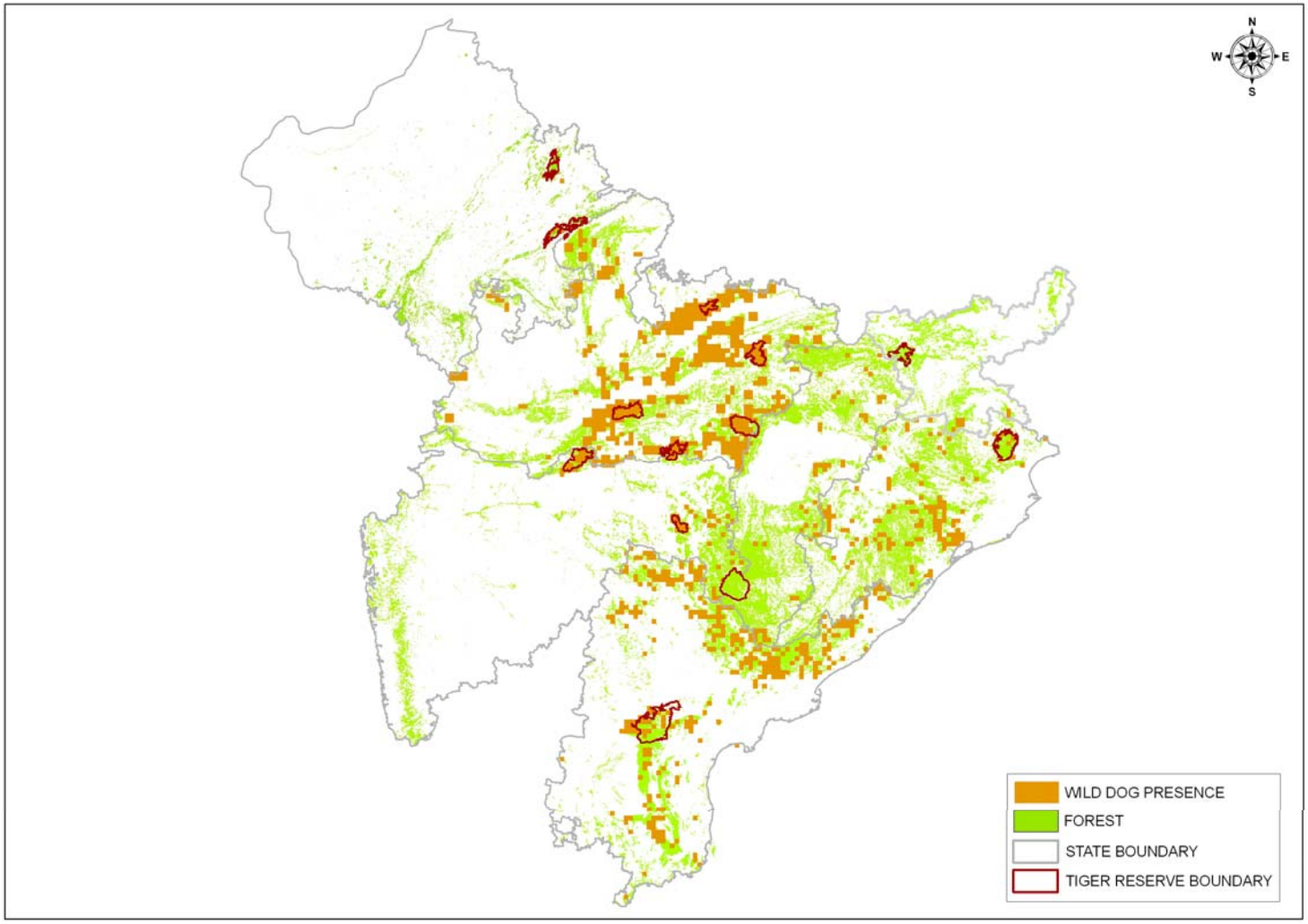


Figure 3.5 **Sloth Bear occupied forests, individual populations, their extents and habitat connectivity in Central Indian Landscape and Eastern Ghats Landscape Complex**

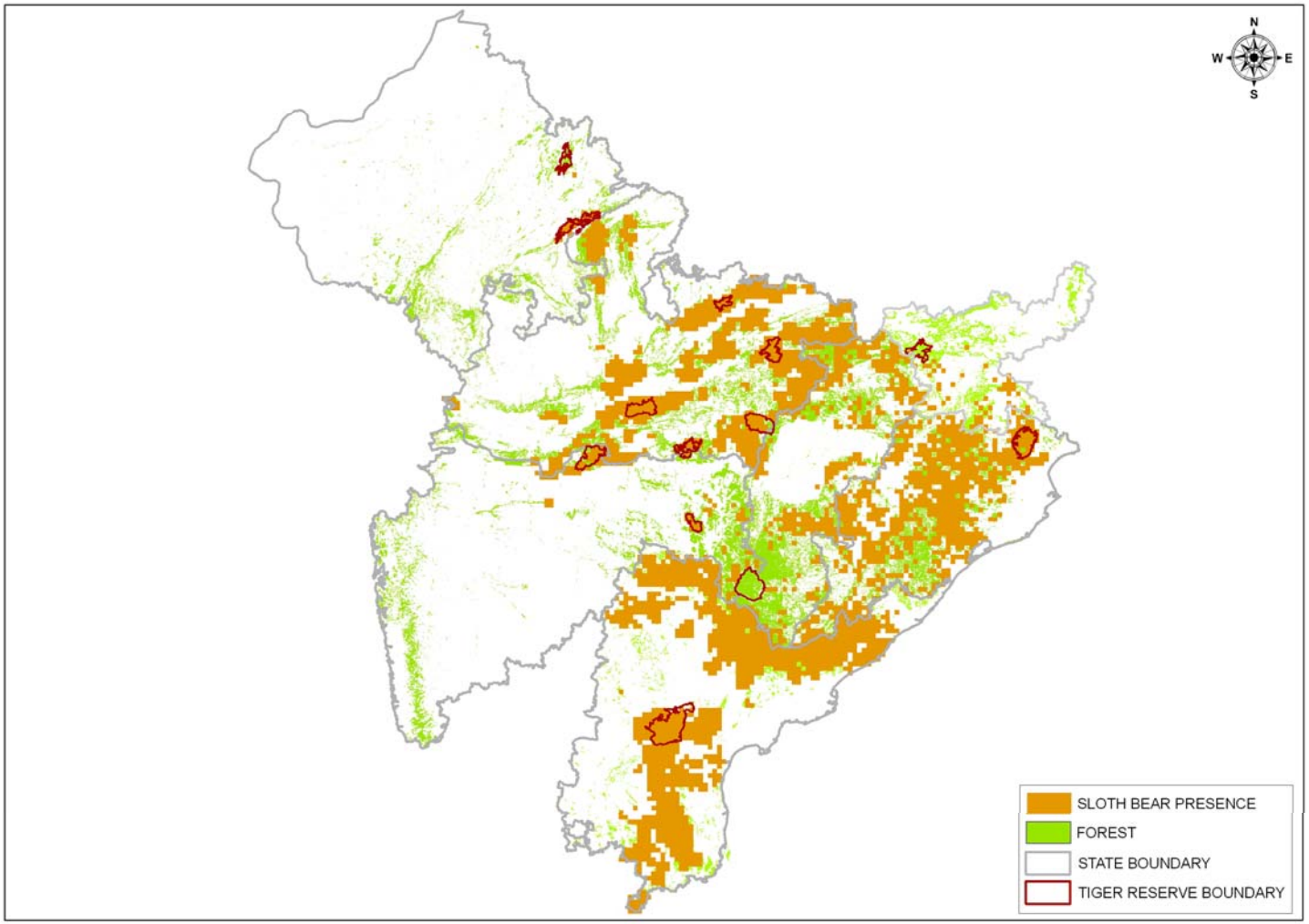


Figure 3.6 **Chital occupied forests, individual populations, their extents and habitat connectivity in Central Indian Landscape and Eastern Ghats Landscape Complex**

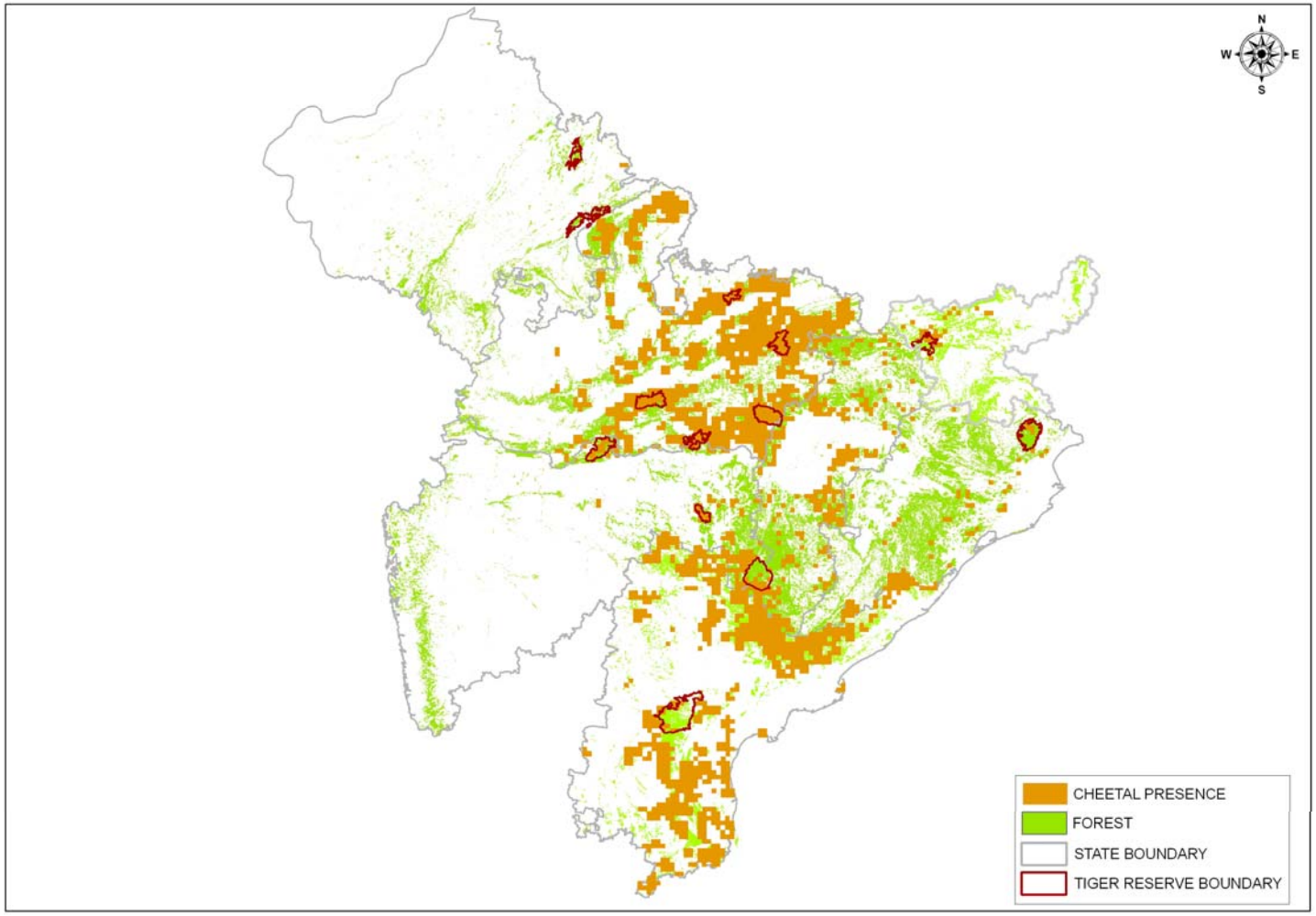


Figure 3.7 **Sambar occupied forests, individual populations, their extents and habitat connectivity in Central Indian Landscape and Eastern Ghats Landscape Complex**

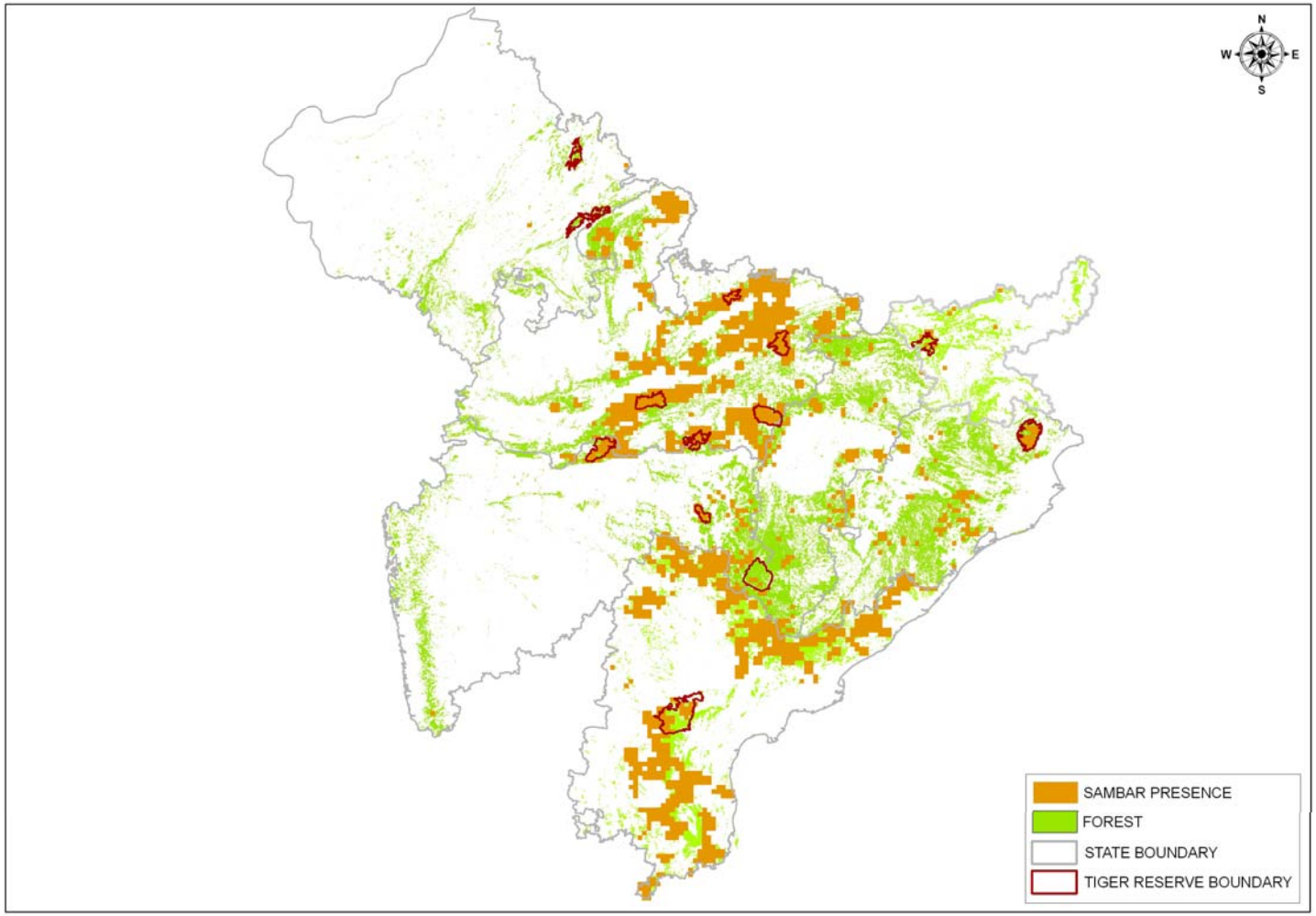


Figure 3.8 **Wild Pig occupied forests, individual populations, their extents and habitat connectivity in Central Indian Landscape and Eastern Ghats Landscape Complex**

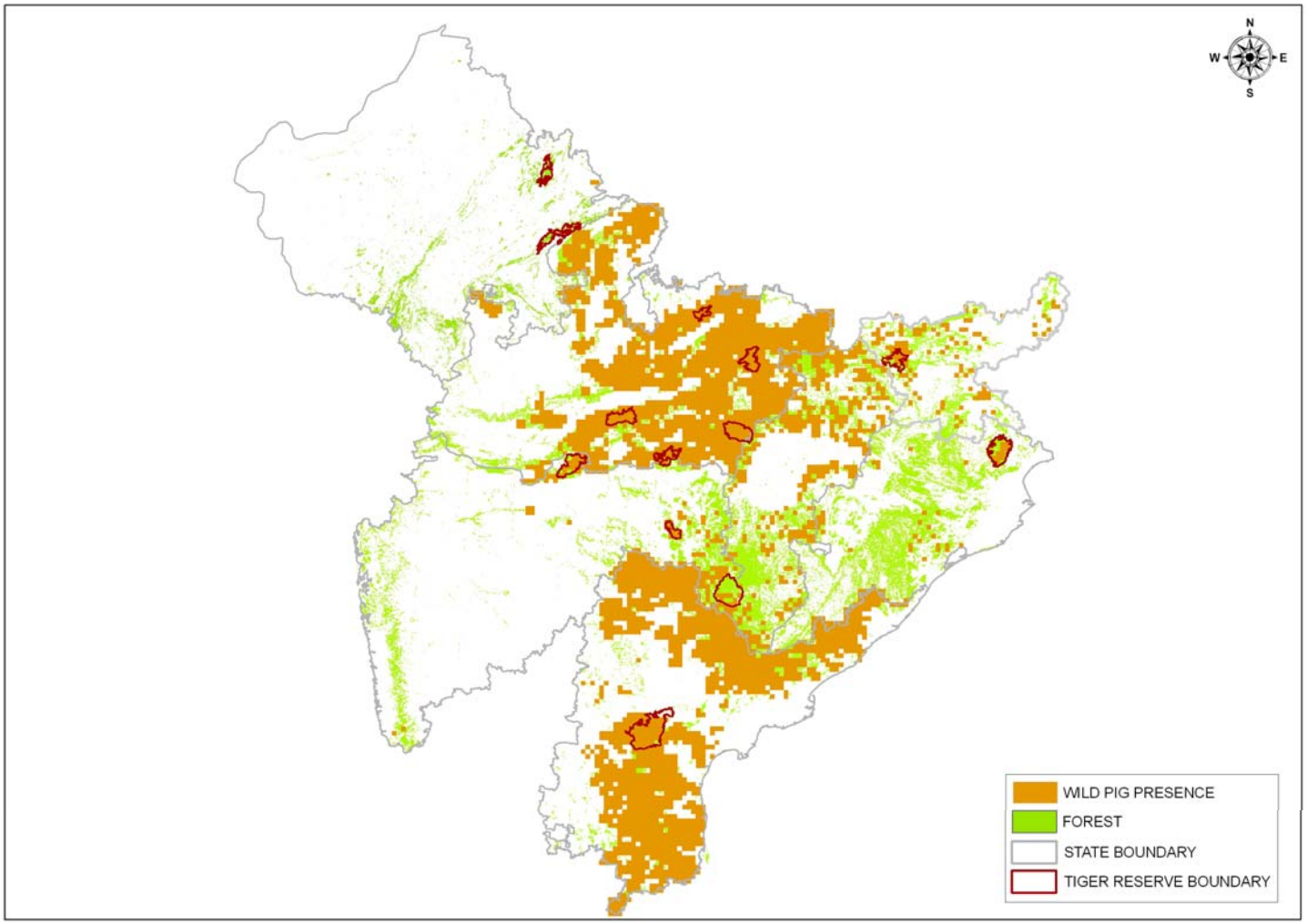
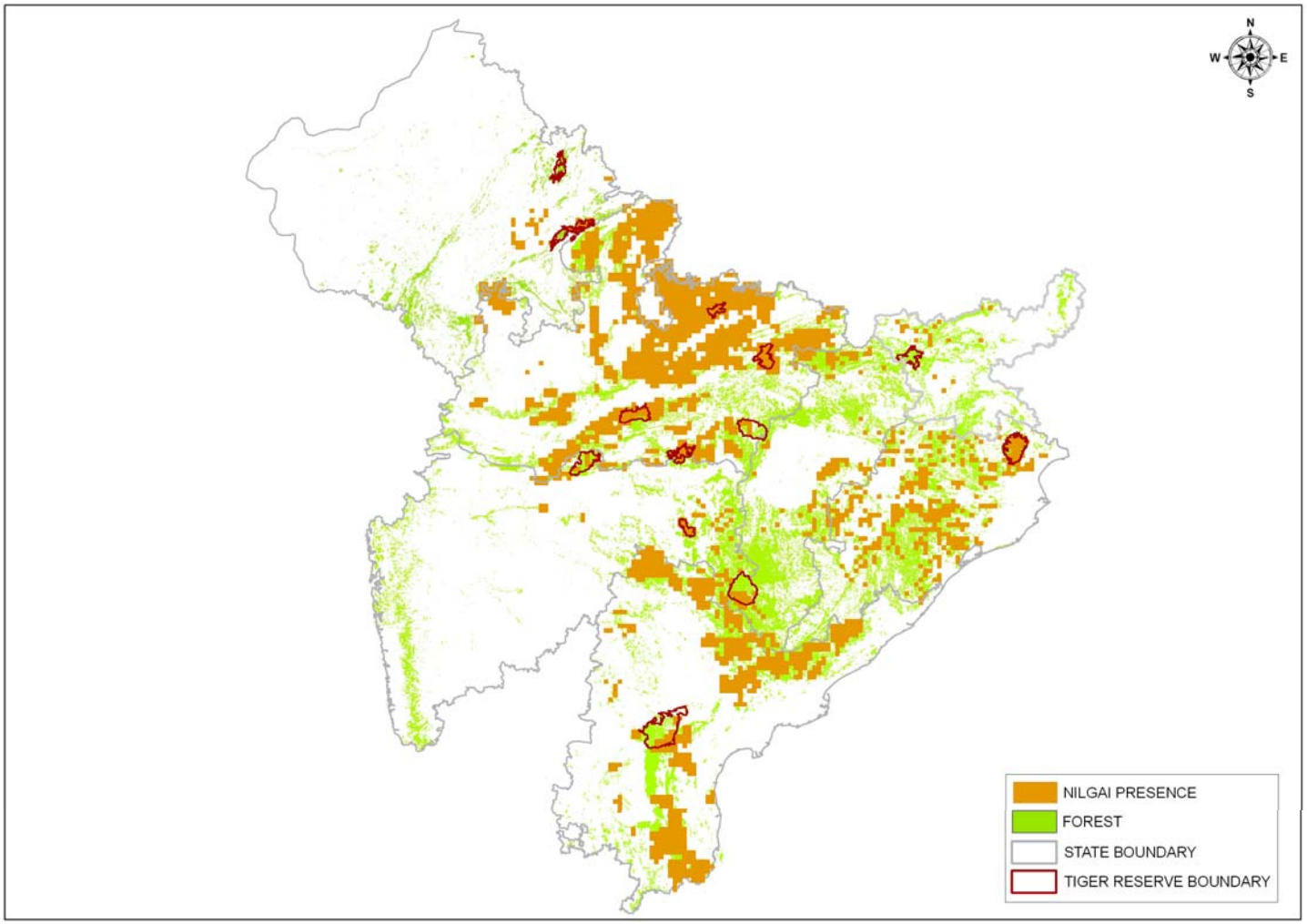


Figure 3.9 **Nilgai occupied forests, individual populations, their extents and habitat connectivity in Central Indian Landscape and Eastern Ghats Landscape Complex**



Rajasthan

Rajasthan has a forest cover of 21,292 km^2 comprising 6% of the geographic area of the state. There is only a single tiger population in Rajasthan in the Ranthambore Tiger Reserve. The contigious forest patch harbouring this population is 496 km^2 with a recorded tiger occupancy in 344 km^2. The population is geographically isolated with "stepping stone" connectivity through Kailadevi Sanctuary to Kuno Wildlife Sanctuary in Madhya Pradesh. This connectivity if revived can serve as a conduit for dispersing tigers to repopulate Kailadevi as well as Kuno. Ranthambore tigers have been reported to disperse through the narrow "ridge top" forest connectivity in the districts of Kota and Bundi towards the South-West. This corridor can potentially connect the forests of Chittorgarh and Mandsaur with the tiger source of Ranthambore.

Population Size: The total population of tigers in the state of Rajasthan was estimated to be 32 with a standard error range of 30-35 tigers.

Recommendations -

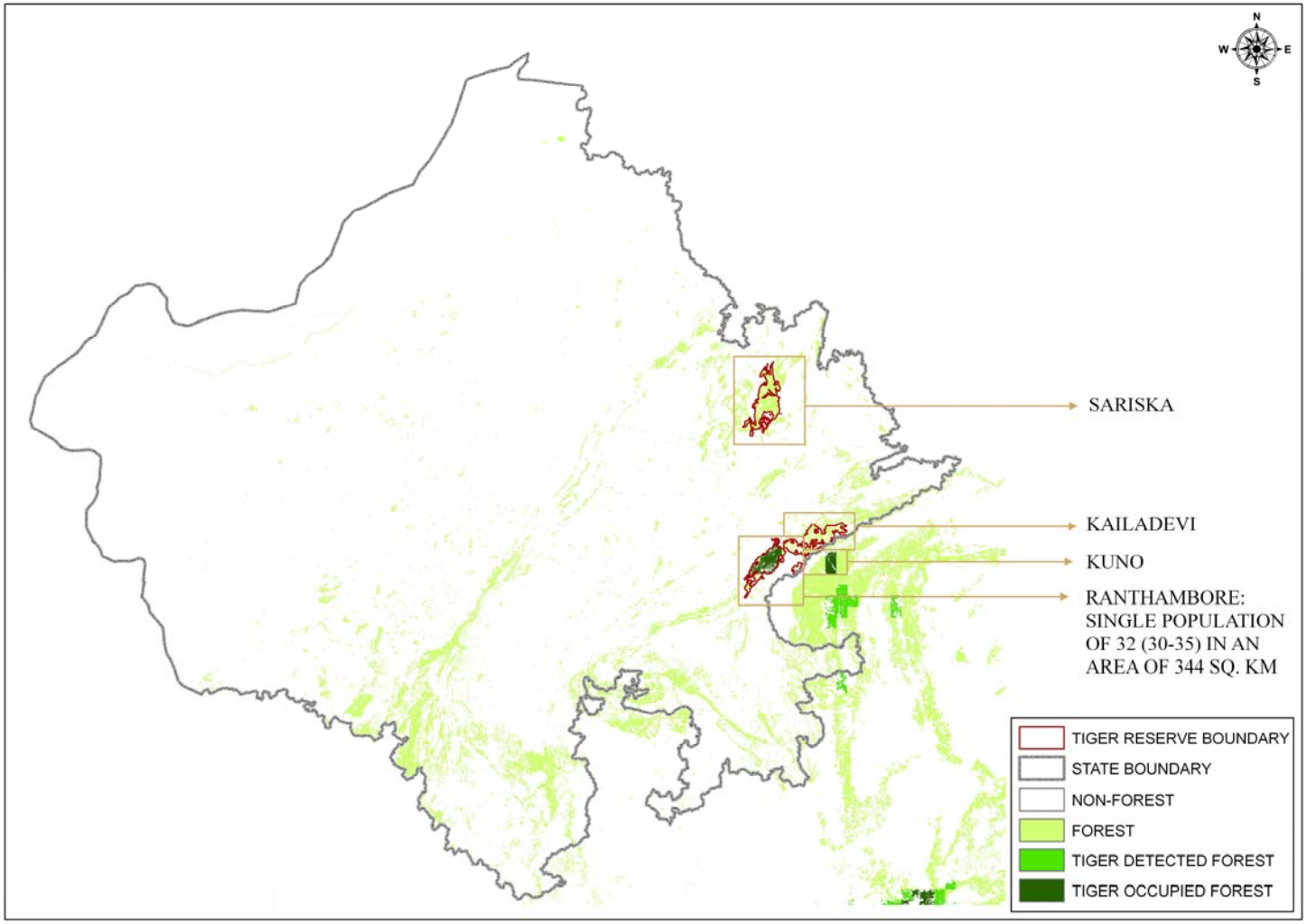
(1) Consolidate the area covered by the tiger reserve, so as to increase the tiger occupancy throughout forested habitat in Sawai Mansingh and Kailadevi Sanctuaries. This would permit the tiger population to increase and tend towards becoming a self sustaining viable unit.

(2) Improve the potential habitat connectivity between Ranthambore, Kuno Wildlife sanctuary and reserve forests of Sheopur district to form a viable Arid zone western most tiger conservation unit in India (Figure 1).

Good potential tiger habitat exists in Sariska Tiger Reserve where tigers became locally extinct in late 2004. The landscape consists of over 700 km^2 of forests. Parts of this forest also have a good prey base. The possibility of natural colonization by tigers of this landscape unit is remote as the closest source population of Ranthambore has no habitat connectivity with Sariska.

The area has potential for reintroduction through restorative measures and continued management of the introduced population by supplementation.

Figure 3.10 Tiger occupancy, population extent and potential habitat connectivity in Rajasthan



Madhya Pradesh

Madhya Pradesh has a forest cover of 80,717 km², comprising 26% of the geographic area of the State.

Madhya Pradesh reported tiger presence in 15,614 km², leopard presence in 34,736 km², dhole presence in 28,508 km² and Sloth bear presence in 40,960 km² of forested habitat. Amongst prey species wild pig occupied 59,903 km² nilgai 41,704 km², gaur 5,577 km², chital 41,509 km², and sambar 33,550 km² of forested habitats. The relect population of Barasingha was restricted to a single landscape of Kanha (231 km²).

Tigers were distributed in four major populations, namely the landscapes of

a) Kanha having a recorded tiger presence in 3,162 km², supporting a population of 89 tigers (± 1 se range 73-105).

b) Pench having a recorded tiger presence in 718 km² and supporting a population of 33 (± 1 se range 27-39) tigers. The Kanha-Pench landscape is still a contigious forest patch of 16,000 km², having sporadic tiger presence recorded besides the 2 major source populations constituting about 7-12 (± 1 se range) tigers.

c) Satpura landscape of 12,700 km² has its largest tiger population located in and around the Satpura Tiger Reserve with a tiger occupancy in 1,503 km² and supporting 39 (± 1 se range 26-52) tigers. Five other smaller tiger populations occur, one towards the north-east of the tiger reserve and the other 4 between Satpura Tiger Reserve and Melghat Tiger reserve in Maharashtra. These populations harbour between 9-15 tigers.

d) Bandhavgarh landscape covers an area of 2000 km² and has a tiger occupancy in 1575 km². The major tiger population is in and around the Bandhavgarh Tiger reserve comprising 47 (± 1 se range 37-57) tigers

e) Panna landscape covers an area of 3500 km² and has 2 discrete tiger occupied areas of 787 and 187 km². The larger population of Panna Tiger reserve and its surrounds sustains 24 (± 1 se range 15-32) tigers. The smaller population is a relict, comprising of 1-2 tigers likely sustained by north eastern dispersal of tigers from Panna. These seem to be over estimates due to excess of tiger signs recorded in comparison to Phase-III verification of the source population.

There are eight small tiger populations in the State. These are either historical relicts or are sustained by dispersing individuals from the major populations. Habitats harboring these small tiger populations form crucial linkages for existence of metapopulation structure. It is essential to explore some means of providing an enhanced legal status or other mechanisms for conserving these areas and populations to ensure long term tiger survival in the larger landscapes.

Sheopur-Shivpuri poplution (3-6 tigers, ± 1 se range) has remnant linkages with the western most arid zone tiger population of Ranthambore, but has lost its connectivity with the Panna Tiger landscape. Jabalpur-Damoh-Sagar tiger population (14-23 tigers, ± 1 se range) historically formed the connecting link between Bandhavgarh and tiger populations on the Northern banks of the Narmada. Bandhavgarh's linkages through Nagod and Pawai to Panna are now severed. Relict tiger populations exit on the northern banks of Narmada forming the Raisen population consisting of 7-12 (± 1 se range) tigers. These populations have no linkages to any major source population and their future seems bleak. The remnant tigers in Betul-Hoshangbad-East Nimar form an intermediate presence between two source populations the Satpura Tiger reserve in Madhya Pradesh and Melghat Tiger Reserve in Maharashtra. Few Tigers tenaciously hold their ground in the forests of Seoni-Balaghat intervening Kanha and Pench Landscape. This population forms a crucial linkage for the largest metapopulation unit in Central India connecting the populations of Kanha and Pench (Madhya Pradesh and Maharashtra). Scattered tiger presence is reported in Mandla district, these tigers are likely dispersing individuals from Kanha, Bandhavgarh and serve to genetically connect tiger populations of Eastern Madhya Pradesh to Chattisgarh (Achanakmar Sanctuary). Dispersing tigers from Bandhavgarh source sustain a sporadic tiger occupancy in the district of Shahdol and Sidhi forming potential linkages through Sanjay National Park to Palamau in Jharkhand.

Population Size: Total tiger population in the State of Madhya Pradesh was estimated to be 300 with a standard error range of 236 to 364 tigers.

Conservation Reccommendations:

1) Manage the Kanha-Pench landscape and the Satpura-Melghat (Mahrashtra) landscape within the framework of a metapopulation. This requires landscape level landuse planning targeted for each district harbouring connecting forests.

2) The Kanha tiger reserve buffer needs to be extended south-west in the tehsil of Baihar in Balaghat district so as to enhance the conservation value of this major source population.

3) Tiger habitat in Betul-Hausangabad-East Nimar needs protection and restorative management for enhancing the value of these forests for sustaining dispersing tigers from Melghat and Satpura Tiger Reserve and maintain connectivity between these 2 sources.

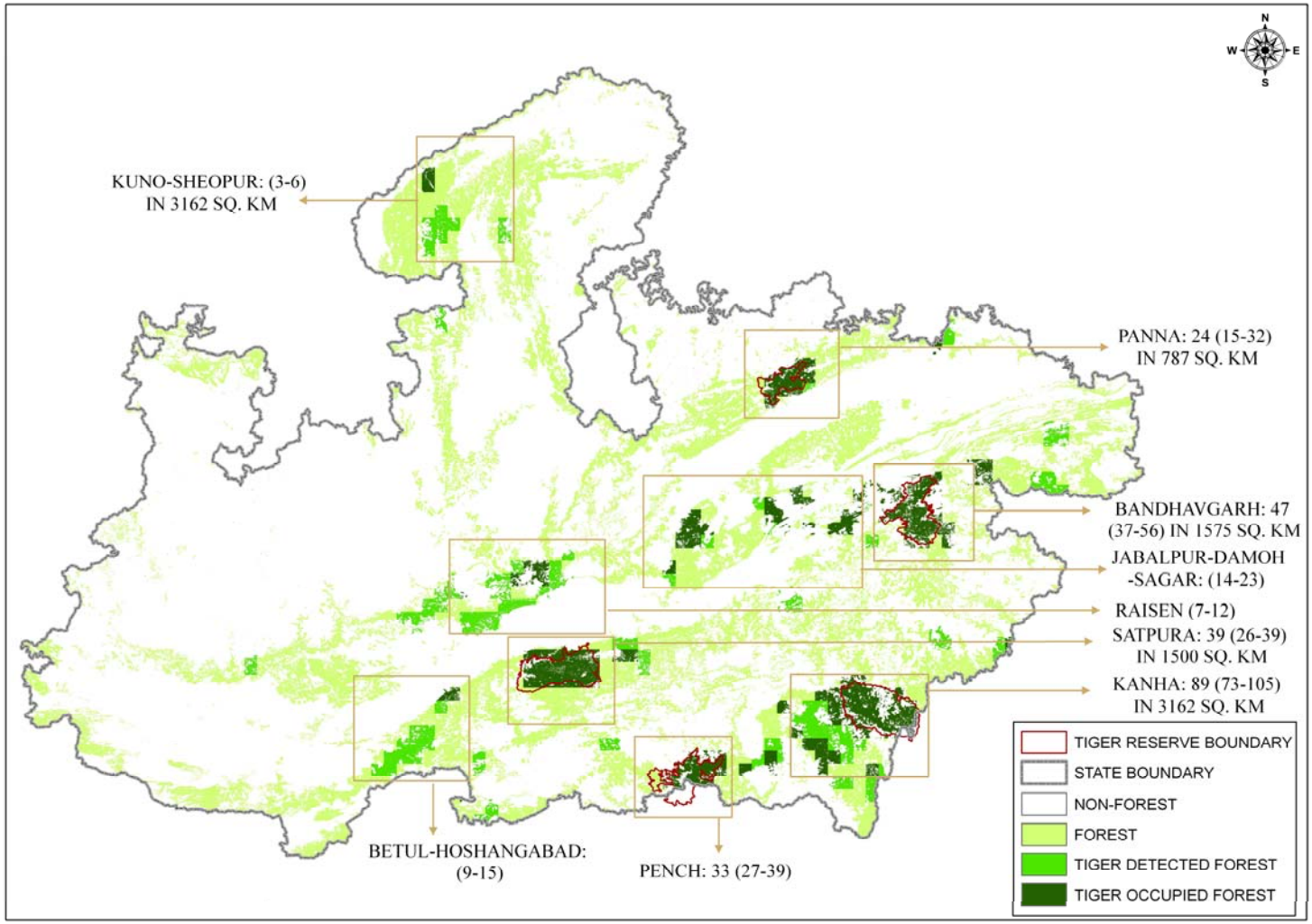
4) The contiguous forest North–East of Satpura Tiger Reserve in the tehsils of Parasia and Amarwara of Chindwara district need more protection and restorative management to enhance the source value of the Satpura Tiger Reserve. A unified administrative control of these forests would be beneficial.

5) The stepping stone connectivity forests (about 10 km stretch) in Parasia tehsil of Chindwara district that form the connecting link between Maikal and Satpura Landscape needs restoration and protection to reconnect these two major tiger occupied landscapes in MP.

6) The connecting forests North East of Bandhavgarh Tiger Reserve in the tehsil of Beohari, Jaisingh Nagar in Shadol district and Jopad banas tehsil of Siddhi District need protection and restorative management. These forests will then serve as a conduit for dispersing tigers from the high density Bandhavgarh source and help repopulate Sanjay and Chattiisgarh forests.

7) Low density Tiger presence is distributed all along the forests on the Northern banks of Narmada extending from Jabalpur all the way to West Nimar. These tigers tenaciously hold their ground in spite of all odds. Urgent restorative actions to enhance protection, habitat quality especially in terms of prey availability are required for ensuring their survival in the future (Figure 2).

Figure 3.11 Tiger occupied forests, individual populations, their extents and habitat connectivity in Madhya Pradesh



Maharashtra

The state has a total forest cover of 53,619 km² with mapable tiger occupancy reported in 4,273 km². Maharashtra reported leopard presence in 4,982 km², dhole presence in 4,352 km² and Sloth bear presence in 6,557 km² of forested habitat. Amongst prey species wild pig were reportd from 7,370 km², nilgai 4754 km², chital from 5,970 km² and sambar from 5,730 km² of forested habitat.

Tigers were distributed in three major populations, namely

a) Melghat comprising a part of the Satpura Landscape, having a recorded tiger presence in 1,828 km², supporting a population of 30 (± 1 se range 21-39) tigers. The tiger distribution in Melghat is contigious with the population in Madhya Pradesh forming a meta population with the Satpura Tiger Reserve as the other source population.

b) Pench (Maharashtra) being contigious with the forest patch of Pench Tiger Reserve in MP forming a part of the Maikal landscape, has a recorded tiger presence in 424 km² and supports a population of 19 (± 1 se range 16-23) tigers, some of which it shares with MP.

c) Tadoba-Andhari landscape of 2000 km² has a tiger occupancy in 775 km² and supports 34 (± 1 se range 27-41) tigers. This landscape has potential to serve as a source for the Navegaon-Indravati Landscape through the Northern forest patches in the Districts of Chandrapur, Garhchiroli and Bhandara. In the south stepping stone forest patches exist in the Tehsils of Gond Pipri and Sirpur.

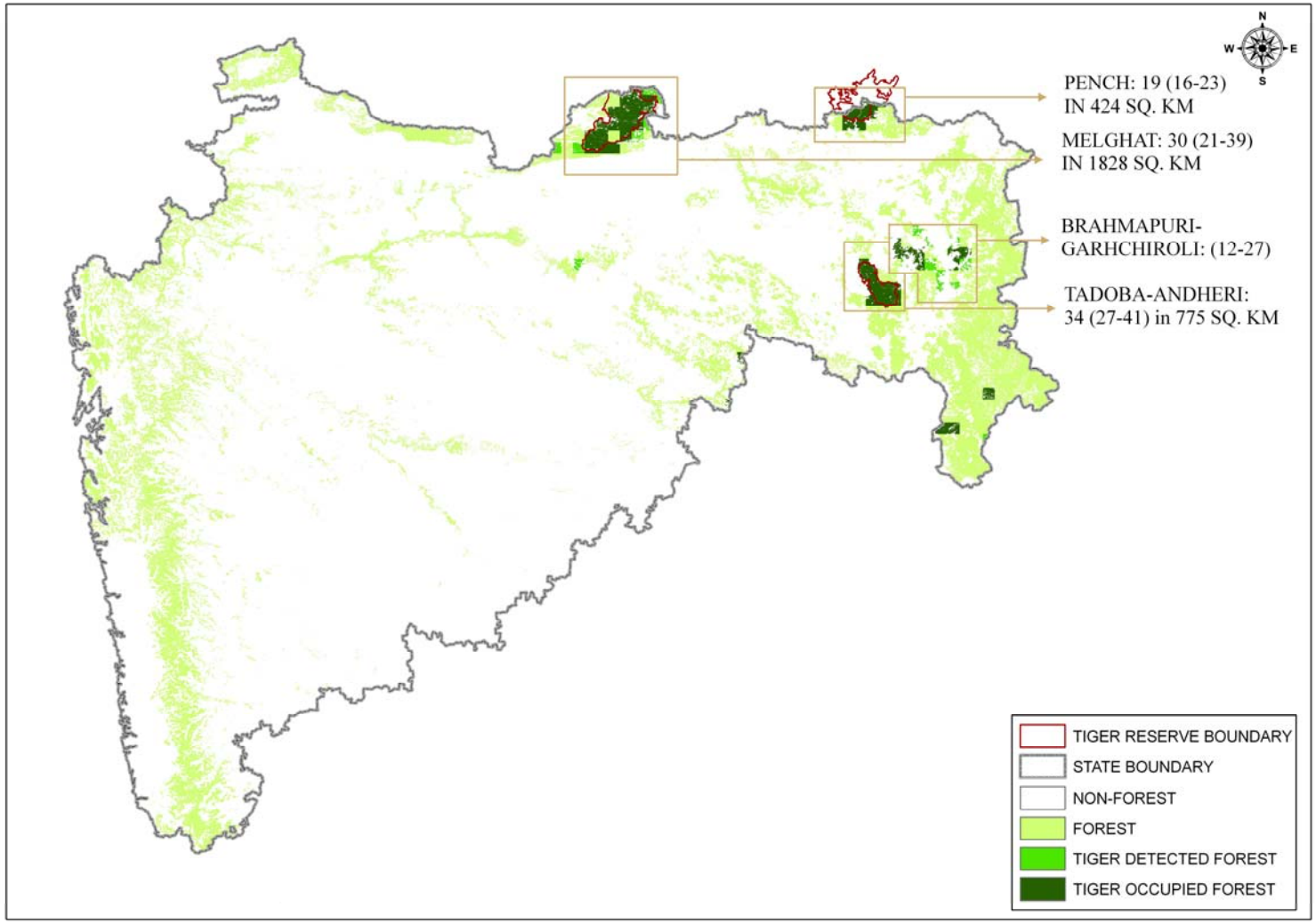
Sporadic tiger presence of about 12-27 (± 1 se range) tigers is recorded in the forests of Bhrampuri, Garhchiroli, Nagbir, Chimur, and Ahiri tehsils. This possibly indicates habitat connectivity to populations in Indravati Tiger Reserve in Chattisgarh and the Northern forests of Anhdra Pradesh.

Population Size: Total tiger population in the State of Maharashtra was estimated to be 103 with a standard error range of 76-131 tigers. Sixty percent GPS coordinates of Maharashtra beats were unmapable. However, high density tiger occupancy was mapped for the state and included in the above estimate.

Conservation Recommendations:

Tiger source populations of Melghat, Tadoba, and Pench need to be consolidated through enhanced protection and habitat management especially in forest areas surrounding these tiger reserves. This would increase the survival of dispersing tigers thereby increasing the tiger population and its effective source value. Interstate cooperation for management of Melghat and Pench is vital for the long term survival of the Satpura and Maikal Landscape tiger populations. Habitat connectivities of the Tadoba-Andhari population towards the north and south need protection and restorative management to maintain and enhance the value of this source for the larger landscape (Figure 3).

Figure 3.12 Tiger occupied forests, individual populations, their extents and habitat connectivity in Maharashtra.



Chattisgarh

The state has a total forest cover of 27,967 km² with tiger occupancy reported in 3,609 km². Chattisgarh reported leopard presence in 14,939 km², dhole presence in 3,794 km² and Sloth bear presence in 20,951 km² of forested habitat. Amongst prey species wild pig were reported from 25,058 km², nilgai 9,250 km², chital from 18,540 km² , gaur from 3,369 km² ,and sambar from 7,604 km² of forested habitat.

Tigers were distributed in three populations, namely the landscapes of

a) Achanakmar having a recorded tiger presence in 1,066 km², supporting a population of 19 (± 1 se range 18-22) tigers. Forested habitat of Achanakmar is a part of the Maikal landscape and is contagious with the tiger habitat of Kanha-Pench landscape in Madhya Pradesh likely forming a meta population.

b) Few tigers (6-8, ± 1 se range) are recorded in the forests of Udanti having an occupancy of 636 km². The habitat and tiger occupancy in this block is contigious in Orissa with Sonabeda Wildlife Sanctuary and forms a part of the larger Indravati Landscape.

c) Indravati likely forms a major source in the largest intact habitat patch of 34,000 km². It has habitat connectivity with tiger source populations of Tadoba, and Kanha and is also connected with tiger occupied forests in Northern Andhra Pradesh and Western Orissa. Unfortunately no information is available to assess the occupancy or population size of this important Tiger occupied landscape.

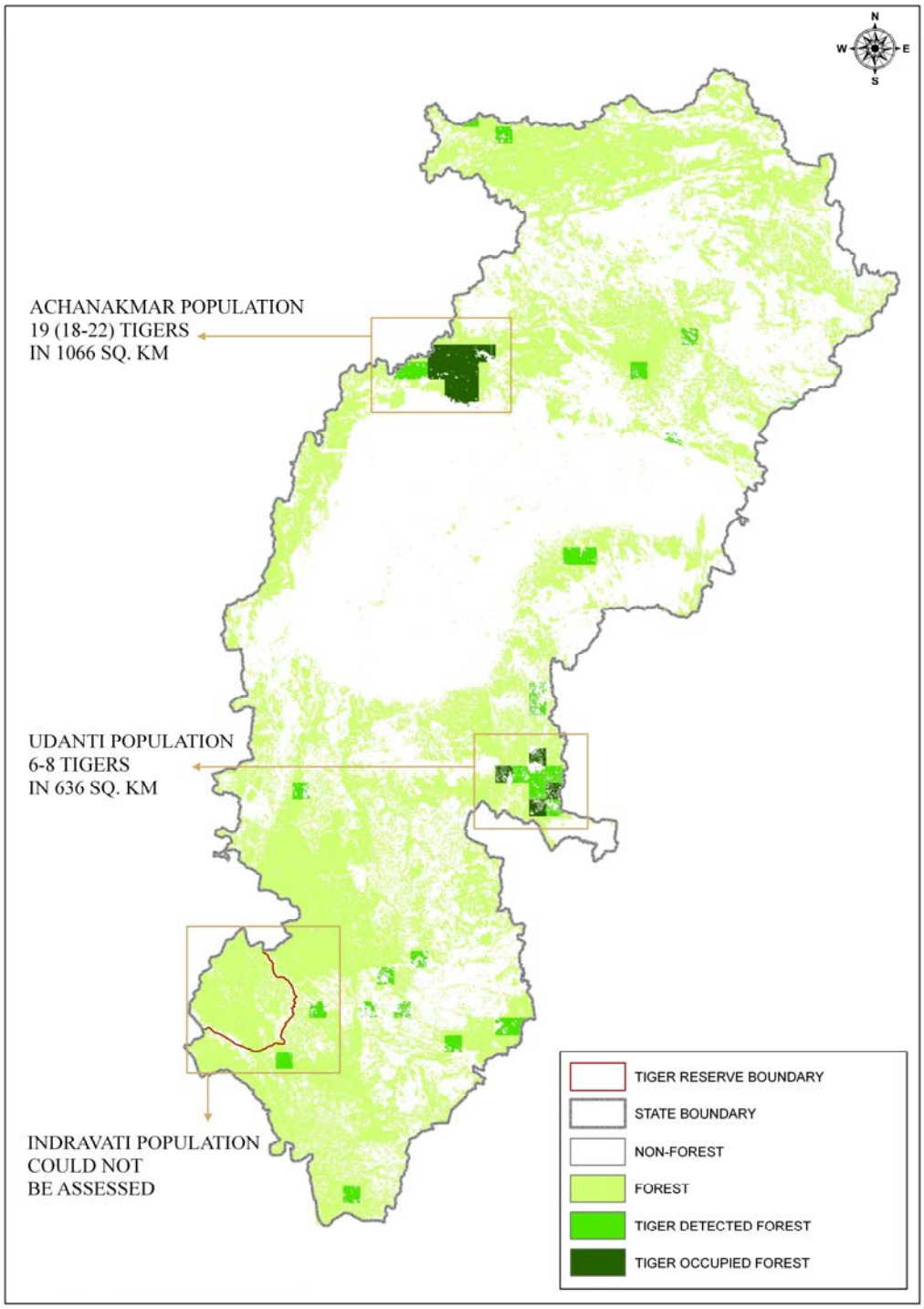
Sporadic tiger occurrences are recorded in Northern and Southern Chattisgarh (Figure 4).

Population Size: The tiger population for the state of Chattisgarh (except Indravati) is estimated to be 26 with a standard error range of 23-28 tigers.

Conservation Recommendations:

Tiger population status and associated threats for the Indravati Tiger Reserve needs to be assessed urgently as it is vital to sustain tiger occupancy of this large landscape. Achanakmar-Kanha (MP) and Udanti-Sonabeda (Orissa) linkages need to be sustained through protection and restorative management for long term survival of these populations.

Figure 3.13 Tiger occupied forests, individual populations, their extents and habitat connectivity in Chattisgarh



Orissa

The state has a total forest cover of 27,427 km² with mapable tiger occupancy reported in 9,144 km². Orissa reported mapable leopard presence in 25,516 km², dhole presence in 8,215 km² and Sloth bear presence in 43,236 km² of forested habitat. Amongst prey species wild pig were reported from 21,525 km², nilgai 711 km², chital from 6,040 km², Gaur from 2,772 km² and sambar from 6,112 km² of forested habitat.

Tigers were distributed in four larger occupied units, three smaller units and sporadic occurrences largely in Southern and Central part of the State. The larger occupied units comprise of :

a) Simlipal Landscape comprising of 3824 km² patch of forest has recorded tiger presence in 2 units having a total tiger occupancy of 2297 km² with an estimated tiger population of 20 (17-34) tigers.

b) Sonabeda-Udanti-Indravati Landscape is part of a contiguous forest patch of 34,000 km² having a tiger occupancy in Orissa of 570 km² of about 9 (7-11) tigers.

c) Tiger population in the tehsil of Malakangari in the district of Koraput comprising the sanctuary of Balimela and Kondakamberu comprises a part of the forested patch of 6254 km² that extends from East Godavari, Khammam and Vishakapatnam of Andhra Pradesh. Tiger occupancy in this forest patch in Orissa was reported in 879 km². Sporadic tiger presence is recorded in several places within Koraput district.

d) Satkosia Landscape is part of a forest patch of 13,459 km² and has tiger occupancy in 787 km² with several smaller pockets reporting tiger presence. The low density population was estimated to about 6 tigers. The area covers the districts of Kulbani, Gangam, and Kalahandi.

The smaller tiger occupied units having between 6-8 tigers were :

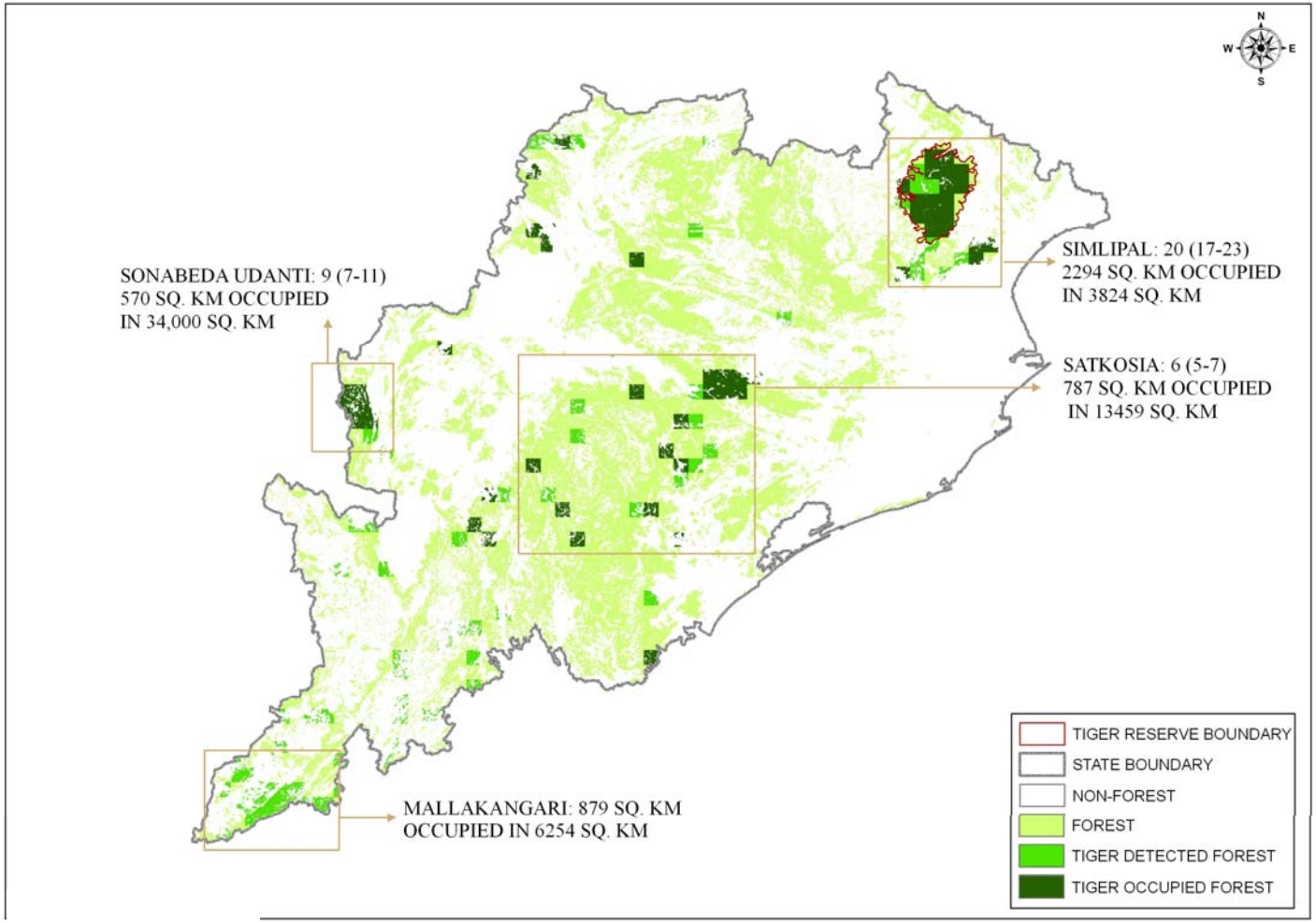
a) In the forested area of Raigarha tehsil in Koraput district with a tiger occupancy of 97 km².
b) The tiger occupancy of 221 km² was recorded in Sundergarh tehsil.
c) The Bargarh tehsil having an occupancy of 142 km².

The total tiger population in Orissa was estimated to be 45 (37 to 53) tigers.

Conservation Recommendations:

The major source population of tigers in Orissa is in Simlipal. Due to its large size and good habitat it can potentially sustain a viable population for long term conservation. It also has the potential to connect with the forests of Saranda in Jharkhand. However, currently the tiger population occurs at low density. This needs to be rectified by better protection, and enhancement of prey populations through reduction of anthropogenic pressures. The tiger population in Sonabeda has to be conserved through inter state cooperation and coordination with Chattisgarh. The Southern tiger population shares its gene pool with the tiger populations of eastern Andhra Pradesh and need to be managed as a meta population (Figure 6 and 7).

Figure 3.14 Tiger occupied forests, individual populations, their extents and habitat connectivity in Orissa



Jharkhand

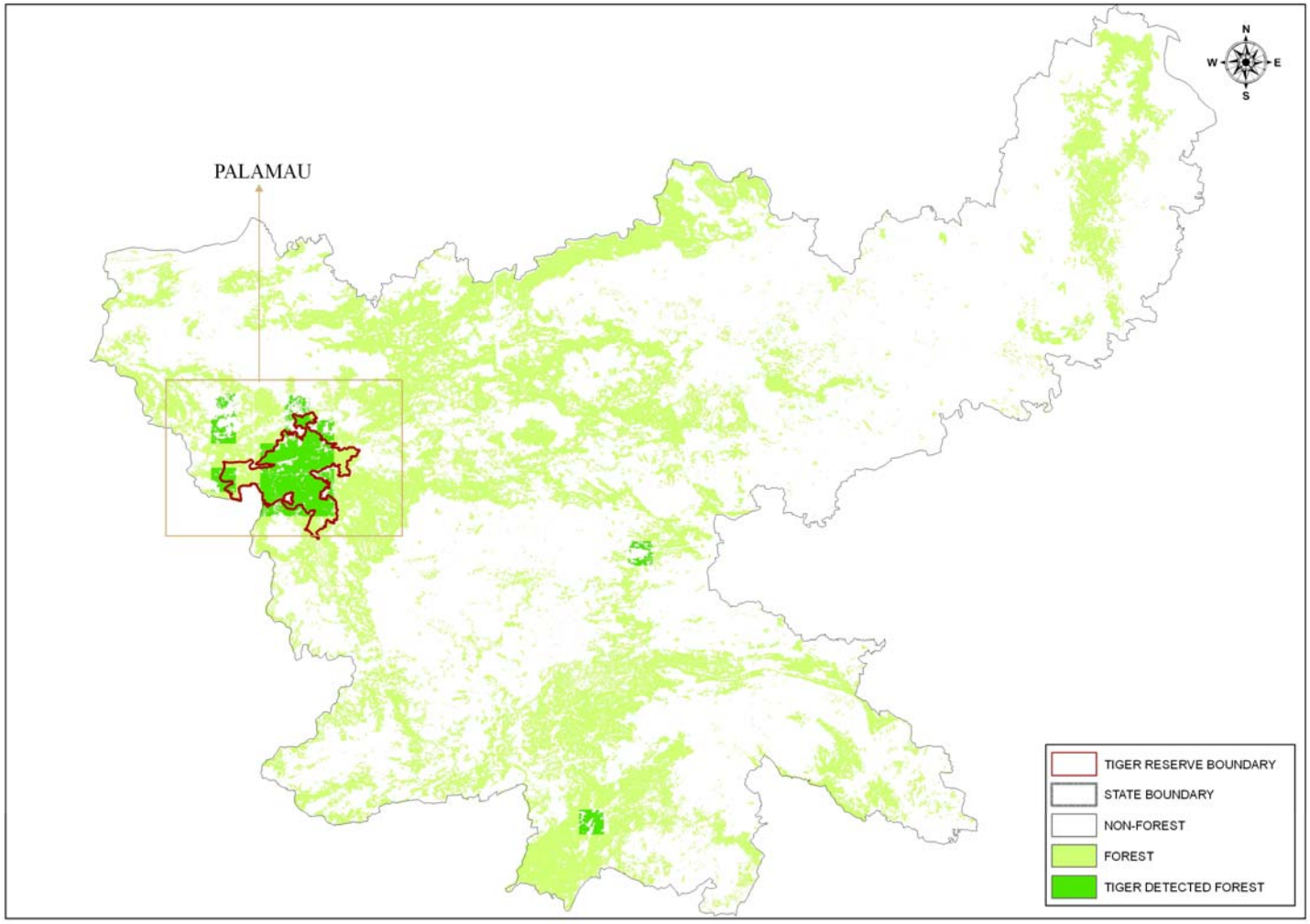
Jharkhand has a forest area of 23,630 km² with mapable tiger occupancy reported in 1488 km². Jharkhand reported mapable leopard presence in 131 km², dhole presence in 578 km² and Sloth bear presence in 2,640 km² of forested habitat. Amongst prey species wild pig were reported from 6,226 km², nilgai 1,108 km², chital from 721 km², gaur from 67 km² and sambar from 721 km² of forested habitat.

Tiger presence was reported from the forests of Saranda and in the forests of Ranchi tehsil. Both these areas form a contiguous forest patch of 7,448 km² that extends into Northern Orissa. The Palamau Tiger reserve did not report any tiger signs during the phase I survey. However, questionnaire survey of Phase I data indicates tiger presence which requires further field verification for evaluating status of the population. Subsequent data provided by the state was not as per the Phase I protocol but indicating presence and absence of tigers conducive only for mapping occupancy. Due to this limitation it was not possible to estimate population size of tigers for this state.

Conservation Recommendation

Palamau Tiger Reserve forms a crucial linkage via forests of Chattisgarh upto Sanjay National Park in MadhyaPradesh and possible links through stepping stone forests to Bandhavgarh. The forest patch containing Palamau is 12580 km² spread in three states and has the potential to harbor a good tiger population. The major problem in managing this tiger population is insurgency. If this problem is resolved, and anthropogenic pressures reduced by community participation in conservation management with appropriate economic incentives, this area could serve as a good source population of tigers.

Figure 3.15 Tiger occupied forests, individual populations, their extents and habitat connectivity in Jharkhand



Andhra Pradesh

Andhra Pradesh comprises of two major disjunct landscape complexes namely the Godavari basin Landscape in the Northern portion of the state (considered herein under the Central Indian Landscape) and the Eastern-Ghat Complex in the South Central part of the State.

The state has a total forest cover of 54,544 km² with tiger occupancy reported in 22,128 km². Andhra Pradesh reported mapable leopard presence in 37,609 km², dhole presence in 41,093 km² and Sloth Bear presence in 54673 km² of forested habitat. Amongst prey species wild pig were reported from 58,336.00 km², nilgai 26526 km², chital from 37,814 km², gaur from 3,139 km², and sambar from 33,159 km² of forested habitat.

In the part of the Central Indian highlands and Northern Eastern Ghats Landscape, Andhra Pradesh has four distinct tiger populations interconnected through forested habitat. These populations are :

a) In the district of Adilabad having a tiger occupancy of 3955 km² distributed in 2 major blocks with a few sporadic occurrences.Tiger population was estimated to be 19 (17 to 34).

b) The second population is in the district of Karimnagar, Warangal and Khamam (West) having a tiger occupancy of 2233 km² in two blocks with an estimated population of 12 (10-14) tigers.

c) The third population is in the district of Khamam (East), East Godavari, and Vishakapatnam having a tiger occupancy of 6019 km² distributed in two blocks with an estimated population of 11 (9 to 13) tigers.

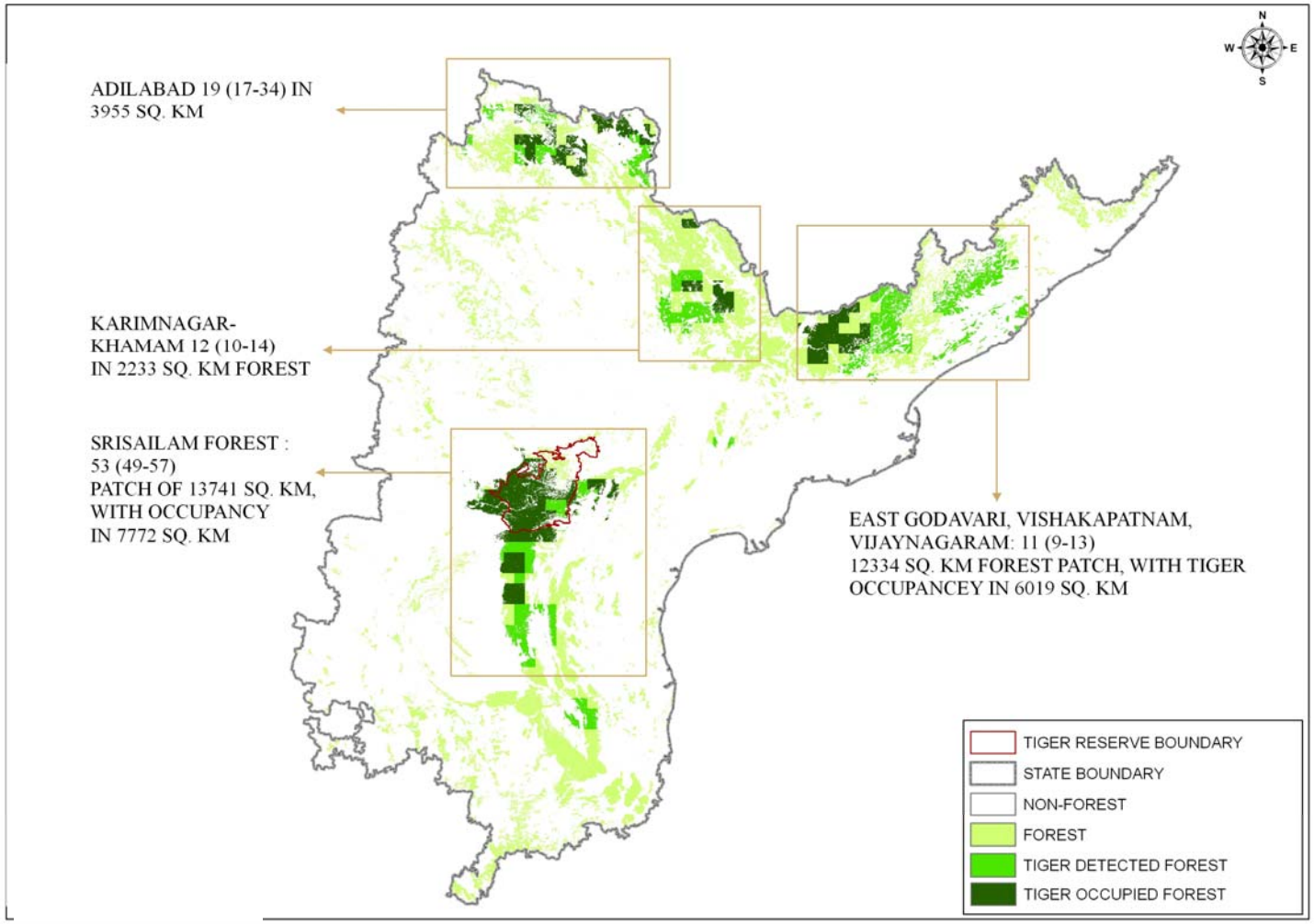
Among the Southern Eastern Ghats the major tiger population is located in the Srisailam-Nagarjuna Sagar Tiger Reserve and adjoining forests in the districts of Kurnool, Parakasam, Chuddapah, Mahbubnagar and Guntur having a tiger occupancy in a single block of 7772 km² having a population of about 53 (49 to 57) tigers.

The Tiger population for the State of Andhra Pradesh was estimated at 95 (84 to 107).

Conservation Reccommendations:

The source population of tigers in Srisailam needs to be fostered through preybase enhancement and protection so that it sustains a larger high density tiger population. This population can than provide dispersing tigers to repopulate the Southern Eastern Ghats (eg. Tirupati forests). The Northern tiger populations are disjunct though the habitat in terms of forest cover is contiguous. These populations can be interconnected by prey base restoration. Tiger populations in Northern Andhra Pradesh are a part of the larger tiger occupied landscape of Indrawati, extending through Chattisgarh, Maharashtra and Orissa. These populations need to be managed with interstate cooperation and a holistic landscape management plan (Figure 5 and Figure 7). Enhancing the legal status of the Forests harbouring tigers in the districts of Adilabad, Karimnagar, Khamam and East Godavri would foster tiger conservation in this region.

Figure 4.2 Tiger occupied forests, individual populations, their extents and habitat connectivity in Andhra Pradesh.



t

Western Ghats Complex

Principal Investigators

Qamar Qureshi, K. Sankar, Rajesh Gopal, Y.V. Jhala

Research Team

Bhaskar Acharya, Dr. Amit Kotia, Indrani Sasmal, Jaysooryan K.K., John C.E., M. Selvan, N. Sridharan, Navonil Das, Prudhvi Raj G., Ramachandran K., Shubham Dutta, Subhadeep Bhattacharjee, T. Ramesh, J. Peter Prem Chakravarthi, Ramachandran K.

5. Western Ghats

The Western Ghats is one of the major tropical evergreen forested regions in India rich in biodiversity especially endemic species. The landscape has already lost a large part of its forest cover, and the remaining forests are threatened with ever increasing anthropogenic pressures (Rodgers and Panwar 1988). This nesseciates strict conservation measures for preventing further loss of biodiversity and ecosystem processes.

These forests play a major economic role by maintaining water supply to the Krishna, Godavari and Cauvery river systems of peninsular India which have importance for irrigation and hydro-electric power. The scale of forest degradation which is causing loss of dry season flow and siltation of reservoires is a cause for concern.

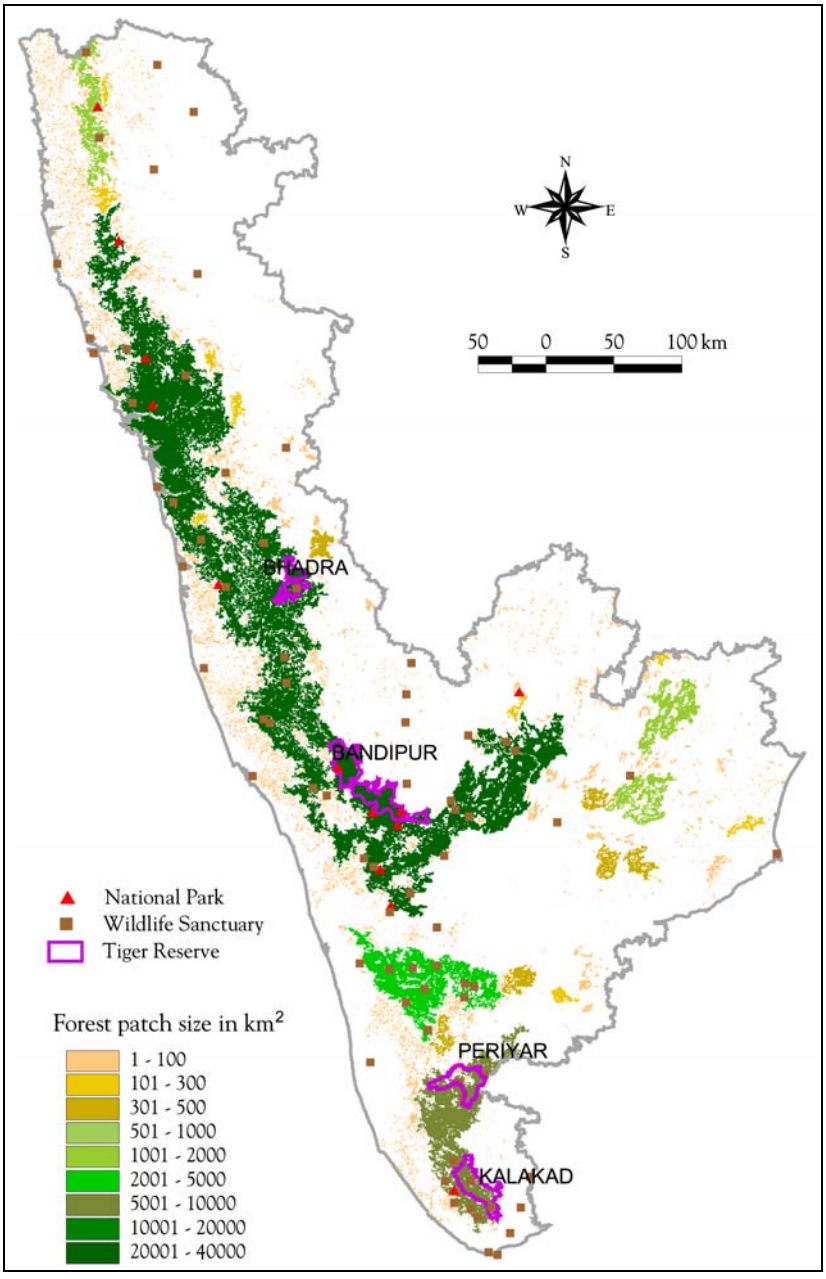
The high rainfall, gentle slopes and good soil resources of the Western Ghats are conducive for commercial plantation of tea, coffee, cocoa, rubber, cardamom, pepper and quinine, This has lead to logging and clearance of natural forest on a large scale and their replacement by monoculture plantations. The States of the Western Ghats have high human densities with a growing population. Thus, there is increasing pressure for the diversion of forest lands for agriculture and development.

India has some 15000 species of higher plants, of which around 4000 (27%) are reported from the Western Ghats, which is only 5% of over total land area (Rodgers and Panwar 1988). Botanical values include a great range of major associations, each with a very high proportion of endemics. These endemics are often highly localised by dispersal barriers and many are extremely vulnerable due to increasing habitat disturbance. High levels of endemism are found in vertebrates especially in herpetofauna (Mani 1974).

The Western Ghats were historically a good habitat for the tiger which was distributed throughout its forests. Currently most of the northern Western Ghats have lost their tiger populations while the southern portion of this landscape complex is still a major stronghold for the species due to its large and contiguous forested tracts (Figure 5.1).

Total geographic area : 281726 km^2
Political units : Tamilnadu, Kerala, Karnataka, Maharashtra (partially).
Average population density : 318.7 km^{-2}
Total protected area : 10009.9 km^2 (5.8% of the total Land Area)
Total forested area : 101467 km^2

Figure 5.1: Distribution of Protected Areas and various size of forest patches in the Western Ghats landscape



Major biogeographic zones : 1. Western Ghats (Malabar Plains (5A) & Western Ghats Mountains (5B)), 2. Deccan Peninsula (Central Plateau (6D) & Deccan South (6E)) and 3. Coasts (East Coast (8A) & West Coast (8B))

Table 5.1: Landscape Characteristics of the Western Ghats Landscape Complex

Parameters	Value
Number of forest patches	4983
Forest patch density per 1000 km²	6.1
Mean forest patch area (km²)	13.7
Mean forest perimeter to area ratio	34.6
Total forest core area (km²)	11123
Number of disjunct forest core areas	242
Mean forest core area (km²)	2.03
Median forest core area (km²)	13.5
Total forest core area in forest patches >1000 km²	10969

Tiger Habitat Status:

Districts from which tigers have become locally extinct within the recent historical past from the Western Ghat Landscape was 17%. Currently tigers occupy 21,435 km² of forests within the Western Ghat Landscape comprising 21% of the forested area. Tiger occupancy in the landscape complex was 34,094 km² having tiger population of 412 (336 to 487).

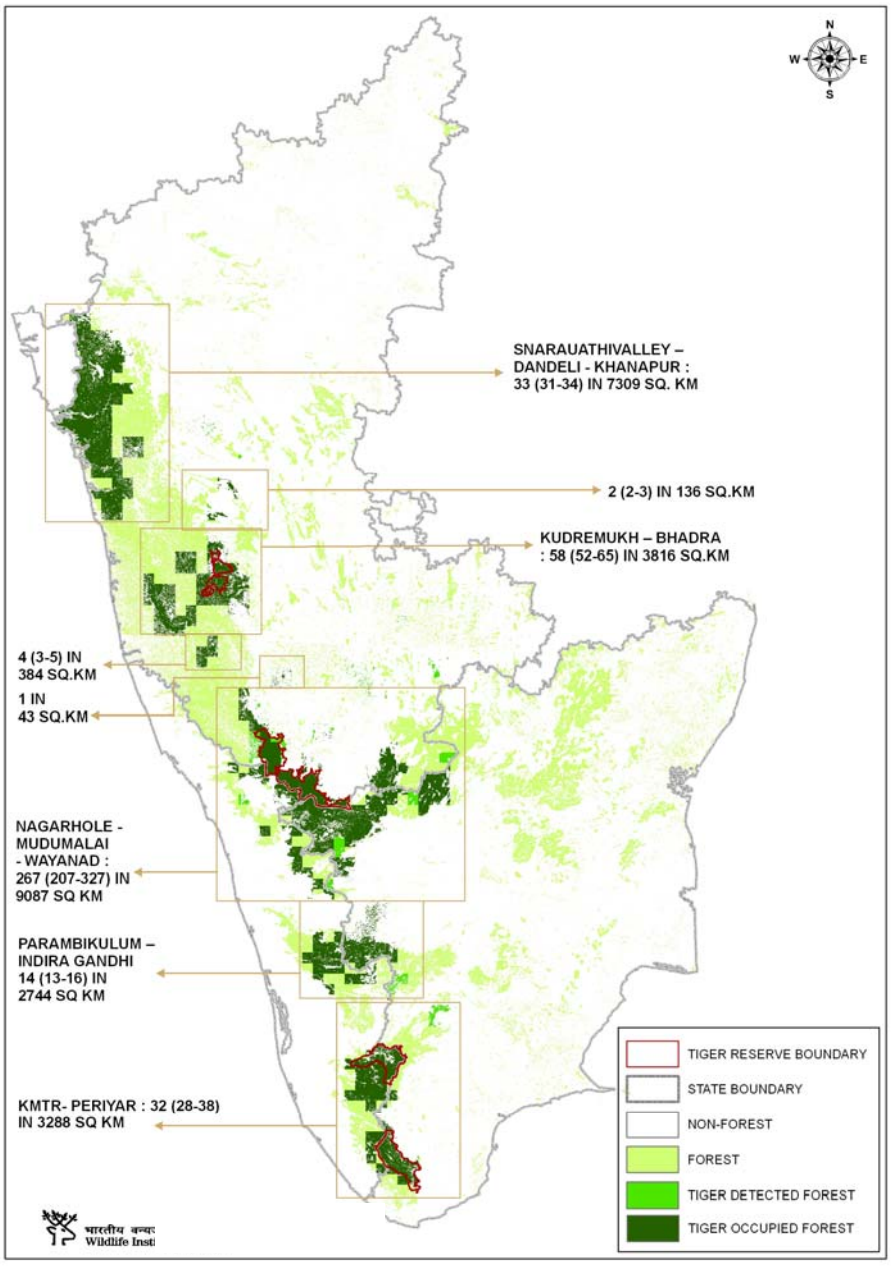
The Western Ghat landscape complex consists of 3 major forested landscape units (Figure 4.2).

1) North-Central Western Ghat Landscape: The largest of these landscapes extends from the district of Pune in the north and stretches south along the Western Ghats to the district of Palghat in Kerala, and to the eastern district of Dharmapuri in Tamil Nadu (39,600 km²). There are several National Parks, Sanctuaries and Tiger Reserves in this landscape eg. Koyna, Radhangir, Bhagwan Mahavir, Ansi, Kudremukh, Bhadra Tiger Reserve, Nagarhole-Bandipur Tiger Reserve, Silent Valley, Dr. Jayalalitha, Eravikulum, Mukurthi and Bannergatta. This landscape covers contiguous forest area of 39,000 km² and has the highest potential for long term tiger conservation. Though the area coverage is large, the forested landscape towards the North is narrow along the Western Ghat ridge. This area needs protection and prey restoration for fostering tiger conservation.

2) South-Central Western Ghat Landscape: Forested areas to the south of Palghat gap comprising the sanctuaries of Chimmory, Parambikulam, Anamud, Thattekadu, Indira Gandhi, Chinnur, Idukki, Shola forest and Kodai Kanal. This covers a contiguous area of about 4400 km^2. This area, though not having any National Park or Tiger Reserve, has a potential for tiger conservation. It is also connected to the South through degraded forest patches which may likely permit tiger movement with the landscape comprising of Periyar-complex.

3) Southern Western Ghat Landscape : Periyar-Agastyamalai-Kalakad is the Southern most tiger occupied landscape covering an area of about 6000 km^2. It has some potential connectivity with the Northern forests, which can be restored by management and protection (in the tehsils of Palaiyam, Udumbanchola, Todupulai and Pirmed). This would enhance the value of this landscape as a metapopulation within a larger landscape of over 10,000km^2.

Figure 5.2 **Tiger occupied forests, individual populations, their extents and habitat connectivity in Western Ghats**



Landscape occupancy of Co-predators and prey in Western Ghats

Leopard occupancy was detected in 43,353 km² (Figure 5.3), Wild Dog occupancy was detected in 46,321 km² (Figure 5.4), Sloth bear occupancy was detected in 40,877 km² (Figure 5.5), Chital occupancy was detected in 58,847 km² (Figure 5.6), Sambar occupancy was detected in 69,790 km² (Figure 5.7), Wild Pig occupancy was detected in 50,576 km² (Figure 5.8), Gaur occupancy was detected in 29,531 km² (Figure 5.9) and Elephant occupancy was detected in 18,232 km² (Figure 5.10).

Figure 5.3 Leopard occupied forests, individual populations, their extents and habitat connectivity in Western Ghats Complex

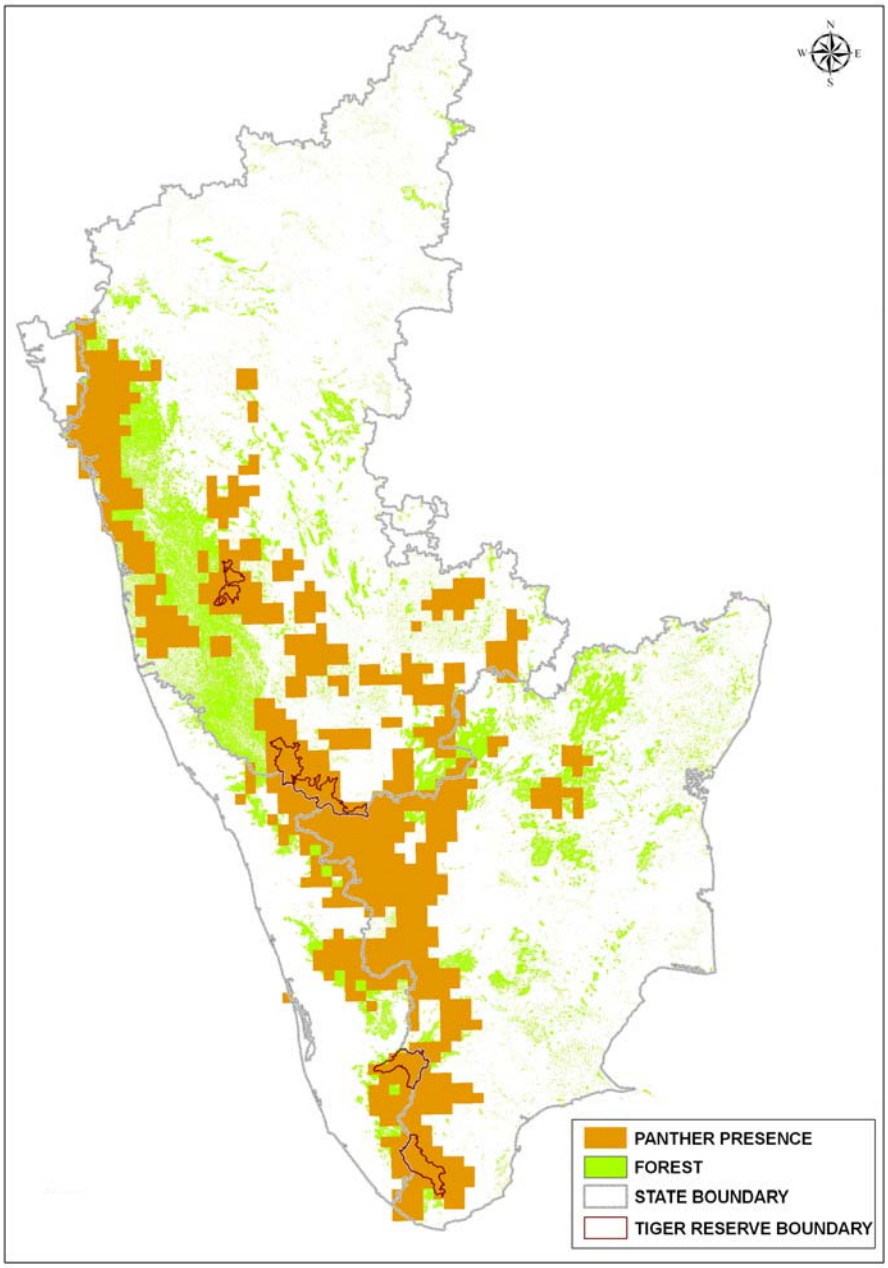


Figure 5.4 **Wild Dog occupied forests, individual populations, their extents and habitat connectivity in Western Ghats Complex**

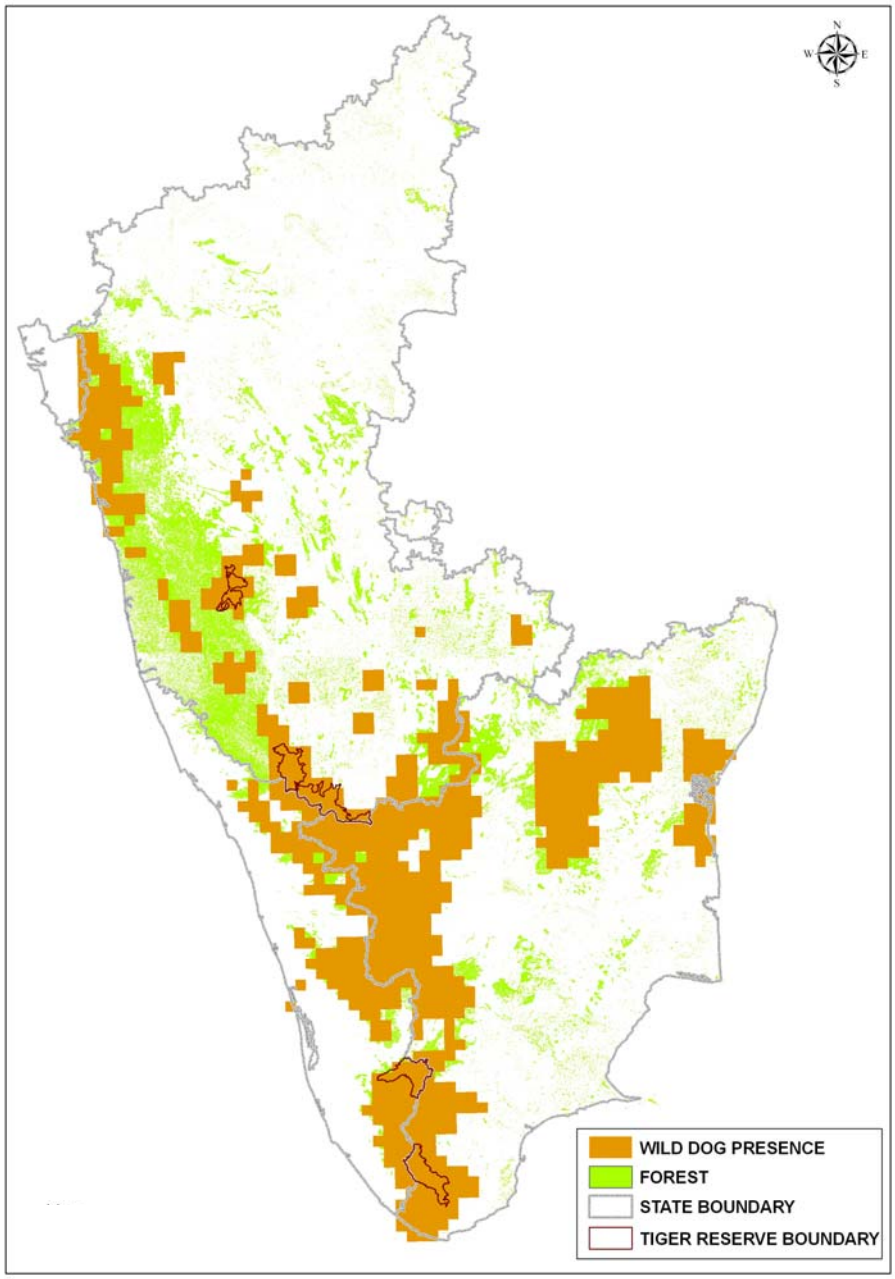


Figure 5.5 **Sloth Bear occupied forests, individual populations, their extents and habitat connectivity in Western Ghats Complex**

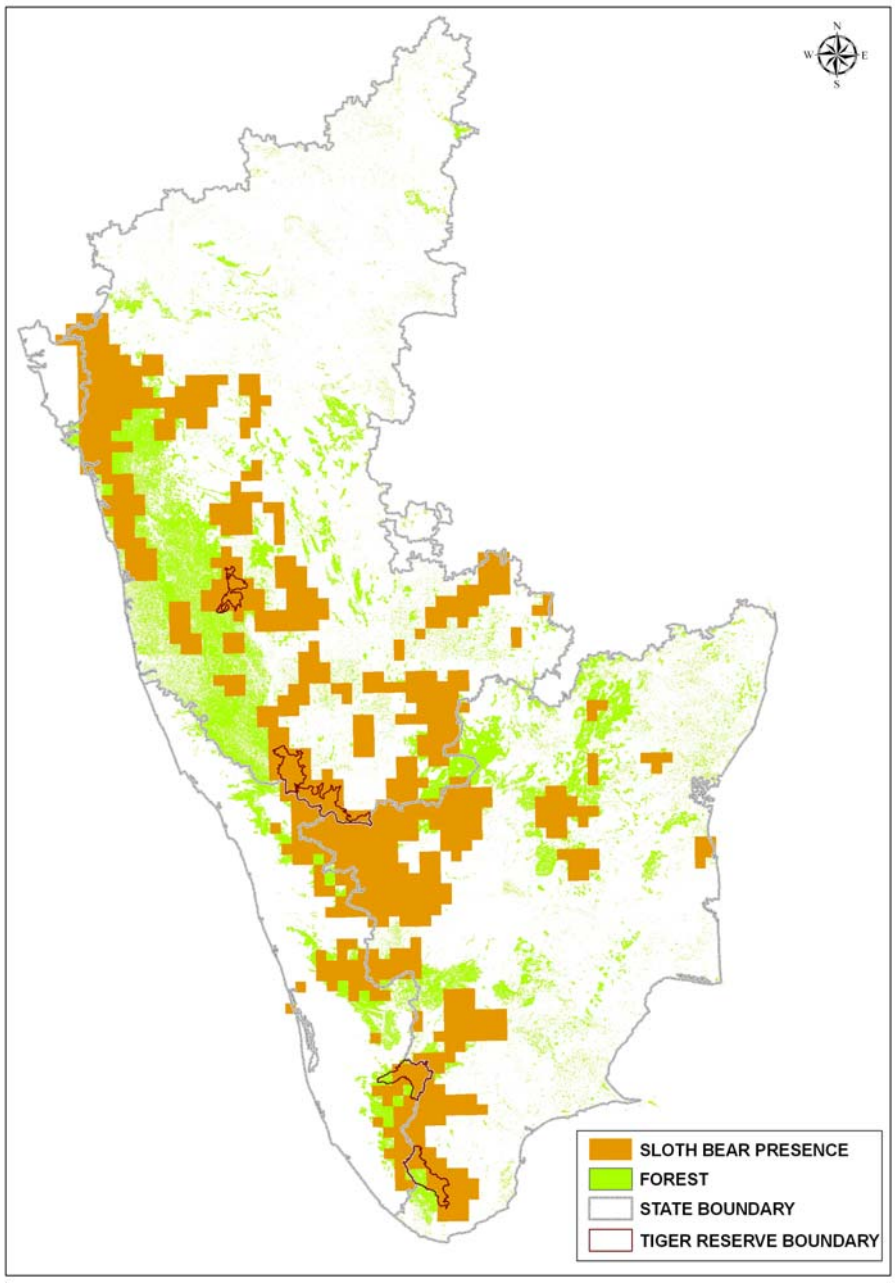


Figure 5.6 **Chital occupied forests, individual populations, their extents and habitat connectivity in Western Ghats Complex**

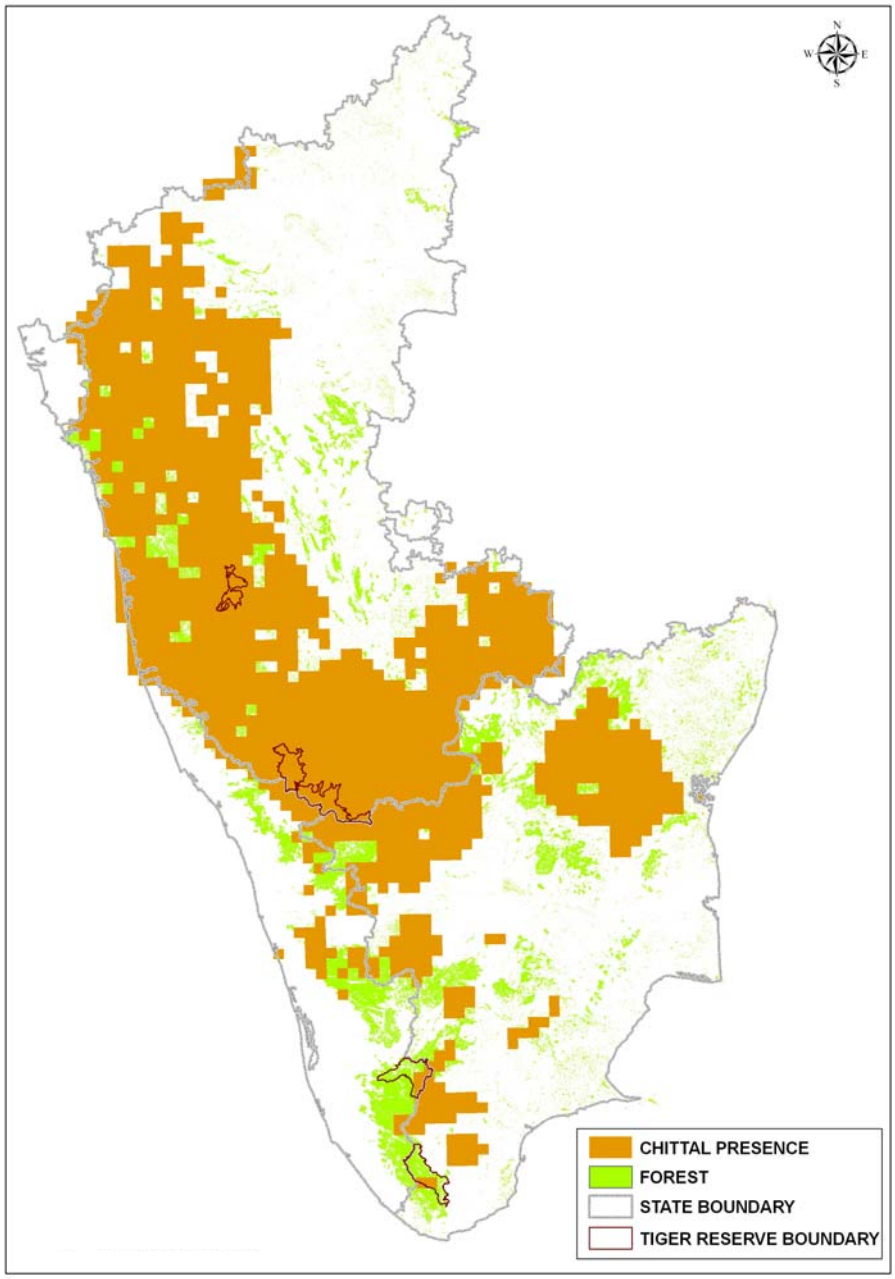


Figure 5.7 **Sambar occupied forests, individual populations, their extents and habitat connectivity in Western Ghats Complex**

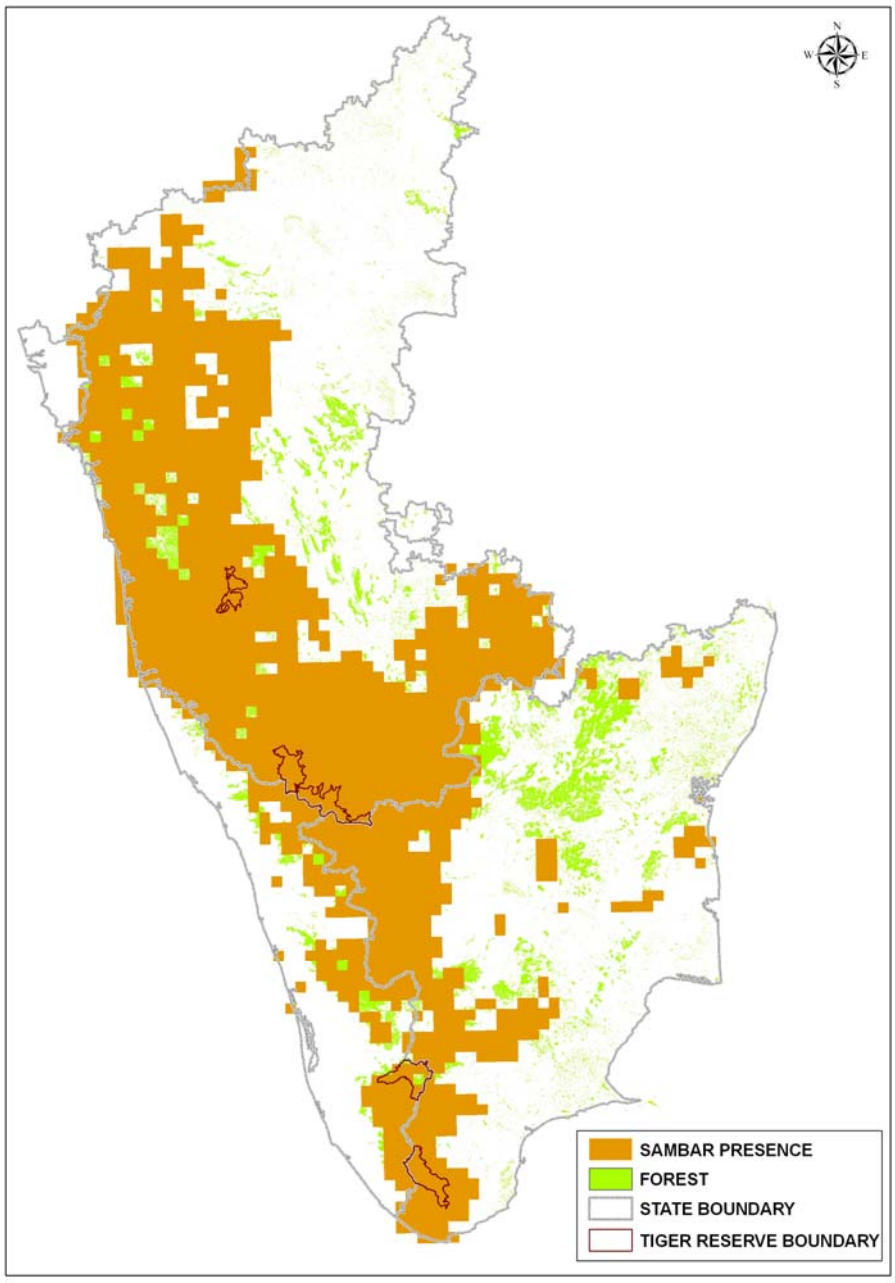


Figure 5.8 **Wild Pig occupied forests, individual populations, their extents and habitat connectivity in Western Ghats Complex**

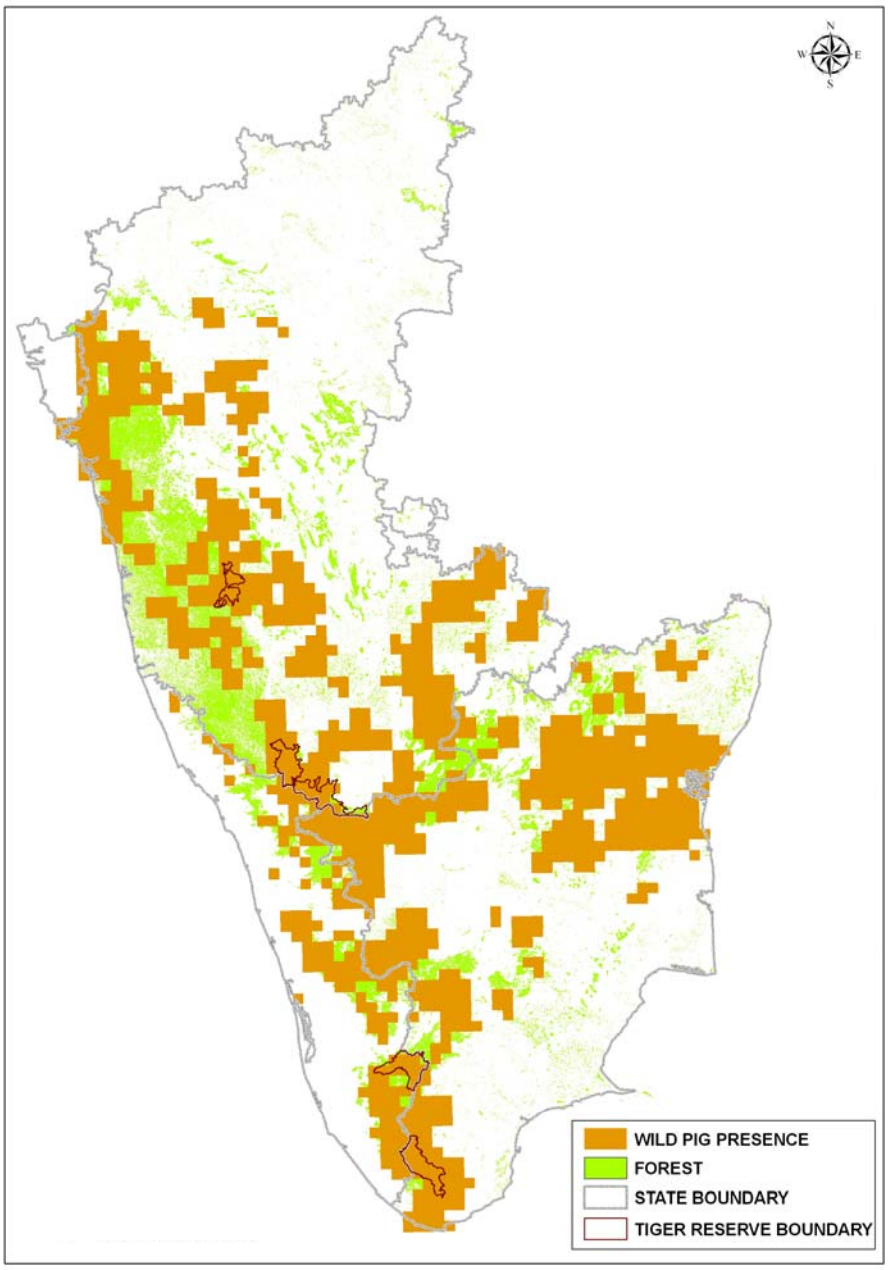


Figure 5.9 Gaur occupied forests, individual populations, their extents and habitat connectivity in Western Ghats Complex

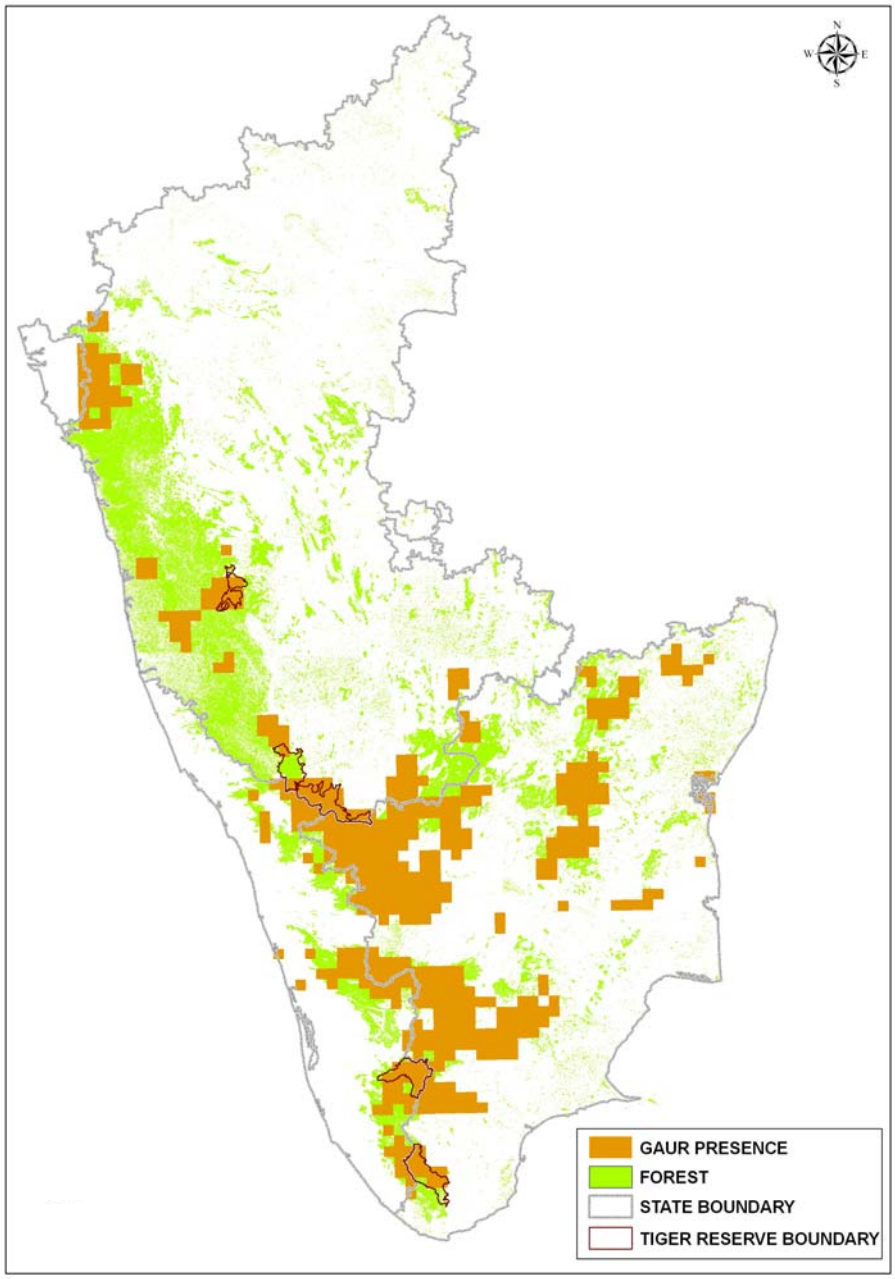
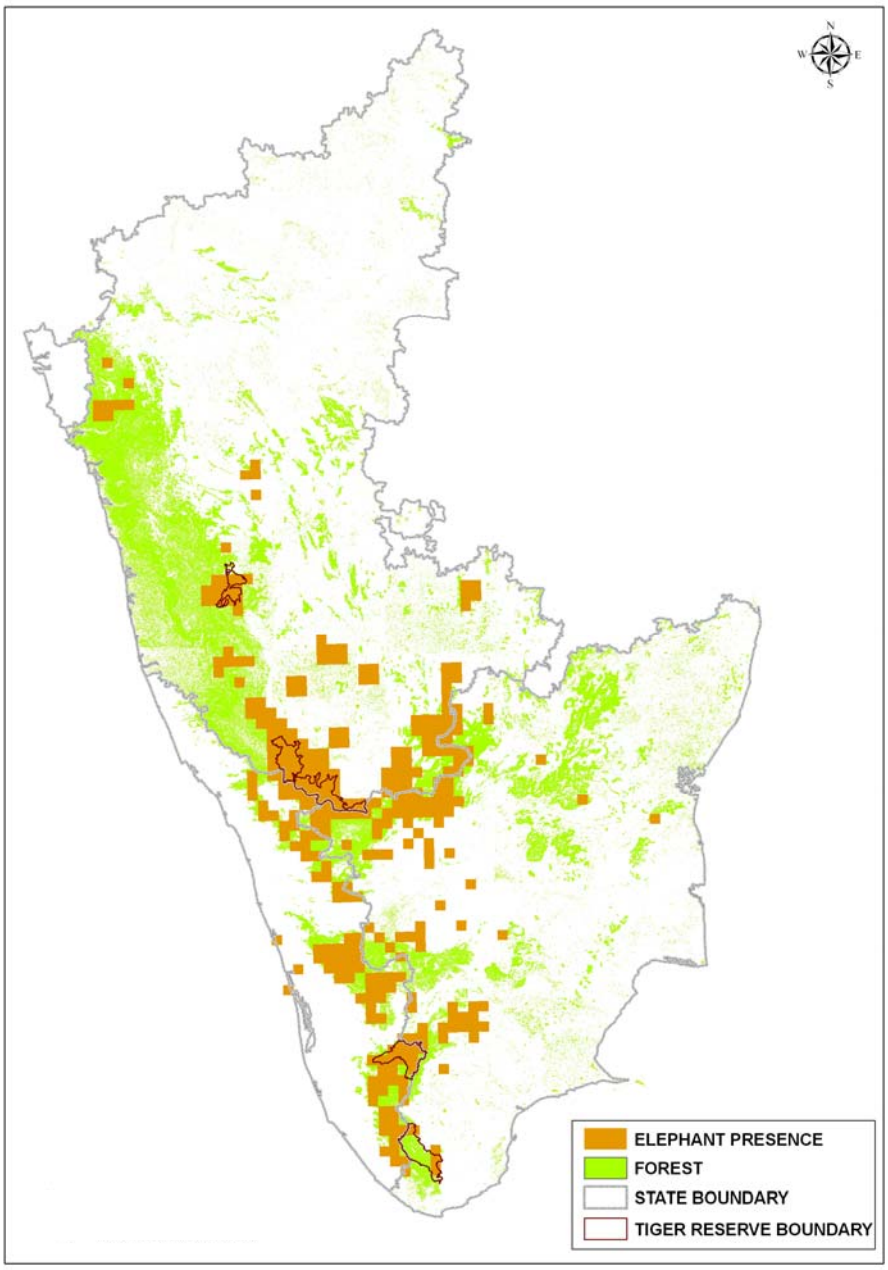


Figure 5.10 Elephant occupied forests, individual populations, their extents and habitat connectivity in Western Ghats Complex



KARNATAKA

The forest cover of Karnataka is 40,236 km², comprising 21% of the geographic area of the State. Forests of Tiger Conservation Priority I &II were 24,182 km² in Karnataka. Currently tigers occupy an area of 18,715 km² of these forests having estimated tiger population of 290 (241 to 339). Leopard occupancy 20,506 Km², Sloth Bear occupancy was 20,749 km² and Dhole 15,862 km².

Amongst prey species occupancy of Chital was 42,349 km², Sambar was 43,412 km², Wild pig 21,999 km².

Karnataka has three populations of tigers constituted by:

a) Nagarhole-Madumalai-Wayanad Population: This population extends from Madumalai Wildlife Sanctuary (Tamil Nadu) – Wayanad Wildlife Sanctuary (Kerala) – Bandipur-Nagarhole Tiger Reserve (Karnataka)- forests of Nilgiri and Periyar districts of Tamil Nadu and Biligiri Rangaswami Temple Sanctuary to Cauvery Sanctuary (Karnataka). The forest patch containing this population (and several other tiger populations) extends from Palghat gap (Palghat District Kerala) northwards to Bhimasankar Sanctuary in the District of Pune, Maharashtra and eastwards in the district of Dharampuri in Tamil Nadu covering a forest area of 39,000 km². This population has a tiger occupancy of 10,800 km². In Karnataka tiger occupancy of this population is 3,651 km² with an estimated tiger population of 192 (152 to 232).
b) Kudremukh-Bhadra: This population of tigers, though distinct from the Madumalai-Waynad-Nagarhole population, occurs in the same contiguous forest patch that extends form Palghat Gap (Kerala) to Bhimasankar (Maharashtra) of 39,000 km². Tiger occupancy of this population was 7054 km² with an estimated tiger population of 58 (52 to 65)
c) Sharavathi Valley-Dandeli-Khanapur Population: This population of tigers too is within the same contiguous forest as the above two populations. Several Protected areas like Sharavathi valley, Attiveri, Dandeli, Sanctuaries in Karnataka having tigers, constitute this population. Adjacent areas of Anshi, Netravali, and Mollem in Goa are likely to have dispersing tigers from this population. Tiger occupancy of this population was 7309 km² with an estimated population of 33 (31 to 34) tigers.

Total tiger population for the sate of Karnataka was estimated at 290 (241 to 339) tigers.

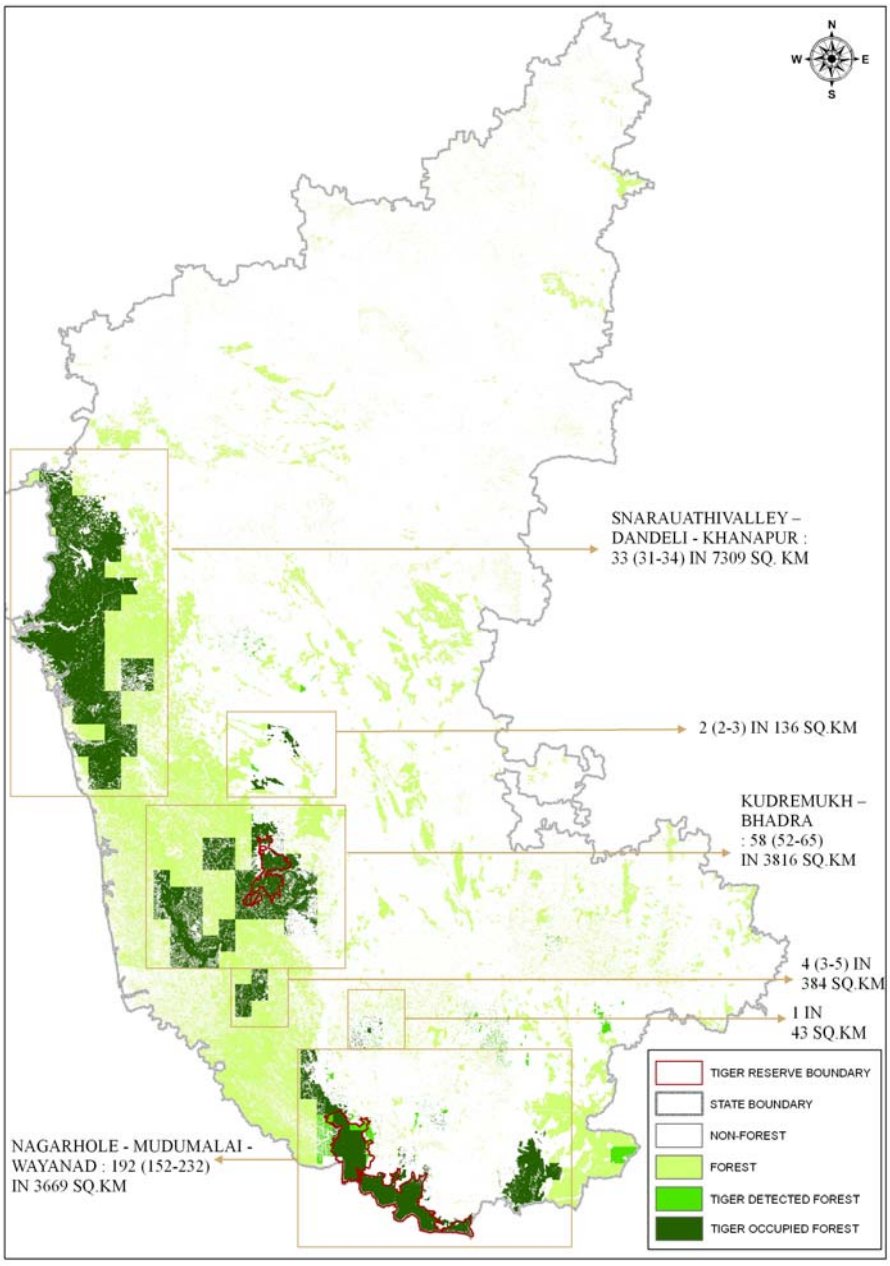
Conservation Recommendations

1) The tiger populations of Karnataka are doing well in terms of population size, extent, and connectivity in relation to tiger populations in other parts of the country. The major conservation concern is to provide protection form poaching of tigers and their prey both for commercial purposes and subsistence. Tigers have a good chance of long term persistence in the Western Ghat landscape complex provided the several populations that currently exist continue to exchange individuals through contiguous forest corridors. Such movement and meta-population structure can be ensured by enhancing the tiger friendliness of intervening matrix through enhanced prey base and reduction of anthropogenic disturbances.

2) Sporadic tiger occurrences are reported between the southern Madumalai-Wayanad-Nagarhole Population and the Kudremukh-Bhadra population lending evidence that these two populations likely exist as a meta-population. Tiger presence is also recorded between Kudremukh-Bhadra population and Sharavathi Valley-Dandeli-Khanapur Population, these populations too likely exchange dispersing tigers. Thus, all tiger populations within Karnataka and across the state to Tamil Nadu and Kerala are likely forming a meta-population. This attribute needs to be fostered by forest and prey base contiguity.

3) The Protected areas of Goa can possibly sustain tiger populations as they can be easily colonized by dispersing tigers from Sharavathi Valley-Dandeli-Khanapur Population. Management to enhance prey base in these protected areas would enhance the chances of fostering breeding tigers.

Figure 5.12 Tiger occupied forest, individual populations, their extents and habitat connectivity in Karnataka



TAMIL NADU

The forest cover of Tamil Nadu is 24,662 km², comprising 19% of the geographic area of the State. Forests of Tiger Conservation Priority I &II were 8400 km² in Tamil Nadu. Currently tigers occupy an area of 9211 km² of these forests having estimated tiger population of 76 (56 to 95). Leopard occupancy 14484 km², Sloth Bear occupancy was 13224 km² and Dhole 19,658 km².

Amongst prey species occupancy of Chital was 13567 km², Sambar was 15900 km², Wild pig 19,768 Km², Nilgai 2505 Km², and Gaur was 15442 km².

Tamil Nadu has three major populations of tigers constituted by:

a) KMTR-Periyar Population: Extending from Kalakad–Mundunthurai in Tamil Nadu to Peppara and Periyar in Kerala having a tiger occupancy of 3,288 km² in a forested area of 6000 km². Within Tamil Nadu tiger occupancy of this population was 1,625 km² with an estimated tiger population of 6-8 tigers.

b) Parambikulum-Indira Gandhi Population: Extending from Indiragandhi Wildlife Sanctuary-Chinnar Wildlife Sanctuary (in Tamil Nadu) and Parambikulam Wildlife Sanctuary in Kerala. This population has a tiger occupancy in 2,744 km² within a contiguous forest patch of 4,400 km². Within Tamil Nadu the tiger occupancy of this population was 1691 km² with an estimated population of 6-8 tigers.

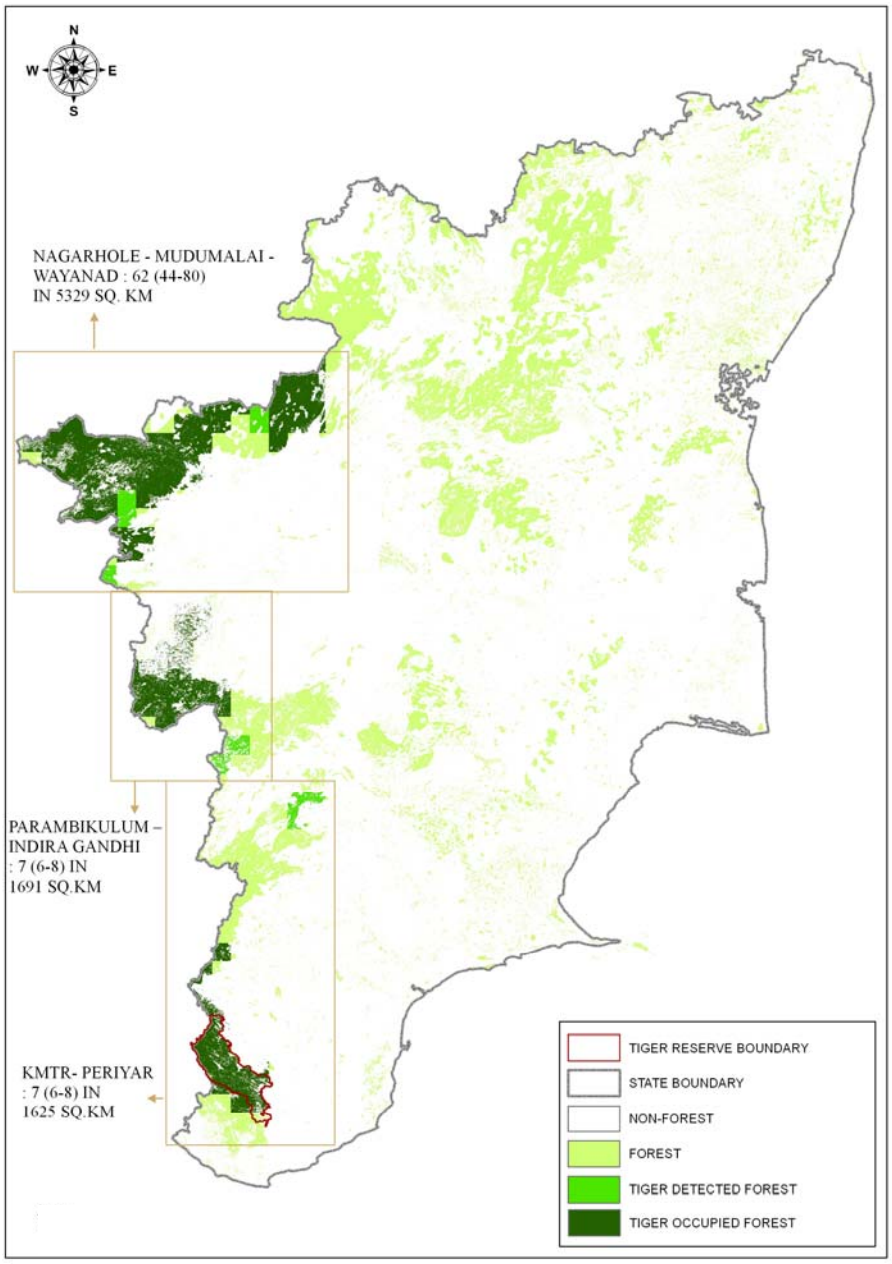
c) Nagarhole-Madumalai-Wayanad Population: The third population extends from Madumalai Wildlife Sanctuary (Tamil Nadu) – Wayanad Wildlife Sanctuary (Kerala) – Bandipur-Nagarhole Tiger Reserve (Karnataka)- forests of Nilgiri and Periyar districts of Tamil Nadu and Biligiri Rangaswami Temple Sanctuary to Cauvery Sanctuary (Karnataka). The forest patch containing this population (and several other tiger populations) extends from Palghat gap (Palghat District Kerala) northwards to Bhimasankar Sanctuary in the District of Pune, Maharashtra and eastwards in the district of Dharampuri in Tamil Nadu covering a forest area of 39,000 km². This population has a tiger occupancy of 10,800 km². In Tamil Nadu alone tiger occupancy of this population is 5326 km² with an estimated tiger population of 62 (44 to 80) tigers.

Conservation Recommendations

1) Since Kalakad-Peryar Landscape and Indiragandhi-Parambikulam landscape are rainforest habitats. Prey densities and consequently tiger densities are naturally low in such forests. This attribute dictates that larger conservation areas would be needed for maintaining a genetically and demographically viable tiger population. The current tiger occupancy and density can be enhanced by strict protection and control of subsistence level poaching of wild ungulates.

2) Madumalai tiger population is part of the single largest tiger population in India. It acts as a source for populating the Northern and Eastern parts of the Western Ghat landscape complex. This tiger population is capable of existing at reasonably high density due to the deciduous nature of its forests. This population needs to be fostered with strict protection from poaching to enhance its contribution for long term tiger conservation.

Figure 5.13 Tiger occupied forest, individual populations, their extents and habitat connectivity in Tamilnadu



KERALA

The forest cover of Kerala is 15,631 km², comprising 40% of the geographic area of the State. Forests of Tiger Conservation Priority I & II were 13,367 km² in Kerala. Currently tigers occupy an area of 6,168 km² of these forests with tiger population of 46 (39 to 53). Leopard occupancy 8,363 km², Sloth Bear occupancy was 6,904 km² and Dhole 10,801 km².

Amongst prey species occupancy of Chital was 2931 km², Sambar was 10,469 km², Wild pig 8,809 km², and was Gaur 5615 km².

Kerala has three major populations of tigers constituted by:

a) KMTR-Periyar Population: Extending from Kalakad–Mundunthurai in Tamil Nadu to Peppara and Periyar in Kerala having a tiger occupancy of 3,288 km² in a forested area of 6000 km². Within Kerala tiger occupancy of this population was 2,314 km² with an estimated population of 23 (20 to 27) tigers.

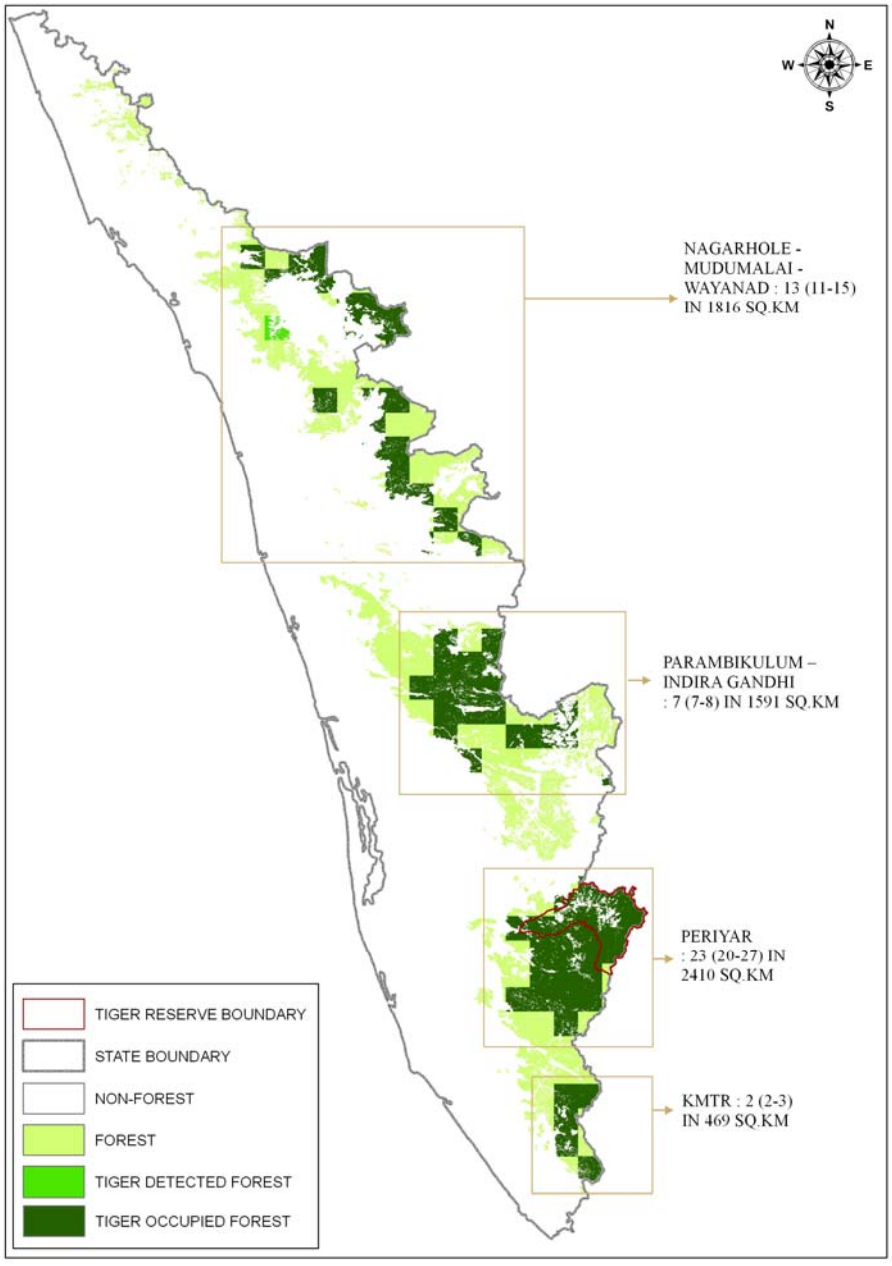
b) Parambikulum-Indira Gandhi Population: Extending from Indira Gandhi Wildlife Sanctuary-Chinnar Wildlife Sanctuary (in Tamil Nadu) and Parambikulam Wildlife Sanctuary in Kerala. This population has a tiger occupancy in 2,744 km² within a contiguous forest patch of 4,400 km². Within Kerala the tiger occupancy of this population was 1425 km² with an estimated population of 7 to 8 tigers.

c) Nagarhole-Madumalai-Wayanad Population:The third population extends from Madumalai Wildlife Sanctuary (Tamil Nadu) – Wayanad Wildlife Sanctuary (Kerala) – Bandipur-Nagarhole Tiger Reserve (Karnataka)- forests of Nilgiri and Periyar districts of Tamil Nadu and Biligiri Rangaswami Temple Sanctuary to Cauvery Sanctuary (Karnataka). The forest patch containing this population (and several other tiger populations) extends from Palghat gap (Palghat District Kerala) northwards to Bhimasankar Sanctuary in the District of Pune, Maharashtra and eastwards in the district of Dharampuri in Tamil Nadu covering a forest area of 39,000 km². This population has a tiger occupancy of 10,800 km². In Kerala alone tiger occupancy of this population is 1816 km² with an estimated population of 13 (11 to 15) tigers.

Conservation Recommendations

Tiger populations in Kerala are viable if managed as a contiguous population across Tamil Nadu and Karnataka. By itself the State cannot support a demographically and genetically viable population. Thus, inter state cooperation and for conservation planning is mandatory. Though, tiger populations in Kerala are by themselves small due to the nature of the habitat, their importance should not be undermined as they form crucial linkages for genetic exchange in the Western Ghat tiger populations and thus permit long term persistence of these populations.

Figure 5.14 Tiger occupied forest, individual populations, their extents and habitat connectivity in Kerala



North Eastern Hills

and

Brahmaputra Flood Plains

Principal Investigators
Rajesh Gopal, Qamar Qureshi and Y.V. Jhala,

Research Team

Ashem Rahul Singh, Dr. Jimmy Borah, Dr. Karabi Deka, Peer Muzamil Shams, Rajni Sharma, Raju Lal Gurjar Subhadeep Bhattacharjee, Tana Mewada, Uday K. Das, Umeshkumar Tiwari

6. North East Hills and Brahmaputra Flood Plains

The north east is one of the most important areas in the Indian subcontinent from a conservation perspective. Of all zones in India, it is perhaps the richest in communities, species and endemics. There are more species in this zone which have been included in Schedule I of the Wildlife (Protection) Act, 1972 than anywhere else in the country.

This area represents the transition zone between the Indian, Indo-Malayan and Indo-Chinese biogeographical regions, as well as a meeting place of the Himalayan Mountains and peninsular India. The north east is the biogeographical gateway for much of India's fauna and flora and as a consequence has the richest biological values (Rodgers & Panwar 1988).

The lowland-highland transition zone has the highest diversity of biomes and ecological communities. The Khasi-Jaintia hills of Meghalaya were described as a one of the richest botanical habitats of Asia as early as 1854. It is not only the plant communities that are diverse, but also the animal communities exhibit species richness not found elsewhere in the region (Rodgers & Panwar 1988). North east India contains large populations of many important mammalian fauna like the elephant (*Elephas maximus*), rhino (*Rhinoceros unicornis*), water buffaloes (*Bubalis bubalis*) and a diverse Primate community. The north east landscape complex is still biologically inadequately explored. The tiger, though widely distributed throughout this landscape complex due to the large patch sice and contiguity of forest patches (Figure 5.1), it inherently occurs at low densities due to low prey availability in dipterocarp dominated ever green forests. The Brahmaputra flood plains, in contrast, have high prey biomass and in turn support one of the highest tiger densities reported in the world (Karanth & Nichols 2000).

Total geographic area : 271129 km^2.
Political Units : It consists of Sikkim, Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Tripura & West Bengal partially or fully.
Average population density : 114 km^{-2} (Figure 13)
Total protected area : 12527 km^2 (6.8% of the total Land Area)
Total forested area : 156896 km^2
Major biogeographic zones : 1. Trans Himalaya- Tibetan Plateau (1B), 2. Himalaya (Central Himalaya (2C) & East Himalaya (2D)), 3. Gangetic Plains-Lower Gangetic Plains (7B) and 4. North East (Bramhaputra Valley (9A) & North east Hills (9B))

Table 6.1: Landscape Characteristics of North East Hills And Brahmaputra Flood Plains

Parameters	Value
Number of forest patches	3824.0
Forest patch density per 1000 km²	4.5
Mean forest patch area (km²)	18.5
Mean forest perimeter to area ratio	34.2
Total forest core aera (km²)	15588.0
Number of disjunct forest core areas	241.0
Mean forest core area (km²)	3.03
Median forest core area (km²)	9
Total forest core area in forest patches >1000 km²	14867

Tiger Habitat status:

Districts from which tigers have become locally extinct within the recent historical past from the North East Hills and Brahmaputra Flood Plains andscape was 22.5%. Currently tigers occupy 4230 km² of forests within the North East Hills and Brahmaputra Flood Plains Landscape. Potential habitat for tiger occupancy in the landscape complex: 64295 km² (41% of the forested area)

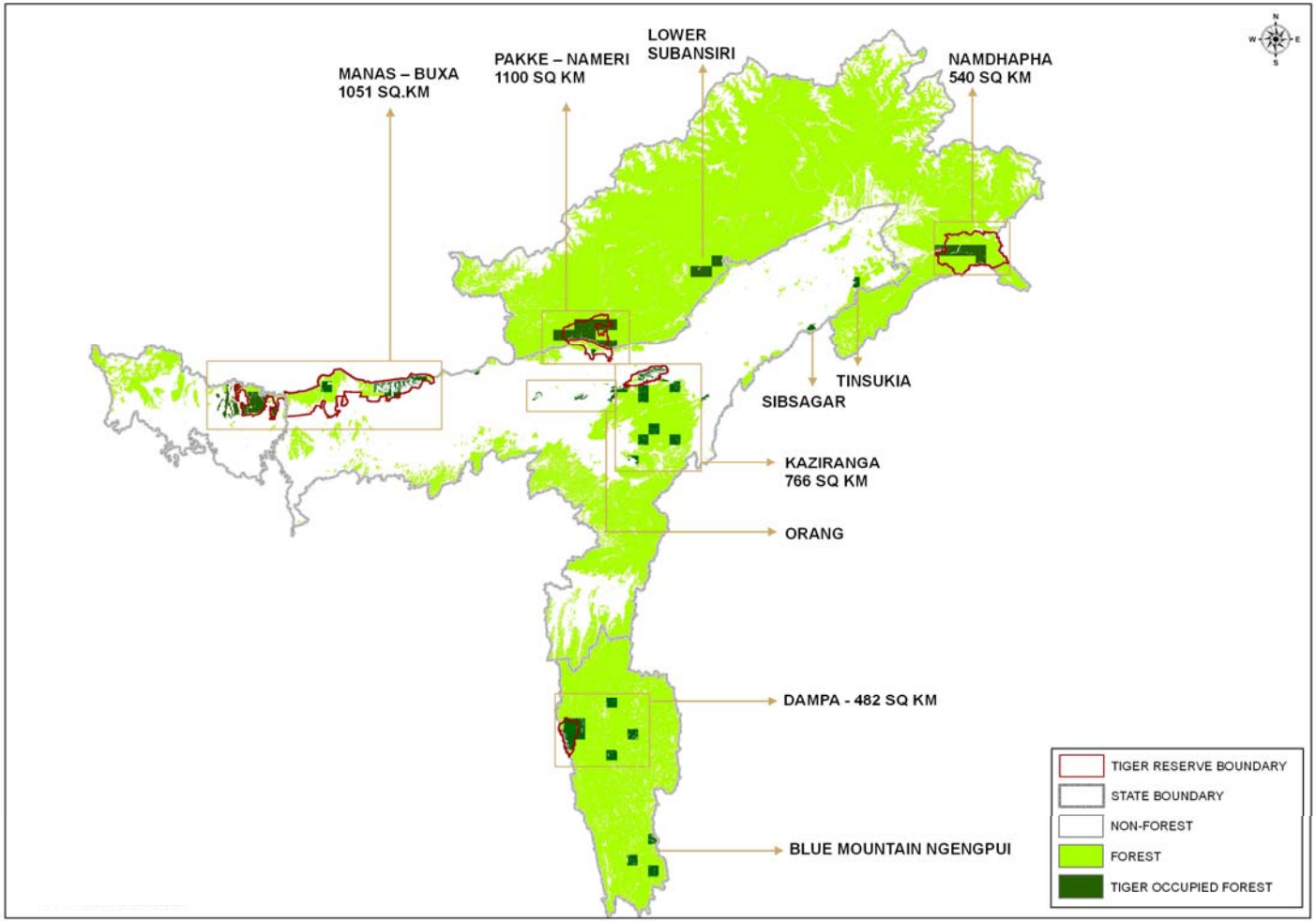
(1) The largest contiguous forested landscape is over 136,000 sq km. This landscape unit commences in the North West from Pakke Tiger Reserve through the forests of Palia, Tale valley, Mouling and Dr. D. Ering Sanctuaries into Dibung National Park and upto Namdapha Tiger Reserve in the East. The landscape continues south through some degraded areas into Intanki National Park, and further South to Dampa Tiger Reserve and Blue Mountain National Park. Kaziranga National Park in the Bhramaputra flood plains is connected through the Karbi Anglong Hills to Intanki in the South. This connectivity through Karbi Anglong is crucial for dispersal of tigers from their source population in Kaziranga. Kaziranga has lost its connectivity to the North (to Pakke) due to intensive agriculture on Northern banks of Bhramaputra flood plains. Intanki National Park is also connected westwards through priority III forests upto Balphakram National Park. This landscape has contiguous forest across the International border with Myanmar. The weak links in this landscape are the forests in the districts of Mon, Mokok Chung, Tuensang, Zuheboto, Wokha, and Pekh in the East. The landscape between Balphakram National Park and Intaki National Park through the districts of Karbi Anglong, West Khasi Hills, East Khasi Hills and East and West Garo Hills is fragmented. The major source populations of

tigers in this landscape are Kaziranga and Pakke in India and dispersing tigers from Bhutan and Myanmar.

(2) Manas - Ripa Chirang - Buxa/Jaldapara – Gorumara - Singhalila landscape unit. This landscape is about 7,200 km² with a single block of 5000 km² from North and West Bengal (Gorumara) to the coniferous forests of Sikkim (Singhalila). The connectivities in the Bhramaputra plains are patchy and fragmented, but the landscapes are connected through the forests of Bhutan. On the Indian side, "stepping stone" connectivity exists between Gorumara, Jaldapara, Buxa, and Ripa Chirang through the district of Jalpaiguri. Connectivity between Ripa Chirang and Manas is lost on the Indian side. This landscape needs to be managed through transboundary International cooperation with the Government of Bhutan.

(3) The tiger populations in this landscape have historical evolutionary significance as they share the connecting gene pool with south eastern tiger populations and represent the entry point of tigers into the Indian sub-continent.

Figure 6.1 **Tiger occupied forests, individual populations, their extents and habitat connectivity in North East Hills and Brahmaputra Flood Plains**



Landscape occupancy of Co-predators and prey in North East Hills and Brahmaputra Flood Plains

Leopard occupancy was detected in 5,629 km^2 (Figure 6.2), Wild Dog occupancy was detected in 2,037 km^2 (Figure 6.3), Bear occupancy was detected in 1,058 km^2 (Figure 6.4), Chital occupancy was detected in 280 km^2 (Figure 6.5), Sambar occupancy was detected in 2,632 km^2 (Figure 6.6), Wild Pig occupancy was detected in km^2 (Figure 6.7), Gaur occupancy was detected in km^2 (Figure 6.7) and Elephant occupancy was detected in km^2 (Figure 6.7).

Figure 6.2 Leopard occupied forest, individual populations, their extents and habitat connectivity in North East Hills and Brahmaputra Flood Plains

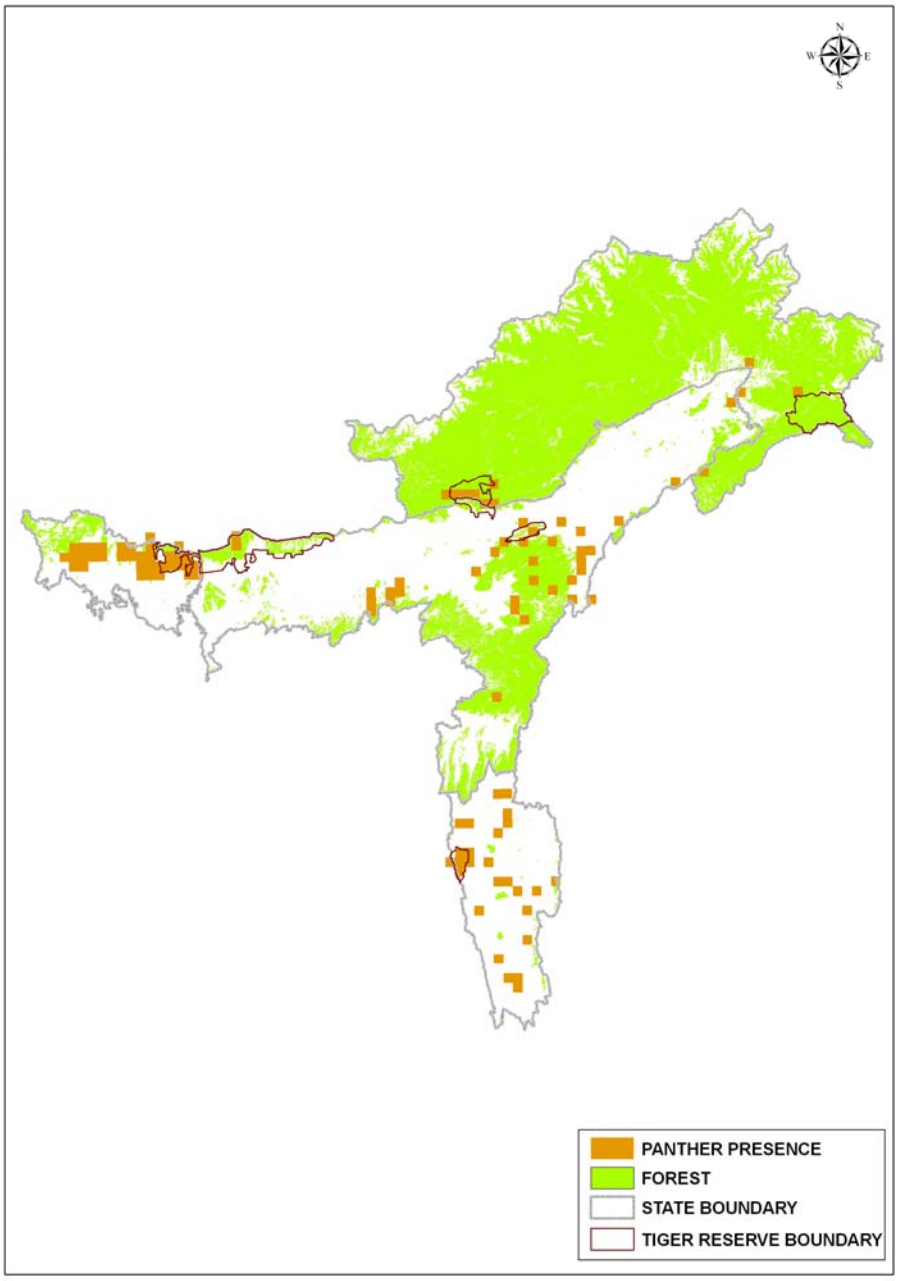


Figure 6.3 **Wild Dog occupied forest, individual populations, their extents and habitat connectivity in North East Hills and Brahmaputra Flood Plains**

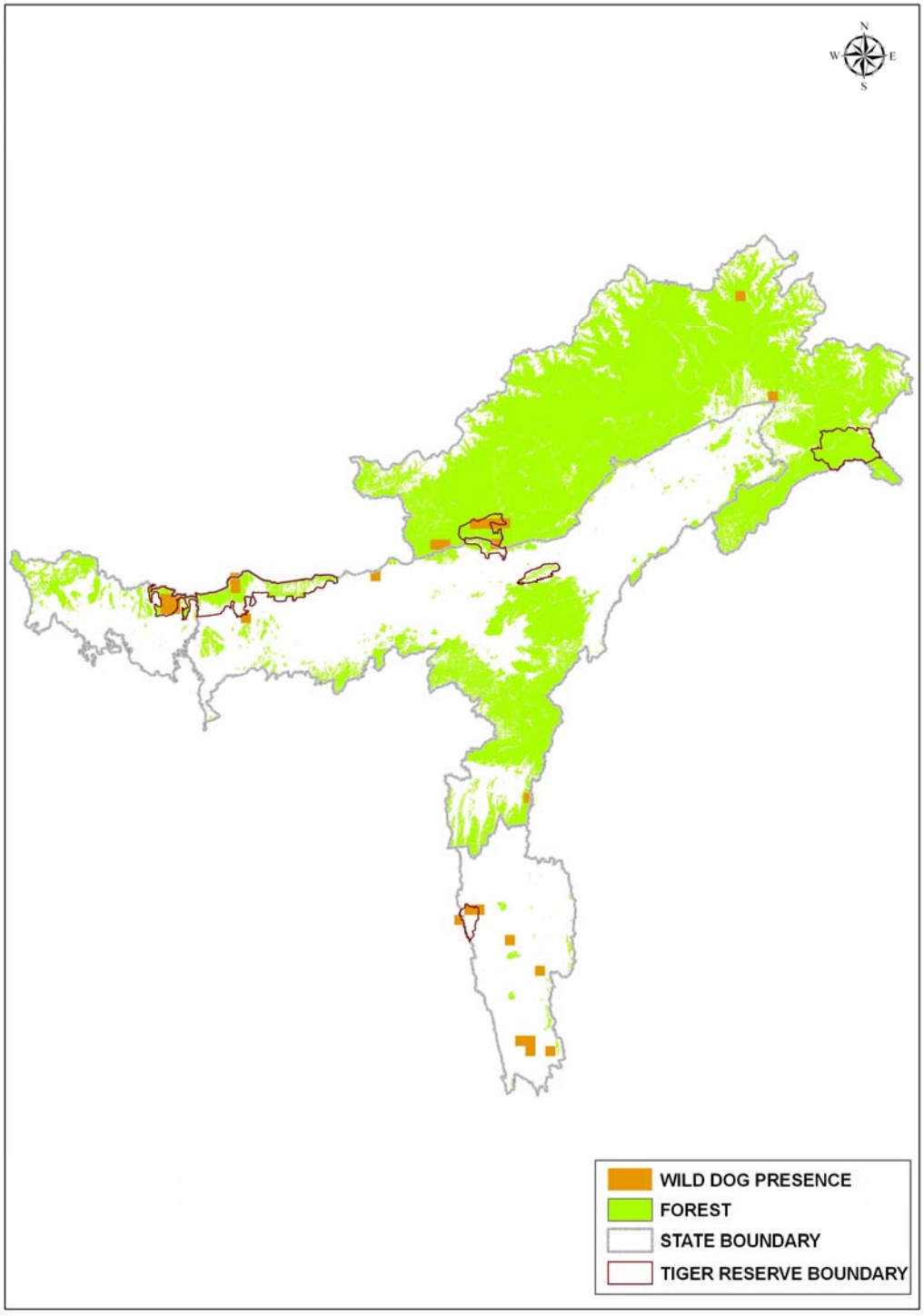


Figure 6.4 **Sloth Bear occupied forest, individual populations, their extents and habitat connectivity in North East Hills and Brahmaputra Flood Plains**

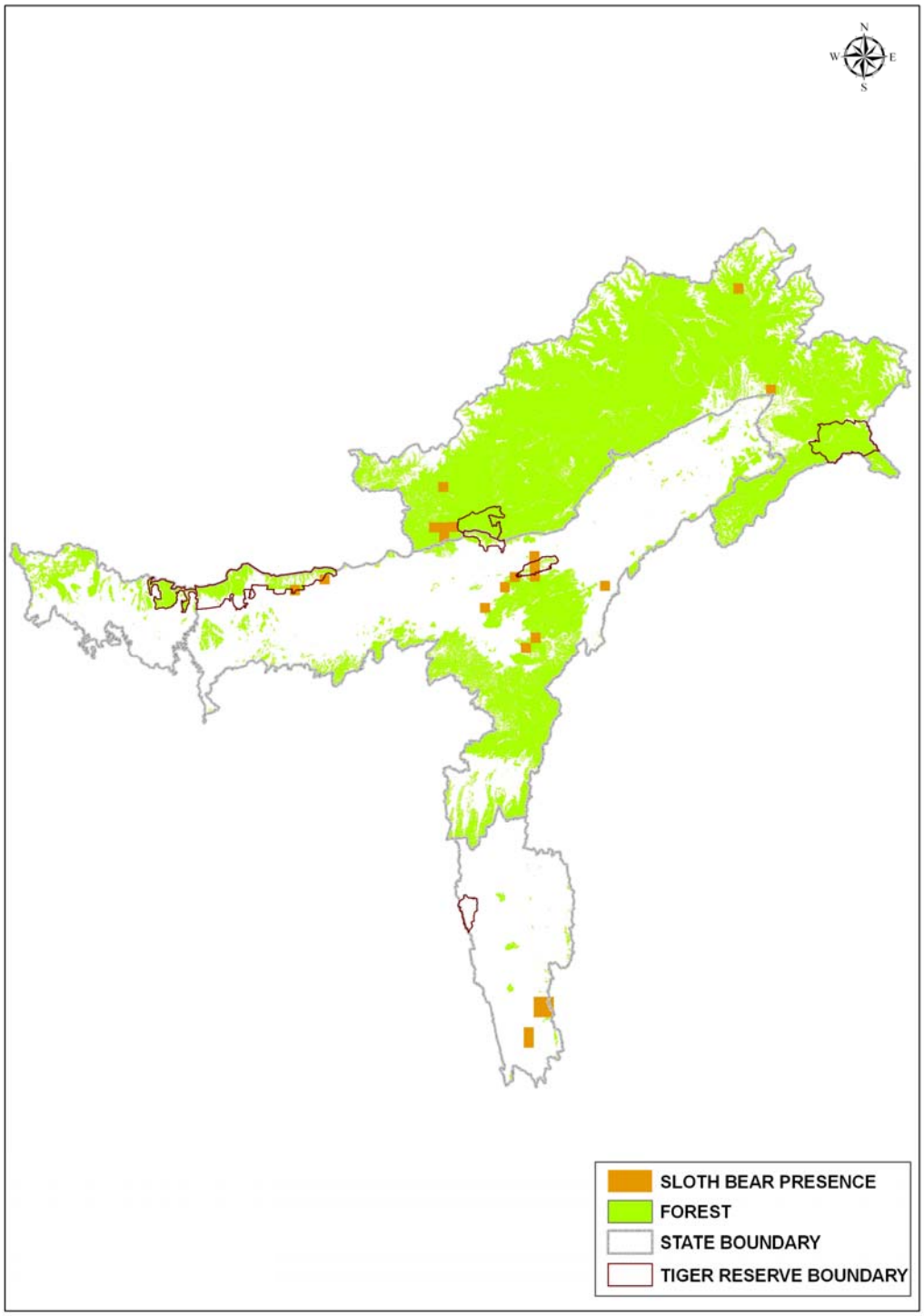


Figure 6.5 **Chital occupied forest, individual populations, their extents and habitat connectivity in North East Hills and Brahmaputra Flood Plains**

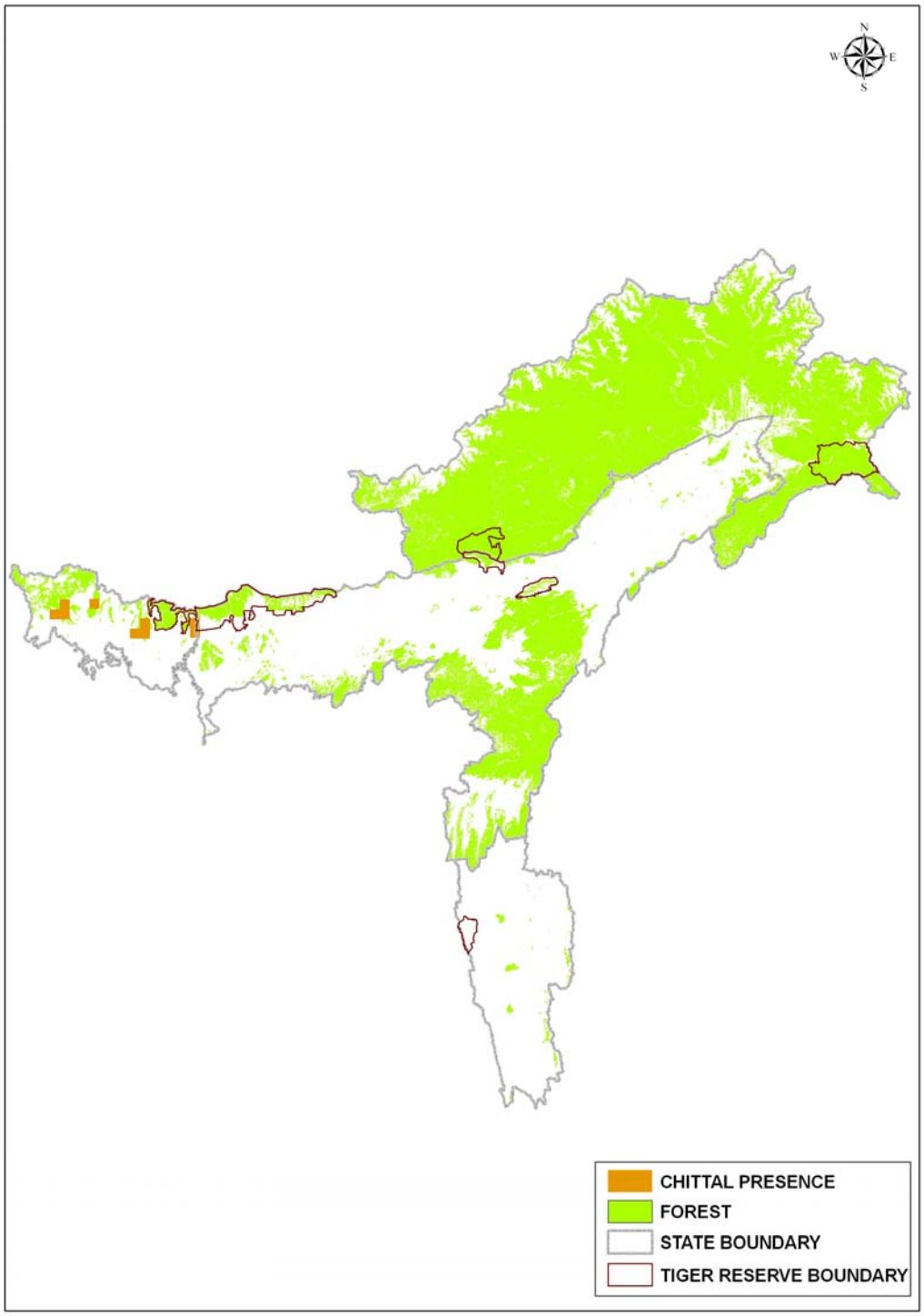


Figure 6.6 **Sambar occupied forest, individual populations, their extents and habitat connectivity in North East Hills and Brahmaputra Flood Plains**

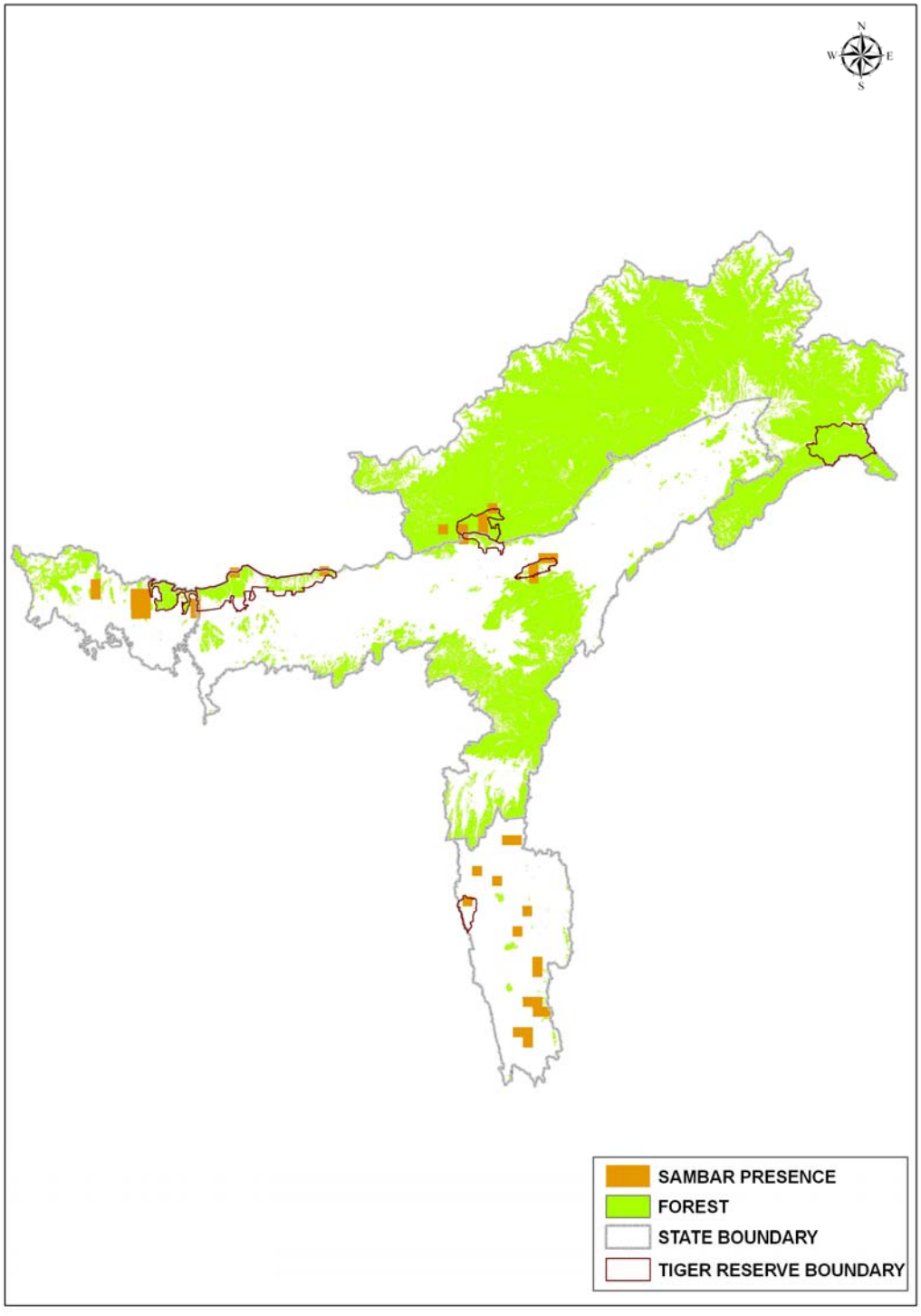


Figure 6.7 **Wild Pig occupied forest, individual populations, their extents and habitat connectivity in North East Hills and Brahmaputra Flood Plains**

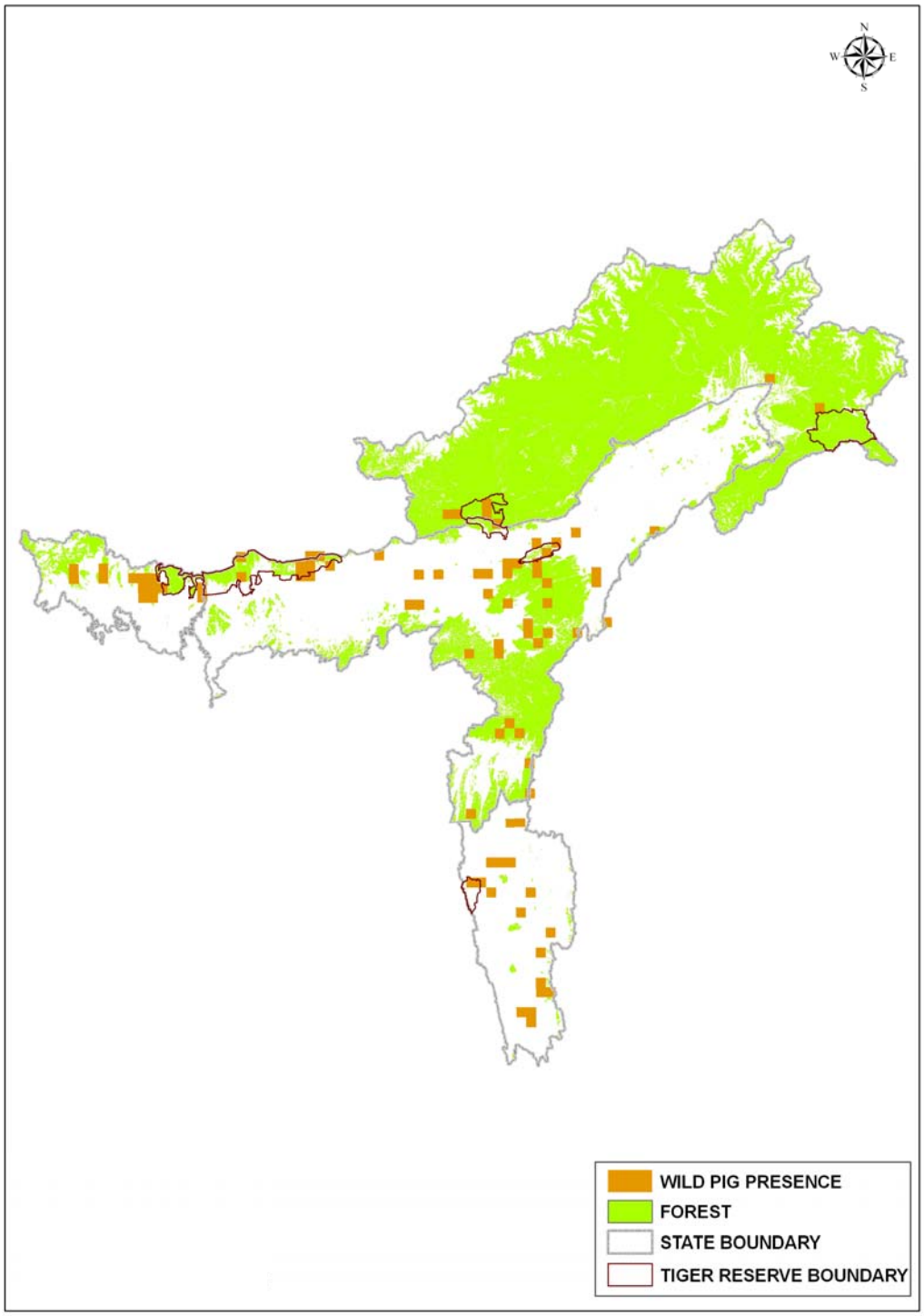


Figure 6.8 **Gaur occupied forest, individual populations, their extents and habitat connectivity in North East Hills and Brahmaputra Flood Plains**

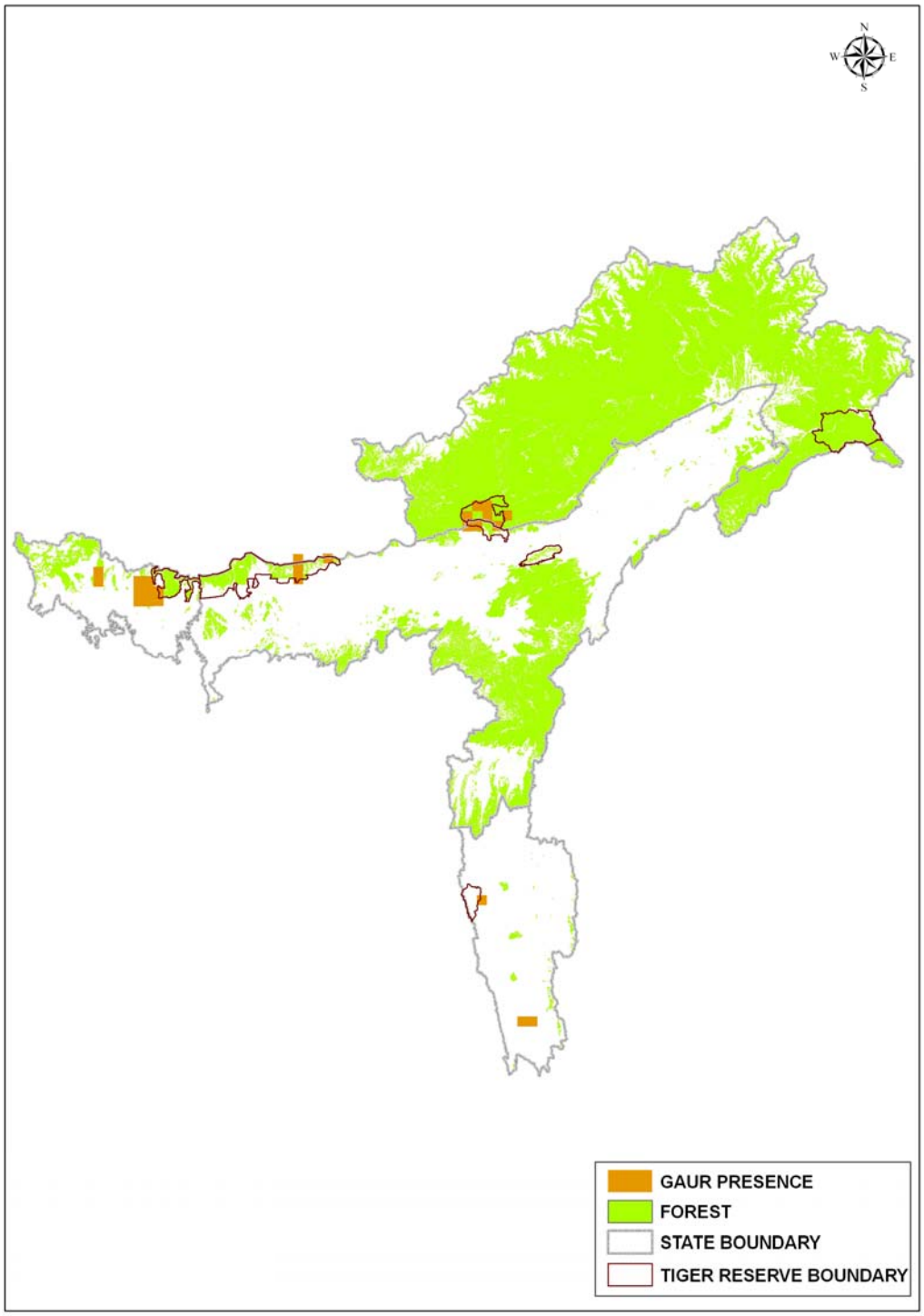
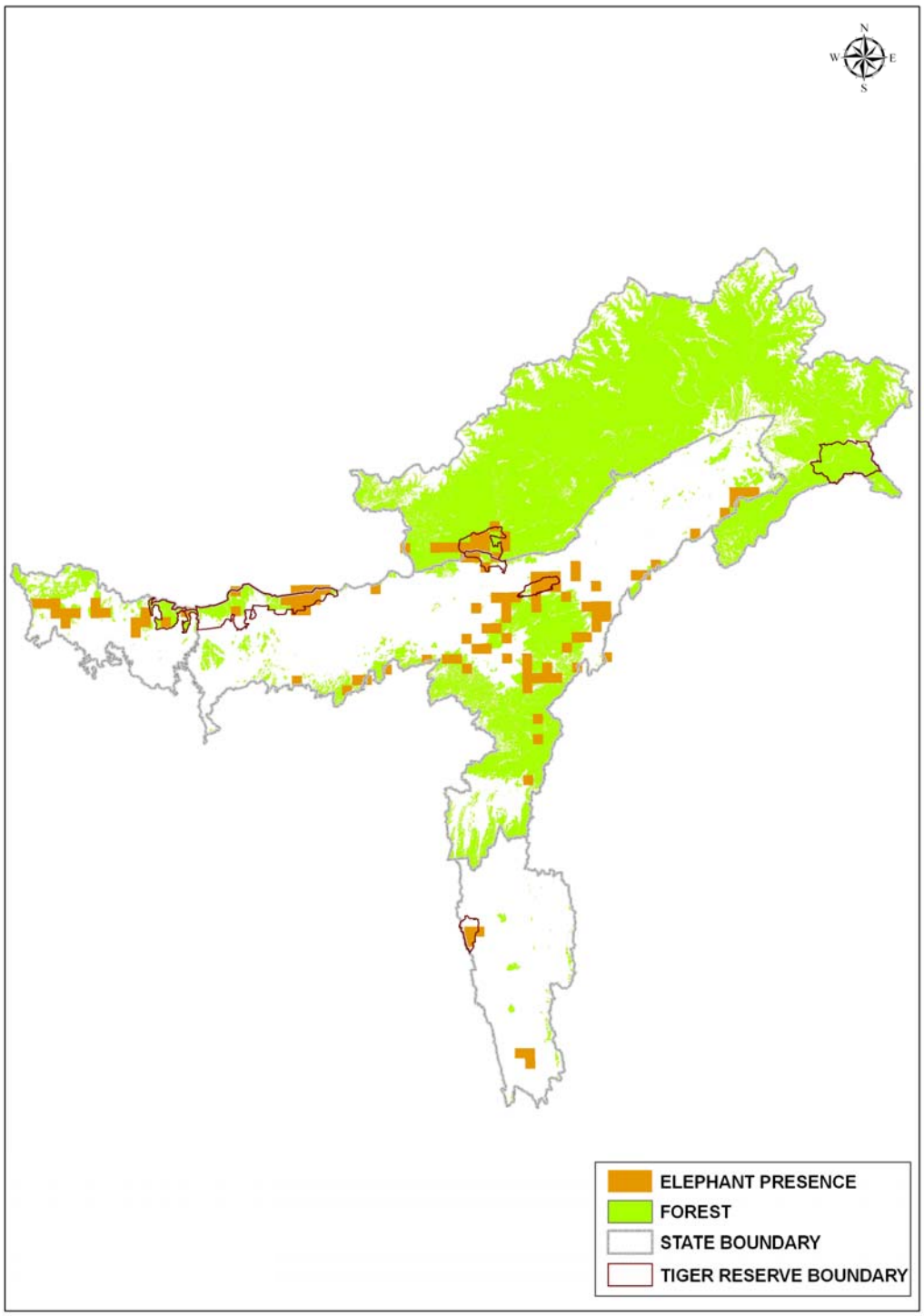


Figure 6. 9 Elephant occupied forest, individual populations, their extents and habitat connectivity in North East Hills and Brahmaputra Flood Plains



ASSAM

The forest cover of Assam is 27,938 km^2, comprising 36% of the geographic area of the State. Forests of Tiger Conservation Priority I &II were 20,359 km^2 in Assam. Currently tigers occupy an area of 1,164 km^2 of these forests. Leopard occupancy was 1,500 km^2, Sloth Bear occur in about 380 km^2 and Dhole in 285 km^2.

Amongst prey species Sambar was recorded in 270 km^2, Wild pig in 2,047 km^2 and Gaur in 337 km^2. Hog deer in 1178 km^2, Swamp deer in 100 km^2, Wild Buffalo in 590 km^2.

Assam has three tiger populations with sporadic occurrences reported in small protected areas.

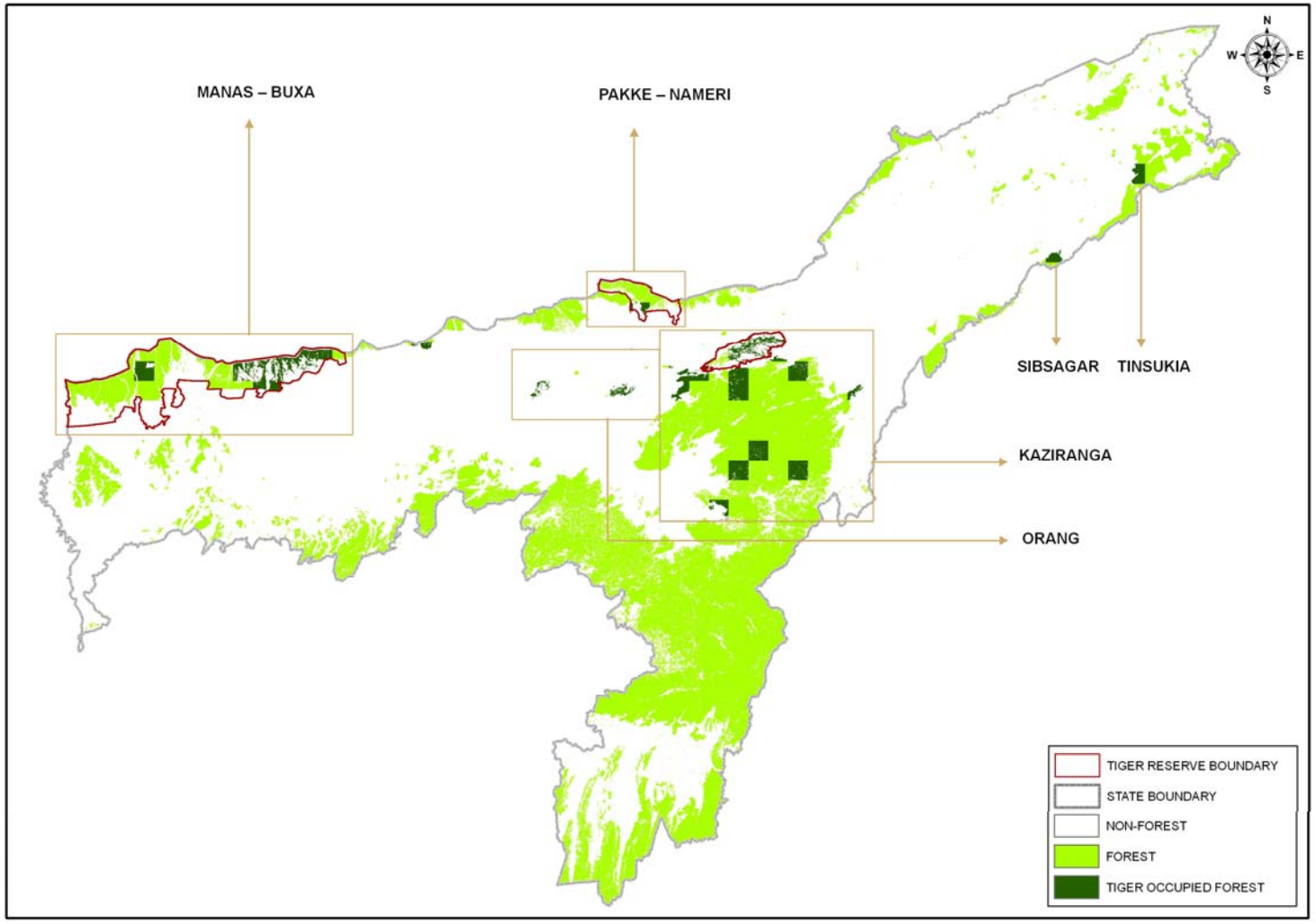
a) Buxa-Manas Population: This tiger population extends from Buxa tiger reserve in West Bengal to Manas Tiger Reserve in Assam with Royal Manas of Bhutan. This population exists in a contiguous forest extent of 7200 km^2 with a tiger occupancy of 1051 km^2. In Assam tiger occupancy in this population was 455 km^2 constituted by Manas Tiger Reserve and Bor Nadi Sanctuary.
b) Pakke-Nameri Population: This tiger population extents from Nameri Tiger Reserve in Assam to Pakke Tiger reserve in Arunachal Pradesh. The forest extent containing this population is 135,707 km^2 and is contiguous till Namdapha Tiger Reserve in the east, it extends south to Intaki National Park and further south to Dampa Tiger reserve. Kazaringa connects to this forest extent through the Karbi Anglog hill forests. Tiger occupancy of this population was 1100 km^2 of which about 200 km^2 is in Nameri, Assam.
c) Kaziranga-Karbi Anglong Population: This population extends from Kazaringa National Park through the hill forests of Karbi Anglong. Tiger occupancy of this population was 766 km^2.
d) Sporadic tiger occurrences were reported from Orang, Laokhowa, Burachapori, forests in the tehsils of Sibsagar and Tinsukia bordering Arunachal Pradesh.

Conservation Recommendations

The source populations of Assam are meager, constituted by Kaziranga and Manas, both prone to stochastic events of environment as well as insurgency and being of small size. Under such conditions long term tiger conservation can be ensured by

1) Increasing the size of the source population of Kaziranga by inclusion of the Karbi Anglong hills as buffer habitat. This would entail conservation partnership with the tribal council of Karbi Anglong to enhance the prey base and protection of tigers.
2) Manas is recovering from the aftermath of insurgency due to support of the local population, exemplifying the importance of involving the local people in conservation efforts. The importance of the Manas Tiger population as a source is enhanced when managed in conjunction with Royal Manas in Bhutan and Buxa Tiger Reserve in West Bengal.
3) Nameri tiger population is viable when managed in conjunction with Pakke population. The sporadic tiger occurrences of tigers within forest patches along Bhramaputra are sustained by dispersing individuals form Kaziranga. Forest patches with tigers are also found along the Arunachal Boarder. An example of such forest is the Jeypore forest division which is also a good repository of biodiversity and would benefit with an enhanced legal status.

Figure 6.10 Tiger occupied forest, individual populations, their extents and habitat connectivity in Assam



ARUNACHAL PRADESH

The forest cover of Arunachal Pradesh is 68,186 km², comprising 81% of the geographic area of the State. Forests of Tiger Conservation Priority I &II were 59,827 km² in extent in Arunachal Pradesh. Sampling in Arunachal Pradesh was not done in every forest rest of India, instead supervised information on tiger presence was used for survey. Only areas known to have or had high potential for tiger occupancy were surveyed. Currently tigers were reported to occupy an area of 1,685 km² of these forests. Leopards reported to occupancy 670 km², Bear (black and sun bear) occupancy was reported at 199 km² and Dhole 675 km².

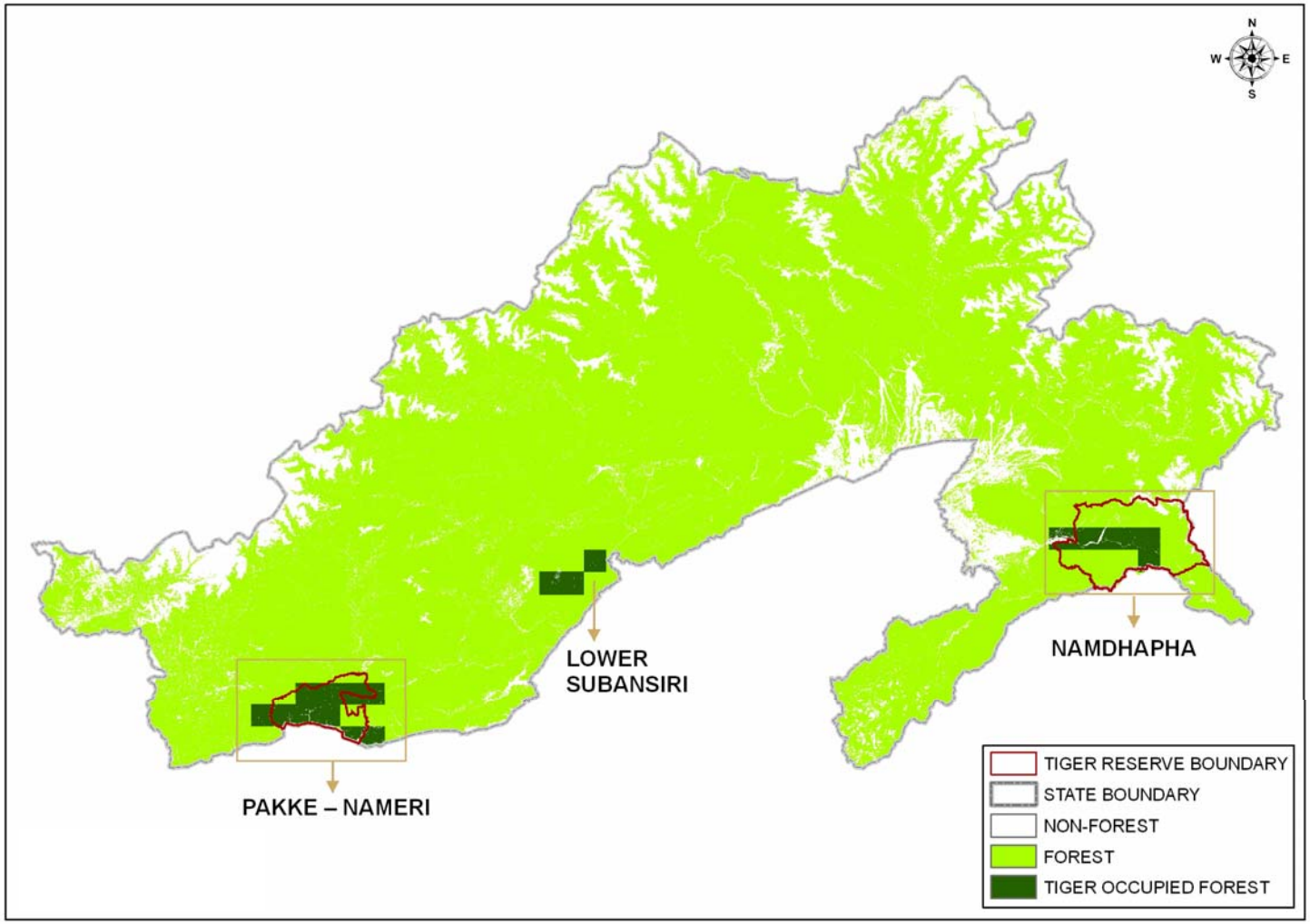
Arunachal Pradesh has two tiger populations Pakke-Nameri and Namdapha with sporadic occurrences reported in the forests of lower Subansiri, east Kameng, Changlang and Tirap districts.

a) Pakke-Nameri Population: This tiger population extents from Nameri Tiger Reserve in Assam to Pakke Tiger reserve in Arunachal Pradesh. The forest extent containing this population is 135,707 km² and is contiguous till Namdapha Tiger Reserve in the east, it extends south to Intaki National Park and further south to Dampa Tiger reserve. Kazaringa connects to this forest extent through the Karbi Anglog hill forests. Tiger occupancy of this population was 1100 km² of which about 874 km² is in Pakke Arunachal Pradesh. Pakke has the largest tiger population in Arunachal.
b) Namdapha has a small tiger population having a tiger occupancy of 540 km². It probably shares tiger contiguity with Myanmar.

Conservation Recommendations

Due to the nature of the forests and habitats of Arunachal Pradesh prey and consequently tiger densities are naturally low. Under such situation large tracts of contiguous habitat are required to support viable populations of tigers. Tigers continue to exist in Arunachal due to the vastness of the contiguous landscape. The source populations of Arunachal Pradesh are meager, constituted by Pakke and Namdapha. The value of these populations as sources for dispersing tigers would be enhanced by management to increase prey base and through participatory conservation models in tribal owned forests. These populations represent the historical entry points of tigers as a species into the Indian Sub-continent and would therefore have higher genetic and conservation value.

Figure 6.11 Tiger occupied forest, individual populations, their extents and habitat connectivity in Arunachal Pradesh



MIZORAM

The forest cover of Mizoram is 17,961 km², comprising 85% of the geographic area of the State. Forests of Tiger Conservation Priority I &II were 9,084 km² in extent in Mizoram. Currently tigers occupy an area of 758 km² of these forests. Leopard occupancy was 2,324 km², Bear occupancy was 479 km² and Dhole 776 km².

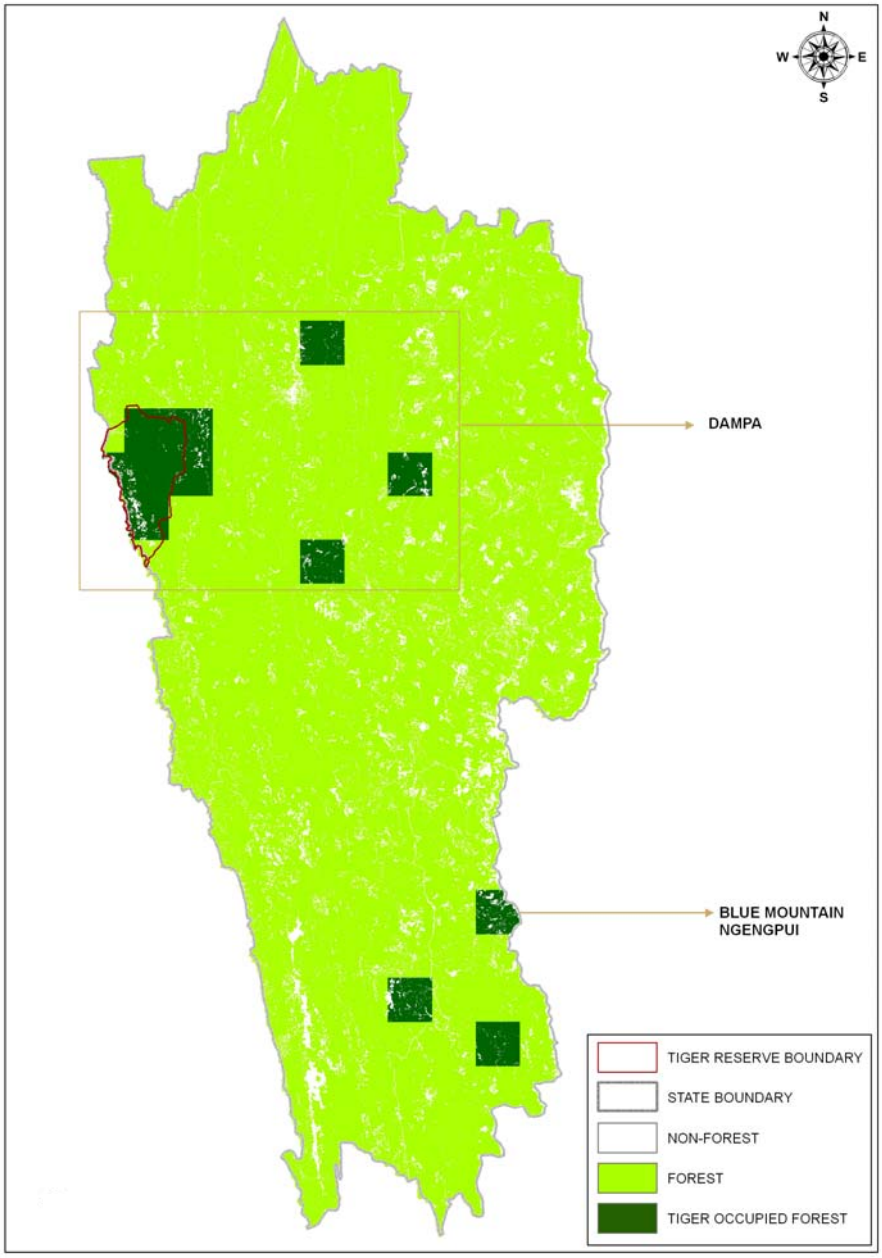
Amongst prey species Sambar was recorded in 1700 km², Wild pig 1489 km² and was Gaur 281 km².

Mizoram has a single tiger population in Dampa Tiger Reserve and a few scattered occurrences in Blue Mountain – Ngengpui forests which are contiguous with Myanmar. Dampa has a tiger occupancy 482 km² in a contiguous forest extent of 135,707 km² within India.

Conservation Recommendations

Due to the nature of the forests and habitats of Mesoram prey and consequently tiger densities are naturally low. Under such situation large tracts of contiguous habitat is required to support viable populations of tigers. Tigers continue to exist in Mesoram due to the vastness of the contiguous landscape which also extends into Myanmar.

Figure 6.12 Tiger occupied forest, individual populations, their extents and habitat connectivity in Mizoram



Northern West Bengal

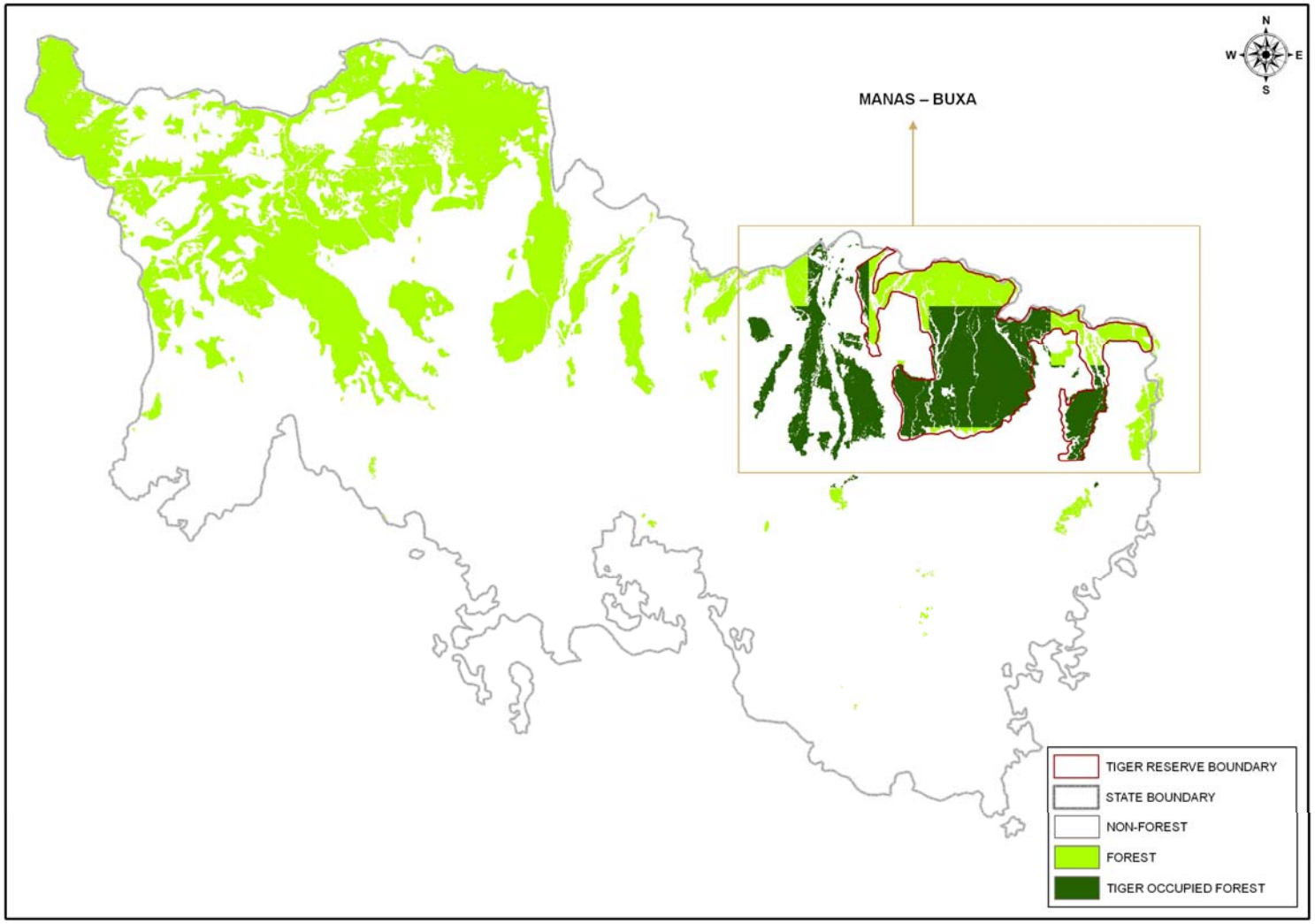
The forest cover of West Bengal is 9081 km², comprising 12% of the geographic area of the State. Currently tigers occupy an area of 596 km² of these forests. Leopard occupancy was 1,135 km², and Dhole in 301 km².

Amongst prey species Sambar was recorded in 2,632 km², Chital in 280 km² and Wild pig in 4,439 km².

Nothern West Bengal has one tiger population comprised of Buxa, Jaldapara and Gorumala with sporadic occurrences reported in small protected areas.

Buxa-Manas Population: This tiger population extends from Buxa tiger reserve in West Bengal to Manas Tiger Reserve in Assam with Royal Manas of Bhutan. This population exists in a contiguous forest extent of 7200 km² with a tiger occupancy of 1051 km². In West Bengal tiger occupancy of this population was 596 km² constituted by Buxa Tiger Reserve, Gorumara and Jaldapara Wildlife Sanctuaries. The source population of tigers in Bhutan are maintaining the tiger occupancy in Buxa and these habitat linkages need to be fostered.

Figure 6.13 Tiger occupied forest, individual populations, their extents and habitat connectivity in Northern West Bengal



Sundarbans

Principal Investigators
Y.V.Jhala, Qamar Qureshi and Rajesh Gopal

Research Team

Rishi Kumar Sharma

7. Sunderbans

The Sunderban mangroves are part of the sub continent's largest mangrove system, and harbour a tiger population in a unique ecological setting. These forests have salt water crocodiles (*Crocodylus porosus*), estuarine and marine turtles, three species of fresh water dolphins and avifauna. With its network of tidal rivers, channels, mudflats, creeks and an archipelago of around 54 islands, - Sunderbans provide a dynamic eco-system which is geologically still under formation,

Sunderbans provide shelter to a large number of euryhaline / brackish water algae, a wide variety of fishes, and to crustaceans like shell-fish, prawns, estuarine crabs and ghost shrimps in its rivers and nutrient enriched creeks. They serve as nurseries for several commercially important fish species. Besides the tiger other species of interest are fishing cat (*Felis viverrina*), chital, rhesus monkey (*Macaca mulatta*), wild pig (*Sus scrofa*), otters, Irawady and Gangetic dolphins, monitor lizards (*Varanus spp*), snakes (including python), estuarine crocodiles, sharks, and a large variety of local and migratory birds.

Ecological services of Sunderbans are extremely valuable to local communities. On an average, 500 quintals of honey and 30 quintals of wax are being collected every year by local people under license from the forest department.

Although deltaic mangrove systems are known to be very productive, most of that productivity remains confined to the aquatic system, and the habitat can support only low densities of terrestrial mammalian prey, and in turn, tigers. Although the inherent inaccessibility of these habitats makes scientific documentation and research efforts more challenging, nevertheless it imparts some degree of natural protection to tigers. Perhaps the best protection for Sundarbans tigers is their fearsome reputation of being habitual man-eaters.

Total geographic area : 2585 km^2
Political units : South 24 Paragana(s) (West Bengal).
Population density : 1437.4 km^{-2}
Total protected area : 2585 km^2
Total forested area : 1474 km^2 (Figure 29)

Major biogeographic zone :

It comes under east coast 8B of biogeographic zones, and Sunderbans mangroves of ecoregions.

Table 7.1:Landscape Characteristics of the Sunderbans

Parameters	**Value**
Number of forest patches	737
Forest patch density per 1000 km²	12.3
Mean forest patch area (km²)	3.1
Mean forest perimeter to area ratio	16.6
Total forest core area (km²)	534.4
Number of disjunct forest core areas	128
Mean forest core area (km²)	0.72
Median forest core area (km²)	14.29
Total forest core area in forest patches >1000 km²	534.42

The Sunderbans comprise of a total forested landscape of 1474 km² in West Bengal stretching into Bangladesh. The mangrove forest is traversed by several tidal channels forming small to large forest islands. Animal movement across the smaller channels is common. Tigers have been recorded to cross larger (>5 km width) channels as well. Therefore, the total mangrove forests of India and Bangladesh have a tiger population that can potentially share their gene pool. Tiger occupancy in the Indian Sunderbans was reported to be 1586 km².

The Sunderbans are isolated and do not have any forest connection to other tiger occupied landscapes (North Eastern Hills). Being the only forest in the region, there is heavy biotic pressure for forest resources, fisheries, and non timber forest produce (NTFP) collection. These need to be regulated and the forest protected to ensure the long term survival of the tiger in this unique landscape.

Figure 7.1 Forest cover, forest patches and human density of the Sunderban landscape

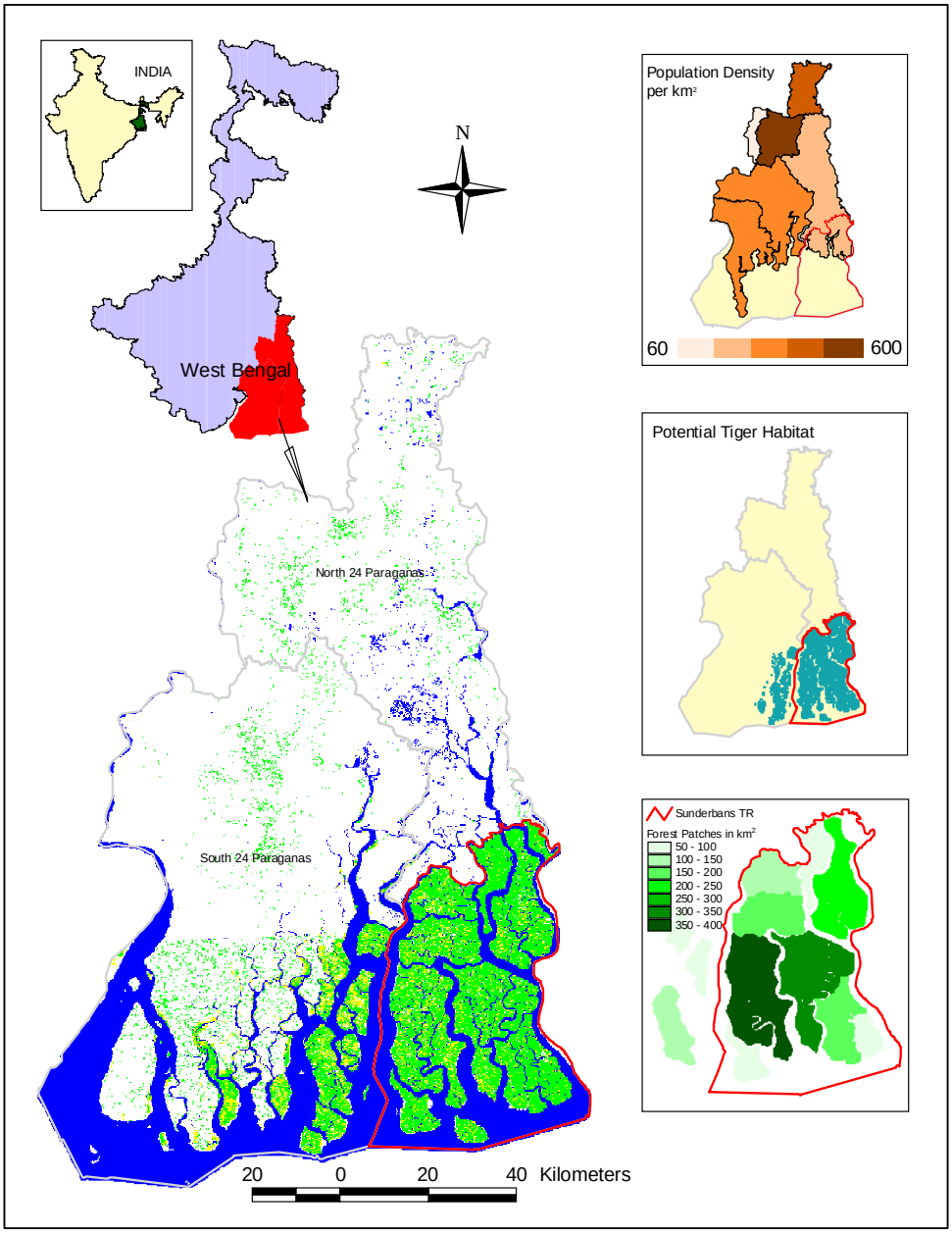
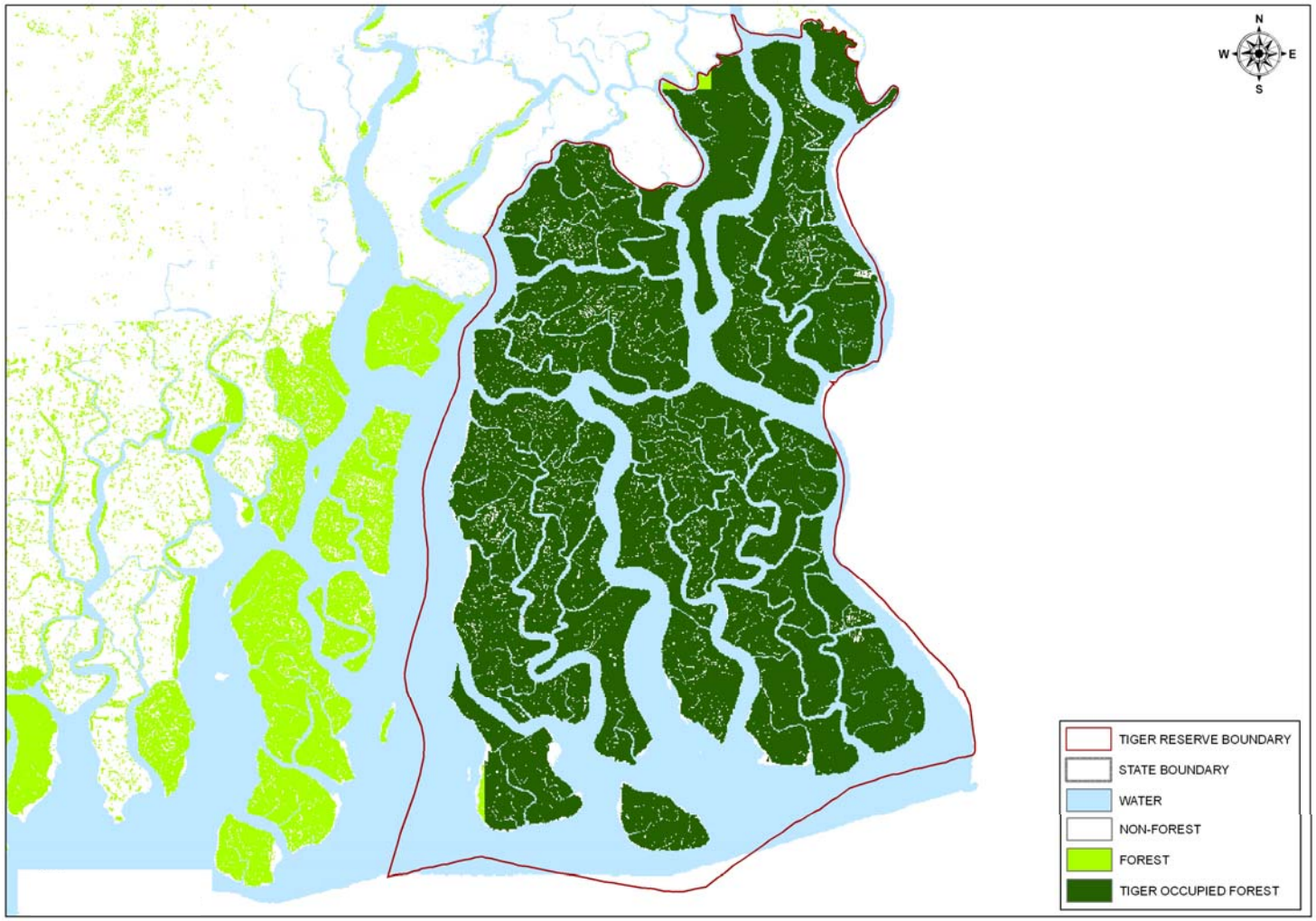
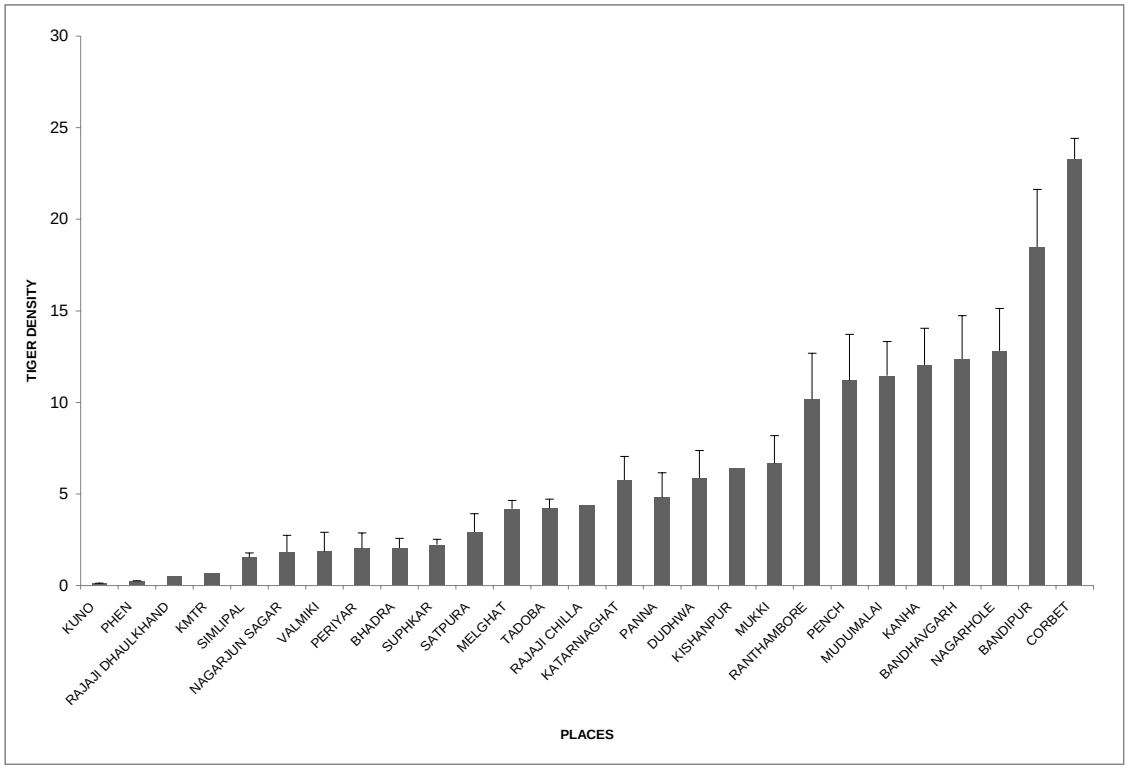


Figure 7.2: Tiger occupied forest, individual populations, their extents and habitat connectivity in Sunderbans



Phase III

Double sampling for estimating absolute densities of tigers and their prey was done in 5% of the tiger occupied forests spanning across the Indian Sub-continent. We sampled 29 sites covering major tiger populations. Density estimates of tigers from these sampled sites ranged between 0.125 tiger per 100 km² to 20 tigers per 100km² (Figures 8.1 and 8.2).



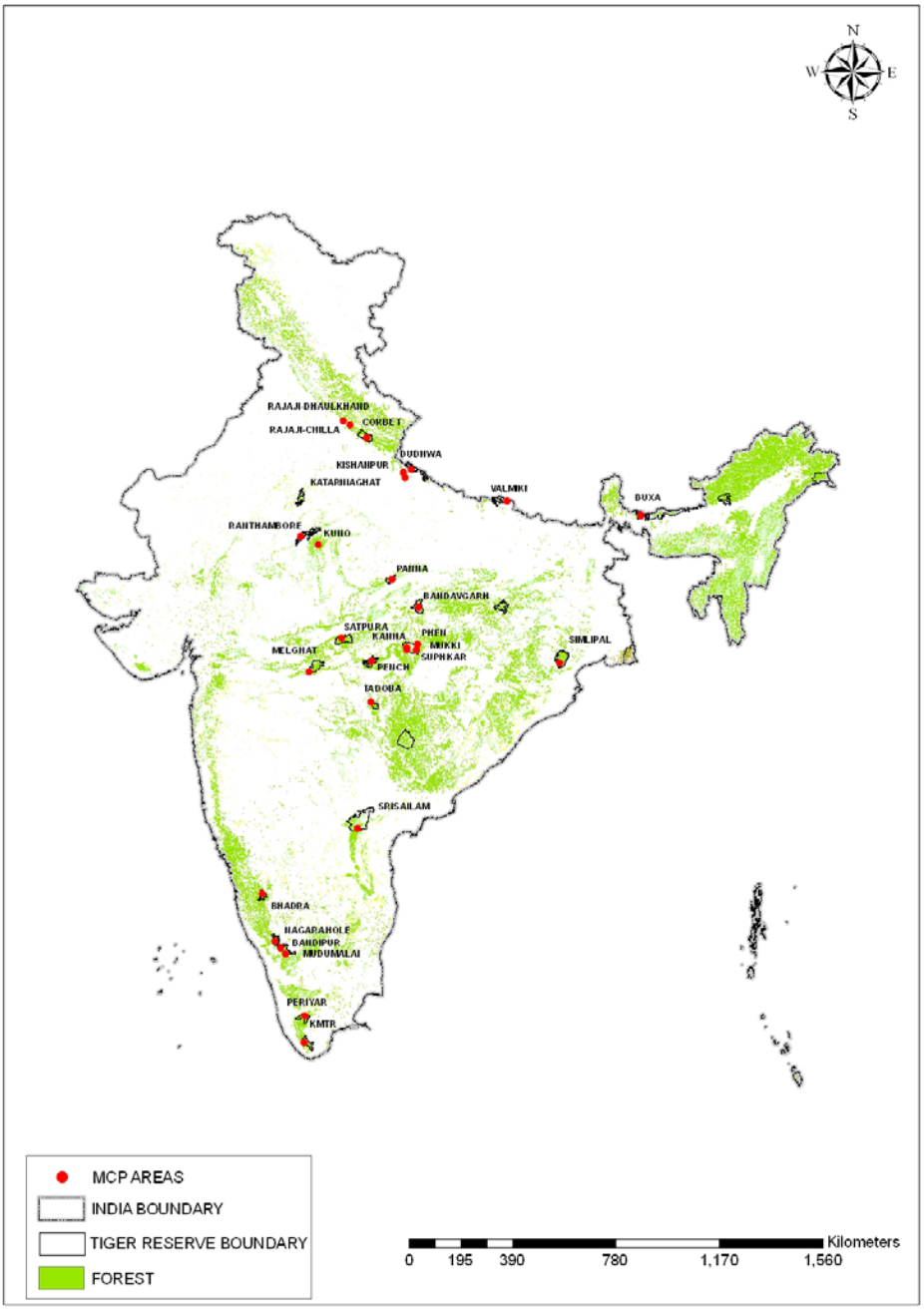
Occupancy models (Royle, 2004) fitted to tigers show a significant positive effect of prey, forest area and canopy, vegation density, and negative effects of human disturbance indices (Table 8.1).

Table 8.1 Occupancy model results for significant covariates. The model was expanded using a stepwise addition procedure. The model allows detection probability, p, to be less than 1.0

Variable	Iter1	Iter2	Iter3	Iter4	Iter5	Iter6	Iter7	Iter8	Iter9
Pconst	0.59	0.6	0.6	0.61	0.61	0.61	0.61	0.61	0.61
Psiconst	-4.04	-4.43	-4.45	-4.44	-4.49	-4.5	-4.52	-4.54	-4.52
Prey	0.68	0.67	0.65	0.61	0.61	0.61	0.61	0.6	0.59
Livestock	–	–	–	–	–	–	–	–	–
Canopy	–	–	–	0.49	0.51	0.52	0.52	0.52	0.5
Lopping	–	–	–	–	–	-0.37	-0.36	-0.36	-0.36
HumanTrail	–	–	-0.43	-0.6	-0.6	-0.56	-0.55	-0.54	-0.54
Premonsoon NDVI	–	–	–	–	–	–	–	0.27	1.07
Premonsoon NDVI CV	–	–	–	–	0.36	0.36	0.39	0.33	0.29
Postmonsoon NDVI	–	–	–	–	–	–	–	–	-0.82
Nightlight Distance	–	–	–	–	–	–	-0.28	-0.28	-0.3
Forest Area	–	0.93	0.92	0.86	0.8	0.76	0.69	0.69	0.66
AIC	2015	1853	1831	1802	1787	1778	1773	17737	1767

* Iter – Model Iteration

Figure 8.2: Locations where absolute densities of tigers and ungulate prey were estimated by double sampling.



Estimating tiger numbers over such vast geographical areas with precision is a daunting task. Herein we attempt to provide estimates of tiger numbers, however, we caution that due to the large variances associated with these numbers they cannot be used for monitoring tiger status. Monitoring of tigers is proposed to be done by mapping site specific spatial occupancy. The report is intended to be used as baseline information for monitoring tiger occupancy status, distribution, relative abundance individual population extents and limits (Appendix 1, and connectivities to guide policy and land use planning in the tiger landscapes of India.

The above assessment has shown that though the tiger has lost much ground due to direct poaching, loss of quality habitat through anthropogenic pressures and and loss of its prey by subsistence level poaching, there is still hope. Individual tiger populations that have high probability of long term persistence by themselves are only a few. These are Nagarhole-Madumalai-Bandipur-Waynad population, Corbett population, Kanha population, and possibly Sunderban and Kaziranga-Karbi Anglong populations. Tiger populations that exist and can persist in a meta population framework are Rajaji-Corbett, Dudhva-Katarniaghat-Kishenpur (along with Bardia and Shuklaphanta in Nepal), Satpura-Melghat, Pench-Kanha, Bhandra-Kudremukh, Parambikulum-Indira Gandhi, and KMTR-Preiyar, provided their connectivities are protected and maintained. The landscapes that have potential but are currently in need of conservation inputs in terms of prey enhancement, protection, habitant restoration and community participation are Sirsailam Nagarjun Sagar, Simlipal, Ranthambore-Kuno Palpur, Indravati–Northern Andhra Pradesh, and Bandhavgarh-Sanjay-Palamau. To ensure the long term survival of tigers in India it is imperative to offer strict protection to established source populations and manage areas with restorative inputs by involving local communities in buffer and corridor areas by providing them with a direct stake in conservation. Tigers are a conservation dependent species requiring large contiguous forests with fair interspersion of undisturbed breeding areas. This leaves little choice other than to evolve strategies by mainstreaming conservation priorities in regional development policy and planning for managing Priority areas identified in the landscape complexes. Such an approach would ensure that breeding tiger populations have a possibility to share genetic material and exist in a meta-population framework, thereby enhancing the possibility of their survival.

References

Bailey, R. G. and H. C. Hogg. 1986. A world ecoregions map for resource reporting. Environmental conservation 133:195-202

Bailey, R. G. 1989. Explanatory supplement to ecoregions map of the continents. Environmental Conservation 164:307-309.

Birkey, A. K. 2001. NDVI and a simple model of deciduous forest seasonal dynamics. Ecological Modelling 1431-2:43-58.

Broquet, T and E. Petit. 2004. Quantifying genotyping errors in noninvasive population Genetics. Molecular Ecology 13: 3601–3608

Buckland, S. T. Anderson, D. R., Burnham, K. P. & Robson, D. S. 1993. Distance sampling: estimating abundance of biological populations. Chapman and Hall, New York.

Carbone, C., G. M. Mace, S. C. Roberts and D. W. McDonald. 1999. Energetic constraints on the diet of terrestrial carnivores. Nature, 402:256-288.

Carbone, C., Christie, S., Conforti, K., Coulson, T., Franklin, N., Ginsberg, J. R., Griffiths, M., Holden, J., Kawanishi, K., Kinnaird, M. Laidlaw, R. Lynam, A. MacDounald, D. W., Martyr, D., McDougal, C. Nath, L., O'Brain, T. Sciendensticker, J., Smith, D. J. L., Sunquist, M., Tilson, R. & Wan Shahruddin, N. W. 2001. The use of photographic rates to estimate densities of tiger and other cryptic mammals. Animal Conservation 4:75-79.

Carbone, C. and J. L. Gittleman. 2002. A common rule for the scaling of carnivore density. Science 225:2273-2276.

Chao, A. & Yang, H.-C. 2003. Program CARE-2 (for Capture-Recapture Part. 2). Program and User's Guide published at http://chao.stat.nthu.edu.tw.

Choudhury, S. R. 1970. Let us count our tiger. Cheetal 14(2): 41-51.

Chundawat, R. S., N. Gogate, A. J. T. Johnsingh. 1999. Tigers in Panna: Preliminary results from an Indian tropical dry forest. Pages 123-129 in J. Seidensticker, S. Christie and P. Jackson, editors. Riding the Tiger: Tiger conservation in human-dominated landscapes. Cambridge University press, London, U.K.

Conn, P. B., Bailey, L. L., and J. R. Saeur (2004) Indices as surrogates to abundance for low-abundance species. Pages 59 to 74 in W. L. Thompson (ed.) Sampling rare or elusive species. Island Press Washington.

Croft, T. A. 1973. Burning waste gas in oil fields. Nature, 245, 375-376.

Croft, T. A. 1978. Night-time images of the earth from space. Scientific America 239:86-98.

Dinerstein, E., E. Wikramanayake, J. Robinson, U. Karanth and A. Rabinowitz. 1997. A framework for identifying high priority areas and actions for the conservation of tigers in the wild. Part 1. World Wildlife Fund, US and Wildlife Conservation Society, Washington D.C., USA.

Efford, M. 2007. Density 4.0: software for spatially explicit capture-recapture. Department of Zoology, 487 University of Otago, Dunedin, New Zealand. http://www.otago.ac.nz/density.

Eidenshink, J. C. 1992. The 1990 conterminous U.S. AVHRR data set. Photogrammetric Engineering and Remote Sensing 586: 809-813.

Ghimere, R. B. 1979. Parks and people: Livelihood scenes in national parks management in Thailand and Madagascar. Development and Change 25:195-229.

Gunatilake, H. M. and U. Chakravarty. 2000. Forest reserves extraction by local communities: A comparative dynamic analysis. Miland: Fondaziane Eni Enrica Matter Nota Di Lavoro. 41:2000.

Jhala, Y. V. and Qureshi, Q. Eds. 2004. Monitoring tiger status and habitat: a field guide. A Technical Publication of the Project Tiger Directorate, New Delhi. 40pp.

Jhala, Y. V., Q. Qureshi and R. Gopal. 2005. Methodology for estimating and monitoring tiger, prey and habitat: Technical note. The Indian Forester 131(10): 1393-1398.

Jhala, Y. V., Q. Qureshi and R. Gopal. 2005. Monitoring tigers, co-predators, prey and their habitat. Revised second edition. : Technical publication of Project Tiger Directorate, New Delhi and Wildlife institute of India, Dehradun.

Johnsingh, A. J. T., K. Ramesh, Q. Qureshi, A. David, S. P. Goyal, G. S. Rawat., K. Rajapandian and S. Prasad. 2004. Conservation status of tiger and associated species in the Terai Arc Landscape, India. RR-04/001, Wildlife Institute of India, Dehradun.

Johnson, L. F., D. E. Roczen, Youkhana S. K., Nemani R. R., & D. F. Bosch. 2003. Mapping vineyard leaf area with multispectral satellite imagery. Computers and Electronics in Agriculture 381:33-44.

Jones, K. B., K. Ritters, J. Wicrman, R. Tankersly Jr., R. b'Neill, D. Chalonel, E. Smith and A. Neale. 1997. An ecological assessment of the United States Mid-Atlantic region: a Landscape Atlas PA/600/R-97/130. Environmental Protection Agency, office of Research and development, Washington, D.C.

Karanth, K. U. 1995. Estimating tiger (*Panthera tigris*) populations from camera-trap data using capture recapture models. Biol. Conserv.71:333-338.

Karanth, K. U. and M. E. Sunquist. 1995. Prey selection by tiger, leopard and dhole in tropical forests. Journal of Animal Ecology, 64:439-450.

Karanth, U. K. & Nichols, J. D. 1998. Estimation of tiger densities in India using photographic captures and recaptures. Ecology 79:2852-2862.

Karanth, K. U. 1999. Counting tigers with confidence. Pages 350-353 in Seidensticker, J., Christie, S. and Jackson, P. (eds.), Riding the Tiger. Cambridge University Press, London.

Karanth, K. U. and B. M. Stith. 1999. Prey depletion as a critical determinant of tiger population viability. Pages 100-113 in J. Seidensticker, S. Christie and P. Jackson, editors. Riding the

Tiger: Tiger conservation in human-dominated landscapes. Cambridge University press, London, U.K.

Karanth, U. K. & Nichols, J. D. 2000. Ecological status and conservation of tigers in India. Final Technical Report to the Division of International Conservation, U. S. Fish and Wildlife Service, Washington DC and Wildlife Conservation Society, New York. Centre for Wildlife Studies, Bangalore, India. 124pp.

Karanth, U. K. & Nichols, J. D. (Eds). 2002. Monitoring tigers and their prey. A manual for researchers, managers, and conservationists in Tropical Asia. Center for Wildlife Studies. Bangalore. 193pp.

Karanth, U. K., Nichols, J. D. Seidensticker, J., Dinerstein, E. Smith, J. L. D., McDougal, C., Johnsingh, A. J. T., Chundawat, R. S. & Thapar, V. 2003. Science deficiency in conservation practice: the monitoring of tiger populations in India. Animal Conservation 6:141-146.

Karanth, K. U., J. D. Nichols, N. S. Kumar, W. A. Link and J. E. Hines. 2004. Tigers and their prey: predicting carnivore densities from prey abundance. PNAS 101(14):4854-4858.

Karanth, U. K., Chundawat, R. S., Nichols, J. D., and Kumar, S. N. 2004. Estimation of tiger densities in the tropical dry forests of Panna, Central India, using photographic capture-recapture sampling. Animal Conservation 7:285-290.

Kawanishi, K., & Sunquist, M. E. 2004. Conservation status of tigers in a primary rainforest of peninsular Malaysia. Biological Conservation 120:329-344.

Kenney, J. S. and J. L. D. Smith. 1995. The Long-term effects of tiger poaching on population viability. Conservation Biology 95:1127-1133.

Kumar, A. and B. Wright. 1999. Combating tiger poaching and illegal wildlife trade in India. Pages 243-251 in J. Seidensticker, S. Christie and P. Jackson, editors. Riding the Tiger: Tiger conservation in human-dominated landscapes. Cambridge University press, London, U.K.

Kumar, A., R. Chellam, B. C. Choudhary, D. Mudappa, K. Vasudevan, N. M. Ishwar and B. R. Noon. 2002. Impact of rainforest fragmentation on small mammals and herpetofauna in the Western Ghats, south India. Final Technical Report. Wildlife Institute of India publications.

Lele, U., N. Tuinar, S. A. Hussain, A. Zazneta and L. Kelly. 2000. The World Bank forest strategy: striking the right balance. World Bank, Washington D.C.

Mackenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royale, and C. A. Langtimm. (2002). Estimating site occupancy rates when detection probability are less than one. Ecology 83:2248-2255.

Mani, M. S. editor. 1974. Ecology and biogeography in India. Junk, The Hague.

Mazak, V. J. 1981. Panthera tigris. Mammalian Species 152:1-8.

Mazak, V. J. 1996. Der Tiger. Magdeburg, Westarp Wissenschaften. Reprint of 1983 edition.

McGarigal, K. and B. Marks. 1995. Fragstats: spatial pattern analysis program for quantifying landscape structure. U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station, Portland.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human well being. Synthesis Island Press, Washington D.C.

Miquelle, D. G., T. W. Merrill, Y. M. Dunishenko, E. N. Smirnorv, H. B. Quigley, D. G. Pikunov, and M. G. Hornocker. 1999a. A habitat protection plan for the Amur tiger: Developing political and ecological criteria for a viable land-use plan. Pages 273-295 in J. Seidensticker, S. Christie and P. Jackson, editors. Riding the Tiger: Tiger conservation in human-dominated landscapes. Cambridge University press, London, U.K.

Miquelle, D. G., T. W. Merrill, Y. M. Dunishenko, E. N. Smirnorv, H. B. Quigley, D. G. Pikunov, and M. G. Hornocker. 1999b. Hierarchical spatial analysis of Amur tiger relationships to habitat and prey. Pages 71-99 in J. Seidensticker, S. Christie and P. Jackson, editors. Riding the Tiger: Tiger conservation in human-dominated landscapes. Cambridge University press, London, U.K.

Mishra, H. B., C. Wemmer and J. L. D. Smith. 1987. Tigers in Nepal: management conflicts with human interests. Pages 149-163 in R. L. Tilson and U. S. Seal, editors. Tigers of the world: The biology, biopolitics, management and conservation of an endangered species. Noyes Publications, Park Ridge, New Jersey.

Narain S., H. S. Panwar, M. Gadgil, V. Thapar and S. Singh. 2005. Joining the dots: The report of the tiger task force. Project Tiger, Ministry of Environment and Forest, New Delhi.

National Biodiversity Strategy and Action Plan – India. 2000. <http://unpan1.un.org/intradoc/groups/public/documents/APCITY/UNPAN011408.pdf>. Accessed 2006 April 20.

New, M., D. Lister, M. Hulme and I. Makin. 2002. A high-resolution data set of surface climate over global land areas. Climate Research 21:829-856.

Oindo, B. O. and A. K. Skidmore. 2002. Interannual variability of NDVI and species richness in Kenya. International Journal of Remote Sensing 232:285-298.

Opdam, P., J. Verboom and R. Pouwels. 2003. Landscape cohesion: an index for the conservation potential of landscapes for biodiversity. Landscape Ecology 182:113-126.

Panwar, H. S. 1979. A note on tiger census technique based on pugmark tracings. Indian Forester (Spec. Issue) 18-36.

Panwar, H. S. 1979. Population dynamics and land tenures of tiger in Kanha National Park. Pages 35-47 in Proc. Of the *Symposium on Tigers*, Project Tiger Directorate, New Delhi.

Panwar, H. S. 1979. Population dynamics and land tenures of tiger in Kanha National Park. Indian Forester Special issue: 18-36.

Panwar, H. S. 1987. Project tiger: the Reserves, the tigers and their future. Pages 110-117 in R. L. Tilson and U. S. Seal, editors. Tigers of the world: The biology, biopolitics, management and conservation of an endangered species. Noyes Publications, Park Ridge, New Jersey.

Pollock, K. H., Nichols, J. D., Brownie, C & Hines, J. E. 1990. Statistical inference for capture-recapture experiments. Wildlife Monograph 62:135p.

Pollock, K. H., Nichols, J. D., Simons, T. R., Fransworth, G. L., Bailey, L. L., ad J. R. Sauer 2002. Large scale wildlife monitoring studies: statistical methods for design and analysis. Environmetrics 13:105-119.

Prugh, L. R., C. E. Ritland, S. M. Arthur, and C. J. Krebs 2005. Monitoring coyote population dynamics by genotyping faeces. Molecular Ecology 14: 1585–1596.

Qureshi Q., Gopal R, Shirish Kyatham, Basu S., Mitra A, Y.V. Jhala 2006. Evaluating Tiger Habitat at the Tehsil level. Project Tiger Directorate, Govt. of India, New Delhi, and Wildlife Institute of India, Dehradun TR No.06/001, PP162

Rabinowitz, A. 1999. The status of the Indochinese tiger: Separating fact from fiction. Pages 148-165 in J. Seidensticker, S. Christie and P. Jackson, editors. Riding the Tiger: Tiger conservation in human-dominated landscapes. Cambridge University press, London, U.K.

Rahman, A. F., J. Gamon, D. A. Sims and M. Schmidts. 2003. Optimum pixel size for hyperspectral studies of ecosystem function in southern California chaparral and grassland. Remote Sensing of Environment 842:192-207.

Rexstad, E., and K. P. Burnham. 1991. User's guide for interactive program CAPTURE. Colorado Cooperative Fish and Wildlife Research Unit, Fort Collins, Colorado, USA.

Rodgers, W. A. and H. S. Panwar. 1988. Planning a Wildlife Protected Area network in India. Wildlife Institute of India, Dehradun. Volume 1 and 2.

Royale, J. A. and J. D. Nichols (2003). Estimating abundance from repeated presence absence data or point counts. Ecology 84: 777-790.

Royale, J. A. 2004. Modeling abundance index data from anuran calling stations. Conservation Biology 18(5):1378-1385.

Sawarkar V. B. 1987. Some more on tiger tracks. Cheetal 28(4):1-8.

Seidensticker, J., C. McDougal, N. Dunstone and M. L. Gorman. 1993. Tiger predatory behaviour, ecology and conservation. Pages 105-125 in N. Dunstone and M. L. Gorman, editors. Proceedings on symposium on Mammals as predators. Zoological Society of London, U.K.

Seidensticker, J., S. Christie and P. Jackson, editors. 1999. Riding the Tiger: Tiger conservation in human-dominated landscapes. Cambridge University press, London, U.K.

Sharma, S. 2001. Evaluation of the pugmark census technique. M.Sc. Thesis, Wildlife Institute of India, Saurashtra University, Rajkot. 103pp.

Sharma, S., Jhala, Y. V. & V. B. Sawarkar 2005. Identifying individual tigers from their pugmarks. J. Zoology.

Singh, L. A. K. 1999.Tracking tigers: Guidelines for estimating wild tiger populations using the pugmark technique. WWF - Tiger Conservation Programme, World Wide Fund-India. pp 36

Skalski, J. R. and Robson, D. S. 1992. Techniques for wildlife investigations: Design and analysis of capture data. Academic press. 237 pp.

Smirnov, E. N. and D. C. Miquelle. 1999. Prey depletion as a critical determinant of tiger population viability. Pages 61-70 in J. Seidensticker, S. Christie and P. Jackson, editors. Riding the Tiger: Tiger conservation in human-dominated landscapes. Cambridge University press, London, U.K.

Smith, J. L. D., S. C. Ahearn and C. McDougal. 1998. Landscape analyses of tiger distribution and habitat quality in Nepal. Conservation biology 126:1338-1346.

Smith, J. L. D., McDougal, C. Ahern, S. C. Joshi, A., & Kathey, C. 1999. Metapopulation structure of tigers in Nepal. In Seidensticker, J., Christie, S. and Jackson, P. (eds.), Riding the Tiger. Cambridge University Press, London. 383pp.

Sunquist M., K. U. Karanth and F. Sunquist. 1999. Ecology, behaviour and resilience of the tiger and its conservation needs. Pages 5-18 in J. Seidensticker, S. Christie and P. Jackson, editors. Riding the Tiger: Tiger conservation in human-dominated landscapes. Cambridge University press, London, U.K.

Terborgh, J. 1991. Diversity and the tropical rain forest. Freeman, New York.

Townsend, J. R. G., C. O. Justice, D. Skole, J. P. Malingrean, J. Chilar, P. M. Teillet, F. Sadowrhi and S. Rutienburg. 1995. The 1 km resolution global data set: needs of the international geographic-biosphere programme. International Journal of Remote Sensing 1517:3417-3441.

Wegge, P., C. P. Pokheral, S. R. Jnawali. (2004). Effects of trapping effort and trap shyness on estimates of tiger abundance from camera trap studies. Animal Conservation. (7):251-256.

Wikramanayake, E. D., E. Dinerstein, J. G. Robinson, K. U. Karanth, A. Rabinowitz, D. Olson, T. Mathew, P. Hedao, M. Connor, G. Hemley and D. Bolze. 1999. Where can tigers live in the future? A framework for identifying high-priority areas for the conservation of tigers in the wild. Pages 225-272 in J. Seidensticker, S. Christie and P. Jackson, editors. Riding the Tiger: Tiger conservation in human-dominated landscapes. Cambridge University press, London, U.K.

Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. The analysis and management of animal populations, Academic Press, San Diego, CA.

Xu, Y.C., Li, B., Li, W.S., Bai, S.Y., Jin, Y., Li, X.P., Gu, M.B., Jing, S.Y. and Zhang, W. (2005). Individualization of tiger by using microsatellites. Forensic Science International. 151: 45-51.

Appendix 1.1

Faculty Members involved in conducting Training and Research Team associated in data collection in the Central Indian and Eastern Ghat Landscapes:

Dr. P.K. Mathur	Dr. S. Chowdhury	Sh. B.C. Chaudhary
Dr. P.K. Malik	Dr. S.P. Goyal	Dr. V.P. Uniyal
Mrs. Bitapi Sinha	Dr. S.Sathyakumar	Dr. K. Sankar
Dr. Ruchi Badola	Dr. S.A. Hussain	Dr. K. Vasudevan
Dr. Bivash Pandav	Dr. Parag Nigam	Dr. D. Chakraborty
Dr. K. Sivakumar	Dr. B.S. Adhkari	

Research Team (63 Nos.)

Agni Mitra	Pridhuvi Raj
Aishwarya Maheshwari	Purnima manar
Amit Kotia	R.K. Jagdish Singh
Aniruddha Majumdar	Rajarshi Chakraborti
Asheem Rahul Singh	Rajendra P. Gupta
Ashish K. Gharai	Rajiv Pillai
Ashish Kumar Bais	Rajni Sharma
Bhaskar Acharya	Raju Lal Gurjar
Chandrima Home	Ramalhandran. K
Durg Singh Rajjpurohit	Rashid Raja
Harshad Mangave	Rinima Hazarika
Hem Singh Gahlot	Rishi Kumar Sharma
Indrani Sasmal	Satyaranjan Behra
J.Peter Prem Chakravarthi,	Shalini Bharadwaj
Janmajay Setty	Shantanu Basu
Jayasooryan K.K.	Shilpi Gupta
Jimmy Borah	Shirish Kayatham
John C.E.	Shubhadeep B.
Joseph Vettakaven	Shubham Dutta
Jyoti Singh	Sumit Dhokia
Jyotirmay Jena	T. Ramesh
Kamal Singh Negi	Tamo Dadda
Karabi Deka	Tana Mewada
Kuladeep Roy	Tripti Negi
Kunwar Sain	Tripti Shah
M. Selvan	Udaya Kumar Das
Manish Bharadwaj	Umesh Kumar Tiwari
Mohit Bodyal	Ved Prakash Ola
N.Sridharan	Vibhav Srivastava
Navonil Das	Vidyadhar Atkore
Parabita Basu	Vishal Vasant paitl
Peer Muzamil Shams	

Office Staff: Babita and Vivek Badoni

Appendix 1.2

National and International Peers who participated in developing and implementing the monitoring exercise

National Peers

Andhra Pradesh	Shri M.G. Gogate
Chattisgarh	Shri P.K. Mishra
Madhya Pradesh	Shri A.S. Negi
Maharashtra	Shri P.K. Mishra
Orissa	Shri P.K. Mishra
Rajasthan	Sh. P.K. Mishra
	Dr. A.P. Dwivedi

International Peers

Dr. Luigi Boitani, Prof. University of Rome, Italy

Dr. John Seidensticker, (IUCN) Smithsonian Institution, USA

Dr. Chris Carbone, Zoological Society of London, UK

Dr. Ramona Maraj, IUCN, Canada

Dr. Andrew Royale, Bio Statician, Pataxent Wildlife Research Center (USGS), USA

Appendix 1.3

Tiger, Co-Predators, Prey, and Habitat Monitoring in the Sunder Bans

1) Phase I:

Form 1: Sign survey:- Since due to the mangrove swamps and the ever present threat from tigers it is not possible to conduct extensive search for tiger signs on foot. However, the same nature of the habitat permits extensive exploration by boat. Tigers as well as all other large animals leave substantial signs while crossing or foraging around tidal creeks and channels. In the Sunderbans, trail search paths proposed for tigers and co-predators in phase I for other parts of the country will be replaced by creek / channel searches by boat. The search would be conducted at a time when the tidal conditions expose a suitable strip of mudflats along the mangrove edge. All animal & human (tiger, otters, lesser cats, chital, wild pig, rhesus, water monitor and crocodiles), signs (pug/hoof/foot prints, fecal pellets/scats/spraints, rake marks, vocalizations, direct sightings, etc.) should be recorded in the prescribed format. One side of the selected creeks/channels should be searched at a time, since close approach to the shore is needed to decipher the signs to species identity. On the return, the other side of the creek/channel should be searched. For every sign a visual estimate of the exposed shore width (watermark to the edge of the mangrove) should be recorded. The beginning GPS coordinates, end GPS coordinates, and GPS coordinates of all forks in the channel/creek should be noted (so that the sampled creek/channel can be mapped and measured for quantifying effort). If GPS unit is available with each survey team then the lat. & long. for every tiger sign observed should be recorded. The minimum creek/channel shore length that should be covered by the sign survey for each block would be 50 km consisting of a minimum sample of 3 separate survey paths each over 15 km length (about 2 hr boat search).

Form 2: Prey Encounter Rates:- Here too the foot line transect will be replaced by channel transects by boat. Encounter rates are not possible on small creeks by motorized boats, since sighting distance is smaller than the flight distance of most animals. Therefore, encounter rates should be attempted on channels of width >30m. A minimum of 15 km of suitable channel/s should be selected for collecting encounter rate data in each census block (60-80 km^2 area). The selected transect may be in the form of a continuous single channel of 20 km length or consist of 2 or more channels adding up to > 20 km length (approximately 2 hr travel in a medium size boat at slow speed). The beginning and end point GPS coordinates of the channel need to be recorded besides the start and end time on the prescribed data form. If there are more than 1 channel transects in a census beat (for e.g. 3) these need to be appropriately labeled as 1/3, 2/3, 3/3 with the name of the census block. Each channel transect needs to be sampled a minimum of 3 times. Sightings of all animals (chital, wild pig, rhesus, water monitor, crocodiles, tiger, otters, and lesser cats) need to be recorded with associated information (activity e.g. foraging, basking, etc.) as prescribed in the form 2. For every sighting the distance of the animal from the edge of the water should be visually estimated.

Form 3: Habitat & Anthropogenic Pressures:- The data formats for these aspects remain the same with a few modifications (see attached data formats). The vegetation plot size in the case of the mangrove forests of the Sunderbans would be 10m radius semi-circular plot, as the sampling will be done from the boat. The plot would be sampled along one side of the channel/creeks in the same place here encounter rates and sign surveys were conducted. On an average one plot for every 2 km transect needs to be sampled. Since the transect lines are not straight, GPS coordinates for each plot needs to be recorded. Form 3c (1 m radius plot) need not be filled in the context of the Sunderbans. The form 3 is appropriately modified to asses understory and ground cover.

Form 4: Ungulate Pellet Counts: Cannot be done in the Sunderbans.

2) Phase III:

Prey Monitoring/Estimation: Since it is not possible to sample unbiased foot transects in Sunderbans and sampling is done on water channels (convenience sampling) it may not be appropriate to extrapolate prey densities for the sampled census block to obtain absolute number of ungulates. However, the methodology would still be appropriate for monitoring population trends and for estimating relative densities. The WII team along with the FD staff will sample the channel transects. Sighting distances (perpendicular) will be recorded using laser range finders. This data will be used to model effective strip widths of the channel transects. Simultaneously the channel transect shores will be searched for sign encounter rates. Attempt will be made to establish correlations between estimated prey densities and prey signs.

Tiger Population Estimation:

Due to the limitations of working in the Sunderbans there is no single clear cut method for estimating the tiger population. The approaches proposed here would need to be tested in an experimental framework.

1) If a reasonable number of tigers are radio-collared with a specific design in a limited area, it would be theoretically possible to use these collared tigers in a Mark-Recapture framework for estimating population size of the tigers in that area of the Sunderbans. If intensive trapping of tigers is done in a small area (250-400 km^2) for radio-collaring or management purpose and photographic record of their stripe patterns (head and both flanks) is kept (along with age and gender), it would be possible to use this information for estimating the population of tigers in that area.

2) Due to the unique nature of the tidal washing of the mangrove, there are naturally created strips of mud flats that are ideal for recording tiger pugmarks. These mud strips are regularly washed by the changing tide condition every day. Tigers regularly cross these mud strips of channels and creeks to commute between mangrove forest patches. Thus the density and decay rates of tiger pugmark sign can easily be estimated in the Sunderban habitat. With radio-collared tigers it would be possible to estimate the pugmark sign deposition rate based on the daily movement rates and paths of tigers (from a reasonable number of collared tigers). Once these parameters (sign density, sign deposition and sign decay rates) are estimated, it would be possible to estimate the tiger density in the different areas of the Sunderbans.

All of the above proposed methods require data from radio-collared tigers. Thus, the phase III for tiger density estimation is dependent on timely deployment and reasonable number of radio-collars deployed on tigers in the Sunderbans (minimum of 10 to 12 tigers would need to be radio collared, 5-6 in a contagious area of 250-400 km^2, and remaining spaced throughout the tiger reserve). It must be noted that these are all experimental approaches that would require a minimum of a year to 3 years of data to evaluate and apply.

Data Sheet-1

Data Sheet for Tiger, Other Animals & Human Sign Encounter Rate

Observer Name: _____ Date: _____ Start Time: _____ End Time:_____

Begin GPS: Lat: _____N, Long: _____E End GPS: Lat: _____N, Long : _____E

Forest Circle_____ Forest Block & Range: _____ Beat _____

Approx. Kms. travelled: _____Km. Time Spent in any other activity_____Min.

SL No	Time	GPS Location (only for tiger sign)						*Animal Species	^Sign Type	Mangrove Type			Creek Bank Type			Sign		Width of mud flat (water to Mangrove edge)
		Lat.			Long.					Tall >10'	Medium 4-10'	Small <4'	Steep	Moderate	Gentle	Fresh	Old	
		D	M	S	D	M	S											
1.																		
2.																		
3.																		
4.																		
5.																		
6.																		
7.																		
8.																		

* Animal species to be recorded: tiger, fishing cat, jackal, monitor lizard, crocodile, chital, wild pig, rhesus macaque, humans and others.

^ Sign types to be recorded are pugmark/hoof mark/foot print, scat/pellet (with condition), vocalization and direct sighting.

Data sheet 1 ctd…

1) Has any tigress with cubs been reported during the past 12 months?
Yes____ No____ Approximate date/month_____
a) Seen by staff, b) Pug Marks,
c) Reported by local persons, d) Seen by officials (√ the appropriate)
How many cubs _____, approximate age of cubs _____.

2) In case tigers are known to be present in the beat, but no sign was obtained during the sampling period then mention on what evidence was this conclusion made (pugmark, direct sighting, scat, other sign) _____.
Approximate date/month_____ Tiger presence was last recorded in the beat.

3) How many livestock predation events have been recorded in the past 3 months, _____ by tigers, which carnivores if known_____, _____, _____.

4) GPS Coordinates at all creek/channel junctions in serial order of survey

Sl.No.	Time	Lat			Long		
		Degree	Minutes	Second	Degree	Minutes	Second
1							
2							
3							
4							
5							
6							
7							

5) Comments & Remarks:

_____

_____

Data Sheet-2

Encounter Rate on Line Transects

Observer Name: _____ Date: _____ Start Time: _____End Time:_____

Begin GPS: Lat: _____N, Long: _____E End GPS: Lat:_____N, Long : _____E

Forest Circle_____ Forest Block & Range: _____ Beat _____

Approx. Kms. Travelled: _____Km.

S. No	Time	Species*	Total Number (Adults & Young)	Young	Mangrove Type			Bank Type			Approximate distance of animal from water edge	Activity of the animal(s) Basking, foraging, moving, etc.
					Tall >10'	Medium 4-10'	Small <4'	Steep	Medium	Gentle		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

*Species that need to be recorded on the transect: chital, rhesus, macaque, wild pig, monitor lizard and estuarine crocodile and other mammalian species seen.

Data Sheet-3A

VEGETATION

(To be recorded at every 15 minute travel interval)

Name of Observer: ……. Date: …… Forest Circle: …… Forest Division……

Range: …….. Beat: …… ID No. of Line Transect: ……

Sl No	GPS Reading at every plot from beginning of creek transect						Location of Plot- Left side/ Right side	Tree Species (Descending Order of Abundance, (Give Names)					Grass/Herbs/Sedges Species (Descending Order of Abundance including reg. mangroves, all vegetation < 4 ft.)					Density of Vegetation 0 to 4 0- Open 4- very dense	Remarks
	Lat			Long															
	Deg	Min	Sec	Deg	Min	Sec		1	2	3	4	5	1	2	3	4	5		

Data Sheet-3B

Human Disturbance

Name of Observer: …….. Date: …… Forest Circle: …… Forest Division……
Range: …….. Beat: …… ID No. of Line Transect: ……

Sl No	GPS locations of the beginning of creek transect and at every 15 min. travel interval thereafter						Human Disturbances 0-4 Rating, 0-None, 4-Very high			
	Lat			Long			Wood Cutting 0-4	Lopping 0-4	Fishing evidence seen from the vegetation plot Y/N	People Seen from the plot Y/N
1	Deg	Min	Sec	Deg	Min	Sec				
2										
3										
4										
5										
6										
7										
8										
9										
10										

Are there any permanent human settlements in the beat? *(Yes/No)*. If Yes, how many? _____. Approximate human population_____,
Is there NTFP collection in the beat_____ *(Yes/No)*. If yes, what NTFP is collected_____, _____, _____, _____,

Rate NTFP collection on a scale of 0-4, 0-No to 4-Very high _____, _____, _____, _____.
Intensity of fishing .....and tiger prawn seed collection ..... in the beat at 0-4 scale (*0 is nil, 4 is very high)*

Appendix 1.4 Literature used for historical map preparation:

Adams, E. G. P. 1938. Measurements of tigers shot in the Nilgiris – 1925-37. Journal of Bombay Natural History Society. 40:553.

Adams, E. G. P. 1948. Tiger eating panther? Journal of Bombay Natural History Society. 48:353.

Adams, E. G. P. 1948. Death cry of tiger. Journal of Bombay Natural History Society. 48:354.

Adams, E. G. P. 1948. Charged by unwounded bison. Journal of Bombay Natural History Society. 48:575.

Adams, E. G. P. 1950. Jungle memories. Journal of Bombay Natural History Society. 48:125.

Ahmed, Q. 1945. Abnormal behavior of a tiger. Journal of Bombay Natural History Society. 45:410.

Alikhan, I. 1937. Association between a leopardess and a tigress. Journal of Bombay Natural History Society. 38:384-385

Anderson, K. 1999. The man-eater of segur. In M. Rangarajan, editor. Indian wildlife, Hunting and Shooting. Oxford University Press. New Delhi.

Anonymous. 1927. Notes on Tiger preferring carrion to live bait. Journal of Bombay Natural History Society. 31:1025.

Archer, D. M. 1959. Tippoo's Tiger. H. M. S. O. London.

Bailey, F. M. 1939. Occurrence of tigers in Sikkim. Journal of Bombay Natural History Society. 411:166.

Battye, R. K. M. ,1939. Occurrence of tigers in Sikkim. Journal of Bombay Natural History Society. 411:166.

Beadon, C. 1910. White Tigers. Journal of Bombay Natural History Society. 10:774.

Bhattacharya, A. 1947. The tiger cult and its literature in lower Bengal. In:Man in India. 27:49-50.

Bhupa, N. N. 1908. Thirty seven years of big game shooting. Rowland Ward Ltd., London.

Biscoe, W. F. 1895. The poisonous plants of Bombay. Journal of Bombay Natural History Society. 09:490.

Boar, N. L. 1929. A careless tiger. Journal of Bombay Natural History Society. 33:194-195.

Boswell, K. 1947. 'Death Cry' of tiger. Journal of Bombay Natural History Society. 47:368-370.

Bradden, E. 1999. Sports in lower Bengal. In M. Rangarajan, editor. Indian wildlife, Hunting and Shooting. Oxford University Press. New Delhi.

Brander D. A. 1908. The degeneration of tigers in the Central Provinces. Indian Forester. 34:678 - 681.

Brander, D. A. 1999. Tigers in the wild. In M. Rangarajan, editor. Indian wildlife, Hunting and Shooting. Oxford University Press. New Delhi.

Burton, R. G. 1906. Some notes on tigers and panthers. Journal of Bombay Natural History Society. 17:1016.

Burton, R. G. 1920. A sporting diary of H. H. Bikaner. Journal of Bombay Natural History Society. 272:386.

Burton, R. G. 1920. Maneating tigers on Saugor Island in the 18th Century. Journal of Bombay Natural History Society. 272:385-6.

Burton, R. G. 1920. Tigers in trees. Journal of Bombay Natural History Society. 272:383-385.

Burton, R. G. 1933. The Book of the Tiger. Natraj Publishers, Dehradun.

Burton, R. W. 1925. An Encounter with fighting tigers. Journal of Bombay Natural History Society. 30:252-256.

Burton, R. W. 1935. A tiger feeding on a cow when yet alive. Journal of Bombay Natural History Society. 37:945-946.

Burton, R. W. 1947. A man Eating Tiger of the Nelliampathy hills. Journal of Bombay Natural History Society. 47:148.

Burton, R. W. 1918. Notes from the oriental sports magazine News series, 1869 to 1879. Journal of Bombay Natural History Society. 25: 491-493.

Burton, R. W. 1961. The senses of the tiger. Journal of Bombay Natural History Society. 58:791-792.

Campbell, T. J. 1894. Tiger eating a bear. Journal of Bombay Natural History Society. 19:101.

Capper, S. 1914. Black tigers Felis tigris. Journal of Bombay Natural History Society. 23:343.

Chakrabati, K. and Chaudhuri, A. G. 1972. Wildlife Biology of the Sundarbans Forests - observations on Tigers. In:IUCN Special Issue, 151:11-31.

Champion, F. W. 1929. Tiger tracks. Journal of Bombay Natural History Society. 33:285-287.

Chandra, B. 1970. Status of tiger in India with particular reference to Rajasthan. Report submitted to Indian Forest College, Deharadun.

Chopra, D. D. 1949. An encounter with a tiger. Indian Forester. 759:367-368.

Choudhary, S. R. 1972. Tigers Census in India. The Cheetal. 151:67-76.

Choudhary, C. M. 1961. Recovery of a ringed tiger. Journal of Bombay Natural History Society. 58:508.

Clifford, B. 1913. Vitality of a tiger. Journal of Bombay Natural History Society. 22:189.

Clive, J. Mc. 1928. A Tussle between Tiger and Buffaloes. Journal of Bombay Natural History Society. 323:586.

Corbett, G. Q. 1948. Journal of Bombay Natural History Society. 48:175-176.

Corbett, J. 1944. Man-eaters of Kumaon. Oxford University Press, London.

Corbett, J. 1999. The Pannar man eater. In M. Rangarajan, editor. Indian wildlife, Hunting and Shooting. Oxford University Press. New Delhi.

Daniel, J. C. 1970. The Tiger In India:An enquiry- 1968-69. Journal of Bombay Natural History Society. 67:227-321.

Daniel, J. C. 2001. The Tiger in India:A Natural History. Natraj Publishers, Dehra Dun.

Daver, S. R. 1949. Man-Eater of Bindawal. Indian Forester. 756:223-8.

Dent, T. V. 1936. Tigers in Sunderbans. Journal of Bombay Natural History Society. 38:178.

Divyabhanusinh. 1987. The white predator:Chronicles in the Akbarnama. Zoo's Print. 29:13-16.

Editorial note. 1948. Journal of Bombay Natural History Society. 48:176-180.

Ellison, B. D. 1925. H. R. H. The Prince of Wales' Sport in India. William Heinemann Ltd., London.

Fenton, L. L. 1905. Tigers hamstringing their prey before killing. Journal of Bombay Natural History Society. 16:756.

Ferris, W. B. 1900. A mark on the skin of a man eating tiger. Journal of Bombay Natural History Society.12:410.

Fletcher, F. W. F. 1911. Sport on the Nilgiris and in Wynaad. McMillan and Co. Ltd., London.

Forrest, D. 1970. The Tiger of Mysore, the life and death of Tipu Sultan. Chatto and Windus, London.

Forsyth, J. 1889. The Highlands of Central India. London:Chapman and Hall Ltd. Calcutta:Thacker, Spink and Co.

Fraser, S. M. 1902. Tiger netting in Mysore. Journal of Bombay Natural History Society. 14:388.

Garga, D. P. 1948. How far can a tiger swim? Journal of Bombay Natural History Society. 47:545.

Gee, E. P. 1959. Albinism and partial albinism in tigers. Journal of Bombay Natural History Society. 56 3:581-587.

Gee, E.P. 2000. The Wildlife of India. Harper Collins, New Delhi.

Gilbert, R. 1895. Man eating tigers. Journal of Bombay Natural History Society. 101:83.

Hawkins, T. B. 1955. A large tiger. Journal of Bombay Natural History Society. 52:586.

Ingen, V. 1929. An unusual find in a tiger's skull. Journal of Bombay Natural History Society. 33:194–195.

Ingen. V. 1940. Variation in colour of tigers and panthers. Journal of Bombay Natural History Society. Vol 42:655-656.

Islam, Ul. S. 2001. Hunting Dangerous Game with the Maharajas. Himalayan Books Publishers, New Delhi.

Keighley, V. A. S. 1912. Notes on tigers [Viceroy's shoot]. Journal of Bombay Natural History Society. 21:1063.

Khajuria, H. 1963. The wild dog and the tiger. Journal of Bombay Natural History Society. 60:448.

Khan, T. A. 1961. Man-eaters of the Sundarbans. International Publishers, Lahore.

Kinloch, A. P. 1927. Man eating tigers. Journal of Bombay Natural History Society. 32:209.

Kumar, S. B. 1958. Tigers and porcupines. Journal of Bombay Natural History Society. 55:550-551.

Lapersonnae, V. S. 1932. Remarkable behavior of tigers. Journal of Bombay Natural History Society. 36:235-236.

Lister, F. H. 1938. Occurrence of tigers in SIkkim. Journal of Bombay Natural History Society. 403:553.

Longerede. 1946. A tiger climbing a tree. Journal of Bombay Natural History Society. 46:390.

Lotian, A. C. 1934. An unusual tiger. Journal of Bombay Natural History Society. 37:479.

Lydekker, R. 1924. The Game Animals of India, Burma, Malaya and Tibet. Rowland Ward, Ltd., London.

Maharaja of Surguja. 1936. Journal of Bombay Natural History Society. 38:384-385.

Malhotra, A. K. 1981. The `Pucca Sahib' tigers of Rewa. Indian Wildlifer. 14:35-6.

Melville, G. 1949. The man eater of Jhabrawala. Indian Forester. 757:268 - 269.

Meston, D. G. 1946. Man-eaters in the Darrang district, Assam. Journal of Bombay Natural History Society. 46:178.

Milroy, A. J. W. 1927. Tigers and elephants. Journal of Bombay Natural History Society. 32:370.

Montresor, L. B. 1906. Cannibalism amongst tigers and panthers. Journal of Bombay Natural History Society. 172:543 - 545.

Morris, R. 1927. A tigress with five cubs. Journal of Bombay Natural History Society. 31:810-811.

Morris, R. 1929. Tiger pooking. Journal of Bombay Natural History Society. 33:194-195.

Morris, R. C. 1929. Wounded tiger returning to kills. Journal of Bombay Natural History Society. 33:425-426.

Morris, R. 1934. A tailless tiger. Journal of Bombay Natural History Society. 37:719.

Morris, R. C. 1935. Tiger feeding on a live cow. Journal of Bombay Natural History Society. 38:386.

Morris, R. 1938. Measurements of Tigers. Journal of Bombay Natural History Society. 40:114.

Morris, R. C. 1938. Measurements of tiger, panther, bison and sambar. Journal of Bombay Natural History Society. 403:555.

Morris, R. C. 1941. Unusual behaviour of panthers and tigers. Journal of Bombay Natural History Society. 423:655-656.

Morris, R. C. 1945. A tiger's record as a 'cattle killer'. Journal of Bombay Natural History Society. 45:597.

Morris, R. 1946. Rarity of man eating Tigers in South India. Journal of Bombay Natural History Society. 461:177-178.

Morris, R. C. 1948. A tale of many tigers. Journal of Bombay Natural History Society. 48:175-176.

Morris, R. 1952-53. Unrecorded sounds made by Tiger and Wild Dog. Journal of Bombay Natural History Society. 512:1-4.

Narain, V. 1927. Encounter between wild buffalo and a pair of tigers. Journal of Bombay Natural History Society. 31:1025.

Noronha, R. P. 1999. Tigers in Bastar. In M. Rangarajan, editor. Indian wildlife, Hunting and Shooting. Oxford University Press. New Delhi.

Oswald, A. 1960. The white tigers of Rewa. The Cheetal 22:63-7.

Pitman, C. R. 1913. Tiger taking off carcass of sloth bear. Journal of Bombay Natural History Society. 223:619.

Pocock, R. W. 1929. Tigers. Journal of Bombay Natural History Society. 33:505-541.

Prater, S. H. 1929. The occurrence of tigers on the islands of Bombay and Salsette. Journal of Bombay Natural History Society. 334:973.

Prater, S. H. 1940. The number of tigers shot in reserved forest in India & Burma during the year 1937-1938. Journal of Bombay Natural History Society. 41:881-888.

Rangarajan, M. 1998. The Raj and the natural world:The war against 'dangerous beasts' in colonial India. In:Studies in history. 14:265-300.

Rangarajan, M. 1998. From Princely symbols to conservation Icon:A Political history of the lion in India:occasional paper No. 54. Nehru Memorial Museum and Library, New Delhi.

Rangarajan, M. 1999. Indian Wildlife, Watching and Conserving. Oxford University Press.

Rangarajan, M. 2001. India's Wildlife History. Permanent Black, New Delhi.

Rashid, M. A. 1979. A note on the tiger census conducted in Gujarat state from 15th to 21st April, 1979. Journal of Bombay Natural History Society. 762:357-9.

Rice, W. 1999. Hunting large animals. In In M. Rangarajan, editor. Indian wildlife, Hunting and Shooting. Oxford University Press. New Delhi.

Rice, W. 1999. Tigers on foot. In:Indian wildlife, Watching and conserving. Oxford University Press.

Ritchie, W. D. 1950. A tiger fight. Journal of Bombay Natural History Society. 49:535.

Robinson, F. B. 1928. White Tigers. Journal of Bombay Natural History Society. 323:584.

Robinson, R. 1969. The white tigers of Rewa and Gene Homology in the Felidae. Genetica. 40:198-200.

Roychoudhury, A. K. 1980. Is there any lethal gene in the tiger of Rewa? Current Science. 49:518-20.

Rule, W. F. 1945. Calling up tigers. Journal of Bombay Natural History Society. 45:597-598.

Sankhala, K. 1969. The tiger in Rajasthan. Indian Forester. 95(11):763 - 770.

Sankhala, K. 1978. Tiger ! The story of the Indian tiger. William Collins sons & co. ltd. London.

Sankhala, K. 1979. Tigers in the wild their distribution and habitat preferences. The Cheetal. 20 2-3:35-57.

Schaller, G. B. 1967. The Deer and the Tiger:A Study of Wildlife in India. University of Chicago Press, Chicago.

Schilling, T. 1957. Tiger Men of Anai. George Allen & Unwin, London.

Seshadri, B. 1969. The Twilight of India's wildlife. Oxford University Press, Bombay.

Sethi, P., Mohan, D., Rao, D. D. B., Upadhyay, S., Mohapatra, K. K., Hanfee, F., Khalid M. A. & Singh, T. P. 2000. Strategies and action plan for biodiversity conservation in Uttar Pradesh. Tata Energy Research Institute, New Delhi. Volume 1, 2 & 3.

Shankariah, G. M. 1961. Capture of live tiger. Indian Forester. 878:493 - 495.

Shehan, 'Big Bore'. 1924. A Guide to Shikar in the Nilgiris. London.

Siddiqi, N. A. & Choudhury J. H. 1987. Man-eating behaviour of tigers Panthera tigris Linn of the Sundarbans-twenty-eight years record analysis. Tiger Paper, 143:26-32.

Singh, A. 1970. The tiger of the Terai with special reference to the Kheri forests of Uttar Pradesh, India. IUCN Bulletin, New Series. 18:556.

Singh, B. 1943-44. Journal of Bombay Natural History Society. 44 2:291.

Singh, K. 1972. Project Tiger:a planning proposal for preservation of tiger Panthera tigris tigris in India. Report submitted to MoEF, New Delhi.

Singh, K. 1999. Shikar camps. In:Indian wildlife, Watching and Conserving. Oxford University Press.

Singh, K. S. 1986. Bihar- Home of the White tiger. The Cheetal. 134:24-27.

Singh V. B. 1969. Tigers in Uttar Pradesh. The Cheetal. 12:106-113.

Smith, M. A. 1999. My Shikaree friends. In M. Rangarajan, editor. Indian wildlife, Hunting and Shooting. Oxford University Press. New Delhi.

Somerville, A. 1924. Shikar near Calcutta. Ames, London.

Spaak, A. & Malhotra, A. K. 1981. White tigers of Rewa. Indian Wildlife. 14:35-6.

Stuart-Baker, E. C. 1920. The power of scent in wild animals. Journal of Bombay Natural History Society. 27:112.

Swire, C. 1931. Three Tigers at a kill. Journal of Bombay Natural History Society. 34:796-797.

Tawar, A. K. 1961. Man-eaters of the Sundarbans. London.

Thapar, V. 2006. Tiger:The Ultimate Guide. Oxford University Press, New Delhi.

Thornton, I. W. B., K. K. Yeung & Sankhala, K. S. 1967. The genetics of the white tigers of Rewa. Journal of Zoology. 152:127-35.

Tiwari, S. K. 2004. Wildlife in central India. Swarup & sons, New Delhi. 1, 2 & 3.

Todd, W. H. 1927. Tiger! Tiger!. London.

Vanderzee, J. H. 1898. Journal of Bombay Natural History Society. 11:148-14

Appendix 1.5 Details of spatial and attribute data used for assessing patterns of tiger distribution

Biogeography

We have used biogeographic classification based on Rodgers and Panwar (1988) and Ecoregion classification by Wikramanayake et al. (2002).

Biogeographic Classification of India

BIOCODE	ZONE	PROVINCE
1A	Trans Himalaya	Ladakh Mountains
1B	Trans Himalaya	Tibetan Plateau
2A	Himalaya	North-West Himalaya
2B	Himalaya	West Himalaya
2C	Himalaya	Central Himalaya
2D	Himalaya	East Himalaya
3A	Desert	Thar
3B	Desert	Katchchh
4A	Semi-Arid	Punjab Plains
4B	Semi-Arid	Gujarat Rajputana
5A	Western Ghats	Malabar Plains
5B	Western Ghats	Western Ghats Mountains
6A	Deccan Peninsula	Central Highlands
6B	Deccan Peninsula	Chotta Nagpur
6C	Deccan Peninsula	Eastern Highlands
6D	Deccan Peninsula	Central Plateau
6E	Deccan Peninsula	Deccan South
7A	Gangetic Plain	Upper Gangetic Plain
7B	Gangetic Plain	Lower Gangetic Plain
8A	Coasts	West Coast
8B	Coasts	East Coast
8C	Coasts	Lakshadweep
9A	North-East	Brahmaputra Valley
9B	North-East	North-East Hills
10A	Islands	Andaman
10B	Islands	Nicobar

Table 1 Details of remotely sensed data used for analyzing patterns governing tiger occupancy.

	Dataset	***Sensors***	***Spatial Resolution***	***Radiometric Resolution***
1	Forest Cover	IRS 1D LISS III	23.5 m	4 Multispectral bands
2	Normalized Difference Vegetation Index (NDVI)	Advanced Very High Resolution Radiometer (AVHRR)	1000 m	3 Multispectral bands
3	Digital Elevation Model (DEM)	Shuttle Radar Topography Mission (SRTM)	90 m	2 bands
4	*Night-time visible lights*	US Air Force Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS)	1000 m	1 band

Night Light Data

Night light data was obtained form NOAA/NGDC using the Defense Meteorological Satellite Program's Operational Line-scan system (DMSP/OLS) for a pixel size of 2.7 km x 2.7 km. The visible (0.47 - 0.95 μm) and near-infrared (VNIR) spectral bands which are sensitive to the night-time light of cities, towns, fires, lightning, etc. are useful for mapping human habitation (Elvidge et al. 1997b). The high contrast between lit and unlit areas and the sensor's spatial resolution makes it a useful tool to identify regions of intense human activity (Croft 1973, 1978).

AVHRR-NDVI

Normalized difference vegetation index (NDVI) composites with 10-day interval for four years were derived from the 1-kilometer (km) advanced very high resolution radiometer (AVHRR) data acquired by the National Oceanic and Atmospheric Administration's (NOAA) Television Infrared Observation Satellite (TIROS) (Townsend 1995).

Advanced Very High Resolution Radiometer (AVHRR) to derive the Normalized Difference Vegetation Index (NDVI), is a way to quantify the biomass of actively photosynthesizing vegetation (Eidenshink, 1992). The relationship between NDVI and vegetation is well documented (Birkey, 2001; Rahman, 2003). NDVI has been used to predict the vineyard leaf area index (Johnson et al., 2003), to monitor vegetation response, and to determine the change in vegetation cover over time. Species richness of vascular plants and mammals was related to a standard deviation and coefficient of variability of NDVI in Kenya (Oindo and Skidmore, 2002). NDVI maps were used to locate urbanization, forest, and other areas (Jones et al., 1997).

Ecoregion Mapping

Ecoregions of the Continents characterize global potential natural vegetation at approximately 1/2-degree resolution. The dataset is based on a Russian vegetation map prepared by Gerasimov in 1964 which was updated by the US Fish and Wildlife Service (Bailey and Hogg, 1986 and Bailey 1989). Projected to geodetic coordinates at the World Conservation Monitoring Center, England.

Code	Description
1	Rock and ice
2	Andaman Islands rain forests
3	Brahmaputra Valley semi-evergreen forests
4	Chin Hills-Arakan Yoma montane forests
5	Eastern highlands moist deciduous forests
6	Himalayan subtropical broadleaf forests
7	Lower Gangetic Plains moist deciduous forests
8	Malabar Coast moist forests
9	Maldives-Lakshadweep-Chagos Archipelago Tropical Moist Forest
10	Meghalaya subtropical forests
11	Mizoram-Manipur-Kachin rain forests
12	Nicobar Islands rain forests
13	North Western Ghats moist deciduous forests
14	North Western Ghats montane rain forests
15	Orissa semi-evergreen forests
16	South Western Ghats moist deciduous forests
17	South Western Ghats montane rain forests
18	Sundarbans freshwater swamp forests
19	Upper Gangetic Plains moist deciduous forests
20	Central Deccan Plateau dry deciduous forests
21	Chhota-Nagpur dry deciduous forests

22	East Deccan dry-evergreen forests
23	Khathiar-Gir dry deciduous forests
24	Narmada Valley dry deciduous forests
25	Northern dry deciduous forests
26	South Deccan Plateau dry deciduous forests
27	Himalayan subtropical pine forests
28	Northeast India-Myanmar pine forests
29	Eastern Himalayan broadleaf forests
30	Northern Triangle temperate forests
31	Western Himalayan broadleaf forests
32	Eastern Himalayan subalpine conifer forests
33	Western Himalayan subalpine conifer forests
34	Terai-Duar savanna and grasslands
35	Rann of Kutch seasonal salt marsh
36	Deccan thorn scrub forests
37	Northwestern thorn scrub forests
38	Thar desert
39	Goadavari-Krishna mangroves
40	Indus River Delta-Arabian Sea mangroves
41	Sundarbans mangroves
42	Northeastern Himalayan subalpine conifer forests
43	Central Tibetan Plateau alpine steppe
44	Eastern Himalayan alpine shrub and meadows
45	Karakoram-West Tibetan Plateau alpine steppe
46	North Tibetan Plateau-Kunlun Mountains alpine desert
47	Northwestern Himalayan alpine shrub and meadows
48	Pamir alpine desert and tundra
49	Western Himalayan alpine shrub and Meadows
50	Yarlun Tsangpo arid steppe
51	Baluchistan xeric woodlands

Forested areas in each ecoregion that currently harbour tigers or have potential tiger habitat were estimated.

Climatological Data

The precipitation data (New et al., 2002) was generated from a 10' latitude/longitude data set of mean monthly surface climate over global land areas. The climatology includes 8 climate elements precipitation, wet-day frequency, temperature, diurnal temperature range, relative humidity, sunshine duration, ground frost frequency and windspeed—which was interpolated from a data set of station means for the period between 1961 to 1990. This data was used to understand the influence of meterological factors of tiger distribution and for evaluating potential tiger habitat.

Census data :

Human population data was obtained from the office of Registrar General, India for the year 1991, under the section Primary Census Abstract (PCA). The PCA gives the data on number of houses and households, total population, Scheduled Castes and Scheduled Tribes, population in the age group 0-6 years, number of literates, number of workers classified by industrial categories, marginal workers and non workers. These data are available at the resolution of the village level for rural areas, and at ward level for cities and towns. We summarised this data at the Tehsil level to model tiger distribution.

Forest Cover Map

Forest Cover map was obtained from Forest Survey of India (FSI 2003). The assessment is based on digital interpretation of satellite data for the entire country. LISS-III sensor data of IRS-1C satellite with a resolution of 23.5 m has been used. This was one of the main layers in the GIS that was used for deriving landscape characteristics.

Roads & Drainage

The roads and drainage maps of digital chart of the world (ESRI 1992) for the country at a scale of 1: 1000,000 was used. Euclidean distances and densities were generated using ArcGIS (ESRI) software.

Protected Areas

The locations of the Protected Areas, National Parks, Wildlife Sancturies, and Tiger Reserves were obtained from the Wildlife Database cell, Wildlife Institute of India and Project Tiger Directorate.

Core Areas

Forested habitats are like islands in a sea of human dominated landscapes. People living on the edges (and within forests) utilize these forests to varying degrees, depending on their life styles, legal status of the forests, and implementation of protection measures. These anthropogenic pressures penetrate inwards from the edges. To model these effects and to assess the amount of forest that likely remains free of such disturbances we buffered each forest patch with an inward buffer of 3 km. These buffered "disturbance free" patches are referred to as cores.

Landscape Characterization

For the Landscape characterization and evaluation, fragmentation metrics like forest patch size, distribution and density, patch shape complexity and core area metrics were calculated using Fragstat (McGarigal and Marks 1995).

We derived Euclidian distance from protected areas, night light, drainage, roads and density of roads and drainage in 10 x 10 km grids to asses the human influence and habitat suitability **(Appendix 3)**.

Appendix 1.6: Forest occupancy of Tigers, Co-Predators, Prey and population estimates of tigers.

State	Tiger km²	Leopard km²	Dhole km²	Sloth Bear km²	Chital km²	Sambar km²	Wild Pig km²	Nilgai km²	Tiger Numbers		
									No.	Lower limit	Upper limit
Shivalik-Gangetic Plain Landscape Complex											
Uttarakhand	1901	3683	-	853	2161	2756	3214	422	178	161	195
Uttar Pradesh	2766	2936	190	3130	5537	2641	7761	8375	109	91	127
Bihar	510	552	323	532	576	321	570	494	10	7	13
Shivalik-Gangetic	**5177**	**7171**	**513**	**4515**	**8274**	**5718**	**11545**	**9291**	**297**	**259**	**335**
Central Indian Landscape Complex and Eastern Ghats Landscape Complex											
Andhra Pradesh	14126	37609	41093	54673	37814	33159	58336	26526	95	84	107
Chattisgarh	3609	14939	3794	20951	18540	7604	25058	9250	26	23	28
Madhya Pradesh	15614	34736	28508	40959	41509	33551	599033	41704	300	236	364
Maharashtra	4273	4982	4352	6557	5970	5730	7370	4754	103	76	131
Orissa	9144	25516	8215	43236	6040	6112	21525	711	45	37	53
Rajasthan	356	-	-	-	-	-	-	-	32	30	35
Jharkhand**	1488	131	-	2640	721	721	6226	1108	**Not Assessed**		
Central Indian	**48610**	**131**	**85962**	**2640**	**721**	**721**	**6226**	**1108**	**601**	**486**	**718**
Western Ghats Landscape Complex											
Karnataka	18715	20506	15862	20749	42349	43412	21999	-	290	241	339
Kerala	6168	8363	10801	6904	2931	10469	8809	-	46	39	53
Tamil Nadu	9211	14484	19658	13224	13567	15909	19768	2505	76	56	95
Western Ghats	**34094**	**43353**	**46321**	**40877**	**58847**	**69790**	**50576**	**2505**	**402**	**336**	**487**
North East Hills and Brahmaputra Flood Plains											
Assam*	1164	1500	285	380	-	270	2047	-	70	60	80
Arunachal Pradesh*	1685	670	675	199	-	353	412	-	14	12	18
Mizoram*	785	2324	776	479	-	1700	1489	-	6	4	8
Northern West Bengal *	596	1135	301	-	280	309	491	-	10	8	12
North East Hills and Brahmaputra	**4230**	**5629**	**2037**	**1058**	**280**	**2632**	**4439**	-	**100**	**84**	**118**
Sunderbans	**1586**	-	-	-	**1184**	-	**1591**	-	**Not Assessed**		
Total Tiger Population									**1411**	**1165**	**1657**

* Population estimates are based on possible density of tiger occupied landscape in the area, not assessed by double sampling.

** Data was not amenable to population estimation of tiger. However, available information about the landscape indicates low densities of tiger in the area ranging from 0.5 to 1.5 per 100 km².

National Tiger Conservation Authority
Ministry of Environment & Forests
Government of India
Bikaner House, Annexe-V
Shahjahan Road, New Delhi - 110 011
Ph : +91 11 23389645
Telefax : +91 11 23384428
www.projecttiger.nic.in

Wildlife Institute of India
Post Bag No. 18
Chandrabani
Dehradun - 248 001
Uttarakhand
Ph : +91 135 2640111 - 115
Telefax : +91 135 2640117
www.wii.gov.in