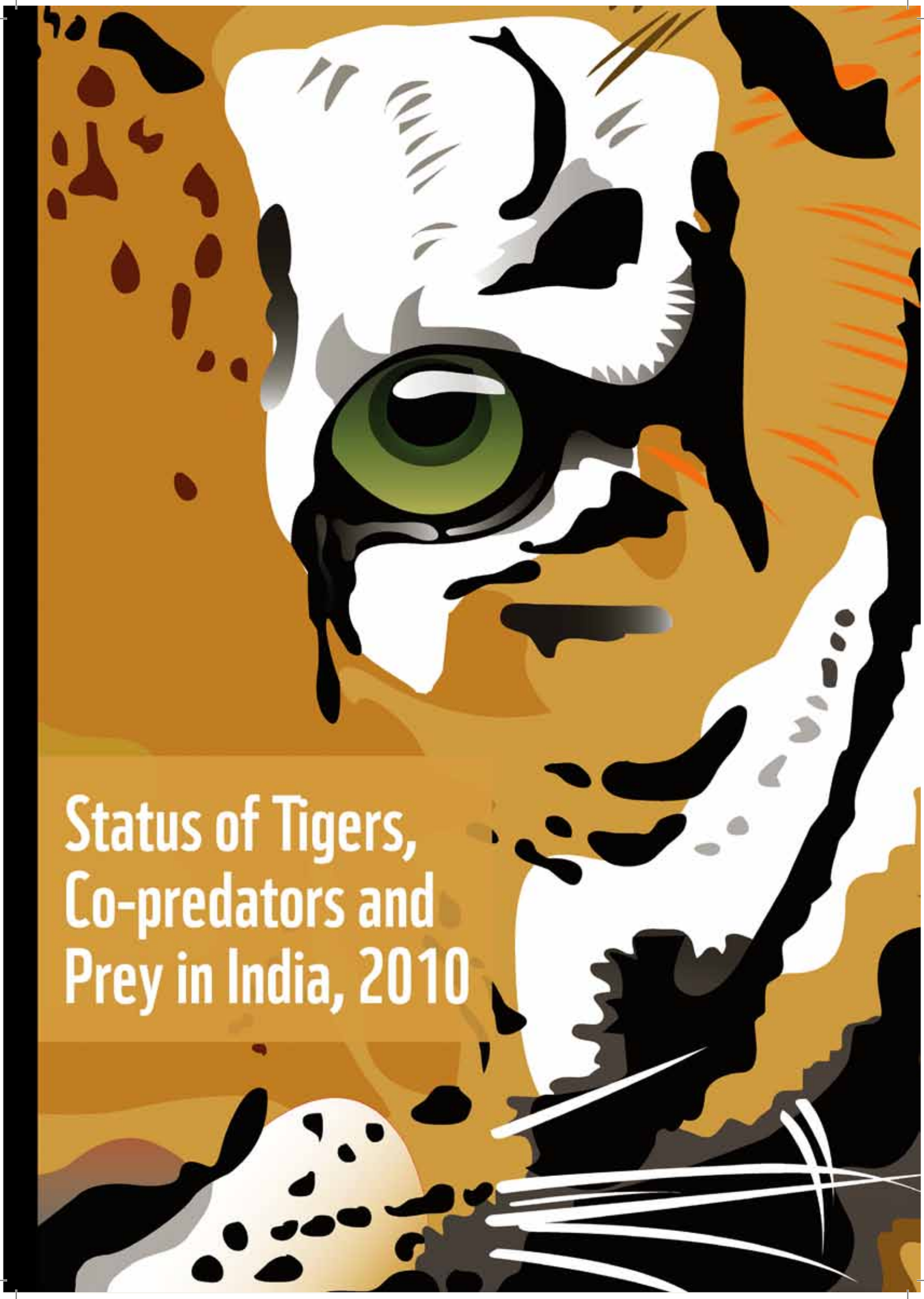

Status of Tigers, Co-predators and Prey in India, 2010

Status of tigers, co-predators and prey in India, 2010

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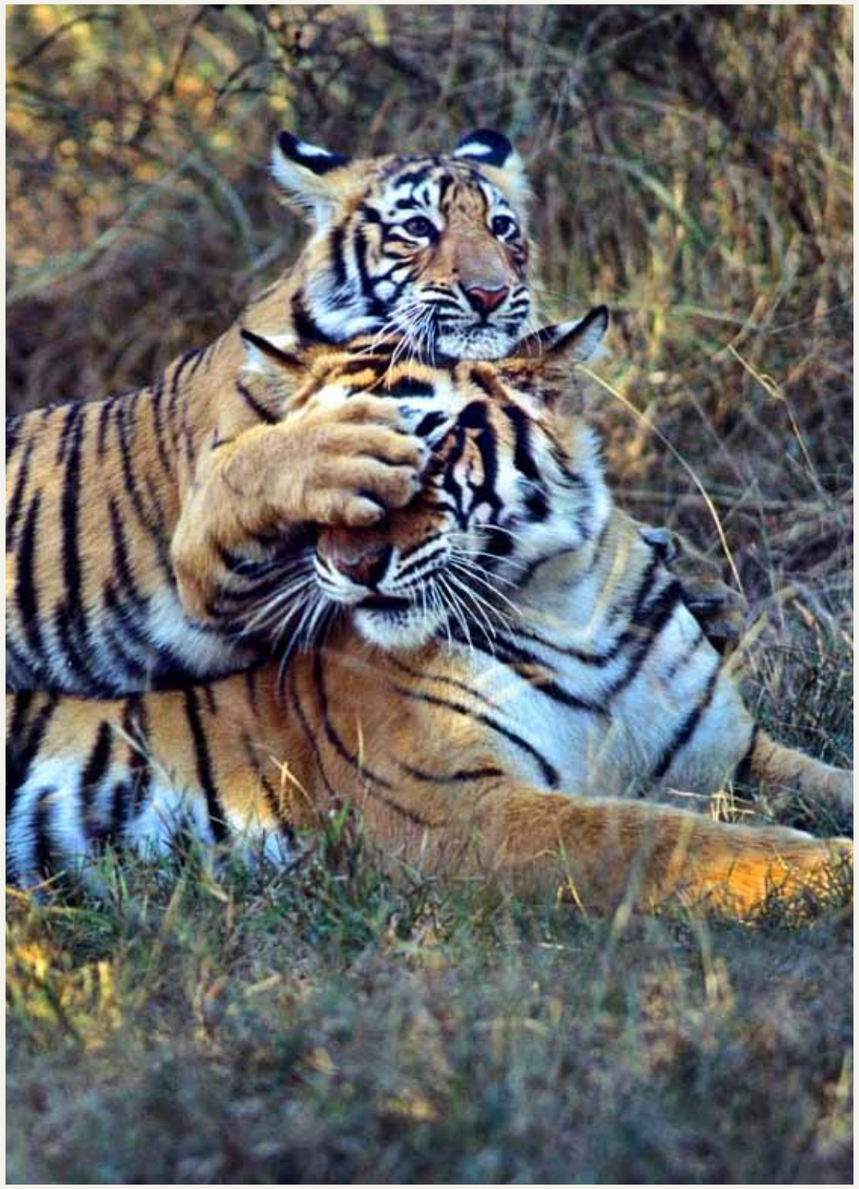

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जयंती नटराजन
Jayanthi Natarajan

सत्यमेव जयते

राज्य मंत्री (स्वतंत्र प्रभार)
पर्यावरण एवं वन मंत्रालय
भारत सरकार
नई दिल्ली–110 003

MINISTER OF STATE (INDEPENDENT CHARGE)
ENVIRONMENT & FORESTS
GOVERNMENT OF INDIA
NEW DELHI-110 003

22th July, 2011

Foreword

Tiger conservation in the contemporary era has attracted much global attention due to the highly endangered status of the tiger. A combination of factors such as habitat shrinkage, decline in prey species, poaching for medicinal and cultural value and the ever expanding human population, are direct threats faced by tigers. Given that India has the maximum number of tigers and its source areas amongst the Tiger Range Countries, it is the responsibility of the country and its people to ensure its survival.

'Status of the Tiger, Co-Predators and Prey in India, 2010', is a country wide assessment of tiger and its prey along with the habitat quality across all tiger landscapes of the country. This study has been structured by data obtained through extensive, unprecedented effort, co ntributed by the Forest Departments, wildlife biologists and non-governmental organisations across all forested habitats of the 17 tiger States of India. Latest advances in Science such as remotely triggered cameras to photograph tigers, landscape applications such as remote sensing and Geographical Information System and other computer software have been used to analyse the data and obtain results. Based on these results, appropriate suggestions have been made for conservation of tigers and their habitat. All important forest corridors that allow movement of tigers across larger landscapes have also been identified.

Altogether, this study presents the much needed information to policy makers, conservationists and academia on important tiger populations in India, size of landscape occupied by them and the important corridors needed for their long-term survival.

This is a truly commendable effort towards Science based monitoring of tigers and will be of immense help in assisting formulation of conservation policy and management strategies for effective conservation of the species and the biota that they represent for future generation of Indians and the world community.

Jayanthi Natarajan

(Jayanthi Natarajan)

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EXECUTIVE SUMMARY

This report synthesizes the results of the second countrywide assessment of the status of tigers, co-predators and their prey in India. The first assessment was done in 2006 and its results subsequently helped shape the current policy and management of tiger landscapes in India. The current report is based on data collected in 2009-2010 across all forested habitats of 17 tiger States of India with an unprecedented effort of about 477,000 man days by forest staff, and 37,000 man days by professional biologists. The results provide spatial occupancy, population limits, and abundance of tigers, habitat condition and connectivity (Fig E1). This information is crucial for incorporating conservation objectives into land use planning across landscapes so as to ensure the long term survival of free ranging tigers which serve as an umbrella species for the conservation of forest biodiversity. The study reports a countrywide increase of 20% in tiger numbers but a decline of 12.6% in tiger occupancy from connecting habitats.

The methodology consisted of a double sampling approach wherein the State Forest Departments estimated occupancy and relative abundance of tigers, co-predators, and prey through sign and encounter rates in all forested areas (Phase I). Habitat characteristics were quantified using remotely sensed spatial and attribute data in a geographic information system (Phase II). A team of trained wildlife biologists then sampled a subset of these areas with approaches like mark-recapture and distance sampling to estimate absolute densities of tigers and their prey (Phase III), using the best modern technological tools (remote camera traps, GPS, laser range finders). A total effort of 81,409 trap nights yielded photo-captures of 635 unique tigers from a total camera trapped area of 11,192 km^2 over 29 sites. The indices and covariate information (tiger signs, prey abundance indices, habitat characteristics) generated by Phase I & II were then calibrated against absolute densities using Generalized Linear Models (GLM) and the relationships were used for extrapolating tiger densities within landscapes. Tiger numbers were obtained for contiguous patches of occupied forests by using average densities for that population block. Numbers and densities were reported as adult tigers with a standard error range. Habitat suitability for tigers was used to model least cost pathways joining tiger populations in a GIS and alternative routes in Circuitscape. These were aligned on high-resolution satellite imagery to delineate potential habitat corridors.

Tiger occupied forests in India were classified into 6 landscape complexes: (a) Shivalik Hills and the Gangetic Plain, (b) Central India (c) Eastern Ghats, (d) Western Ghats, (e) North-Eastern Hills and Brahmaputra Plains, and (f) Sundarbans. Tiger populations within these landscape complexes were likely to share a common gene pool, since tiger habitats within these landscape complexes were contiguous in 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). Most tiger source populations were found to be “small”, since Reserve sizes in a densely populated country like India are relatively small due to the high demand for land by people. Such small tiger populations can only survive if protected from poaching, and if they remain connected with each other through habitat corridors. Within each landscape there still exists some habitat connectivity, the “umbilical cords”, that permit a few tiger populations to exist as metapopulations. This enhances the conservation potential of each of the single populations and the probability of their long-term persistence and highlights the importance of maintaining these corridors.

Occupancy models incorporating imperfect detections and covariates, as well as GLM models for tiger density, showed that tiger occurrence and density were dependent on availability of habitats that were remote, with minimal human disturbance and having a high availability of large wild prey (chital, sambar, gaur, and wild pig). This result supports the Government policy of including inviolate core areas in Tiger Reserves. Corridor habitats and buffer areas of tiger reserves can sustain low intensity use by humans, especially traditional livelihoods like subsistence agriculture, pastoralism, and agroforestry or eco-friendly tourism. However, high density human habitation and infrastructure development like power fencing, highways and industry become insurmountable barriers to the movement of tigers and restrict gene flow between wildlife populations making them susceptible to local extinctions. These buffer areas also need effective strategies to manage human-tiger conflict.

The **Shivalik Hills and Gangetic Plain Landscape** had about 20,800 km² of potential tiger habitat on the Indian side. The landscape is characterized by the ability to sustain high density of tigers at landscape scales and therefore conservation investments here, pay dividends. In 2010, tigers occupied 6712 km² of forested habitats with an estimated population of 353 (320 to 388) in five separate populations. These were Rajaji and Corbett in Uttarakhand, Dudhwa-Pilibhit and Suhelwa in Uttar Pradesh, and Valmiki in Bihar. In comparison to 2006, this landscape showed an increase of 30% in area occupancy by tigers and a population increase of 19%. The most important tiger population within this landscape was Corbett having tiger presence in 2,287 km² with an estimated population of 214 (190-239). Rajaji was the only Reserve performing below its potential for tigers and requires thoughtful managerial interventions. Several less protected forests like Ramnagar and Pilibhit recorded good tiger populations that could even rival some Tiger Reserves. This landscape has contiguous habitat connectivity from Kalesar in Haryana to Kishanpur in Uttar Pradesh. The habitat corridor across the Ganga, between the townships of Rishikesh and Haridwar is almost defunct, causing a near extinction event of tigers in the vast landscape west of the Ganga. The Rajaji-Corbett habitat linkage is vital for tiger survival in the western part of this landscape. The Dudhwa-Valmiki landscape is now connected only via Nepal forests, and needs to be managed through cooperation with Nepal. Tiger populations of Corbett and Ramnagar currently form a single unit, but connectivity between these habitats is threatened by development along the Ramnagar-Ranikhet highway. Urgent intervention is required to legally secure the remaining two corridors between Corbett and Ramnagar. Important but more tenuous corridors that require attention are a) those across the Gola river near Haldwani, Khatima-Surai Range into Pilibhit, b) corridors connecting Kishanpur, Dudhwa National Park and Katarniaghat (units within Dudhwa Tiger Reserve) and,c) Dudhwa Tiger Reserve with the adjoining National Parks and National Forests of Nepal. Valmiki and Chitwan National Parks need to be managed as one tiger population through cooperation with Nepal.

Within the forest area of the **Central Indian Landscape** (inclusive of Nagarjunasagar Srisailam of the Eastern Ghats) tiger presence in 2010 was reported from 39,017 km² with an estimated population of 601(518 to 685) distributed in 20 tiger populations with a few other sporadic occurrences. Tiger occupancy recorded a decline of 20% since 2006, while population size remained stable. Most occupancy losses were observed from northern Andhra Pradesh (Adilabad, Khammam, East Godavari, and Vishakhapatnam) and from the northern banks of the Narmada in Madhya Pradesh. These areas harboured low-density tiger populations and therefore their loss did not result in a proportional decline in tiger populations, which was compensated by good increments in high density tiger populations within reserves.

The Central Indian landscape has five metapopulations of tigers that have a long-term future provided they remain connected through corridors. These are (a) Pench-Kanha-Achanakmar landscape of about 20,000 km² with tiger occupancy of over 5,500 km² and an estimated population of 126 tigers (b) Satpura-Melghat landscape of 12,700 km² with a tiger occupancy in 4,432 km² and a population estimate of 78 tigers (c) Bandhavgarh-Sanjay-Guru Ghasidas-Palamau landscape of over 25,000km² with a current tiger occupancy in 3,844 km² and a population estimate of about 74 tigers. Including Guru Ghasidas National Park under the ambit of Project Tiger would be beneficial for tiger conservation in this last remaining large forest patch. (d) Kanha-Navegaon-Tadoba-Indravati landscape of over 35,000 km² with tenuous corridor connectivity is potentially connected and can continue to exist as a metapopulation with restorative management. The landscape has a tiger occupancy in about 6,929 km² (with Indravati not assessed) and a minimal population of 150 tigers, e) Ranthambhore-Kailadevi-Kuno-Sheopur landscape with Ranthambhore as the only source population that covers a large habitat patch of over 6,000 km² with a tiger occupancy in 870 km² and 34 tigers. Simlipal has narrow forest connectivity with Satkosia that requires further field verification. Bottlenecks in the corridor connectivity are identified in the report and need restorative management to maintain gene flow between major Central Indian tiger populations. The Western Ghats part of Maharashtra (included here for convenience) shows tiger occupancy in 1,119 km² with connectivity to forests of Goa and onto Anshi-Dandeli in Karnataka. A major cause of concern was reduction in tiger signs from habitat corridors between Pench and Satpura, Melghat and Satpura, Chandrapur and northern Andhra Pradesh (Adilabad), Indravati and Adilabad and between Srisailam and Shri Venkateshwara forests. These corridors form vital links between tiger metapopulations of Central India.

The **Eastern Ghats** forests extending from Nagarjunasagar Srisailam to ShriVenkateshwara forests have about 15,000 km² of potential tiger habitat. Tigers currently occupy 3,159 km² of forested habitats with an estimated population size of 60 (53 to 66) in a single contiguous forest block constituted by the Srisailam-Nagarjunasagar Tiger Reserve and adjoining forests in the districts of Kurnool, Prakasam, Cuddapah, Mahbubnagar and Guntur. This landscape has the potential to support higher densities of tigers than currently reported. Major problems in achieving this potential are biotic pressure, especially livestock grazing, and poaching of tiger prey for subsistence. Some of the lowest tiger prey density estimates were obtained from Srisailam. Forest corridors connect Srisailam forests with those of Siddavatam and Shri Venkateshwara (with a major bottleneck near the town of Siddavatam). Srisailam is on its way to recovery with the end of insurgency in these forests and can serve as a source for populating the forests upto Shri Venkateshwara. Loss of tiger occupancy within this landscape is a cause of concern.

In 2010, occupancy of tigers within the **Western Ghats Landscape** was 29,607 km² and registered a decline of about 11.5% compared to that of 2006. The current tiger population was estimated at 534 (500 to 568) registering a rise of about 32 % since 2006. Loss of occupancy was from marginal low tiger density areas constituted by territorial forests adjoining Anshi-Dandeli and Kudremukh National Park, not of much consequence with respect to tiger numbers, but of great significance in being indicative of corridor losses. The Western Ghats landscape complex consists of three landscape units: (a) Forested areas from the district of Pune in Maharashtra 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 (Nagarahole-Mudumalai-Wayanad, Kudremukh-Bhadra and Sharavathi Valley-Anshi-Dandeli) that

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exist as metapopulations (b) Forest areas south of Palghat upto Kodaikanal having some connectivity with the Periyar landscape (c) the Periyar-Kalakad-Mundanthurai landscape unit of about 10,000 km² area. The single largest population of tigers in India is within this landscape comprising the complex of Nagarahole-Mudumalai-Bandipur-Wayanad within the states of Karnataka, TamilNadu and Kerala. This complex has tiger occupancy in 11,100 km² with an estimated tiger population of about 382 (354-411) tigers, constituting the single largest tiger population in the world.

Within the **North-Eastern Hills and Brahmaputra Plains**, only the State of Assam conducted an almost full coverage with Phase I, while Arunachal and Mizoram had partial coverage. Therefore, tiger occupancy (4,900 km²) and population numbers (118 to 178 tigers) should be considered as minimal. The North East Hills and Brahmaputra Flood Plains Landscape is 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 to the south and through riverine islands to the east (Orang) and north (Nameri). Kaziranga is the major source within this landscape with over 100 tigers. (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. Habitat corridors connecting Kaziranga with Orang, Nameri and to the Karbi-Anglong hills need restorative management. Manas is on its way to recovery and needs restorative management inputs.

The **Sundarbans Landscape Complex** is the smallest isolated landscape that likely has a single population of tigers across India and Bangladesh with tiger occupancy in

1,645 km² on the Indian side. Population estimation of the Sundarbans tigers was done with a combination of camera trapping and satellite telemetry. A tiger density of 4.3 (se 0.3) tigers per 100 km² was estimated. The total population for the Indian Sundarbans was estimated to be between 64 to 90 tigers. More sampling by camera traps, and collared tigers is required for precise estimates. Satellite telemetry showed that tigers move often between the Bangladesh and Indian parts of the Sundarbans and therefore the Sundarbans tiger population needs to be managed through cooperation with the Government of Bangladesh.

State wise summary of tiger occupancy and estimated population is provided in table ES.1. State wise summary of copredator and prey occupancy is provided in table ES.2.

After the presentation of the results of this report in March 2011, Forest Departments of Madhya Pradesh, West Bengal, Bihar and Karnataka communicated their reservations regarding the assessment of tiger status in their States. These are being considered separately. Madhya Pradesh reassessed the Kanha landscape in 2011 by Phase-I data collection. This data shows an increase in occupancy and abundance of tigers in this landscape.

Overall, the results show that the country had tiger occupancy of 81,881 km² with an estimated population of 1,706 (1520 to 1909) tigers in 2010. The 2010 assessment has shown that though the tiger population has increased due to good management of Tiger Reserves and Protected Areas, it has lost ground within connecting habitat corridors. These corridors are lifelines for individual populations to survive for the long-term. Their loss does not bode well for the tiger. Poaching can wipe out individual tiger populations, but these can be re-established by reintroductions as has been done in Sariska and Panna. However, once habitats are lost, it is almost impossible to claim them back for restoration. Currently, only a few populations Nagarhole-Bandipur-Mudumalai-Wayanad-Moyar-Segur, Corbett population, Sundarbans (India and Bangladesh) and Kaziranga-Karbi-Anglong populations have the required population size for long term survival without immigration. The remaining tiger populations require habitat connectivity for genetic and demographic viability.

Populations that currently have corridor connectivity and exist as metapopulations are Rajaji-Corbett, Dudhwa-Katarniaghat-Kishanpur (along with Bardia and Suklaphanta in Nepal), Satpura-Melghat, Pench-Kanha, Bhadra-Kudremukh, Parambikulam-Indira Gandhi-Eravikulum, and KMTR-Periyar. Loss of connectivity between these populations would prove detrimental for their persistence. The landscapes that have potential for metapopulation existence but are currently in need of conservation inputs are Srisailam, Simlipal-Satkosia, Ranthambhore-Kuno Palpur-Sheopur, Indravati-northern Andhra Pradesh-Chandrapur-Nagzira-Navegaon, and Bandhavgarh-Sanjay-Guru Ghasidas-Palamau.

Tigers are a conservation dependent species requiring connected forests with good prey and a fair interspersion of undisturbed breeding areas.The high resolution spatial information generated by this study in GIS domain will assist in planning land use at landscape scales and help harmonize conservation concerns with modern day development needs. Such an approach will help our generation in leaving behind the legacy of the tiger and the rich biodiversity that it represents for future generations.

Figure E1

Sampling distribution across India Each dot represents a forest beat sampled for carnivores by three replicate sign surveys, one line transect walked thrice for estimating prey encounters, human disturbance and habitat characteristics. Red dots indicate presence of tiger sign.

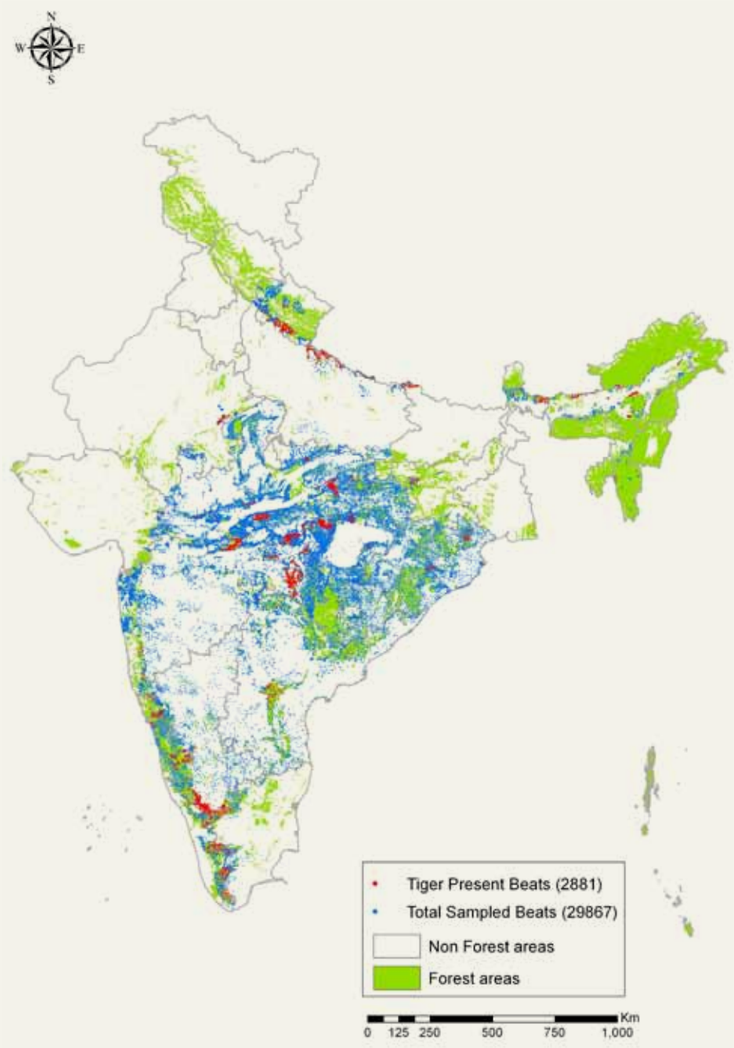


Table ES.1
Tiger Status with regard to forest occupancy and estimated population between 2006 and 2010

State	Tiger Population			Tiger km²		
	2006	2010	Increase/ Decrease/ Stable	2006	2010	Increase/ Decrease/ Stable
Shivalik-GangeticPlain Landscape Complex						
Uttarakhand	178 (161-195)	227 (199-256)	Increase	1,901	3,476	Increase
Uttar Pradesh	109 (91-127)	118 (113-124)	Stable	2,766	2,511	Stable
Bihar	10 (7-13)	8 (-)	Stable	510	750	Increase
Shivalik-Gangetic	297 (259-335)	353 (320-388)	Stable	5,177	6,712	Increase
Central Indian Landscape Complex and Eastern Ghats Landscape Complex						
Andhra Pradesh	95 (84-107)	72 (65-79)	Decrease	14,126	4,495	Decrease
Chhattisgarh	26 (23-28)	26 (24-27)	Stable	3,609	3,514	Stable
Madhya Pradesh	300 (236-364)	257 (213-301)	Stable	15,614	13,833	Decrease
Maharashtra	103 (76-131)	168 (155-183)	Increase	4,273	11,960	Increase
Orissa	45 (37-53)	32 (20-44)	Stable	9,144	3,398	Decrease
Rajasthan	32 (30-35)	36 (35-37)	Stable	356	637	Increase
Jharkhand	-	10 (6-14)	-	1,488	1,180	Decrease
Central India	601 (486-718)	601 (518-685)	Stable	48,610	39,017	Decrease
Western Ghats Landscape Complex						
Karnataka	290 (241-339)	300 (280-320)	Stable	18,715	14,414	Decrease
Kerala	46 (39-53)	71 (67-75)	Increase	6,168	6,804	Stable
Tamil Nadu	76 (56-95)	163 (153-173)	Increase	9,211	8,389	Stable
Western Ghats	412 (336-487)	534 (500-568)	Increase	34,094	29,607	Decrease
North Eastern Hills and Brahmaputra Flood Plains						
Assam	70 (60-80)	143 (113-173)	Increase	1,164	2,381	Increase
Arunachal Pradesh	14 (12-18)	-	-	1,685	1,304	Decrease
Mizoram	6 (4-8)	5	Stable	785	416	Decrease
Northern West Bengal	10 (8-12)	-	-	596	799	Increase
North East Hills, and Brahmaputra	100 (84-118)	148 (118-178)	Increase	4,230	4,900	Increase
Sundarbans	-	70 (64-90)	-	1,586	1,645	Stable
TOTAL	**1,411 (1,165-1,657)**	**1,706 (1,520-1,909)**		**93,697**	**81,881**	

Table ES.2
Status of Co-Predators & Prey with regard to occupied areas of States

State	Leopard km2			Dhole km2			Bear km2			Chital km2			Sambar km2		
	2006	2010	Increase/ Decrease/ Stable	2006	2010	Increase/ Decrease (%)	2006	2010	Increase/ Decrease/ Stable	2006	2010	Increase/ Decrease / Stable	2006	2010	Increase/ Decrease / Stable
Shivalik-Gangetic Plain Landscape Complex															
Uttarakhand	3,683	8,769	Increase	-	-	-	853	4,683	Increase	2,161	5,026	Increase	2,756	6,205	Increase
Uttar Pradesh	2,936	4,234	Increase	190	553	Increase	3,130	3,385	Stable	5,537	5,012	Stable	2,641	3,410	Increase
Bihar	552	735	Increase	323	199	Decrease	532	457	Decrease	576	743	Increase	321	551	Increase
Central Indian Landscape Complex and Eastern Ghats Landscape Complex															
Andhra Pradesh	37,609	10,374	Decrease	41,093	18,478	Decrease	54,673	27,291	Decrease	37,814	13,072	Decrease	33,159	16,284	Decrease
Chhattisgarh	14,939	23,188	Increase	3,794	7,981	Increase	20,951	38,628	Increase	18,540	17,787	Stable	7,604	7,648	Stable
Madhya Pradesh	34,736	24,308	Decrease	28,508	22,557	Decrease	40,959	43,499	Stable	41,509	43,233	Stable	33,551	30,722	Stable
Maharashtra	4,982	18,914	Increase	4,352	15,546	Increase	6,557	21,070	Increase	5,970	16,393	Increase	5,730	16,001	Increase
Orissa	25,516	12,603	Decrease	8,215	6,409	Decrease	43,236	47,433	Stable	6,040	7,617	Increase	6,112	5,747	Stable
Rajasthan	-	754	-	-	-	-	-	640	-	-	592	-	-	592	-
Jharkhand	131	2,645	Increase	-	846	-	2,640	2,067	Decrease	721	1,866	Increase	721	678	Stable
Western Ghats Landscape Complex															
Karnataka	20,506	21,326	Stable	15,862	14,074	Stable	20,749	16,852	Decrease	42,349	14,035	Decrease	43,412	17,568	Decrease
Kerala	8,363	9,274	Increase	10,801	11,098	Stable	6,904	7,812	Increase	2,931	2,698	Stable	10,469	11,323	Stable
Tamil Nadu	14,484	10,060	Decrease	19,658	10,217	Decrease	13,224	9,736	Decrease	13,567	4,027	Decrease	15,909	9,008	Decrease

Introduction

Tiger is an umbrella species for the conservation of the biota of a majority of the eco-regions in Asia. Its role as a top predator is vital in regulating and perpetuating ecological processes and systems. India is home to over 50% of the world's wild tigers in spite of having a growing human population of over a billion. It is also one of the world's fastest growing economies. It is with full recognition of these challenges that India is committed to conserving its tigers and their habitats. India plays an important role in accomplishing the objectives of the Global Tiger Recovery Plan that was ratified at the meeting of world leaders held at St. Petersburg in 2010, out of concern, for the first time in the history of this planet, for a species other than humans. Taking stock of what we have and where, is the first step towards conservation management. Monitoring tiger populations is equivalent to monitoring the health of ecosystems, which the tigers inhabit.

The Protected Areas in India are analogous to small islands in a vast sea of ecologically unsustainable land uses of varying degrees. To ensure that these natural systems continue to provide ecosystem services and remain repositories of biodiversity for future generations it is essential to 1) protect them from human impacts and 2) maintain natural areas of sufficient size so as to allow for ecosystem processes to occur. Tigers, like all large carnivores, need large areas of undisturbed habitats to sustain viable populations. Most Protected Areas in India are too small to sustain tigers in the long-term. This dilemma can be addressed by managing these "small" tiger populations as metapopulations. Tiger reserves and some Protected Areas serve as source populations of tigers while intervening forested areas act as corridors. By permitting dispersing tigers to move between different tiger populations long-term persistence of individual populations is enhanced. 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.

The first step towards effective management and formulation of policy is to gain an understanding of where the tigers are and how many are there. Once policy is formulated and implemented through field management, we then need to know whether it is having the desired effect, i.e. of conserving tigers. This is the role of monitoring; so that results can permit mid-course corrections, if necessary, in management actions and policy. The 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 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.

Currently tigers occur largely in the forest areas of 17 States in India. Nagaland, Meghalaya, Tripura, 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 was 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 Brahmaputra Plains and
6. Sunderbans

The first National level assessment of tiger status along with that of co-predators, and their prey was undertaken in 2006 (Jhala, Gopal and Qureshi 2008). The 2006 tiger status assessment estimated the country's tiger population to be between 1165 and 1675. More importantly the assessment determined the extent and size of individual populations and the status of habitat connectivity between these populations.

The information generated by the 2006 tiger status evaluation exercise resulted in major changes in policy and management of tiger populations. The major outcomes that were the direct or indirect consequence of information generated by the monitoring exercise were a) Tiger Landscape Conservation Plans b) Designation of critical core and buffer areas of Tiger Reserves, c) Identification and declaration of new Tiger Reserves, e) Recognition of tiger landscapes and the importance of corridors at the highest levels of governance, f) Integrating tiger conservation with developmental activities using the power of reliable information in a Geographic Information System database, and last but not the least g) Enhanced public and political awareness and support for tiger conservation.

The present report is the final outcome of the second country wide tiger status monitoring exercise undertaken in 2009-2010 on the direction of the Ministry of Environment and Forests, Government of India, by the Wildlife Institute of India in collaboration with the National Tiger Conservation Authority, State Forest Departments and NGO's. The salient parts of the assessment results were presented in March 2011, through a Press Conference chaired by the then Honorable Minister of Environment and Forests, Shri Jairam Ramesh at Vigyan Bhavan, New Delhi. This report provides the detailed aspects of data collection methodology, analysis, and interpretation of results in a semi-technical manner.

Methods

The approach and methodology for evaluating the status of tigers in India was developed in early 2002 as a pilot study conducted in the Satpura-Maikal landscape of around 50,000 km^2. That study was aimed at addressing the void for a science based approach for assessing status of tigers at landscape scales. The Tiger Task Force appointed by the Prime Minister to address the tiger crisis in India, evaluated several scientific approaches for estimating tiger status and recommended the current approach for a country wide monitoring program (Narain *et al.* 2005). This methodology to evaluate the status of tigers, co-predators, and prey across tiger landscapes of India consists of four phases. The details of the four phases are as follows:

Phase I: Determining occupancy and mapping relative abundance
The Phase I consists of rapid and cost effective assessment of all current and potential tiger habitat across the seventeen tiger states of India. Simple protocols were developed to collect data on:
a) carnivore sign encounters
b) tiger prey encounters
c) indices of human disturbance
d) indices of habitat status and
e) dung counts on plots

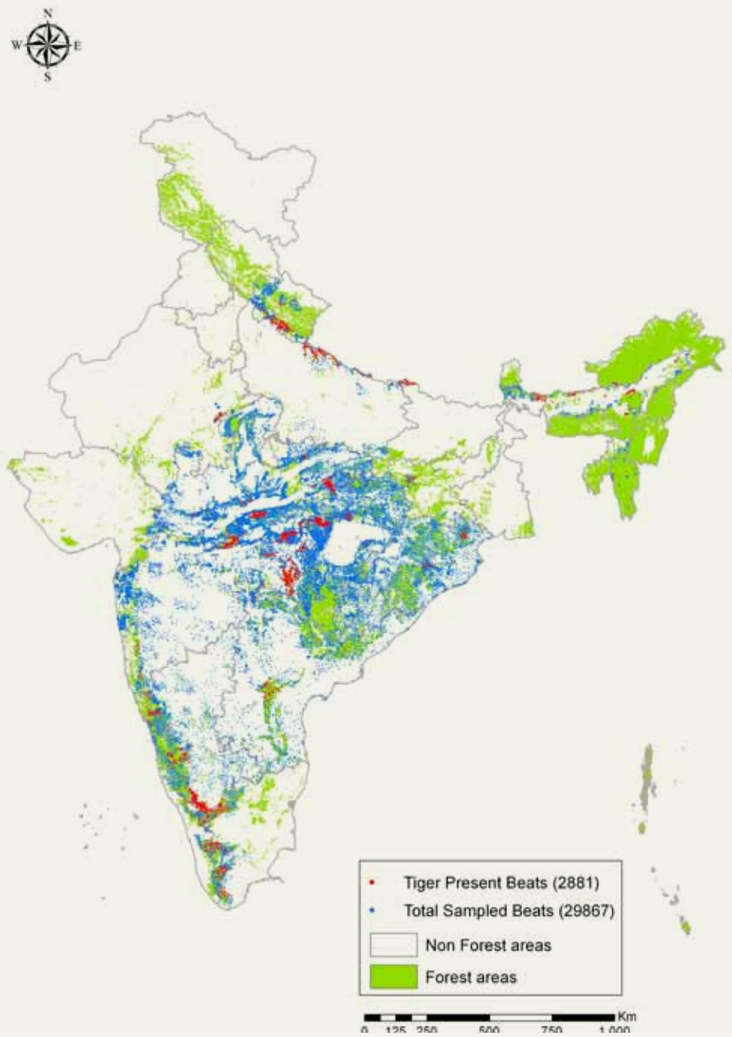
These protocols were published in nine regional languages (Jhala *et al.* 2009). Regional workshops for training of trainers in implementing these protocols were conducted at Corbett, Kanha, Kaziranga and Bandipur Tiger Reserves in 2009. Trained officers in turn conducted training of Rangers and Forest Guards in their respective States. The forest administration system across most of India is based on division of States into Forest Divisions, Ranges, Beats and Compartments in a spatial hierarchical manner. The boundaries of Beats and Compartments are based on natural features that are easily identifiable in the field. Besides each forest beat is allocated to a beat guard who usually has intimate knowledge of his beat. We used this spatial administrative system to systematically distribute sampling units across landscapes. All forest beats (in Protected Areas, Reserve Forests, Protected Forests, and Revenue Forests) were sampled for the above mentioned five indices. The average size of a forest beat was about 16 km^2. With two persons (a Forest Guard and his assistant) sampling a beat, the entire dataset on the above mentioned five aspects was collected within a period of ten days for each beat. Besides the Forest Department staff, most States involved local and regional NGOs and nature club members from local institutions for the Phase I data collection. The entire country was sampled between November 2009 and March 2010 using this protocol. Data collected during Phase I forms the core of the tiger status estimation exercise. A total countrywide effort of 627,207 km walk was expended in collecting the Phase I dataset (table M.1). The spatial coverage was of all forested habitats within the tiger bearing landscapes (Fig. M.1).

Table M1
Sample points and effort expended across various tiger bearing states of India. Each beat is sampled with three spatially independent sign surveys of 5 km each, and three replicate walks of one 2 km long transect.

State	Total no. of Beats Sampled	Sign Survey Effort (Km)	Line Transect Effort (Km)
Shivalik Hills and Gangetic Flood Plains Landscape			
Bihar	64	960	384
Uttar Pradesh	667	10005	4002
Uttarakhand	691	10365	4146
Total	1422	21330	8532
Central India and Eastern Ghats Landscape			
Andhra Pradesh	2363	35445	14178
Chhattisgarh	3483	52245	20898
Jharkhand	208	3120	1248
Maharashtra	6468	97020	38808
Madhya Pradesh	8287	124305	49722
Orissa	3229	48435	19374
Rajasthan	117	1755	702
Total	24155	362305	144930
Western Ghats Landscape			
Karnataka	2198	32970	13188
Kerala	599	8985	3594
Tamil Nadu	596	8940	3576
Goa	94	1410	564
Total	3487	52305	20922
North Eastern Hills and Brahmaputra Flood Plains Landscape			
Assam	529	7935	3174
Mizoram	46	690	276
West Bengal	228	3420	1368
Total	803	12045	4818
Country Wide Effort			
Total	**29867**	**448005**	**179202**

Figure M1

Distribution of sampled beats shown as dots on the forest cover map of India. The red dots signify detection of tiger signs at that location.



Phase II: Remotely sensed spatial and attribute covariates

As part of the Phase II, remotely sensed data that depict landscape characteristics and anthropogenic impacts such as the human footprint were obtained from various sources (Appendix 2). These data consisted of:

a) Landscape characteristics such as forest area, NDVI, forest patch size, forest core areas, digital elevation, distance from protected area and river density;
b) Variables that index anthropogenic impacts such as distance to night lights, distance to major roads and density of road network.

We hypothesized that tiger population distribution and abundance would be determined by
a) Habitat characteristics
b) Prey availability and
c) Anthropogenic pressures

These major covariates could be appropriately surrogated from indices obtained from ground surveys and remotely sensed data and this were used to model tiger occupancy and abundance.

Phase III:

A team of 58 wildlife biologists with a minimum of a Masters Degree in biological science was recruited and trained at the Wildlife Institute of India to collect data in the field. World Wide Fund for Nature, the Wildlife Trust of India, and ARANYAK also partnered with the Wildlife Institute of India for conducting the Phase III data collection. These organizations provided trained professional manpower as well as equipment support for data collection. From amongst this trained professional manpower, teams of 5-7 personnel were deployed at 29 different sites spread throughout the tiger landscapes. These 29 sites were selected based on their regional and national importance for tiger conservation, geographical coverage of the landscapes, and logistical constraints of data collection.

At each of these sites wildlife biologists conducted a) camera trap based mark recapture population and density estimation of tigers, b) distance sampling along line transects for estimating prey abundance and c) collected Phase I data (see above) on carnivore sign encounters, indices of human impacts, and habitat variables.

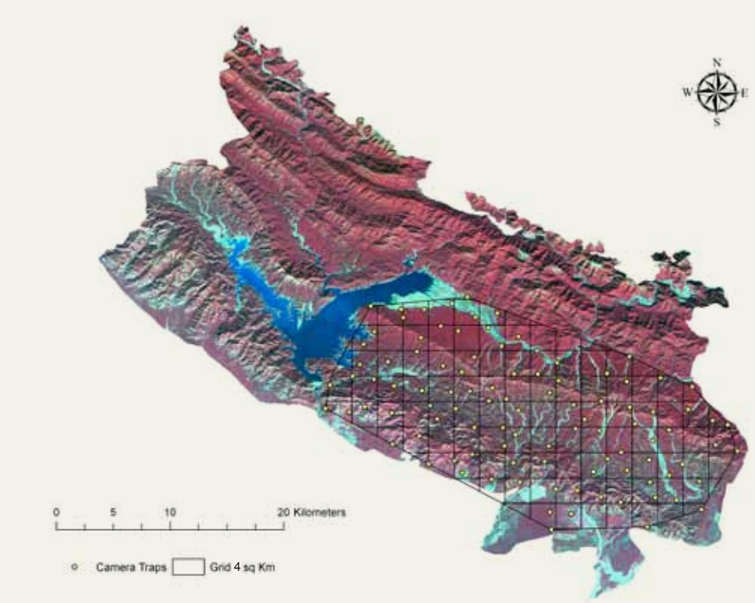
Camera trap based mark-recapture of tigers:

Based on the available tiger occupied habitat at each site, maximum area coverage of 894 km² was sampled. Camera traps were systematically distributed within the study area by superimposing a 2x2 km grid and deploying at least one double sided camera unit (Moultrie, Trailmaster or Reconyx) within each grid. Study areas were extensively searched while conducting sign surveys to find the ideal location within each grid for camera deployment so as to maximize the chances of photo-capturing a tiger. Cameras were usually operated between 40 to 60 days at each site with an effort of over 500 trap-nights per 100 km². Capture data were analyzed using closed population models (Amstrup *et al.* 2005) and spatially explicit likelihood based approaches (Efford *et al.* 2004; Royle *et al.* 2009). For comparison with earlier estimates, tiger density was also estimated using the half mean maximum distance moved by recaptured tigers for computing the effectively trapped area (Karanth and Nichols 2002). Effectively trapped area was computed in a GIS after applying a habitat mask that removed non tiger habitat (deep water body, human settlements, etc) from the computation.

Since many of the camera trapped sites were also sampled in 2006, we compared population estimates obtained in 2010 with those of 2006 using paired statistical tests to evaluate performance of tiger populations at these source sites.

Figure M2

Camera Trap layout in Corbett Tiger Reserve showing the 2x2 km grid based design



Estimating Prey Abundance:
Within each camera trap grid, line transects of 2-3 km length were demarcated. Transects were walked early morning and data were recorded on species sighted, group size, group composition, bearing of walk and bearing of the animal(s) sighted, and distance of the animals(s) using a laser range finder (Bushnell) and see through compass (SUNTO). Program DISTANCE (Thomas *et al.* 2009) was used to compute density of individual species (for species with a reasonable number of sightings) and of two other categories which comprised of ungulate prey and all tiger prey (inclusive of peafowl, langur and all ungulates). To improve model fit and subsequent inference from DISTANCE we pooled data from across similar habitat types to estimate detection probability and effective strip width estimates to obtain more precise, post stratified reserve specific, estimates of density (MacKenzie *et al.* 2005).

Phase IV:
The periodicity of four years and intensity of camera trap based monitoring, though adequate for a country wide status assessment, was not adequate for monitoring important source populations of tigers (Jhala *et al.* 2005, 2011). Source populations

were mostly limited to Tiger Reserves and Protected Areas (with the exception of a few tiger populations outside of PA's). The well being of these populations is crucial for the long-term persistence of tigers within the larger landscapes (Walston *et al.* 2010). Such sources can deplete rapidly when targeted by commercial poachers (Chapron *et al.* 2008) as has been seen in Sariska (Check 2006) and Panna (Gopal *et al.* 2010). Therefore, an annual monitoring scheme has been recommended for important source populations within each tiger landscape (Jhala *et al.* 2011). Source population monitoring is done in the following manner:

a) Either the entire protected area or an area of 300-500 km² is camera trapped annually within a period of 60 days (so as to ensure population closure). The camera density is maintained at one double sided unit per 4 km² and trapping effort of about 500 trap nights per 100 km² is invested. Camera trapped tiger pictures are then digitally processed and compared using the software Extract Compare (Hiby *et al.* 2009). A park specific database of tiger pictures as well as a national database for tiger pictures is then maintained at the park headquarters, National Tiger Conservation Authority, and the Wildlife Institute of India, respectively. Population and density estimation of tigers is subsequently done using closed capture estimators for each year and open population models between years to provide estimates of survival and dispersal between years as well (Pollock *et al.* 1990; Karanth *et al.* 2006).

b) Implementation of MSTrIPES (Monitoring System for Tigers – Intensive Patrolling and Ecological Status) within all source populations. MSTrIPES provides for computer assisted intelligent patrolling for law enforcement as well as seasonal ecological monitoring. It comprises of protocols for data recording and software for data analysis, interpretation and reporting. MSTrIPES uses the Phase I protocols, implemented seasonally (instead of on a 4 year interval) within source populations, conducts statistical comparisons at desired spatial and temporal scales and produces outputs in the form of GIS maps and reports. The advantage of MSTrIPES over other methods of intensive monitoring of source populations is that it generates information from the regular duties of the park staff (while conducting patrols and ecological monitoring). It provides a holistic assessment of status of tigers, other carnivores, mega herbivores, other prey, human pressures, illegal activities, and patrol effort in a manner that keeps the pulse of the major fauna of the Tiger Reserve and provides inputs for adaptive management (Williams *et al.* 2002) and evaluating management effectiveness (Hockings, 2003).

Data Analysis

Data generated by Phase I were attached to a spatial location in the Geographic Information System (Arc GIS 9.1), either by GPS coordinates of Phase I transects or to the centroid of each digitized beat (for states where beat boundaries were available). Once the data were spatially attached, we used GIS to conduct further analysis at spatial scales of 10x10 km grids (an area greater than the average size of tiger home ranges in India (Chundawat *et al.* 1999; Karanth *et al.* 2011; Vattakaven unpub. data; Jhala and Qureshi unpub. data) for generating distribution maps and area coverage of target species. In the case of tigers, we assessed the role of imperfect detections and covariates in estimating occupancy (MacKenzie *et al.* 2006).

The Phase I data collection protocol for carnivore sign surveys was designed to address tiger occupancy that incorporates imperfect detections and covariates.

a) Each 10x10 km grid had several spatial independent replicate surveys (of 5 kilometer each) for detecting tiger signs.
b) The number of surveys in each 100 km² grid was proportional to the amount of tiger habitat in that grid.
c) On an average there were three spatially different searches of five kilometer walk each, in a forest patch of about 15 km². Thus a 10x10 km cell had from three to 30 spatially independent searches for tiger signs, which were used to model imperfect detections (MacKenzie and Royle 2005; Kendall and White 2009).
d) Isolated forest patches of < 15 km² were discarded from this analysis as tigers were unlikely to occupy these small sized habitats.
e) Tiger occupancy was likely to be determined by a) habitat quality and extent, b) Prey availability and c) Anthropogenic pressures. These factors were indexed through remotely sensed variables such as area of habitat, productivity of habitat (NDVI and rainfall), variability in productivity (CV of NDVI), distance to major roads, density of major roads, distance to night lights, ruggedness of the terrain, distance to protected area (source). Ground survey data (Phase I) on prey abundance indices (encounter rates on line transects and dung density) and human disturbance indices (signs of livestock, human trails, wood cutting, lopping, grass removal) were used as covariates for modeling tiger occupancy.
f) Detection of tiger signs was likely to be influenced by the abundance of tigers (Royle and Nichols 2003; Karanth *et al.* 2011). Encounter rates (intensity) of tiger signs were found to be directly proportional to tiger abundance (Jhala *et al.* 2011). We therefore modeled detection probability as a: i) constant across surveys and sites, ii) survey specific and iii) as a function of site specific tiger abundance indexed by average tiger sign.

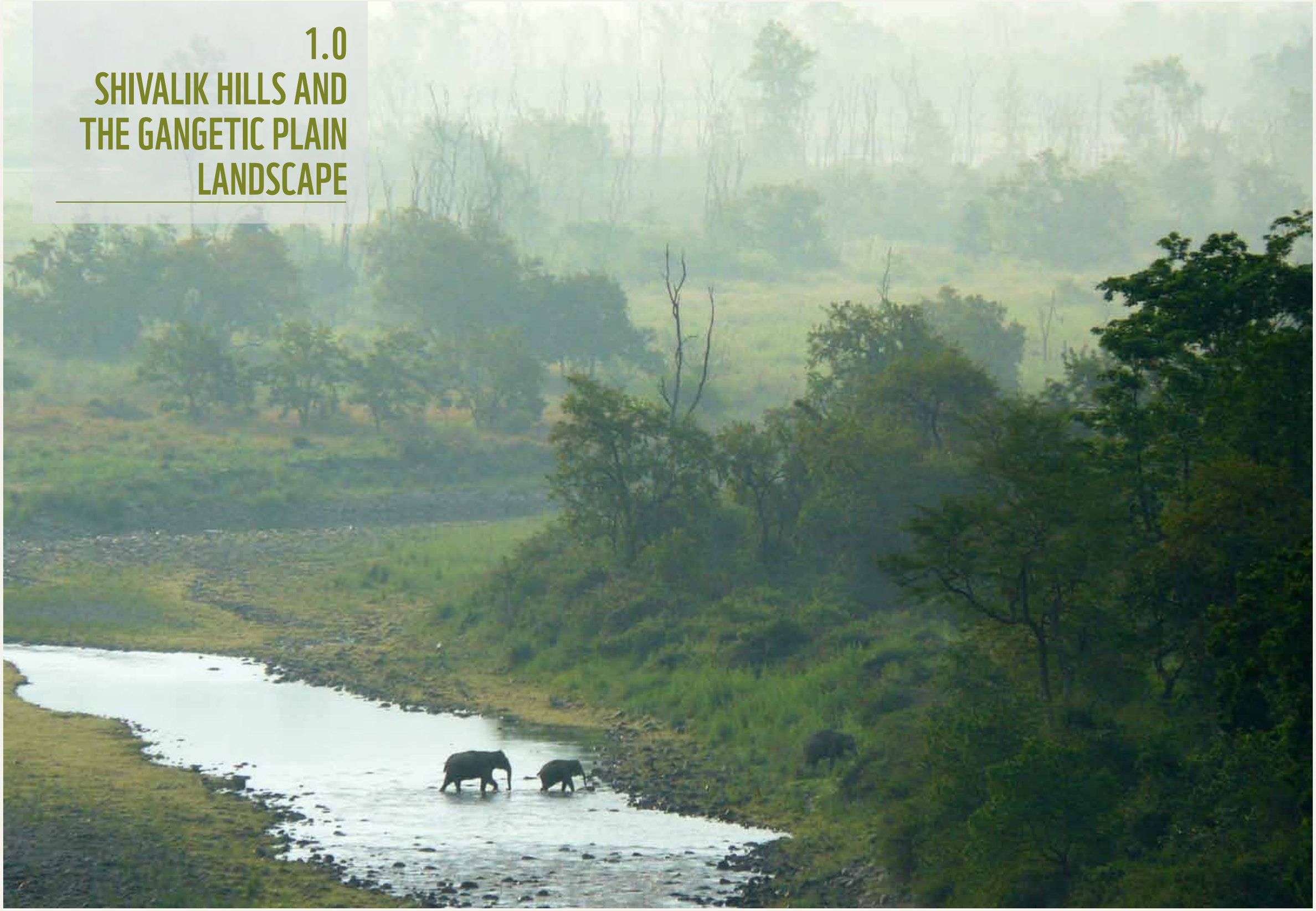
We assess the role of these factors by modeling tiger occupancy and detection probability as a function of the above mentioned covariates (MacKenzie *et al.* 2006; Karanth *et al.* 2011) in PRESENCE (Hines 2006). Model selection was done using Akaike Information Criterion (AIC) (Burnham and Anderson 2002). Covariates were first modeled one at time as a Logit-Link function to model occupancy. Covariates that significantly improved the model over the null model (constant detection and occupancy) were then modeled in combination representing each of the important determinants of tiger occupancy, e.g. habitat size, habitat structure, human disturbance, and prey abundance. Indices that likely had redundant information e.g. ungulate encounters and ungulate dung density, both surrogating prey abundance, were used in the model only if they improved the AIC value significantly and there were no indications that the logit-link model suffered from colinearity. In cases where more than one model fit the data equally well (Delta AIC <2) model averaged parameter estimates were used to infer occupancy (Burnham and Anderson 2002).

Population extents and connectivity:
A grid (10x10 km) was considered occupied when a tiger sign was detected on any of the surveys conducted within it (naïve estimate of occupancy). A high detection probability, sufficient replicate surveys, and good length of sign surveys, resulted in naïve estimates being very close to occupancy estimates corrected for imperfect detections (1-3% increment (see results)). Occupancy estimates modeled by detection probability and covariates using MacKenzie *et al.* (2006) approach provided estimates of cell based probabilities of occupancy. These were extremely useful as an index of habitat suitability for tigers and were used to model habitat corridors and important habitats for source populations. However, tigers are prone to poaching (Kenney *et al.* 1995) and can be extirpated from even the most suitable habitat having good prey availability (Check 2006; Chaprone *et al.* 2008; Gopal *et al.* 2010). Due to these reasons we used the more conservative naïve estimates of occupancy for inferring population extents and size. All adjacent occupied grids were considered to have a contiguous tiger population. The naïve estimate of tiger habitat (in km²) within a cluster of contiguous occupied grids was considered as the area of occupancy by that population. Probability of occupancy estimates modeled using covariate data and incorporating imperfect detections was used to provide weights to tiger habitat within each grid. We used program CIRCUITSCAPE (McRae and Shah 2009) and PATHMATRIX (Ray 2005) in ArcGIS to model connectivity across tiger landscapes using occupancy probabilities as estimates of permeability (conductance). Thus, CIRCUITSCAPE optimized flow of current (tiger movement probability) across habitat patches that had high occupancy probability while low occupancy probability acted as resistance to the current flow (tiger movement). CIRCUITSCAPE output and PATHMATRIX outputs were then overlaid over habitat features (digital terrain model, forest cover, rivers, and streams) village boundary maps, and Google Earth images for evaluating and delineating corridor habitats between tiger source populations.

Tiger Population Size Estimation across Landscapes:
Tiger abundance is determined by the quantity and quality of available habitat (Seidensticker *et al.* 1999). Two factors are paramount in determining habitat quality for tigers; prey availability and human pressures (Karanth *et al.* 2004; Chapron *et al.* 2008; Gopal *et al.* 2010). Abundance of tigers was found to be directly proportional to the quantum of tiger signs (Jhala *et al.* 2011). We used a double sampling approach (Cochran 1999) to first model tiger density (obtained from CTMR estimates) as a function of tiger sign intensity, prey availability indices, habitat extent and human disturbance indices using GLM's (Generalised Linear Model) (Hosmer and Lemeshow 2000). As per the methodology proposed and approved by the tiger task force (Narain 2005), tiger density categories were modeled using indices of abundance and covariates using general linear models. We used logistic regression, wherein tiger density was modeled as an ordinal categorical variable having four to five density categories (none, very low, low, medium and high density). Density categories were inferred from camera trap data obtained from that landscape. Model fit was assessed using AIC and ROC values (Burnham and Anderson 2002; Hosmer and Lemeshow 2000; Williams *et al.* 2002). The best fit model was then used to estimate tiger densities across grids where Phase I and Phase II data were available but camera trapping was not done. For grids where camera trapped tiger densities were available, this actual estimate of density was used, as model based extrapolation was not necessary. Each predicted density category was replaced by the mean tiger density and the standard error for that density category was propagated for the extrapolated grid as well.

Once all contiguous tiger occupied grids within a population block were assigned a tiger density value; an average tiger density for the population block was computed which was then multiplied by the available tiger habitat to obtain an estimate of tiger numbers for that population block. Since in most population blocks, density estimates between grids are likely to vary considerably (as tiger densities usually decline from the core to the peripheral grids), tiger population estimates were likely to have large standard errors. Population estimates at landscape scales, therefore do not have the precision needed for detecting small changes in tiger numbers and monitoring trends in numbers (Jhala *et al.* 2011). Population status monitoring should be done using estimates of occupied area and grid specific changes in indices of tiger abundance, occupancy, and tiger densities (both CTMR as well as model inferred tiger occupancy estimates and densities). Model based tiger population estimates for landscapes and States serve the purpose of converting relevant ecological indices to a comprehensible concept of tiger numbers for the public, policy makers, and managers.

1.0 SHIVALIK HILLS AND THE GANGETIC PLAIN LANDSCAPE



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The Shivalik hills and the Gangetic plain landscape comprises of three parallel geological zones: the Shivaliks, the *bhabar* tract and the *terai* plains. The Shivaliks are young fold mountains with an elevation ranging between 1000-1500 meters that form an intermediate zone between the Indus-Gangetic-Brahamaputra-Irrawaddy Plains and the Himalayas (Wadia 1973; Mani 1974). They are an uplifted ridge system composed primarily of sandstone, clay, gneiss and quartzite. The sedimentary nature of the mountains makes them prone to erosion and thus during the south-west monsoon the several ephemeral streams that originate in this region bring down large quantities of coarse material comprising chiefly of boulders, clay and coarse alluvium.

This eroded material is eventually deposited along the relatively less steep slopes of the *bhabar* which is also a termination zone for most small streams that often disappear amongst the boulders of this region. Many of these streams may re-emerge further south in the wet *terai* zone (Mani 1974).

The *terai* region of India comprises of the flood plains of the Ganga and Brahmaputra rivers. This region is characterised by a high water table, annual flooding, and shifting floodplains and is consequently dominated by tall grass species which may achieve a height of up to six meters (Mathur 1999). The flat disposition of the *terai* results in deposition of fine alluvial sediments brought down by the rivers from the Himalayas. The older alluvium occupies the higher grounds and is called *bhangar* while the *khadar* constitutes the new silts found in lower regions.

For the purpose of this report, we include only the area between the flood plains of the River Yamuna in the west and Gandak in the east.

The *Terai* Arc Landscape (TAL) in India can be divided into two parts: area between the Yamuna and Sharda rivers and the area east of the Sharda. A characteristic of the former area is the existence of a large number of seasonal streams called *raus* which come down from the hills with great vigour causing extensive erosion. Most *raus* have water until the onset of summer and are often used by wildlife. Similarly, sots are perennial streams of similar character that eventually merge with the *raus*. Both *raus* and sots flow into the *terai* and act as water sources throughout the year. This tract is largely *bhabar* with most of the *terai* is taken over by agriculture.

The area to the east of the Sharda comprises primarily of the *terai* grasslands that thrive on the alluvial silts and clay deposits brought down by the meandering rivers from the Himalayas. This region is characterised by large swampy areas that attract migratory water fowl and support conditions conducive to the survival of rare species like the swamp deer, hog deer and the rhinoceros. In this region, the *bhabar* tract and the Shivalik Range in Nepal provide connectivity to most of the Protected Areas on the Indian side.

1.1.1 Location

The TAL is located in the Himalayan and the Gangetic Plains bio-geographic zones and includes the regions of the western Himalayas, upper Gangetic plains and lower Gangetic plains (Rodgers and Panwar 1988). While the Yamuna river (30˚30' to 77˚30') marks its western limit and the Gandak river (27˚15' to 84˚45') bounds it on the east, tiger occupancy until as recently as 2004 has also been recorded from areas further westwards in Kalesar Wildlife Sanctuary in Haryana and Simbalbara Wildlife Sanctuary in Himachal Pradesh (Johnsingh *et al.* 2004). This landscape traverses across the political boundaries of Uttarakhand, Uttar Pradesh and Bihar covering

Major tiger populations, their status, political units and corridors in the Shivalik hills and the Gangetic Plain landscape

Tiger Population	State/s	Tiger abundance 2006	Tiger abundance 2010	Increase/ Decrease/ Stable	Area occupied (km^2) in 2006	Area occupied (km^2) in 2010	Increase/ Decrease/ Stable	Connecting corridors
Rajaji	Uttarakhand	14(11-17)	11 (8-15)	Stable	390	736	Increase	Chilla-Motichur, River Song
Corbett	Uttarakhand	164(151-178)	214 (190-239)	Increase	1428	2287	Increase	Corbett-Rajaji Kosi River: Corbett TR-Ramnagar FD-Terai (W)-Terai (E)- Haldwani FD Gola River: Haldwani FD-Kathgodam-Kaladungi Nikhal-Bhakra Baur River Kilpura-Khatima-Surai Range
Dudhwa-Kheri-Pilibhit	Uttar Pradesh	95(80-110)	112 (106-118)	Stable	1833	2110	Increase	Dudhwa-Katerniaghat Basanta-Khata Pilibhit-Suklaphanta Kilpura-Khatima
Suhelwa	Uttar Pradesh	6(3-10)	5	Stable	490	441	Stable	Suhelwa-Churia Hills
Sohagibarwa-Valmiki	Uttar Pradesh, Bihar	15 (12-18)	9	Decrease	649	850	Increase	Sohagibarwa-Valmiki

NE : Not Estimated

an area of 900 kilometres from east to west with a width of 50-60 kilometres. The total area occupied by this zone is approximately 42,700 km² of which 15,000 km² is forested (Johnsingh *et al.* 2004) and includes three important Tiger Reserves, viz. Corbett, Dudhwa and Valmiki. Several other protected areas lie within this zone under the administration of 20 Forest Divisions.

Most of the TAL between Yamuna and Sharda lies in the *bhabar* tracts and has about 36% forest cover with relatively low human density (334/km²) (Johnsingh *et al.* 2004). This region comprises of the Rajaji National Park and the Corbett Tiger Reserve which is also located around the largest Tiger Habitat Block (THB) of 4000 km² (Johnsingh *et al.* 2004) with an estimated tiger population in 2006 of 164 (151-178) in and around Corbett Tiger Reserve alone (Jhala *et al.* 2008).

The area to the east of the Sharda is characterised by intensive agriculture, high human densities (436/ km²) and low forest cover (17%) (Johnsingh *et al.* 2004). The Protected Areas within this zone comprising of two Tiger Reserves, namely, Dudhwa and Valmiki, lack connectivity and experts predict local extinction of the tiger from isolated pockets like Sohagibarwa Wildlife Sanctuary.

1.1.2 Ecological Background

The wet, marshy conditions of the *terai* support tall grasslands which provide shelter to myriad species of ungulates and their predators. Thus, this region historically has been known for the high density of 'game' and subsequently it attracted hunters during the short winter when possibilities of contracting malaria were low (Seidensticker *et al.* 2010). A large part of the contemporary shikar literature is evolved out of memories from this region which played host to important dignitaries some of whom, like King George V and his party, shot 39 tigers and 18 rhinoceroses in 10 days in 1911 in present day Chitwan National Park (Rookmaaker 2004). Similarly, the royal family of Nepal, in a two-month hunt organised in the *terai* regions of Nepal, shot more than 120 tigers (Singh 1973). The Raja of Singhai often organised swamp deer hunts in the areas around present day Dudhwa Tiger Reserve which was also visited by King George V for pig-sticking (Singh 1973).

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Areas around present day Corbett Tiger Reserve (also the first Protected Area in the country) often find mention in Jim Corbett's accounts about the wildlife and people of India while F.W. Champion's experiments with the self-triggered camera in the 1950s in this region were probably amongst the first experiments in documenting wildlife of an area using such devices. While most hunting stories from this region re-establish the importance of this area as a rich hunting ground, almost exclusively reserved for the royalty, they also echo the existing fear of continuously declining wildlife.

Following the discovery of dichloro-diphenyl-trichloroethane (DDT) in the 1950s and the subsequent control of malaria in the region, most of this area underwent a massive change due to an altered land use policy, settlement of refugees at the time of India's independence, expansion of areas under agriculture during the Green Revolution, reclamation of swamps and other anthropogenic factors (Mathur 1999).

It was during this era of vast transformation of the *terai* that 'Billy' Arjan Singh, experimented hand rearing Tara, a tiger cub and leopard cubs (Prince, Harriet and Juliette), at 'Tiger Haven', his farm near Dudhwa National Park. The lives of these cats witnessed by the world through Billy's books and films left a deep impact on the viewers, aiding large-cat conservation even today.

1.1.3 Conservation Significance

The *terai-duar* savannah of the TAL has been recognised as one of the 200 globally important eco-regions for its intact large mammal assemblages (Olson and Dinerstein 1998). Johnsingh *et al.* (2004) identified nine Tiger Habitat Blocks (THBs) in this region as disjunct forest blocks with varying tiger populations. These THBs possibly formed a continuum of forests with tigers and their prey until recent times when anthropogenic disturbances and reclamation of land for agriculture disrupted the forest continuity, leaving them connected by means of 13 narrow corridors (Johnsingh *et al.* 2004). However, this area still holds the key to long-term tiger conservation by hosting two of the important level 1 tiger conservation units, namely, Rajaji-Corbett and Chitwan-Parsa-Valmiki along with some level 2 tiger conservation units (Wikramanayake *et al.* 1998). Studies indicate that this landscape complex has 20,800 km² of tiger habitat on the Indian side even today (Qureshi *et al.* 2006). Currently, the distribution of tigers in this zone is patchy with high variations in the frequency of occurrence (Johnsingh 2006b) even though this zone contains the single largest contiguous *terai* patch comprising of Pilibhit, Suklaphanta, Kishanpur, Dudhwa, Bardia and Katerniaghat forests.

More importantly, most of the TAL forests in India are connected with the *terai* zones of Nepal. Since key parts of this complex are in Nepal and Bhutan, trans-boundary cooperation is essential for effective tiger conservation (Qureshi *et al.* 2006).

1.1.4 Vegetation

The floral elements of the Shivalik hills and the Gangetic plain landscape include those from the *terai* region, the *bhabar* tracts and the Shivaliks.

The *terai* is popularly known as a wetland and comprises of a multi-dimensional landscape harbouring a range of ecosystems and ecosystem complexes, such as woodland-grassland-wetland ecosystems dominated by graminoid species of

Saccharum, Narenga, Imperata cylindrica and *Typha sp.* (Mathur 1999). The *bhabar* tracts are dominated by moist deciduous forests with sal (*Shorea robusta*) being the predominant species. The Shivaliks have floral elements of the peninsular India, and subtropical and warm temperate regions of the western Himalaya.

This landscape has some species which are closely related to those found in the eastern Himalaya or the Western Ghats such as *Schefflera venulosa, Diospyros embryopteris, Phoebe lanceolota* and *Bischofia javanica* along with endemic species such as *Catamixis baccharoides*.

The extensive belts of timber in this zone attracted large amounts of attention and thus this area has witnessed a long history of forest management starting around 1861.

1.1.5 Fauna

In 1927, F.W. Champion listed 32 species of mammals from the Lansdowne Forest Division of this zone of which the blackbuck and the four-horned antelope no longer exist.

As of today, this region hosts five species of cervids - chital (*Axis axis*), sambar (*Rusa unicolor*), muntjac (*Muntiacus muntjak)*, hog deer (*Axis porcinus*) and the swamp deer (*Rucervus duvaucelii*); three antelope species - nilgai (*Boselaphus tragocamelus*), blackbuck (*Antilope cervicapra*) and four-horned antelope (*Tetracerus quadricornis*); and other ungulates like the Asian elephant (*Elephas maximus*), one horned rhinoceros (*Rhinoceros unicornis*) (re-introduced in Dudhwa), wild pig (*Sus scrofa*) and rare species like the hispid hare (*Caprolagus hispidus*). Amongst large carnivores, leopard (*Panthera pardus*), tiger (*Panthera tigris*), wild dog (*Cuon alpinus*), hyena (*Hyaena hyaena*), the Asiatic black bear (*Ursus thibetanus*) and the sloth bear (*Melursus ursinus*) are found in this zone. Goral (*Naemorhedus goral*) and serow (*Capricornis thar*) can also be found on the slopes of the Shivaliks in this area.

The avifaunal diversity of this region is also vast with Sharma *et al.* (unpublished data) reporting 549 species of birds from Corbett Tiger Reserve and Pandey *et al.* (1994) reporting 312 species of birds from Rajaji National Park alone. The Himalayan quail (*Ophrysia superciliosa*) represents a genus endemic to this region but has not been sighted with certainty since 1876. A small section of the Western Himalaya Endemic Bird Area (EBA) falls within this zone and has 11 species restricted to it, though most are birds found in higher elevations. Amongst the rare and endangered birds, the two that stand-out are the Bengal florican (*Houbaropsis bengalensis*) and the swamp francolin (*Francolinus gularis*).

1.1.6 Ecological Studies

When combined with the Nepal *terai*, wildlife studies in this region outnumber those conducted in any other part of the country. A probable reason for this could be the location of several pioneering research institutes in this zone like the Forest Research Institute (FRI), Indian Council of Forestry Research and Education (ICFRE), Forest Survey of India (FSI), Indira Gandhi National Forest Academy (IGNFA), Survey of India, northern regional centre of the Zoological Survey of India (ZSI), Indian Institute of Remote Sensing (IIRS), Wildlife Institute of India (WII) and the Wadia Institute of Himalayan Geology.

With specific focus on the tiger, research conducted in this zone has laid the foundations for most tiger studies conducted elsewhere in the Indian sub-continent in contemporary times. Chitwan National Park in Nepal, which is contiguous with the Valmiki Tiger Reserve, became the site for the first long-term study on the tiger in 1973 with funding from the Smithsonian Institution and WWF. It was a pioneering study in which tigers were tranquilised, fitted with radio-collars and subsequently data was collected on various aspects of ecology. Seidensticker (1976) examined the factors that allowed co-existence of leopards and tigers in the area based on home ranges, daily movement, niche separation and avoidance behaviour. Around the same time, Dinerstein (1979a,b) experimented with sampling techniques to estimate prey densities. Sunquist (1981); Smith, McDougal and Miquelle (1989); and Smith (1993) produced more information on tiger behaviour, social structure and dispersal patterns and dispersal behaviour. The first literature on tiger immobilization techniques was also an outcome of studies conducted in this landscape by Seidensticker, Tamang and Gray (1974) and Smith, Sunquist, Tamang and Rai (1983). Tamang (1982) studied the status of tigers and their impact on prey. Meta-population studies on tigers of the region by Smith, Ahearn and McDougal (1998) paved the way to understanding more complex issues pertaining reproductive performances of the Chitwan tigers and the contribution of variance in reproductive performance to variance in inbreeding estimates as studied by Smith and McDougal (1991) based on data from 1973-89. In more recent times, Gurung, Smith, McDougal, Karki and Barlow (2008) have shifted focus to conservation issues and human tiger conflict.

Within the same landscape, Royal Karnali-Bardia Wildlife Reserve has also been a part of several studies by Dinerstein (1979a, 1979b, 1980) which started in 1975. In more recent times Wegge, Odden, Pokharel and Storaas (2009) re-visited the area to assess the effects of conservation efforts on populations of tigers, leopards and their prey in Bardia National Park as part of a collaborative program between the Government of Nepal (Department of National Parks and Wildlife Conservation), the Norwegian University of Life Sciences and the Nepal Trust for Nature Conservation.

Apart from the aspects of tiger biology mentioned above, this landscape has also inspired many non-scientific publications on the tiger apart from much scientific literature not mentioned here.

In comparison to the Nepal *terai*, very few studies have been conducted on the tiger in the Indian *terai*. Johnsingh and Negi (2003) initiated a study in this region to gather vital information on the status of the tiger and leopard while also assessing the biotic pressures at a landscape level. Thereafter, another study was conducted by Johnsingh *et al.* (2004) to determine status of the tiger in the region and to identify the existing corridors between Protected Areas. Since 2004, the Wildlife Institute of India has carried out extensive studies in Rajaji National Park, monitoring the impacts of *Gujjar* relocation on the biodiversity of the region. Harihar, *et. al.* (2010) reiterate the revival of Chilla-Motichur corridor to facilitate tiger and elephant movement.

A more widespread study on the status of the tiger and its co-predators in the region was conducted by Jhala, Gopal and Qureshi (2008) in a scientific collaboration of the Wildlife Institute of India and the National Tiger Conservation Authority (NTCA), which reported tiger occupancy in 5,080 km^2 of the forested habitat in this region with and an estimated population of 297 (259 to 335) tigers in this landscape.

Other than scientific studies focussing on the tiger, studies have also delved into other aspects of conservation in this landscape. Long-term studies have been conducted in

the Rajaji-Corbett region with the aim of reducing human-elephant conflict and to identify corridors for movement of elephants in this region. Experiments with re-introductions have been conducted at Dudhwa Tiger Reserve with the rhinoceros and with the gharial at Katerniaghat; while organisations such as the Bombay Natural History Society (BNHS) have done large scale surveys for the Bengal florican. In the Nepal *terai*, extensive studies have been conducted on the hog deer and hispid hare while grassland system dynamics have also been extensively studied.

1.1.7 Conservation Status

Jhala *et al.* (2008) identified six separate populations of tigers in this landscape which has been considered an important zone for tiger conservation with a genetically distinct population of tigers (Sharma *et al.* 2010a). The importance of connecting large tracts of this landscape has been emphasised with the aim of securing a single meta-population of tigers between Nepal and Indian *terai* (Wikramanayake *et al.* 2004; Dinerstein *et al.* 2007) with as little as US$25 being invested per square kilometre with help from public and private sectors (Dinerstein *et al.* 2007).

The tiger occupancy zone from Kalesar in Haryana to Kishanpur in Uttar Pradesh has been identified as the most promising unit for long term tiger conservation in this zone which has already lost tigers from 29% districts where they were historically located. Trans-boundary cooperation would be required to ensure that Protected Areas such as Dudhwa, Sohagibarwa and Valmiki remain connected through the forests of Churia Hills and Protected Areas in Nepal which include Suklaphanta, Bardia and Chitwan for long term persistence of the species in this landscape.

Some potential threats to tigers in this landscape include high dependence of local communities on forest resources, lack of connectivity between forest patches, presence of timber and sand mafia, encroachment of urbanisation into forested landscapes along with evidences of tiger and prey poaching (Johnsingh 2006a). In the period 2000-10, 62 tiger bone and other part seizures were made in states which include the Shivalik hills and the Gangetic plain landscape (WWF 2007). Whether all these tigers were killed within this landscape would require further investigation, albeit it does throw light on the presence of criminal activities detrimental to tigers and their prey in the region.

Shivalik hills and the Gangetic plain landscape in contemporary times is an island complex with increasing levels of human-animal conflict, primarily involving large mammalian species such as tigers, leopards and elephants. Almost 90% of the original *terai* is under intensive agriculture or urbanisation leaving little space for wildlife. Floods, which used to be an important character of this landscape, are being controlled extensively through creation of large dams and by changing river courses. However, little thought is ever put into understanding the role of such floods that shape the grassland ecosystems in the *terai* which further sustain grassland suited species such as the rhinoceros, swamp deer and the Bengal florican. With regulated intensity and reduced flexibility of river waters in the monsoon, the shifting mosaics of woodland-grassland and their interplay have long ceased to exist, threatening the existence of many grassland specialists in this region.

1.2.1 Tiger Occupancy

In this landscape, 318 (10X10 km) grids within potential tiger habitat, below the elevation of 2500 feet, were surveyed. Tiger signs were detected in 132 of these grids, resulting in a naive occupancy estimate of 41.5%. Of the total available tiger habitat covering 15,973 km² in these grids, 7,330 km² constituting 46% of the total habitat, was occupied by tigers.

The null occupancy model (corrected for imperfect detections, with no covariates) provided an occupancy estimate of 44 (se 2.9) % with a detection probability of 40 (se 1.2) %. The best model for tiger occupancy incorporated tiger abundance index for

Table 1.1
Model selection results for estimating tiger occupancy within the Shivalik hills and the Gangetic plain landscape incorporating imperfect detections and covariates of landscape characteristics, prey abundance and human disturbance.

S. No.	Model	AIC	Delta AIC	No.Par.	-2*Log Likelihood
1	ψ (UngER, WDng, NDVIM, NDVIPM, DEM, RdDen, PAD, NitL, For, Cor, Rug),p(AvgTigSgn)	2421.79	0	13	2395.79
2	ψ (UngER, WDng, NDVIM, NDVIPM, DEM, RdDen, NitL, For, Cor, Rug),p(AvgTigSgn)	2422.34	0.55	12	2398.34
3	ψ (NDVICV, Precp, NDVIM, NDVIPM, DEM, RdDen, PAD, NitL, For, Cor, Rug), p(AvgTigSgn)	2438.21	16.42	13	2412.21
4	ψ (UngER, WDng, NDVIM, NDVIPM, DEM, RdDen, PAD, NitL, For, Cor, Rug),p(.)	2509.17	87.38	13	2483.17
5	ψ (UngER, WDng, NDVIM, NDVIPM, DEM, RdDen, NitL, For, Cor, Rug),p(.)	2509.6	87.81	12	2485.60
6	ψ (UngER, WDng, WdC, NDVIM, NDVIPM, DEM, RdDen, PAD, For, Cor),p(.)	2519.48	97.69	12	2495.48
7	ψ (UngER, WDng, WdC, NDVIM, NDVIPM, DEM, Rug, RdDen, PAD, Cor),p(.)	2520.73	98.94	12	2496.73
8	ψ (UngER, RdDis, NDVIM, NDVIPM, DEM, RdDen, PAD, NitL, For, Cor),p(.)	2520.87	99.08	12	2496.87
9	ψ (NDVIM, NDVIPM, DEM, RdDen, PAD, NitL, For, Cor, Rug),p(.)	2522.39	100.6	11	2500.39
10	ψ (UngER, LvStkSn, WDng, NDVIM, NDVIPM, DEM, RdDen, PAD, Cor, Rug),p(.)	2523.98	102.19	12	2499.98
11	ψ (UngER, Trail, WDng, DEM, RdDen, PAD, NitL), p(.)	2524.00	102.21	9	2506.00
12	ψ (UngER, Cor, Trail, WDng, NDVIM, NDVIPM, DEM, RdDen, PAD, Rug), p(.)	2525.40	103.61	12	2501.40
13	ψ (NDVICV, Precp, NDVIM, NDVIPM, DEM, RdDen, PAD, NitL, For, Cor, Rug), p(.)	2525.47	103.68	13	2499.47
14	ψ (UngER, WDng, NDVIM, NDVIPM, DEM, RdDen, PAD, NitL, For, Cor, Rug), p(.)	2527.82	106.03	13	2501.82
15	ψ (UngER, Lvstk, NDVIM, NDVIPM, DEM, RdDen, PAD, NitL, For), p(.)	2529.69	107.90	11	2507.69
16	ψ (.), p(SurveySpc.)	2546.91	125.12	31	2484.91
17	ψ (.), p(AvgTigSign)	2566.38	144.59	2	2562.38
18	ψ (.),p(.)	2650.94	229.15	2	2646.94

UngER – Ungulate Prey encounter per km transect walk, WDng – wild ungulate dung density, NDVIM- Normalized differential vegetation index monsoon, NDVIPM- Normalized differential vegetation index pre-monsoon, DEM - Elevation, RdDen: Density of major metalled roads, PAD – Euclidian distance to nearest Protected Area , NitL- Euclidian distance to Night Lights, For – Area of Forest Cover, Precp-Precipitation, Cor – Area of Forest Core, Rug- Ruggedness of the terrain measured by CV of Digital elevation model, , LvStkER – Livestock encounters per km transect walk, LvStkDng- Livestock dung density, WdC – Number of wood cutting signs on 15m plots along transects, Lop- Number of trees lopped on 15m plots on transects, GrC – signs of grass and bamboo cutting on 15m plots on transects, Trail – presence of human-livestock trails on transects, Hum- Presence of humans on line transect plots, LvstkSn – Presence of livestock on transect plots.

modeling detection probability and included the following covariates (Table 1.1 and 1.2):
a) prey availability indexed by ungulate encounter rates on transects and dung density
b) landscape features indexed by NDVI, elevation, terrain ruggedness, forested area, area of core habitat, and distance of the grid from a Protected Area
c) human disturbance variables indexed by road density and distance from night lights

Table-1.2 Coefficient estimates for the best model selected for estimating tiger occupancy in the Shivalik hills and the Gangetic plain landscape.

Covariates	Coefficient Estimates	SE
a1	-0.561	0.176
Ungulate Encounters per km	0.384	0.198
Ungulate Dung Density	0.563	0.203
NDVI Monsoon	-1.965	0.656
NDVI Pre Monsoon	2.082	0.639
Elevation	-1.858	0.306
Road density	-0.482	0.197
Distance to Protected Area	-0.293	0.186
Distance to Night Lights	0.859	0.243
Area of Forest Cover	0.529	0.264
Area of Forest Core	0.872	0.282
Ruggedness of Terrain	0.414	0.217
b1 (Avg. Tiger Sign)	0.473	0.049

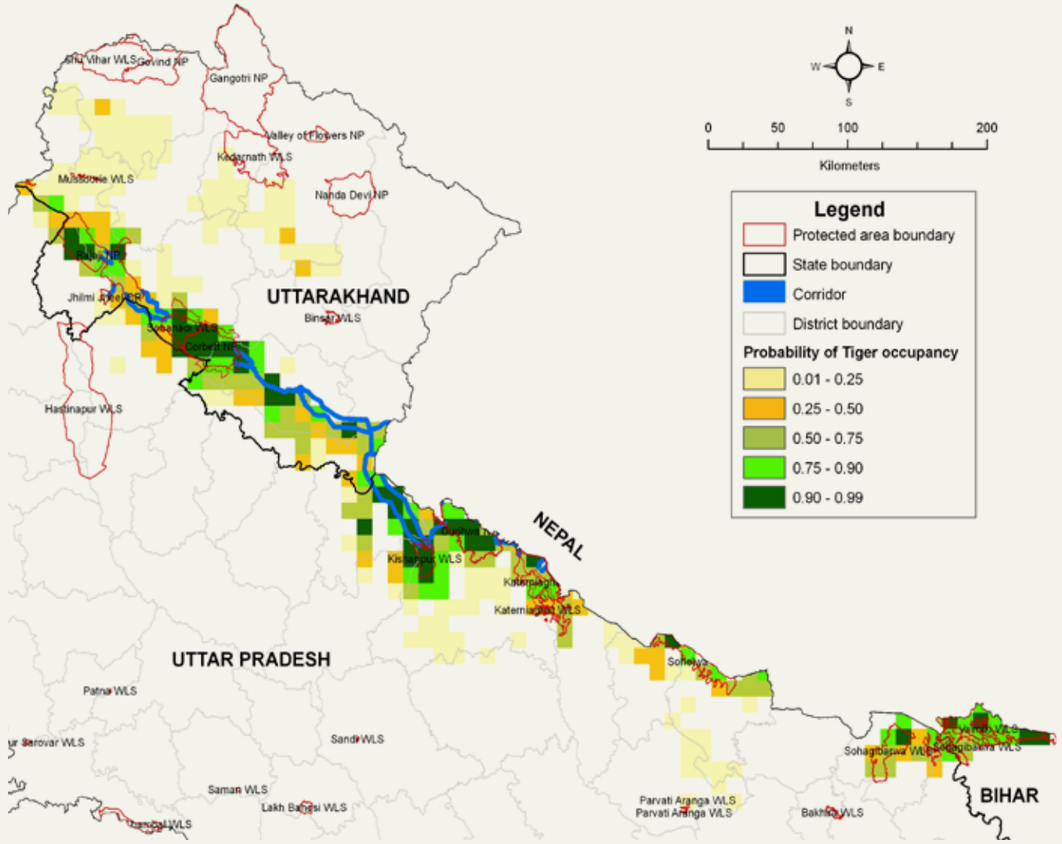
The delta AIC for the top two models was less than two. Therefore, we used the model averaged coefficients, based on AIC weights of these two models to estimate parameters.

The tiger occupancy estimate from the model averaged coefficients was 43.1 (1.9). There was better support for detection probability being a function of tiger abundance (p = 0.546 (se 0.001) in comparison to models incorporating survey specific variation or a constant detection of signs across surveys. With this high detection probability and number of surveys (5 kilometre spatially independent walks) ranging from 3 to 30 (proportional to the amount of tiger habitat in a grid) the increment in tiger occupancy (from 41.5% naive estimate to 43.1 (se 1.8) best model estimates) by incorporating imperfect detections and covariates was marginal. However, the coefficients of covariates used in the models provided good insight into factors that influence tiger occupancy in this landscape. The occupancy probability of a grid habitat can be interpreted as a quantitative estimate of habitat suitability for tigers and was a useful tool for mapping source and corridor habitats (Fig. 1.1).

1.2.2 Tiger Populations Extent and Abundance across the Shivalik hills and the Gangetic plains landscape

Mark-recapture population and density estimates of tigers based on camera-trapping were obtained for Rajaji (Chilla) National Park, Corbett Tiger Reserve, Ramnagar Forest Division, Pilibhit Forest Division, Katerniaghat Wildlife Sanctuary, Kishanpur Wildlife Sanctuary, Dudhwa Tiger Reserve and Valmiki Tiger Reserve. Tiger densities in the Shivalik hills and the Gangetic plain ranged between 3 to 17.8 tigers per 100 km² (see Phase III chapter). After joining contiguous grids with tiger presence, five tiger populations were identified within the Shivalik hills and the Gangetic plain landscape. These include (Fig. 1.2):

Figure 1.1 Tiger habitat in the Shivalik hills and the Gangetic plain landscape showing probability of tiger occupancy modelled by incorporating imperfect detections as well as covariates of landscape characteristics, human disturbance, and prey availability.



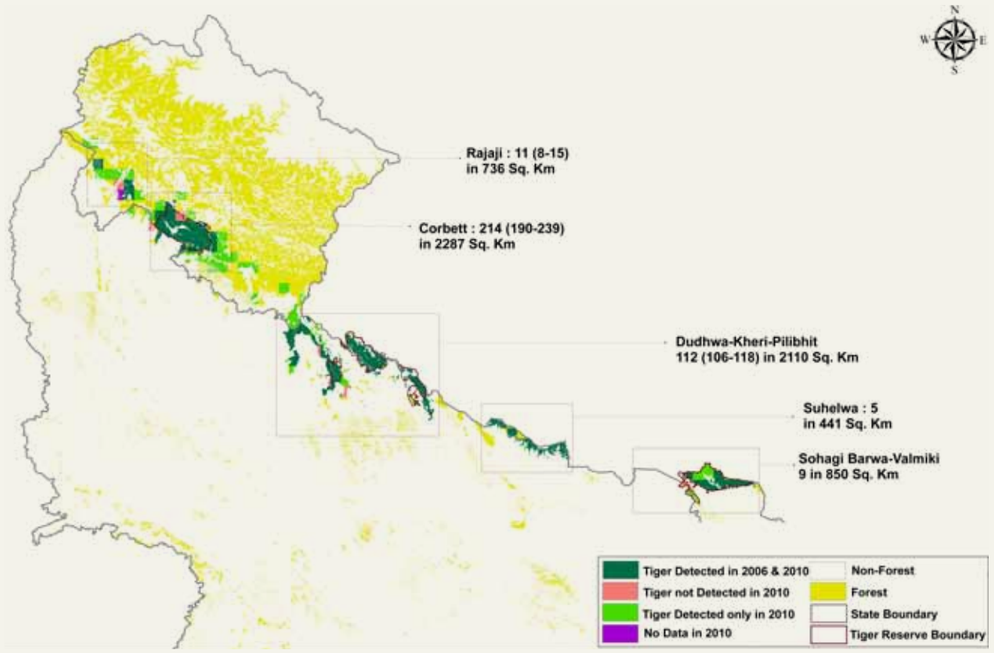
a) The western most population of tigers in Rajaji National Park having tiger occupancy in about 736 km² with an estimated population size of between 8-15 individuals;
b) The single largest tiger population in the landscape around Corbett Tiger Reserve with occupancy of about 2,200 km² and an estimated population between 190 to 239 individuals;
c) The Dudhwa-Kheri-Pilibhit tiger population with occupancy in about 2,110 km² with an estimated tiger population between 106-118 individuals;
d) The small population in Suhelwa (around 5 individuals) shared with Mahadevpuri-Lamahi forests of Nepal with an occupancy of 441 km²;
e) The Valmiki-Chitwan continuum spanning across parts of India and Nepal with 850 km² tiger occupancy on the Indian side with 8-10 individuals and a weak connectivity to Sohagibarwa.

1.2.3 Changes in Occupancy and Abundance from 2006 to 2010

Tiger occupancy in the Shivalik hills and the Gangetic plain landscape was recorded

Figure 1.2

Tiger occupancy, population extent, size and habitat connectivity in Shivalik Hills and Gangetic Plain Landscape



to be around 5,177 km² in 2006 and increased to 6,712 km² (by 29.7%) in 2010. Most of this increment in population extent was in the State of Uttarakhand which is very encouraging (Fig. 1.2). Loss in tiger occupied areas for the period between 2006 and 2010 was observed in the Shivalik Forest Division and the connecting forests between Pilibhit and Kishanpur in Uttar Pradesh. Both these areas are important corridors for maintaining tiger presence in the larger landscape of Kalesar (Haryana) to Kishanpur (UP). The increase in tiger occupancy observed in Uttarakhand, was likely to be an artefact of better data coverage and data collection from areas that were not properly sampled in 2006. We believe that tiger signs have been under estimated in the Forest Divisions of East Terai and Haldwani. More attention needs to be given to these Forest Divisions in terms of data collection as well as conservation as they form part of crucial linkages between the west and eastern tiger populations.

1.2.4 Critical Corridors, Habitat Connectivity and Conservation

This landscape has the potential to have contiguous tiger occupancy from eastern parts of Himachal Pradesh to Kishanpur (UP). From Kishanpur eastward a tenuous connectivity is still maintained through the forests in Nepal (Suklaphanta, Bardia–Khata corridor, Chitwan National Park) from Dudhwa to Valmiki Tiger Reserve. Within this landscape three major source populations occur with two in India. These are:
a) The Corbett population comprises of Corbett National Park, Sonanadi Wildlife

Sanctuary, Lansdowne Forest Division, Ramnagar Forest Division, and Haldwani Forest Division. The high tiger population density in this region is restricted to parts of the Corbett Tiger Reserve. However, the population outside of the Tiger Reserve is also of great significance with Ramnagar Forest Division having a density of 14 tigers per 100 km² and evidences of breeding individuals. This large population of tigers is an indication of good forest health in terms of ungulate prey and cover resulting out of good management practices. The Corbett tiger population serves as a source from where tigers are likely to disperse both westward as well as eastward to maintain the populations in Rajaji and Pilibhit. Due to its size and extent, this single population has a high chance of long term persistence and thus should be the conservation priority in this landscape.

b) The Dudhwa-Kheri-Pilibhit tiger population comprises of Pilibhit, Kishanpur, Dudhwa and Katerniaghat in India and Suklaphanta and Bardia in Nepal. This source population, though fragmented into smaller units, probably still shares a common gene-pool and occasionally exchanges individuals through the tenuous habitat corridors and stepping stone connectivity that exists between them. The densities range between 4-7 tigers per 100 km² and though not as high as those in Corbett, on the Indian side the population is over a 100 adult tigers. Considering the Nepal (Suklaphanta and Bardia National Park) population, the total number of tigers in this source would be over 125 adults. The landscape of this population is fraught with conflict as the lands surrounding the Reserves are very fertile, supporting intensive agriculture and sustaining high human population densities. Conserving tigers in such volatile landscapes is a difficult task and mitigation of conflict in an effective and timely manner is vital. Major conservation investment is required to secure the poor corridor connectivity between the high density sub-populations of this source (Fig. 1.1). Details of conservation action needed for each of these potential corridors are provided in the section on Uttar Pradesh.

c) The Chitwan (Nepal)-Valmiki population has its source population in Chitwan National Park of Nepal. Together with Valmiki which is an extension of the Chitwan Forests (Churia hills) into the Shivaliks of India, the adult tiger population is well

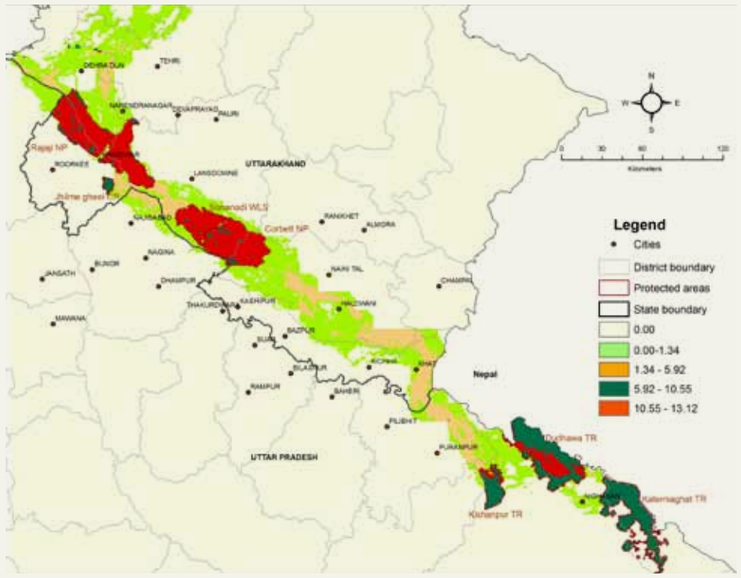
over a 100 individuals. On the Indian side, Valmiki Tiger Reserve has the potential to sustain higher tiger densities by reducing human impacts including poaching of tiger prey in this landscape.

Covariates of tiger prey, habitat quality and extent and human pressures were used to model tiger occupancy. Thus, habitat suitability for tigers in the landscape can be determined from the occupancy outputs (Fig. 1.1).

The Circuitscape model output highlights potential connectivity between Protected Areas in this landscape. This map (Fig. 1.3) provides insight into which areas outside of the Reserves need to be considered sensitive while planning development projects and changing land use patterns. The least cost path analysis (Fig. 1.2) provides the optimal corridor between Protected Areas. Ideally these corridors should be declared as "eco-sensitive" and land use changes that are detrimental to their conservation value discouraged. Some of these corridors require restorative inputs (detailed in the State level section on conservation needs) for achieving their full corridor value in connecting wild gene pools. Currently this least cost corridor analysis considers only the biological aspects to design the optimal corridor path. Circuitscape results provide insights on potential alternative connectivity as well (Fig. 1.3). Intensive site specific ground validation is required to align the boundaries of the corridors suggested herein to maximize wildlife values and minimize impact on local economies.

Figure 1.3

Least resistance pathways connecting potential tiger habitats and source populations within the Shivalik hills and the Gangetic plain landscape modelled in Arc GIS using CIRCUITSCAPE.

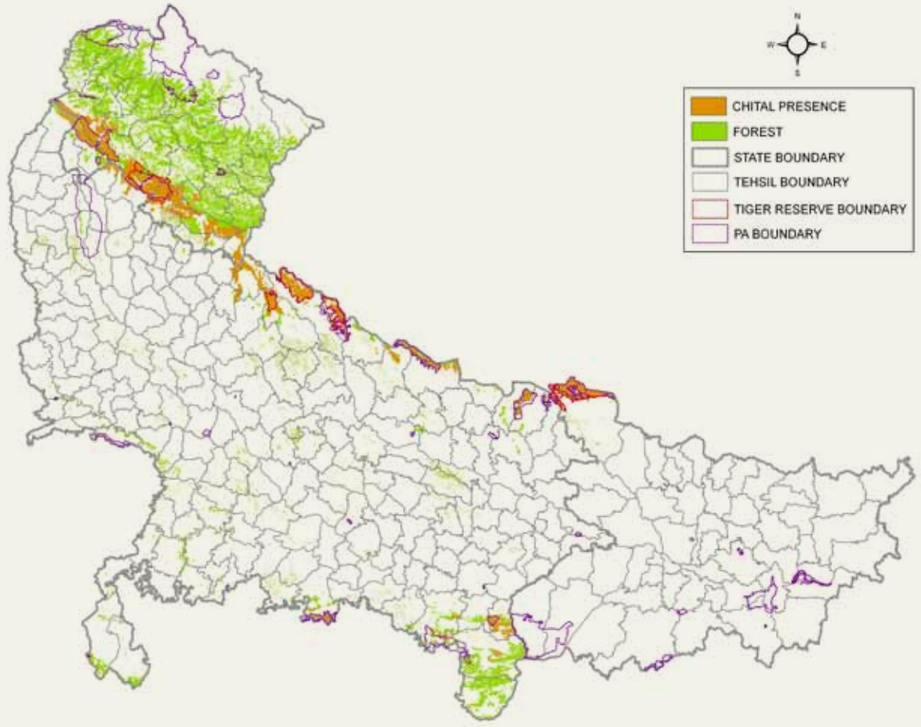


1.2.5 Distribution of Ungulates in the Landscape

a) **Chital** (*Axis axis*)
Chital distribution was limited to the Shivalik hills and the narrow strip of forested habitat along the Shivaliks and within the *terai* (Fig. 1.4.1). They were recorded within all the Protected Areas in the foot-hills of the Shivaliks covering an area of 10,781 km² and showed a patchy distribution in forests of Sonbhadra and Mirzapur in southern Uttar Pradesh.

Figure 1.4.1

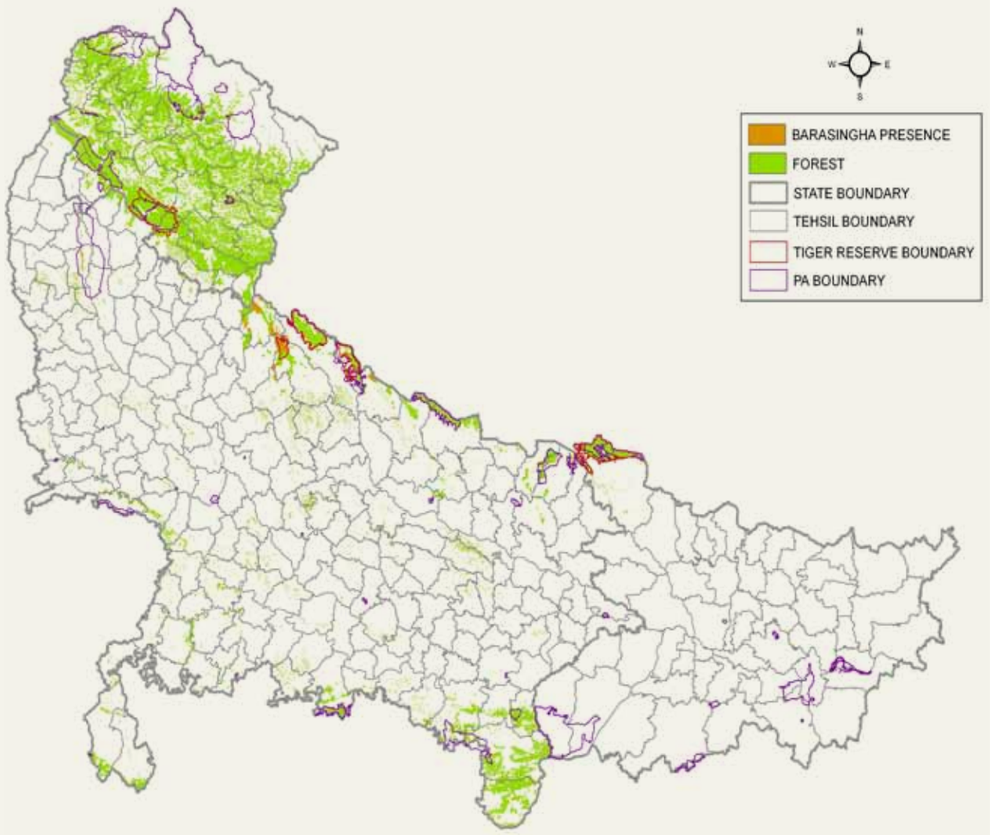
Occupancy of chital in the Shivalik hills and the Gangetic plain landscape



b) **Barasingha** (*Rucervus duvaucelii*)
Most barasingha habitat is under agriculture while the small fragments that remain are threatened by ill-informed grassland management practices such as harrowing and burning. The species occurrence was restricted to habitat pockets in the flood plains of Rivers Ganga, Sharda and their tributaries covering an area of 622 km² (Fig. 1.4.2). Though these populations were genetically connected through occasional movements via river systems until recently, this gene flow is currently highly restricted due to growing townships and infrastructure development along riverine tracts.

Figure 1.4.2

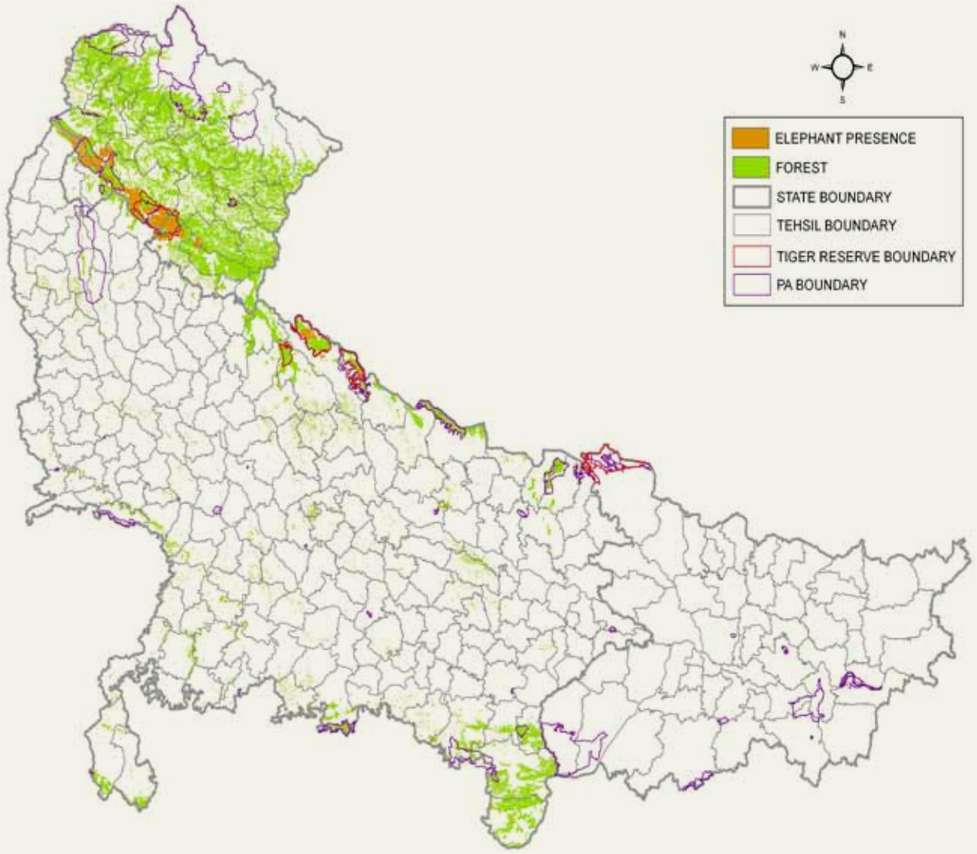
Occupancy of barasingha in the Shivalik hills and the Gangetic plain landscape



c) **Elephant** (*Elephas maximus*)
Elephant occurrence was observed within the Shivalik-Terai belt, west of Katerniaghat within an area of 2,646 km². Contiguous occupancy was recorded from the Shivalik Forest Division of Western Uttar-Pradesh up to Ramnagar Forest Division in Uttarakhand (Fig. 1.4.3). Though the forests are contiguous from Ramnagar Forest Division to Pilibhit-Kishanpur and into Dudhwa via Nepal, elephant occurrence was not reported suggestive of very low density and/or only occasional passage across this landscape. Small populations of elephants are reported to move between Bardia National Park (Nepal), Dudhwa Tiger Reserve and Pilibhit forests. Though Chitwan National Park in Nepal has some elephants, their occurrence was not reported from Valmiki Tiger Reserve.

Figure 1.4.3

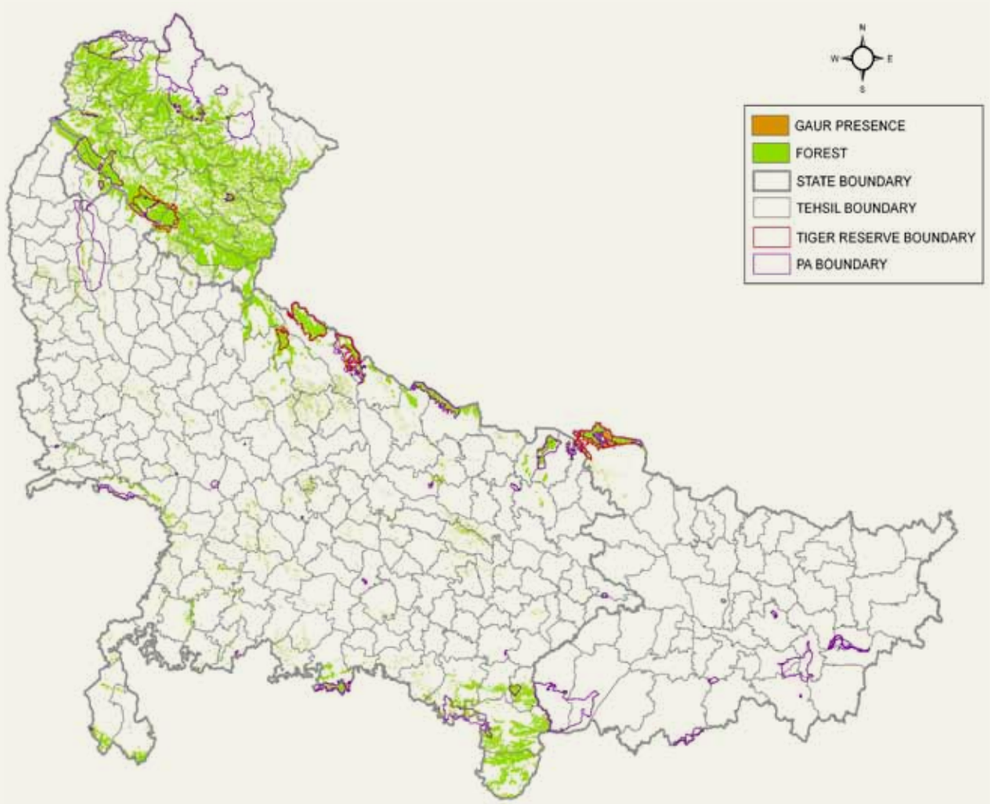
Occupancy of elephant in the Shivalik hills and the Gangetic plain landscape



d) **Gaur** (*Bos gaurus*)
Gaur were reported only from Valmiki Tiger Reserve (202 km²) in this landscape (Fig. 1.4.4).

Figure 1.4.4

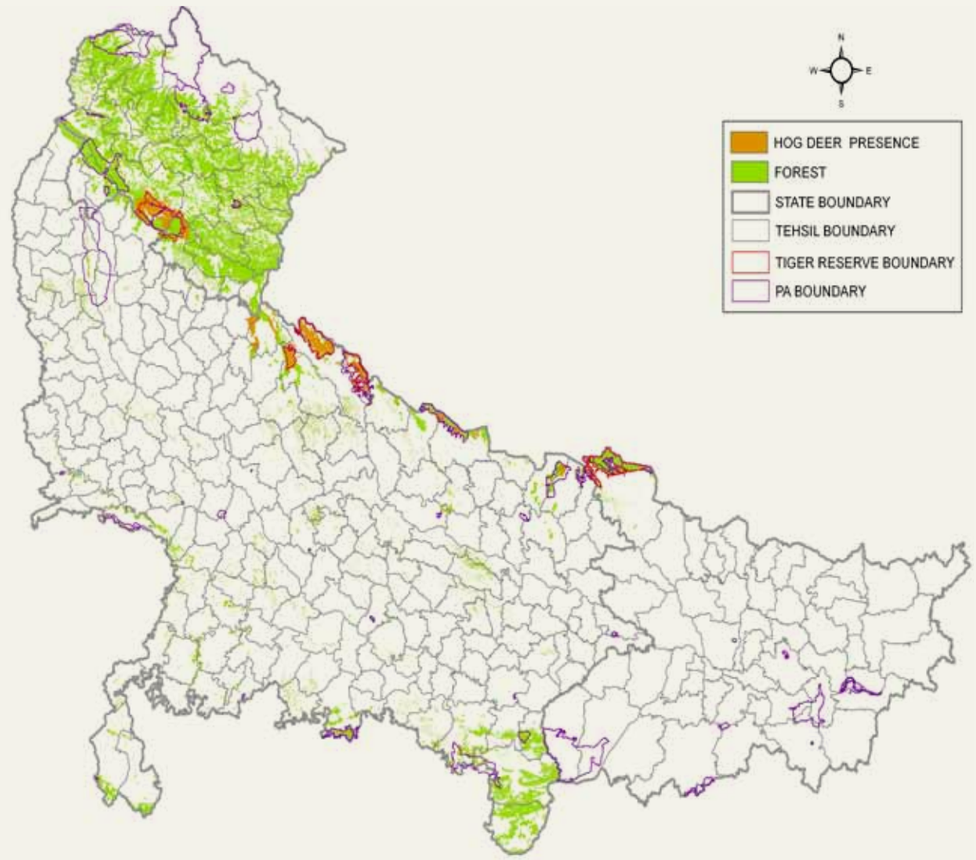
Occupancy of gaur in the Shivalik hills and the Gangetic plain landscape



e) **Hog deer** (*Axis porcinus*)
Hog deer distribution was primarily restricted to the flood plain habitats within Protected Areas (2,919 km²) (Fig. 1.4.5). Small isolated populations do occur on the riverine islands and banks of the Ganga and Sharda rivers. All across its range the hog deer is poached for its meat. The species' habitat too is threatened with the same issues as those for the barasingha. Within Protected Areas the dynamics of the flood plain system have been disrupted by vegetation succession and by inappropriate practices of grassland management that have led to decline of the species. Serious intervention is required to properly manage their remaining habitat.

Figure 1.4.5

Occupancy of hog deer in the Shivalik hills and the Gangetic plain landscape

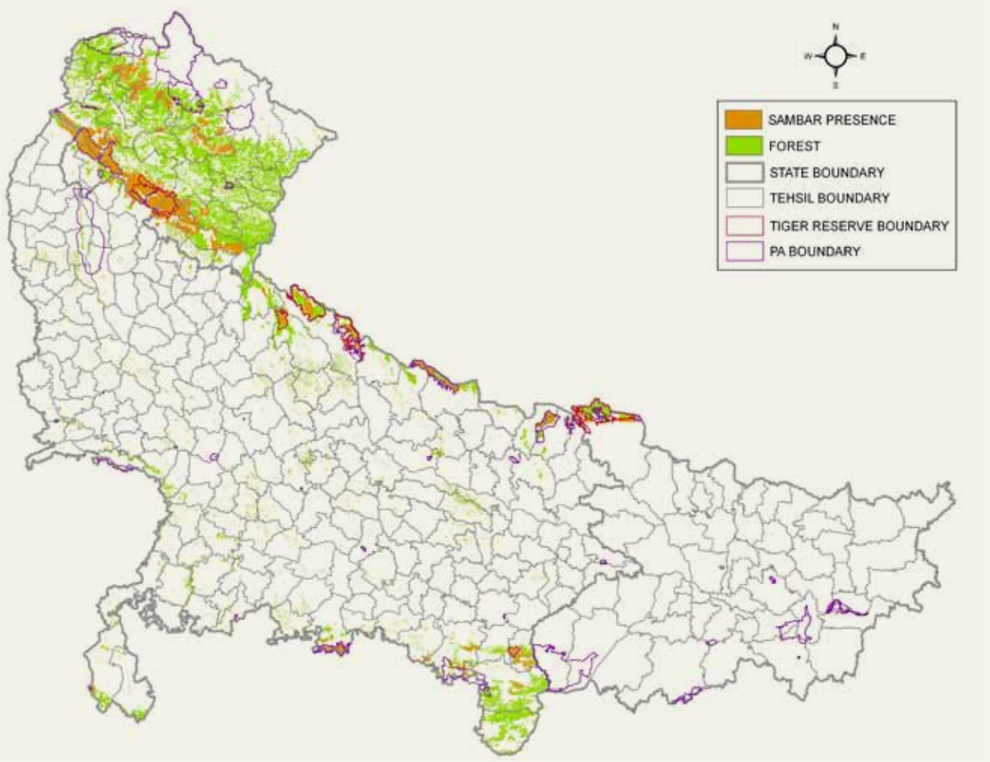


f) **Sambar** (*Rusa unicolor*)

Sambar was one of the most wide spread cervids across the Shivalik hills and the Gangetic plain landscape covering an area of 10,166 km² (Fig. 1.4.6) and constitutes a major prey of tiger. Sambar is the only large ungulate that occurs at high altitudes and is thus an important determinant of tiger occupancy (tiger presence was recorded in the higher reaches of the Himalayas - beyond Uttarakashi - in Uttarakhand).

Figure 1.4.6

Occupancy of sambar in the Shivalik hills and the Gangetic plain landscape



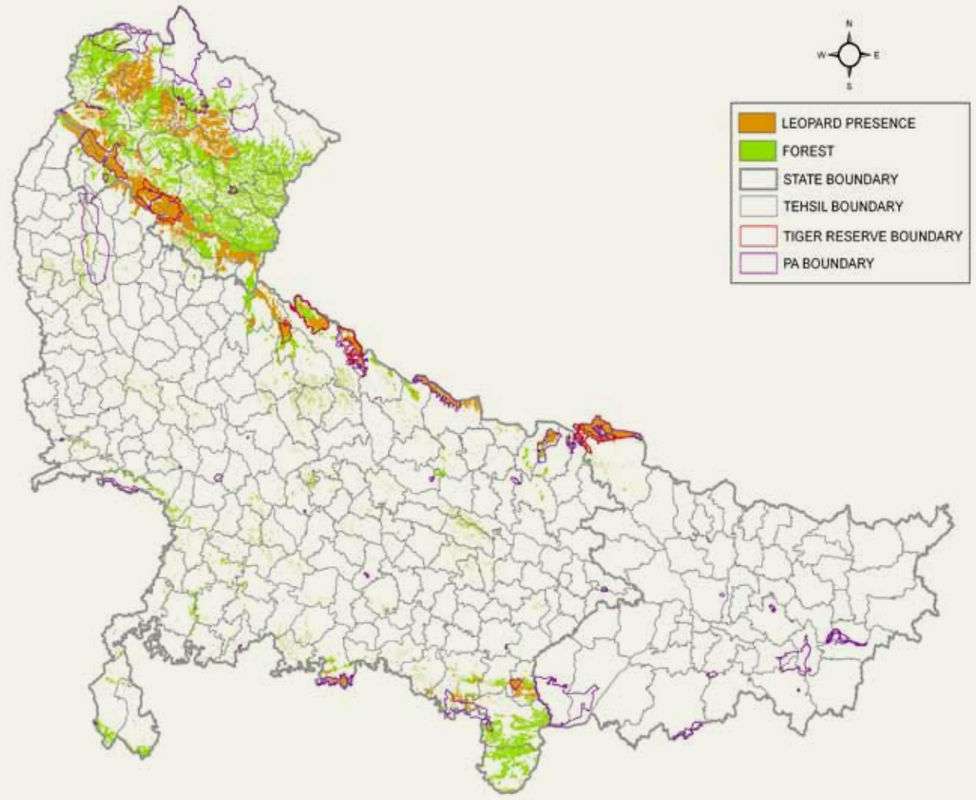
1.2.6 Distribution of Co-predators in the Landscape

a) **Leopard** (*Panthera pardus*)

The population of leopards was contiguous across much of Uttarakhand. Leopards extend their range from the *terai* habitats up to the higher reaches of the Himalayas. The breaks in their distribution seen in Figure 1.5.1, within the forested areas of the landscape are probably artefacts of sampling (areas where data has not been recorded). The recorded occupancy of leopards within forested areas of the Shivalik hills and the Gangetic plain landscape was 11,098 km². High tiger density areas like Corbett and Dudhwa Tiger Reserves though occupied by leopards, had relatively low leopard sign intensity. In areas of low wild prey abundances, leopard-human conflict was of serious magnitude across the landscape.

Figure 1.5.1

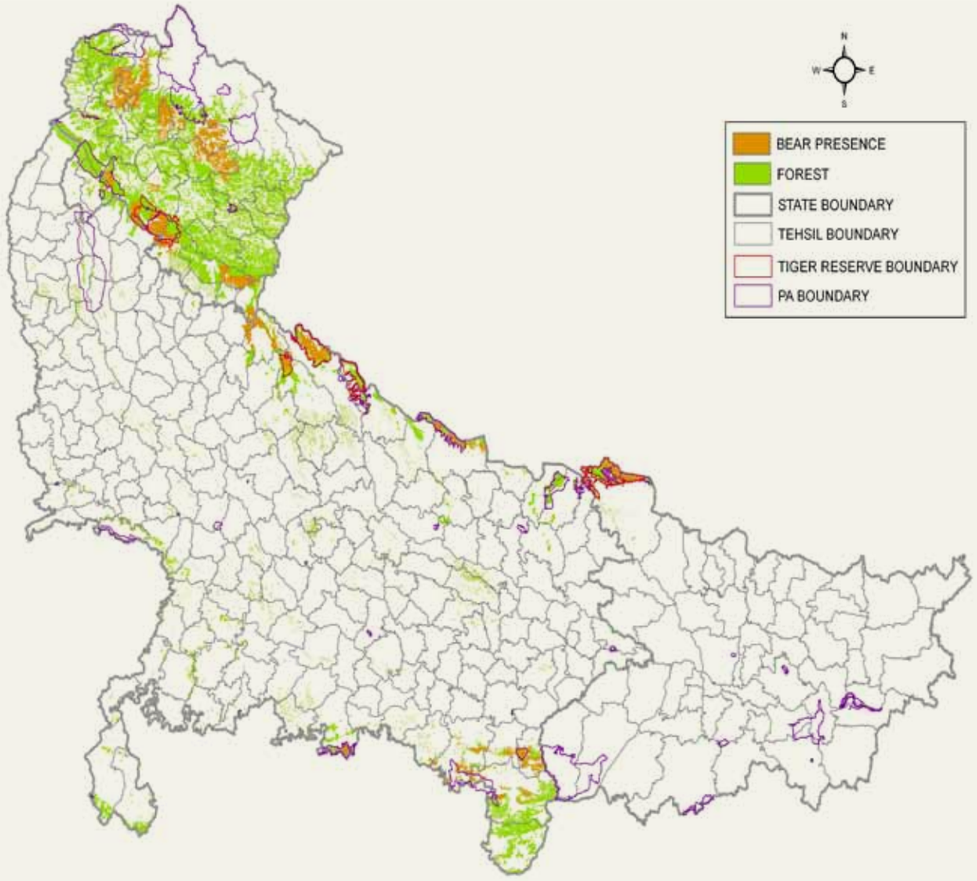
Occupancy of leopard in the Shivalik hills and the Gangetic plain landscape



b) **Bear** (*Melursus ursinus* and *Ursus thibetanus*)
Distinguishing Asian black bear signs from those of the sloth bear require substantial field experience. We therefore did not attempt to segregate the distribution of black and sloth bear from their signs. However, a clear pattern is visible from the distribution map (Fig. 1.5.2). The higher elevation occupied grids were likely exclusively black bear signs, while occupied grids within the Shivaliks, *bhabhar*, and the *terai* were mostly sloth bear with occasional black bear occurrence in the Shivaliks (especially in winter). The total forested area occupied by bears in this landscape was 7,121 km².

Figure 1.5.2

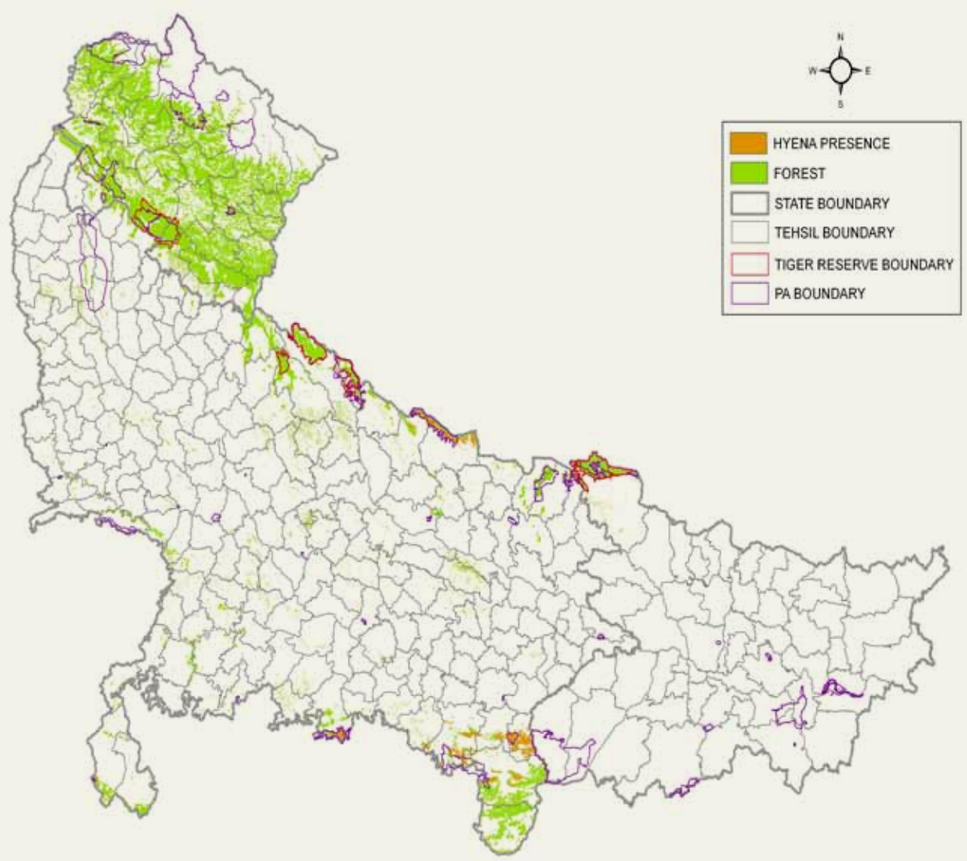
Occupancy of bear in the Shivalik hills and the Gangetic plain landscape



c) **Striped hyena** (*Hyaena hyaena*)
Striped hyena distribution was limited to parts of Rajaji in Uttarakhand (not recorded in Phase I data but recorded in camera traps). No hyena photographs were obtained from Corbett and Dudhwa Tiger Reserves. Since hyena distribution and abundance coincides with that of livestock, they are more common on peripheries of Protected Areas rather than within the core areas. Hyena presence was recorded in Dudhwa and Sohagibarwa. However, the species seems to be more abundant in the Sonbhadra and Mirzapur forests of south-eastern Uttar Pradesh than in the Shivalik-*bhabhar* tracts of this landscape. The total recorded occupancy within forested areas of this landscape was 2,795 km² (Fig. 1.5.3).

Figure 1.5.3

Occupancy of hyena in the Shivalik hills and the Gangetic plain landscape

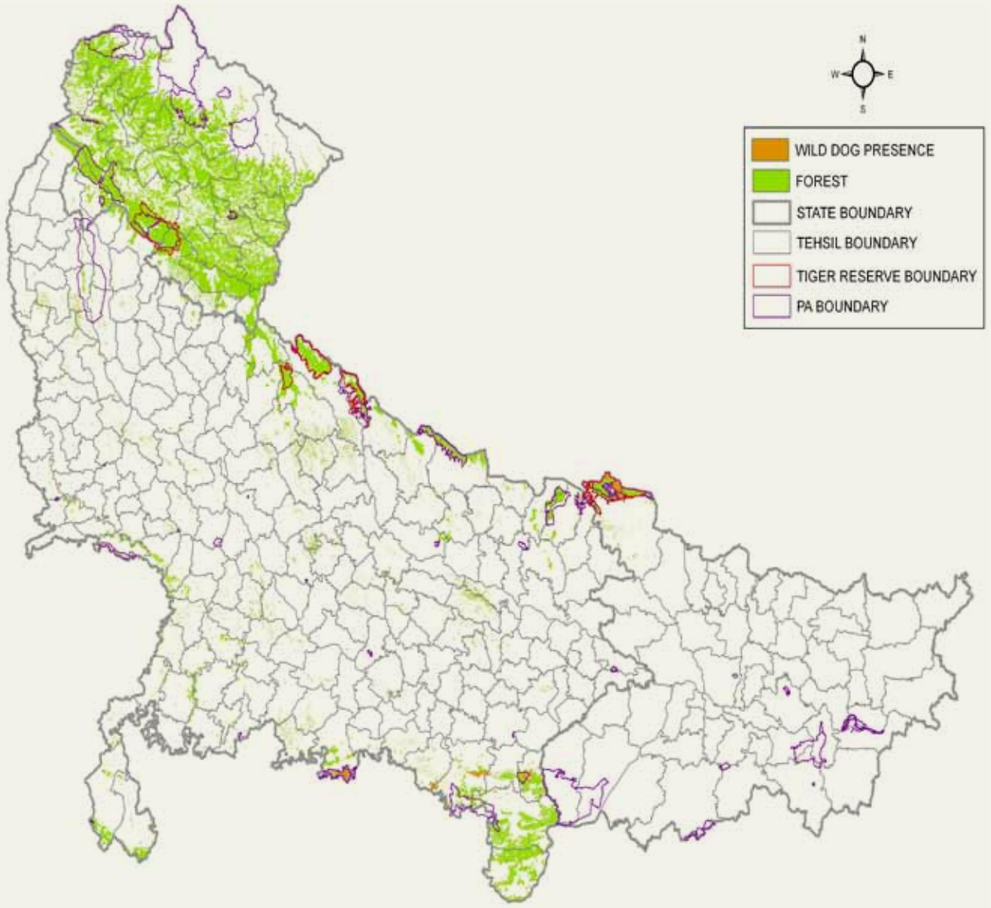


d) **Wild dog** (*Cuon alpinus*)

Dhole was recorded only from Valmiki Tiger Reserve and Mirzapur forests of south-eastern Uttar Pradesh covering an area of 791 km² (Fig. 1.5.4). A record was also obtained from Pratapnagar in Uttarakhand but this could likely be that of a feral dog, although dhole have occasionally been recorded in the higher reaches of the Himalayas.

Figure 1.5.4

Occupancy of wild dog in the Shivalik hills and the Gangetic plain landscape



UTTARAKHAND

The State of Uttarakhand has the highest forest cover amongst the Shivalik hills and the Gangetic plains landscape States with 24,495 km² under forest, constituting almost 46% of the geographical area of the State (State of the Forest Report 2009). With the Corbett Tiger Reserve, six National Parks, five Wildlife Sanctuaries and two Conservation Reserves administered by eight Forest Divisions, this State holds the most important areas for long term persistence of the tiger in this landscape.

The tiger habitat of this region comprises of three Protected Areas of Uttarakhand which include Corbett Tiger Reserve, Sonanadi Wildlife Sanctuary and Rajaji National Park. Corbett Tiger Reserve, one of the first nine Tiger Reserves in the country covers 1,318.54 km² of Garhwal, Almora and Udamsingh Nagar districts of Uttarakhand and a small part of Bijnore district of Uttar Pradesh. It comprises of the Corbett National Park, Sonanadi Wildlife Sanctuary, parts of Kalagarh Forest Division and Ramnagar Forest Division. The Ramganga Reservoir on its western boundary, constructed in 1974, inundated 46 km² of the riverine habitat of the Reserve while 92 villages are located within 2-3 kilometres of the Tiger Reserve.

The Reserve is named after Jim Corbett, the legendary author, conservationist and hunter of man-eating tigers and leopards in this region. Through Corbett's accounts of tigers, it is evident that the distribution of the species has reduced considerably in recent times in this zone. Corbett's first man-eating tigress, later called the 'Champawat Man-eater' was driven across the Kali river, into India from Nepal, after it killed over 200 people. The tigress thereafter spent some time in areas around present day Almora and Nainital districts and continued to kill human beings until she was finally shot. Corbett mentions this area as having witnessed man-eating tigers from the era prior to British accession of India as per official records. However, in contemporary times, tiger distribution is restricted to small islands in the *bhabar* such as Rajaji National Park and Corbett Tiger Reserve, while no recent reports of tigers exist from the higher reaches of districts such as Almora and Lohaghat.

Jhala *et al.* (2008) identified occupancy of tigers in 1,524 km² area in the Corbett landscape comprising of Corbett Tiger Reserve and its surrounding forests of Landsdowne, Kashipur, Ramnagar, western parts of Haldwani, north-western Nainital and lower elevation parts of Ranikhet with an estimated tiger population of 164 (151-178) (Fig. 1.UK.1). The second important population of tigers was in Rajaji National Park covering about 390 km² with a population of 14 (11-17) individuals.

The current (2010) tiger occupancy in the Corbett block covers an area of 2,287 km² with an estimate of 214 (190-239) individuals (Fig.1.UK.1). The Corbett population block has the highest tiger density in the world (9.4 tigers/100 km² at the landscape scale) and serves as a source for the entire landscape extending from Kalesar in Haryana to Pilibhit Forest Division in Uttar Pradesh. The other important tiger population in the State is that of Rajaji National Park covering an area of 736 km² with an estimated tiger population of 11 (8-15).

Several corridors connect different Protected Areas and Forest Divisions of this landscape and are essential to ensure movement of tigers across the entire landscape. These include:

a) Kansrao-Barkot between Rajaji National Park and Dehradun Forest Division.

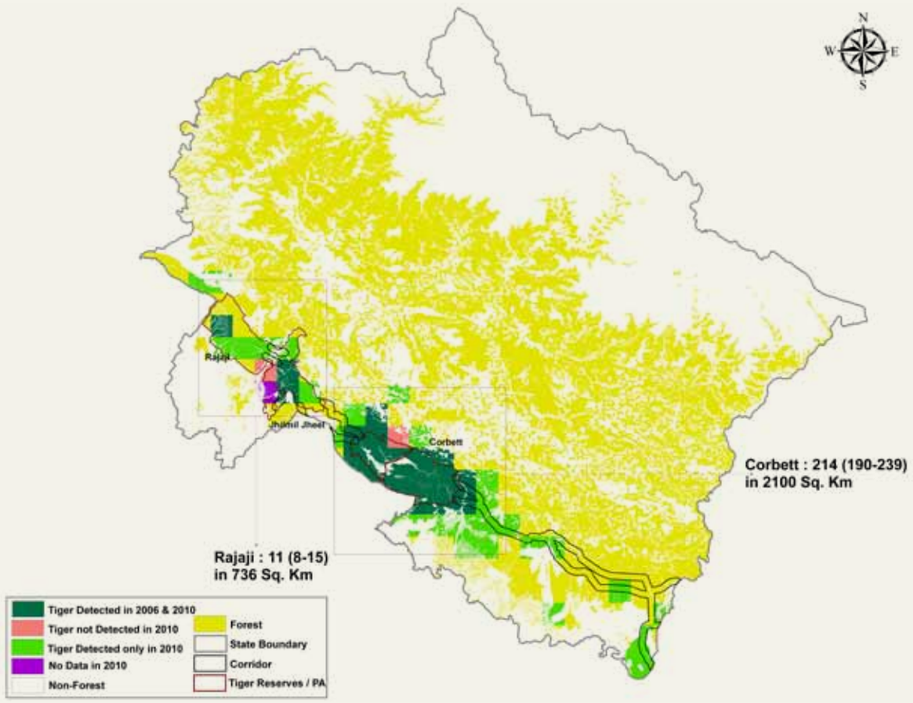
b) A narrow strip of forest west of Lal Dhang town that connects Rajaji National Park with Jhilmil Tal Conservation Reserve.

c) Chilla-Motichur connects the Chilla Range (eastern Rajaji) with Motichur Range (western Rajaji). This corridor is severely impaired (Johnsingh 2006b; Johnsingh 2004), (Fig. 1.UK.1.1), restricting the movement of tigers to western Rajaji, across the Ganga river.

Only two tigresses are known to occupy the area west of Rajaji since 2006, with no immigration of male tigers into this area from eastern Chilla. Thus, the future of tigers in this part of Rajaji National Park seems doomed unless connectivity to the source in eastern Rajaji is restored or tigers are relocated to the western part of Rajaji. A good population of tigers in western Rajaji is essential to maintain tiger occupancy across the Shivalik Forest Division into Kalesar and further into the foothills of Himachal Pradesh where tigers occurred until recently.

The most used part of this region, through the Motichur rau, is constricted by high human habitation due to the growing township of Haridwar on the south. To the north, a settlement (Khand Gaon 3) housing the Tehri dam oustees is located along with an army ammunition dump but is still potentially viable. This portion needs to be restored through acquisition and restorative management.

Figure 1.UK.1
Tiger occupancy, population extent, size and habitat connectivity in Uttarakhand



d) The Song river, flowing into the Ganga between Raiwala and Rishikesh, forms a corridor (Fig. 1.UK.1.1) that is heavily impacted by human habitation and agriculture. A lot has been written on the importance of this critical corridor for elephants as well as other wildlife (Johnsingh 1990; Johnsingh 2004; Menon 2005). However, there has been little progress on ground to restore it. Important considerations for revitalizing these corridors are: mitigation of the impact of the Delhi-Dehradun highway and railway traffic, power canal, and prevention of encroachment of the river islands in the Ganga.

Figure 1.UK.1.1
Chilla-Motichur and Song River Corridors

e) The Rajaji-Corbett corridors comprises of two smaller corridors: one through the Shivalik Hills (Lansdowne Forest Division) and the other through the Shivalik foot-hill forests of Haridwar and Bijnore Forest Division that connects Rajaji to Corbett Tiger Resere (Sonanadi Wildlife Sanctuary). Both these corridors (more so the Bijnore forest corridor) are threatened by the growing township of Kotwdar. The Bijnore corridor faces a severe bottleneck south-east of the township of Kotdwar where it passes through agriculture and human settlements (Fig. 1. 1.UK.1.2).

Figure 1.UK.1.2
Rajaji-Corbett Corridors

f) The Kosi river corridor connects Corbett Tiger Reserve to the Ramnagar Forest Division and onwards to the Forest Divisions of Terai West, Terai East and Haldwani. The connectivity between Corbett Tiger Reserve and the forests east of River Kosi, towards the plains, is impacted by the city of Ramnagar.

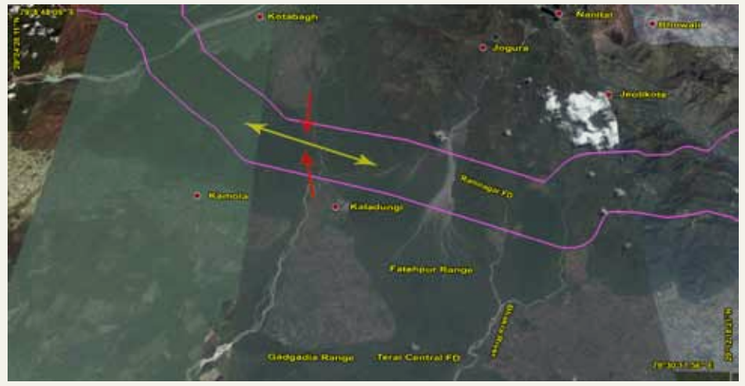
Towards the north, the steeper slopes of the lower Himalayas make the connectivity tenuous for species like the elephant. Linear development of resorts and hotels along the highway from Ramnagar to Almora along the banks of the Kosi makes the intervening habitat matrix hostile to movement of wildlife. Currently only two corridors remain, one to the north of Dhikala entrance to Corbett near Garjia Temple crossing the Kosi river, and another commencing from Bijrani Gate of Corbett eastwardly to Kosi river and beyond. The northern boundary of this southern corridor is south of the Dhikuli village and north of the Tons river (Fig. 1.UK.1.3). The above two corridors are the only remaining vital linkages for gene flow between Corbett and the eastern populations of tigers and elephants in UP (Kishanpur and Dudhwa) and Nepal (Suklaphanta and Bardia National Parks).

Due to the high demand and price of land within these corridors for tourism ventures, policy and legislation needs to be implemented urgently to secure them at the earliest before development deteriorates them further. Settlements in the northern section of the Reserve such as Sundarkhal need to be urgently relocated. Tiger densities and numbers in Ramnagar forests were high at 15.18(2.1) tigers per 100 km² and this population forms a continuous population with Corbett through the above mentioned corridors. It is therefore important to ensure this connectivity for the long term viability of this globally important tiger population.

Figure 1.UK.1.3
Kosi River Corridor

g) The connectivity through the plains (Gadgadia-Terai Central) (Fig. 1.UK.1.4) forests, south of the city of Haldwani is now deteriorated beyond recovery due to the growth of Lal Kuan and Haldwani urban infrastructure, along with agricultute and industry. The plains/foot hills corridor from east of Haldwani passes north of Chorgalia town through the forests of Terai East Forest Division (Fig. 1.UK.1.5). Though the least cost pathway defines the corridor across the Shivalik Hills in the East Terai Forest Division, the forests in the terai belt (plains) that are currently fragmented patches are extremely important for movemet of elephants that are unlikely to use the Shivalik corridor. The Nihil-Bhakra corridor (Fig. 1.UK.1.4) north of Kamala and Kaladhungi is important for tiger movement.

Figure 1.UK.1.4
Nihal-Bhakra Corridor and Gadgadia-Terai Central Corridor



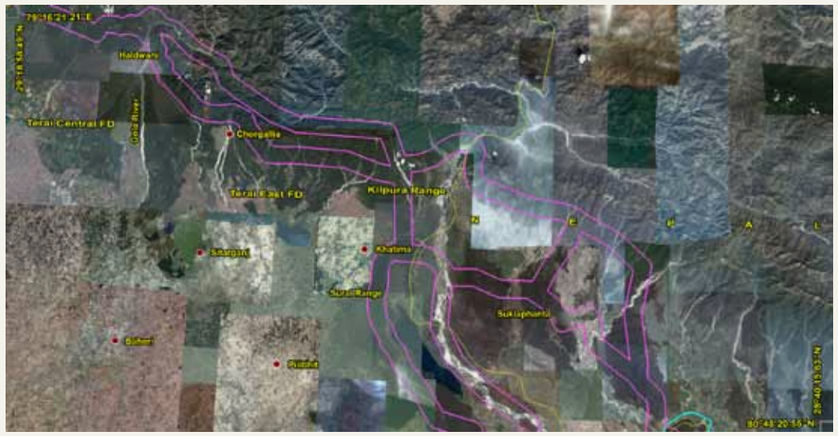
h) The Gola river corridor (Fig.1.UK.1.5) comprises of the north Kosi and south Kosi corridors that connect south west of Rampur village and continue eastwards through the forests of Choti Haldwani and Kaladungi upto the townships of Haldwani and Kathgodam. It is at this juncture that a severe bottleneck exists across the Gola.

Figure 1.UK.1.5
Gola River Corridor-Plains

Fig. 1.UK..1.6
Gola River Corridor-Hills

i) In Terai East, south-west of the township of Tanakpur (Kilpura range) the corridor bifurcates into two branches: the Kilpura corridor going north of Tanakpur to cross River Sharda above the barrage going into Nepal (Churia Hills-Bhramgiri Forests), and the Khatima-Surai corridor going south via Khatima and Surai Range into Plilbhit connecting further to Kishanpur (Dudhwa Tiger Reserve) (Fig.1.UK.1.7).

Figure 1.UK.1.7
Kilpura-Khatima Corridor



UTTAR PRADESH

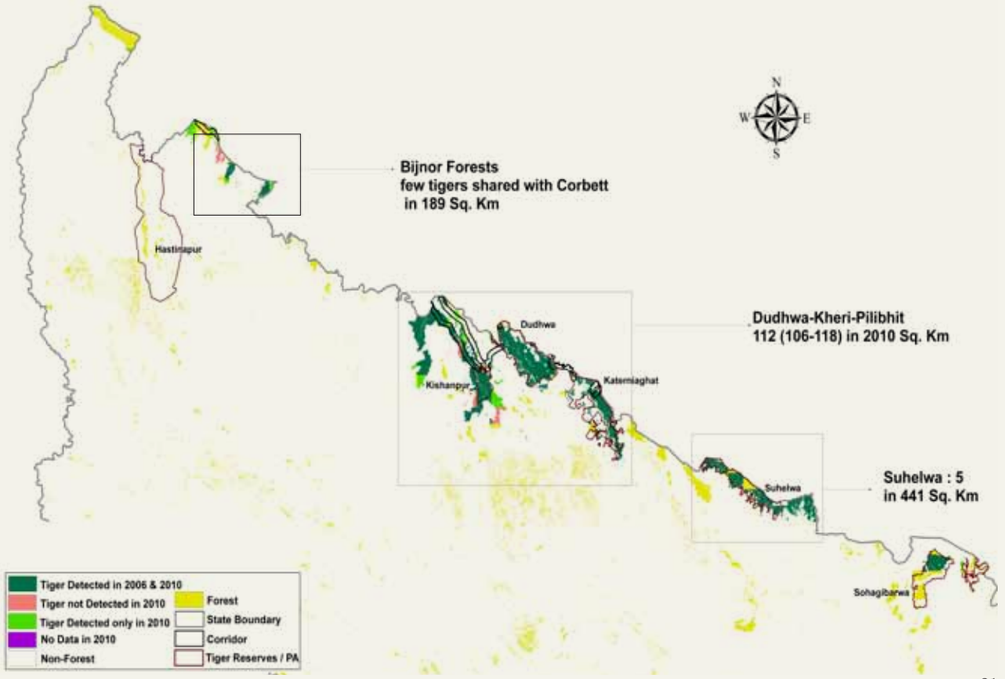
The State of Uttar Pradesh has 14,341 km² forested area which constitutes 5.95% of the total geographical area of the State (State of the Forest Report 2009). Almost all Protected Areas of the State are restricted to the northern border with Nepal, with the State having 3,175 km² of potential tiger habitat of priority I and II. Within this zone are one Tiger Reserve and one proposed Tiger Reserve, viz., Pilibhit. A proposal is awaited from the State government to declare Suhelwa a Tiger Reserve. The State also has one National Park and 23 Wildlife Sanctuaries, covering an area of 5,712 km².

Dudhwa Tiger Reserve comprises of a total area of 884 km² constituted by the Dudhwa National Park, Kishanpur Wildlife Sanctuary and Katerniaghat Wildlife Sanctuary in Bahraich district. Most of Dudhwa National Park is located within the Nighasan *taluka* of Lakhimpur-Kheri district while Kishanpur is in Lakhimpur-Kheri and Shahajahanpur districts. Between Dudhwa and Kishanpur is a distance of 15 kilometres occupied by agricultural fields. The Mohana river forms the northern boundary of Dudhwa while the Suheli river forms the southern boundary. Apart from being a Tiger Reserve, Dudhwa has also been the site for the re-introduction of the rhinoceros, which was introduced in the National Park in 1984-85.

Jhala *et al.* (2008) identified the following tiger populations in the State (Fig. 1.UP.1):
a) A major tiger population in Dudhwa Tiger Reserve complex covering an area of 1,833 km² with an estimated population of 95 (80-110) individuals.
b) A smaller population from the forests of Suhelwa covering 475 km² with around 6 (3-10) individuals.

Figure 1.UP.1

Tiger occupancy, population extent, size and habitat connectivity in Uttar Pradesh

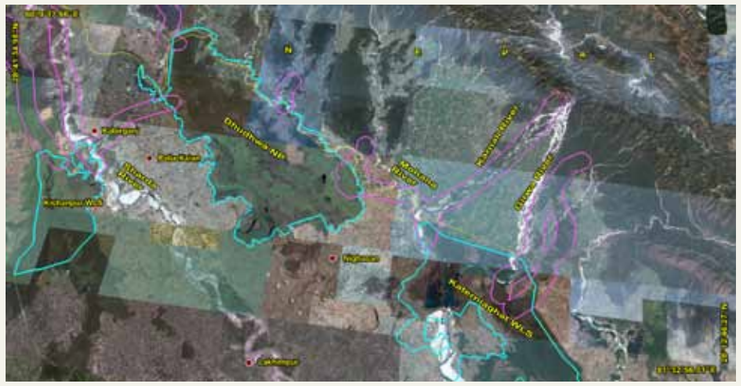


c) Several smaller and sporadic populations from forests of Bijnore with occupancy in 221 km² and Sohagibarwa covering 139 km².
d) Several smaller and sporadic populations were also reported from the forests of Sonbhadra.

The important tiger populations in Uttar Pradesh estimated in 2010 are (Fig. 1.UP.1):
a) Dudhwa-Kheri-Pilibhit comprising of Dudhwa National Park, Kishanpur and Katerniaghat Wildlife Sanctuaries and Forest Divisions of Kheri and Pilibhit with tiger occupancy in 2,010 km² and an estimated population of 112 (106-118) tigers. Tiger density for the landscape was estimated at 5.4 tigers/100 km².
b) Suhelwa with tiger occupancy in 441 km² and with about 5 tigers that are shared with the forests of Mahadevpuri that further connect to Banke National Park of Nepal.

The connectivity between Dudhwa-Kishanpur Wildlife Sanctuary and River Sharda is highly fragmented with oxbow lakes and forest fragments in a primarily agricultural matrix (sugarcane). To the north, it is connected to the Churia hill forests of Nepal through a riverine corridor while to the west river channels and forest patches connect it to Suklaphanta (Fig. 1.UP.1.1). The Mohana river acts as a corridor connecting Dudhwa to Katerniaghat in the east and to Bardia National Park of Nepal in the north (Fig. 1.UP.1.1).

Figure 1.UP.1.1
Dudhwa-Katerniaghat Corridor



The Dudhwa-Katerniaghat corridor along the Mohana has been greatly deforested and needs to be restored to allow movement of wildlife. The other important corridors in this region, essential for movement of animals between Nepal and India are the Basantha and Khata corridors. The Khata corridor along the Girwa river also connects Katerniaghat to Bardia and is often used by elephants, tigers, and rhinos. The river channels in this landscape are also a conduit for the movement of gharials, crocodiles and Gangetic dolphins.

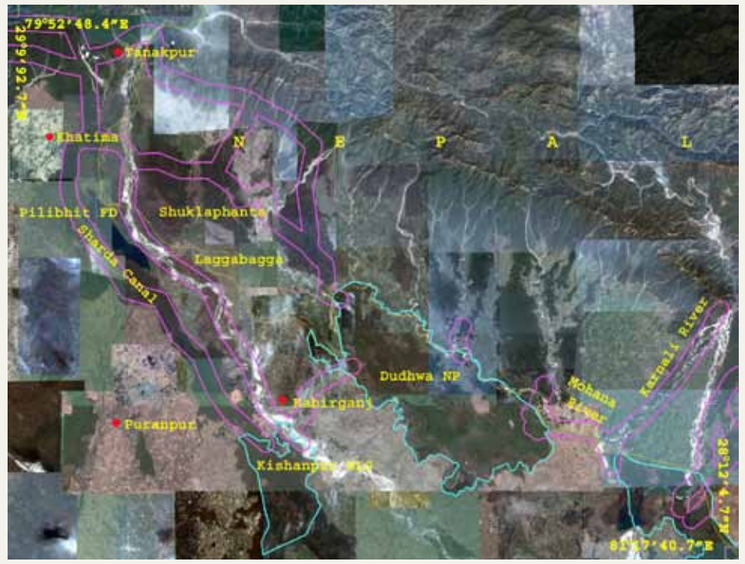
Further east of Dudhwa along the Indo-Nepal border is Suhelwa, composed of forest blocks spanning across Bahraich and Gonda districts. This region experiences high hunting and poaching pressures with restricted protection levels, primarily due to an open international border with Nepal.

On the extreme north-eastern end of Uttar Pradesh, in continuation with Valmiki Tiger Reserve of Bihar is Sohagibarwa Wildlife Sanctuary in Maharajganj and Pharenda *talukas* of Gorakhpur district.

While connectivity between Dudhwa-Katerniaghat-Suhelwa and Sohagibarwa on the Indian side is almost non-existent, forests along the Nepal *terai* connect these areas.

The other important forested area in the State is Pilibhit Forest Division which is connected to the Corbett Tiger Reserve in the north-west by the Surai Range and to Suklaphanta National Park in Nepal to the north-east via forests of Lagga-Bagga (Fig.1.UP.1.2). It forms a continuous narrow corridor along the Sharda canal that stretches south-east into Kishanpur Wildlife Sanctuary. This corridor is well used by tigers forming a contiguous population from Surai Range in Uttarakhand to Pilibhit and Kishanpur. However, the narrow Pilibhit corridor is a bottleneck as dense agriculture and human settlements line its borders (Fig. 1.UP.1.2). The Sharda river forms a minor corridor since it is lined by intensive agricultural activity on both banks. Nonetheless, it is used by tigers and elephants to move between Dudhwa-Kishanpur-Lagga Bagga-Suklaphanta.

Fig. 1.UP.1.2
Pilibhit-Suklaphanta-Dudhwa Corridor



BIHAR

The State of Bihar has a forested area of 6,804 km² constituting 7% of the total geographical area of the State, making it the least forested State of the tiger occupied States in India. The only Tiger Reserve in the State is Valmiki Tiger Reserve located in the extreme north-eastern corner along the international border with Nepal. The State also has one National Park and 12 Wildlife Sanctuaries, most of which are restricted to the southern border with Jharkhand.

Valmiki Tiger Reserve occupies 880.78 km² area of the northern most part of West Champaran district in Bettiah taluka. It is connected to the Chitwan National Park in Nepal to the north through the Churia forests and has a highly undulating terrain, which to some extent restricts movement of animals between the two countries. However, animals are known to move across the international boundaries.

About 142 villages are situated on the peripheries of the Reserve enhancing disturbance levels within the Park. The Reserve also has a weak, interrupted connectivity on the south-west to Sohagibarwa Wildlife Sanctuaries of Uttar Pradesh which enables persistence of tigers in the latter Reserve. Jhala *et al.* (2008) estimated tiger occupancy in 510 km² of the Reserve with an estimated population of 10 (7-13) tigers.

On the southern side of Bihar, Kaimur Wildlife Sanctuary in Rohtas district is connected to the Kaimur Wildlife Sanctuary of Uttar Pradesh. However, since both these Protected Areas lack adequate protection and have very high levels of human disturbance, tiger presence in this zone is unlikely. The Gautam Buddha Wildlife Sanctuary in this region along the Jharkhand border is contiguous with forested regions in Kodarma district of Jharkhand. This area could potentially act as a tiger dispersal route, provided high level of protection is given to the forests in this region.

Tiger occupancy in Valmiki Tiger Reserve was estimated at 750 km² in 2010, with a population of about 8-10 tigers that are shared with Chitwan National Park in Nepal (Fig. 1.BR.1.1). Despite the high human pressures, this area is able to sustain tiger populations due to its proximity and connectivity to the source population of tigers in the Chitwan National Park.

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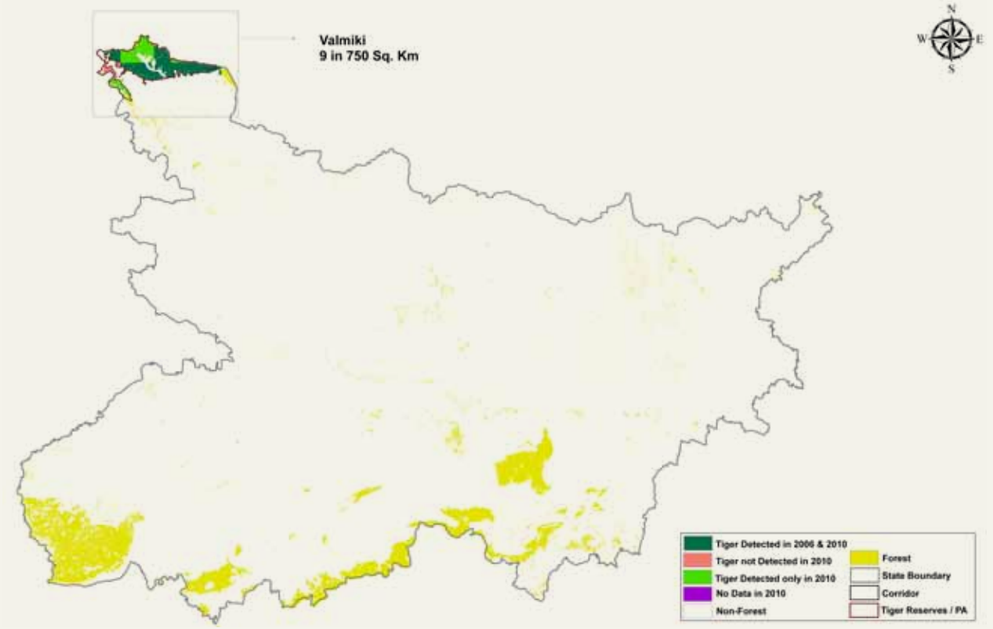
Figure 1.BR.1

Tiger occupancy, population extent, size and habitat connectivity in Bihar



Tiger population status summary for the Shivalik hills and the Gangetic Plain landscape

State	Tiger Population			Tiger km²		
	2006	2010	Increase/ Decrease/ Stable	2006	2010	Increase/ Decrease/ Stable
Uttarakhand	178	227	Increase	1,901	3,476	Increase
Uttar Pradesh	109	118	Stable	2,766	2,511	Stable
Bihar	10	8	Stable	510	750	Increase
Shivalik-Gangetic	297	353	Increase	5,177	6,712	Increase

2.0 CENTRAL INDIA LANDSCAPE AND EASTERN GHATS

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The Central Indian landscape is bounded by the Aravalli Range in the north-west, the Satpura Range in the south, Chota Nagpur plateau in the north east and the Odisha hills in the south-east. Within this zone are located several hill ranges with elevations ranging between 200 m and 1000 m such as the Vindhyas, Mahadeo Hills and the Maikal Range. Much of the region is forested since the hills and plateaus with patches of shallow infertile soils do not permit extensive cultivation.

The Aravallis in the north-west are amongst the oldest mountains in the world. They stretch for over 700 kilometres from Gujarat to Delhi in a southwest-northeast direction (Mani 1974) with an extensive belt in Rajasthan, most of which is mined for granite, marble and limestone. South-east of the Aravallis is the Malwa plateau at an average elevation of 500 m. Ujjain is an important town located on this plateau which slopes gradually to the north and is drained primarily by the Chambal. On the west, this tableland descends into the plains structuring the relatively low Malwa Ghats. Fertile black cotton soil of this Deccan Trap region promotes cultivation of opium, tobacco, cotton, millets and sugarcane with large areas under cultivation.

South of Malwa is located the Vindhya Range running east-west for about 400 kilometres and rising to an average elevation of 760 m (Mani 1974). To the north of the central part of this range lies the Vindhyan tableland with cities like Bhopal. The Vindhyas in the north and the Satpuras in south form a wide valley through which River Narmada flows, after crossing the gorge that lies east of Bheraghat near Jabalpur. Together, the Vindhyas and the Satpuras divide the peninsular region of India from the Indo-Gangetic Plains (Mani 1974). The latter are amongst the most prominent hills of this region extending from eastern Gujarat to Chhattisgarh covering over 900 kilometers with several peaks over 1000 m. Between the Satpuras and the Gawilgarh Hills flows River Tapi which is separated from its tributary Purna by the Gawilgarh Hills.

The northern Sahyadris, through the Saputara Hills in the Dangs of southern Gujarat act as a connecting zone between the Western Ghats and the Central Highlands. Mahadeo Hills (Pachmari Hills) form a part of central Satpuras while beyond the Jabalpur Gap towards the east is the Maikal Range close to Amarkantak plateau from where the Narmada originates at 1065 meters. The Vindhya-Kaimur scarp flanks the alluvial trough of Narmada for over 1000 kilometres once it descends from the marble rock region of Jabalpur (Mani 1974).

The low Kaimur Range with an average elevation of 600 m crosses the centre of the eastern section of the Central Highlands sloping sharply to the Son Valley and gradually to the Ganga Valley in the north. In the south, the Rewah plateau has several coal mines primarily in Umaria district operated by the South Eastern Coalfield Limited. The largest coalfields in India stretch southeast towards the Mahanadi Valley and east towards the Damodar Valley from here.

Along the central northern parts of Madhya Pradesh is located the Bundelkhand Plateau with towns such as Panna and Chhattarpur. The former was once known for its diamond mines while the latter for its paper manufacturing. The region between the Bundelkhand Hills and River Son comprises of a plateau with steep slopes with discontinuous patches of forests.

As one proceeds further east, the main mining belt of India begins. The Chota-Nagpur plateau situated in this zone comprises of the Hazaribagh, Ranchi and Koderma plateau in a step like formation. The western Ranchi plateau being the highest is

Major tiger populations, their status, political units and corridors in the Central India Landscape and Eastern Ghats

Tiger Population	State/s	Tiger abundance 2006	Tiger abundance 2010	Increase/ Decrease/ Stable	Area occupied (km^2) in 2006	Area occupied (km^2) in 2010	Increase/ Decrease/ Stable	Connecting corridors
Sariska	Rajasthan	NE	5	NE	NE	300	NE	None
Ranthambhore	Rajasthan	32(30-35)	31 (30-32)	Stable	344	613	Increase	Ranthambhore-Kailadevi-Kuno-Madhav
Kuno-Shivpuri-Madhav	Madhya Pradesh	5 (3-6)	3	Stable	316	257	Decrease	Ranthambhore-Kailadevi-Kuno-Madhav
Raisen	Madhya Pradesh	10 (7-12)	16 (14-18)	Increase	NE	822	NE	Indore-Dewas
Indore-Dewas	Madhya Pradesh	NE	7	NE	NE	360	NE	Raisen
Satpura	Madhya Pradesh	39(26-39)	43 (42-46)	Increase	1,500	1,671	Increase	Betul-Hoshangabad-East Nimar-Melghat, Satpura-Pench
Panna	Madhya Pradesh	24(15-32)	4	Decrease	787	444	Decrease	Chhatarpur landscape
Pench	Madhya Pradesh	33(27-39)	65 (53-78)	Increase	718	2,857	Increase	Pench-Satpura, Pench-Kanha
Bandhavgarh	Madhya Pradesh	47(37-56)	59 (47-71)	Stable	1,575	2,053	Increase	Bandhavgarh-Sanjay-Dubri-Guru Ghasidas-Palamau Bandhavgarh-Achanakmar-Kanha
Kanha#	Madhya Pradesh	89(73-105)	60 (45-75)	Stable	3,162	2,607	Decrease	Kanha-Pench, Kanha-Phen WLS-Achanakmar Kanha-Navegaon-Nagzira
Achanakmar	Chhattisgarh, Madhya Pradesh	19(18-22)	12 (11-13)	Decrease	1,066	950	Decrease	Kanha-Phen WLS-Achanakmar, Bandhavgarh-Achanakmar-Kanha
Sanjay-Dubri-Guru Ghasidas	Madhya Pradesh, Chhattisgarh	NE	5	NE	NE	675	NE	Bandhavgarh-Sanjay-Dubri-Guru, Ghasidas-Palamau
Melghat	Maharashtra	30(21-39)	35 (30-39)	Stable	1,828	2,761	Increase	Melghat-Betul-Hoshangabad-East Nimar, Melghat-Satpura
Bor	Maharashtra	NE	12	NE		775	NE	Bor-Pench (Maharashtra), Bor-Navegaon-Nagzira
Tadoba-Chandrapur	Maharashtra	34(27-41)	69 (66-74)	Increase	775	3,241	Increase	Tadoba-Andhari-Chandrapur-Garhchiroli-Indravati Tadoba-Navegaon-Nagzira-Kanha
Sayadhri-Sindhudurg	Maharashtra	NE	21 (20-22)	NE	NE	1,119	NE	Sayadhri-Radhangiri WLS-Anshi-Dandeli
Nagzira-Navegaon	Maharashtra	NE	20 (18-21)	NE	NE	657	NE	Kanha-Navegaon-Nagzira Bor-Navegaon-Nagzira Tadoba-Navegaon-Nagzira
Adilabad-Khammam	Andhra Pradesh	19(17-34)	5	Decrease	3,955	731	Decrease	Indravati tiger reserve
Srisailam	Andhra Pradesh	53(49-57)	60 (53-66)	Increase	13,741	3,159	Decrease	Nagarajunasagar-Srisailam-Gundla Brahmeshwaram-Sri Venkateshwara
Simlipal	Odisha	20(17-23)	23 (12-34)	Stable	2,294	1,088	Decrease	Satkosia-Kendujhar-Dhenkanal-Simlipal
Satkosia	Odisha, Chhattisgarh	6(5-7)	8 (7-9)	Increase	787	450	Decrease	Satkosia-Kendujhar-Dhenkanal-Simlipal
Baranwapara	Chhattisgarh	NE	8	NE	NE	428	NE	Udanti Sitanadi-Sonabeda
Palamau	Jharkhand	NE	10 (6-13)	NE	NE	1,116	NE	Bandhavgarh-Sanjay-Dubri-Guru, Ghasidas-Palamau

Madhya Pradesh Govt has reassessed the population status in 2011. NE : Not Estimated

almost continuous with the Sarguja plateau with an average elevation of 1000 m composed of Deccan Lavas, followed by the most extensive Ranchi plateau with an average elevation of 600 m which slopes into the Singhbhum region and is highly dissected peneplain. The River Damodar originates in this region and the Satpahar and Mahadeva Hills in this region have several sacred groves called 'sarna'. Along the border with west Bengal is the Kodarma plateau while further east is located the Manbhum plateau region.

The Eastern Ghats are located parallel to the east coast of India from Mahanadi Valley to further south of Krishna Valley.

2.1.1 Location

This landscape covers a vast area encompassing the States of Madhya Pradesh, Chhattisgarh, Jharkhand and parts of Rajasthan, Maharashtra, Odisha and Andhra Pradesh. The western parts of Maharashtra are a part of the Western Ghats landscape, while parts of Andhra Pradesh form the Eastern Ghats landscape. However, for the sake of convenience and ease of applying conservation policy and management actions, these States are not split but discussed as part of the Central Indian Landscape.

With 19 Tiger Reserves and several other protected areas, 4.1% (Qureshi *et al.* 2006) of this area is under forest cover marked by rapid conversion of forests to other land-uses such as agriculture and mining operations.

Within this landscape are located smaller sub-units of TRs that incorporate one or several Protected Areas that may or may not have the tiger, yet are essential for long term persistence of the species in the region. These include:

a) Sariska: Within the Aravallis of Rajasthan is located the Sariska Tiger Reserve. The isolated nature and inadequate protection levels in the Reserve led to local extinction of the tiger in 2004 (Narain *et al.* 2005). Thereafter, five tigers have been reintroduced in Sariska with the hope of re-establishing a breeding population of the species in the future.

b) Ranthambhore-Kuno-Shivpuri landscape: The Ranthambhore Tiger Reserve in Rajasthan is connected to the Kuno-Palpur landscape in Madhya Pradesh through Keladevi Wildlife Sanctuary and forest patches in the north-east. This landscape unit has over 2500 km² of potential tiger habitat within a forested area of over 4000 km².

c) Panna: This Tiger Reserve is located in the Vindhya Range and formed a part of the Bandhavgarh-Sanjay-Guru Ghasidas-Palamau complex. However, in recent years, Panna has been isolated and forms part of a linear east-west forested patch of about 2000 km². This site has also experienced extinction of the tiger and subsequently five tigers have been reintroduced of which two tigresses have littered. In 2011, a successful introduction was also done of a hand reared tigress that was taught to hunt wild prey.

d) Bandhavgarh-Sanjay-Guru Ghasidas-Palamau: This zone comprises of the Bandhavgarh Tiger Reserve located between the Vindhyas and Satpuras of Madhya Pradesh with a feeble connectivity to Sanjay-Dubri Tiger Reserve in Sidhi district of which the proposed Guru Ghasidas National Park in Chhattisgarh was a part in the undivided state of Madhya Pradesh. To the north-east, this zone is connected to Palamau Tiger Reserve of Jharkhand. This forested landscape is over 13,000 km² and with good management has the potential of harbouring a viable tiger population along with populations of other wildlife of the region.

e) Kanha-Pench-Achanamkmar: Located within the central part of this landscape these Tiger Reserves span across the States of Madhya Pradesh, Maharashtra and Chhattisgarh. The forested landscape covers over 20,000 km² and has two major source populations of tigers (Kanha and Pench Tiger Reserves) existing as a metapopulation.

f) Pench-Satpura-Melghat: While Melghat Tiger Reserve is located on the Gawilgarh Ridge of the Satpuras on the Madhya Pradesh-Maharashtra border, the Satpura Tiger Reserve is located within the same Range to the north-east. Melghat-Satpura landscape covers over 12,700 km² of forested habitat and exists as a metapopulation. Connectivity between Satpura and Pench Tiger Reserves is through stepping stone forest patches.

g) Nagzira-Indravati: This unit spans the insurgency prone areas of Maharashtra and Chhattisgarh covering some of the best forests of this landscape in Bastar. Some of the important Protected Areas in this sub-unit are Navegaon, Tadoba Tiger Reserve and Bhandara Forest Division. The forested landscape covers over 34,000 km² and has the potential to sustain viable populations of endangered species including those of wild buffalo and tigers.

h) Isolated forests of Simlipal and Nagarjunasagar-Srisailam: Both these Tiger Reserves extend over large areas (3800 and 8000 km² respectively) of tiger habitat, located along the Eastern Ghats in Odisha and Andhra Pradesh. However, the presence of left wing extremism has undermined conservation efforts in this region.

Apart from the existing 17 Tiger Reserves in this zone, four new areas have been proposed as Tiger Reserves: Ratapani in Madhya Pradesh, Sunabeda in Odisha, Mukundara Hills (comprising of Darrah, Jawaharsagar and Chambal Wildlife

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Sanctuary) in Rajasthan and Kawal Wildlife Sanctuary in Andhra Pradesh. Proposals have also been invited from Bor, Nagzira-Navegaon Wildlife Santuaries and Guru Ghasidas National Park to be considered as Tiger Reserves.

As per Rodgers and Panwar (1988) this landscape is covered by several bio-geographic zones, which include Semi-Arid (Punjab plains and Gujarat Rajputana), Western Ghats (Malabar plains and Western Ghats mountains), Deccan Peninsula (Central Highlands, Chota-Nagpur, Eastern Highlands, Central plateau and Deccan South) and Gangetic Plains (Upper Gangetic plains and Lower Gangetic plains) and Coasts (East coast and West coast).

While this landscape has amongst the finest tiger habitats of India, it also is a home to India's largest scheduled tribe population most of who are amongst the poorest in the country. Incidentally, this is also the area with the highest concentration of minerals and thus mining interests (Narain *et al.* 2005). This makes conservation a major challenge.

The State of Madhya Pradesh is the highest producer of diamonds, pryophyllite and copper ore while Jharkhand ranks first in iron ore, mica, uranium and asbestos. The best iron ore deposits in India are at Bailadila mines in Dantewara in Chhattisgarh and most of the State revenue is generated from the 28 varieties of minerals mined. The Damodar Valley, south of Rajmahal Hills contains coal bearing Gondwana basins while south of the Ranchi Plateau lies the Singhbhum shear-zone with large tracts of uranium and copper. The Gangpur series to the west of the rich iron ore zone of eastern Singhbhum, has dolomite, limestone, quartzite and phyllite store houses. The other states also have large tracts under mining of minerals like iron ore, fluorite, dolomite, limestone, coal and granite.

These large mineral deposits often result in the conflict of interest between conservation and revenue sources.

2.1.2 Ecological Background

Amongst the oldest mention of this area has been in the Ramayana and the Mahabharata which mention all areas south of the Yamuna as those with vast wilderness full of demons and snakes (Rangarajan 2001). However, historical records from this region date back to the 5th and 14th centuries, making it known that the Aryans had occupied parts of this region which was primarily occupied by Dravidian tribes until then, predominant amongst them being the Gonds after who this area was called Gondwana (Forsyth 1919). Around 14th century, the Mughals starting conquering parts of northern India, which led to an exodus of several Rajputs into this region who established small chieftainships here. Development and exploitation of resources in this zone started only during the reign of Akbar when he had a highway built from Upper India to the Deccan through a gap in the Satpuras. A large city also came up during this period in the valley of Tapi and became the seat of government in the southern provinces while large tracts were reclaimed by Hindu immigrants from the north and the east in the Narmada Valley and the Berar regions until the conquest of most of this region by the Marathas and the plundering Pindaris (Grant 1870; Forsyth 1919). By the time the British entered this zone in 1818, the local tribes of the region had taken to living in the higher reaches of plateaus and hills and continued with their subsistence level agriculture and hunting-gathering. Parts of present day Madhya Pradesh and the Deccan had several urban centres such as Ujjain, Bhopal (Bhojpur), Mandavgarh (Dhar) and Jabalpur. Mandav was called the doorway to Deccan and these centres were ruled by Rajputs and the Sultanate. Sanchi has been described by several Chinese travellers as an important city during the reign of Ashoka and thereafter.

Even for the British, reclamation of most parts of this forested country was a challenge with large tracts remaining unexplored until as late as 1853 (Forsyth 1919). In 1854, Nagpur was annexed by the British due to lack of an heir while Berar regions of the Nizam were under British administration in addition to large tracts in the Narmada and Sagar regions. By 1861, the Central Provinces were constituted and a forest department was created to explore and conserve the timber wealth of these areas.

Most of this area remained under shifting cultivation (called 'dahya' in the Satpuras) practiced mainly by the Korku and the Gond tribes until the British discouraged the practice around 1860s (Mukherjee 1984). Captain J. Forsyth was the first explorer in the western Satpuras in 1862 where he built the 'Bison Lodge' (Mukherjee 1984). With the Forest Act of 1865, large areas were notified as Reserved Forests and the indigenous communities continued to live a marginal life.

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Until the independence of India, most of this area remained under the control of many small and large princely states and partly under the direct administration of the British Rule. Some idea of the abundance of wildlife in this region can be drawn from the shooting records of erstwhile rulers and British in this region. The unpopular highest record for tigers shot is held by Ramanuj Singh Deo of Sarguja who shot 1116 tigers and about 2000 leopards in his lifetime, most of them within the boundaries of his Princely State, followed by 616 shot by the Maharaja of the neighbouring State of Rewa (Rangarajan 2001). Incidentally, it was in the forests of Rewa that the first white tiger was sighted and subsequently captured to raise more such individuals in captivity. Within the same zone, in the erstwhile princely State of Korea, the last quarry of three cheetahs was shot in present day Guru Ghasidas NP in 1951 (Divyabhanusinh 1999). Records exist of tigers being killed extensively in this region until 1900s.

In the Central Provinces the vast tracts of timber led to an organised forest department with most government forests being Reserved Forests where all user rights were recorded and settled. States like Sarguja had their hunting grounds divided into zones with grazing allowed in some and completely banned in the others (Rangarajan 2001).

It was primarily within this zone that Col. Kesri Singh had witnessed and organised over a 1000 tiger shoots in his lifetime with most of them in the Royal hunting grounds of Jaipur at the Ranthambhore Tiger Reserve. However, it would be unfair not to recognise the levels of protection given to wildlife in princely hunting reserves within

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this zone, most of which are the only sites in the country with viable tiger populations even today despite their numbers having dwindled extensively post independence.

Apart from the hunting, and existence of royal hunting grounds, this region also has witnessed several plans of reintroducing large carnivores. In the pre-independence era, the Maharaja of Gwalior introduced African lions while Kuno-Palpur was selected as a potential reintroduction site for the lion in more recent times. Even for the very recent, ambitious cheetah reintroduction plan, seven potential reintroduction sites were proposed from within this landscape.

2.1.3 Conservation Importance

Apart from being the largest tiger occupied landscape in the country and having the largest number of tigers, this landscape also encompasses several biosphere reserves. Of the three biosphere reserves viz., Simplipal, Pachmarhi and Achanakmar-Amarkantak, the former two are also a part of the UNESCO's Man and Biosphere Programme (MAB).

In terms of tiger conservation, this area has been recognised as important with four level I tiger conservation units (TCUs), five at level II, 24 at level III and three sites as priority survey sites. Johnsingh and Goyal (2005) recognised the Satpura-Kanha-Bandhavgarh TCU as the second best in the country with 4000 km² protected area, comprising of Bori, Satpura, Pachmari, Pench, Kanha and Bandhavgarh Protected Areas with a population of about 350 tigers and capable of sustaining upto 500 tigers.

The Palamau-Kodarma and Indravati-Kangerghati-Papikonda landscapes despite having vast tiger habitats of 40,000 and 30,000 km² (Jhala *et al.* 2008) respectively are affected by left wing extremism, high livestock grazing, forest fires and poaching which makes tiger conservation challenging. Similar issues exist also in Nagarjunsagar-Srisailam and Simlipal-Hadgarh landscapes even though they are very productive areas.

2.1.4 Vegetation

According to the Champion and Seth (1968) classification, most of this landscape has tropical dry deciduous forests with small sections of tropical moist deciduous forest in the eastern region and tropical thorn forest in western parts along the junction of Madhya Pradesh, Uttar Pradesh and Rajasthan.

The tropical hill forests of Madhya Pradesh restricted primarily to the Pachmari and Bailadilla Hills comprise chiefly of *Syzigium cumini, Rhus ellipticus, Murraya paniculata, Dillenia pentagyna* and *Sterculia villosa* along with climbers such as *Gnetum ula, Acacia torta* and *Clematis triloba*. Tree ferns like *Cyathea gigantean* and *C. latebrosa* are common in the gorges of Pachmari.

Dry teak forests are found in parts of eastern Rajasthan along the border of Madhya Pradesh and within Madhya Pradesh with species such as *Tectona grandis* and its associates like *Anogeissus latifolia* and *Terminalia spp., Diospyros tomentosa, Hardwickia binata* and others like *Pterocarpus marsupium, Dalbergia latifolia, Cassia fistula, Butea monosperma, Adina cordifolia, Mitragyna parviflora, Bridelia retusa, Aegle marmelos, Lagerstroemia parviflora, Wrightia tinctoria, Bauhinia spp., Dendrocalamus strictus, Woodfordia fruticosa* and *Helictoris isora* while valleys provide transition towards moist deciduous forest.

The Narmada is often considered as a natural boundary between the teak forests of the southern peninsula and the sal forests of northern plains (Forsyth 1919). However, the overlap of the two zones (northern moist sal and southern dry teak forests) occurs in the Raipur Forest Division of Madhya Pradesh.

In the western parts of Madhya Pradesh, teak forests occur while rest of the region inclusive of Chhattisgarh and Jharkhand has sal. Sal forests have species like *Shorea robusta, Terminalia alata, Bombax ceiba, Madhuca longifolia, Mallotus* spp., *Diospyros melanoxylon* and *Ougeinia* and climbers such as *Bauhinia vahlii, Olax scandens* and *Combretum roxburghii* occur frequently.

In the moist peninsular sal forests of eastern Madhya Pradesh, Chhattisgarh and parts of Odisha the predominant species include *Syzygium cumini, Dendrocalamus strictus, Shorea robusta, Bauhinia* spp., *Albizia chinensis, Emblica officinalis, Terminalia* spp., *Adina cordifolia, Mitragyna parviflora, Lagerstroemia* spp., *Anogeissus latifolia* and *Gmelina arborea*. In the undergrowth evergreen species like *Canthium dicoccum* and *Cycas circinalis* are also found. On the plateau of Achanakmar, an area of about one square kilometre is covered by *Drosera* sp. while over 25 species of Pteridophytes can be found in the region. In Singhbhum region, as per Mooney (1938), flat topped hills with elevations over 800 m have *Shorea-Bauhinia-Themeda* associations with *Bauhinia retusa* being predominant, while areas with good soil have *Shorea-Wendlandia-Indigofera* associations and valleys have *Shorea-Moghania-Imperata* associations. *Schleichera oleosa* and *Adina cordifolia* are common species in the region while along streams evergreen species may occur.

Tropical dry forests occur to the west and north of Narmada-Son trench in areas with about 75 cm of rainfall. Common species in these regions include *Anogeissus latifolia, Terminalia alata, T. bellerica, D. melanoxylon, B. serratta, Buchanania lanzan, Madhuca longifolia* var. *Latifolia, Aegle marmelos* and *Cassia fistula*. Common climbers include *Smilax zeylanica, Asparagus racemosus* and *Ichnocarpus frutescens*.

Mixed forests are found in areas around Dhar, Indore, Dewas to Sehore, Sagar, Damoh, Chhattarpur and Sidhi with *Terminalia alata, Acacia pendula, Boswellia serratta, Sterculia urens, Tectona grandis* and *Mitragyna parviflora*. *Boswellia* is conspicuous in these regions along with *Hardwickia binata* and *Soymida febrifuga*. Depending on soil quality, *Chloroxylon swietenia* may be present which is an indicator of this vegetation type and is absent from moist deciduous forests.

The Chambal ravines of Bhind, Morena and Datia have thorn forests with the predominant species being *Acacia* spp., *Anogeissus pendula, Carissa spinarum, Ziziphus* spp., *Wrightia tinctoria, Euphorbia nivlia* and *Prosopis juliflora*.

Hardwickia forests are scattered in patches in drier parts of the Satpuras (Khargaon, Kannod Divisions of Madhya Pradesh) through Maharashtra (Khandesh, Nasik) southwards into Andhra. In such regions, 70% forest comprises of *Hardwickia binata* with other species such as *Boswellia serrata, Lannea coromandelica, Anogeissus latifolia, Albizzia lebbeck, Lagerstroemia parviflora, Diospyros tomentosa, Tectona gradis, Acacia catechu* and *Dendrocalamus strictus*.

In parts of Palamau, *Aegle* forests occur with *Phoenix sylvestris* growing along smaller streams. These forests may occasionally be associated with *Butea, Carissa, Capparis* and *Salvadora*. In this region and on hillsides in Madhya Pradesh and Maharashtra, with about 90 cm rainfall, *Dendrocalamus* brakes are common.

Gregarious forests of *Acacia arabica* dominate the black cotton soil regions of Berar in Maharashtra. Only in areas where the canopy is broken do associates such as *A. eburnea, Balanites aegyptiaca, Dichrostachys cinerea, Acacia leucophloea, Prosopis spicigera, Zizyphus vulgaris, Phoenix sylvestris, Azadirachta indica, Cassia auriculata* and *Capparis grandis* occur.

2.1.5 Fauna

In biogeographic terms this region is considered a part of the peninsular region of India with elements from the northeast, the north (the Himalayan) and the north-west (Mediterranean and Ethiopian) (Mani 1974). The fauna of this region has also been influenced by extra-peninsular faunal elements from the Pliocene times as evident from the fossil remains that contain Pleistocene vertebrate fauna of the peninsula such as crocodiles, chelonians, elephas, rhinoceros, equus and hippopotamus. The region also has Malay type fossil remains of buffalo and Bos sp.

Much information on the fauna of this region comes from the existence of large number of prehistoric cave paintings found in Sidhi, Rewa, Satna, Panna, Mirzapur and parts of the Satpuras, first discovered by Cockburn in early 19th century (Mukherjee 1984). Based on these paintings, the existence of rhinoceros in the Vindhyas, and elephant and wild buffalo in Panna can be inferred (Mukherjee 1984).

Until the 17th century, the lion was common in the Narmada Valley while the distribution of the elephant spanned across much of this landscape. However, while the former is now extinct from the region, small populations of elephants still exist within the eastern parts of this landscape. In an article published by Sukumar (1986), Odisha had about 2000 elephants spread over 21 Forest Divisions including Simlipal while the Singhbhum and Dalbhum regions had about 270 and Palamau had an isolated population of 40 individuals. In recent times, the elephant population from Palamau was recorded to seasonally migrate upto Sanjay NP of Madhya Pradesh.

In the eastern parts, wild buffalo (*Bubalus bubalis*) and swamp deer (*Cervus duvacelli branderi*) still exist, albeit in low numbers and as isolated populations. While the wild buffalo population is on a constant decline, barasingha increased from 70 to 300. In 1951, the last three cheetahs in India were also shot in the eastern parts of this region in present day Korea district (Divyabhanusinh 1999).

In contemporary times, this landscape has four species of canidae, viz., *Canis aureus, Canis lupus, Vulpes bengalensis* and *Cuon alpinus;* seven species of *Felidae,* viz., *Panthera pardus, Panthera tigris, Felis chaus, Caracal caracal, Prionailurus rubiginosus, Prionailurus bengalensis and Prionailurus viverrinae;* six species of *Bovidae,* viz., *Antilope cervicapra, Bos gaurus, Boselaphus tragocamelus, Bubalus*

bubalis, Gazella benetti and *Tetracerus quadricornis* along with several other species of ungulates mainly *Axis axis, Rucervus duvaucelli branderi, Rusa unicolor niger, Muntiacus muntjak, Moschiola meminnae* and *Sus scrofa*.

At least 200 species of birds are known from this landscape with some like the forest owlet (*Athene blewitti*) having been rediscovered from north-west Maharashtra in 1997 (King and Rasmussen 1998; Ishtiaq and Rahmani 2000).

While there is restricted information available on herpetofauna of this region, atleast 104 species with 89 reptiles and 19 amphibians are known from Madhya Pradesh and Chhattisgarh alone (Chandra and Gajbe 2005). According to species inventories, 174 species of butterflies were recorded from Madhya Pradesh and Chhattisgarh (Chandra *et al.* 2007) while 89 from Nagarjunasagar-Srisailam Tiger Reserve (Rao *et al.* 2004) in recent times.

This region is supposed to act as a land bridge for the migration of the wet zone flora and fauna from the north-eastern hills to the Western Ghats according to the Satpura hypothesis proposed by S.L. Hora (Hora 1944). Thus, despite much debate, the Malayan floral and faunal elements present in the Western Ghats are considered to have used the Garo Hills-Rajmahal Hills-Chota Nagpur Plateau and the Satpura Range as a pathway to reach the Western Ghats. However, several alternative routes too have been suggested for this migration such as the Eastern Ghats route for avifauna.

2.1.6 Ecological Studies

Despite the vast network of Protected Areas in this landscape and the extensive tiger occupied areas, few scientific studies have been conducted. The long term studies on other species have been conducted such as those on gaur (Areendran 2009), dhole (Acharya 2008) and chital (Ghuman 2009) in Pench (MP); sambar, chital and nilgai in Sariska (Sankar 1994); sloth bear (Yoganand *et al.* 1999) and chowsingha (Sharma and Rahmani 2003) in Panna and barasingha in Kanha (Martin 1978). River Chambal has been subjected to intermittent studies on otters, gharial, turtles and a breeding centre for gharial has been established on this river.

It is this landscape that initiated the era of ecological studies on the tiger and its prey starting with George Schaller's study in Kanha in the late 1960s. This study provided an impetus for the tiger studies that were to follow soon in the Royal Chitwan National Park of Nepal. Post Schaller's study, the next important long term study on radio-collared individuals, within this landscape, was conducted in Panna Tiger Reserve starting early 1996 to mid-1997. The study showed that due to a low prey base in the area, the radio-collared male tiger had a home range (243 km^2) more than double that of males in Chitwan, while female tigers too had it twice the size of that exhibited by females in Chitwan (Chundawat *et al.* 1999). The study also showed that despite the high presence of livestock in Panna, 80% of the diet of the female with cubs comprised of sambar and nilgai, with a kill once in six days on an average.

Centre for Wildlife Studies in collaboration with the Wildlife Conservation Society, as part of a larger study, estimated populations of tigers and their prey in Ranthambhore, Pench (Madhya Pradesh), Pench (Maharashtra), Tadoba, Panna, Melghat and Kanha between 1995 and 2002. Tiger and its prey estimates from these sites along with those from other sites enabled the determining of a close relationship between abundances of tigers and their prey (Karanth *et al.* 2004).

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Thereafter, a study on 10 radio-collared tigers was conducted in Kanha (2004-09) to study the ecology and ranging patterns of tigers (Vattakaven, Jhala and Qureshi, unpublished data). Tigers were also radio-collared in Ranthambhore and a long term study executed (Sharma *et al.* 2010, Jhala and Qureshi 2011). Several short term studies have been conducted within this landscape to determine the populations or occupancy of tigers (Karanth and Nichols 1998; Biswas and Sankar 2002; David *et al.* 2005; Sharma *et al.* 2009; Gopal *et al.* 2010), their prey (Karanth and Nichols 1998; Mathai 1999; Bagchi *et al.* 2004), identification of corridors (Ravan *et al.* 2005; Joshi 2010; Vattakaven 2010), dietary composition of the tiger (Biswas and Sankar 2002; Reddy *et al.* 2004) and on habitat preferences of prey (Mathai 1999).

Amongst the interesting estimates of tigers from this landscape are those for Panna. In 1996, a very low density of 2-3 tigers/ 100 km^2 was obtained followed by 6.9±2.23/100 km^2 in 2002 (Karanth *et al.* 2004) and 4.9±1.5/100 km^2 in 2006 (Gopal *et al.* 2010) with none left by December 2008. In 2006, the countrywide assessment of tiger status recorded occupancy of 48,610 km^2 with an estimated population of between 486 to 718 tigers within the Central Indian Landscape (Jhala *et al.* 2008). Other than tiger related studies, several other important studies have been conducted in this landscape. Edgaonkar (2008) studied the ecology of leopards in Bori Wildlife Sanctuary and Satpura Tiger Reserve during 2002-06. Jaypal *et al.* (2009) determined the importance of forest structure and floristics in determining the composition of avian assemblages along with that of individual foraging guilds in deciduous forests. Large scale studies have also been conducted in this region to study the ecology of small cats (Mukherjee *et al.* 2004). Many studies in this region have been a consequence of extinction (Narain *et al.* 2005) or relocation (Sankar *et al.* 2010) of some large mammalian species. With the extinction of the tiger from Sariska and Panna and its reintroduction in these areas, wildlife studies found new avenues waiting to be explored. Similarly, experiments with re-introduction of the lion (Johnsingh *et al.* 2007) and cheetah (Ranjitsinh and Jhala 2010) within sites in this zone along with re-introduction of gaur (tiger prey species) in Bandhavgarh enabled scientific research to focus on aspects studied weakly until now.

2.1.7 Conservation Status

This zone comprises of the most threatened habitats of the tiger in India. The species has already faced extinction from two Protected Areas due to poaching while the existence of high levels of human-tiger conflict around other sites like Ranthambhore and Tadoba-Andhari jeopardise tigers at these sites as well.

Anthropogenic disturbances such as livestock grazing, NTFP collection and the network of roads and railways are major threats to tiger conservation along with other seemingly benign activities like uncontrolled tourism. Fragmentation of habitat due to developmental activities and those that add to the state ex-chequer such as mining are major threats.

Jhala *et al.* (2008) identified four important landscapes in this region. These include Kanha-Pench, Satpura-Melghat, Sanjay-Palamau and Navegaon-Indravati. To strengthen such areas and reduce the impact of human disturbance in the tiger breeding zones (core areas of tiger reserves) would be necessary to protect the biodiversity of these regions while reducing cases of human-wildlife conflict.

Several conservation organisations have been active in this zone, promoting research, conservation and spreading awareness regarding biodiversity conservation such as the Satpuda Foundation, Tiger Watch, Wildlife Conservation Trust, WWF and Wildlife Trust of India. Wildlife Trust of India has also developed a wild buffalo monitoring programme for the last remaining individuals in Bastar region. Similarly, several academic organisations such as Indian Institute of Forest Management (IIFM) Bhopal, Tropical Forest Research Institute (TFRI) Jabalpur, Zoological Survey of India (ZSI) and Botanical Survey of India (BSI) have been conducting studies in the region. The role of such local organisations is important in understanding and safeguarding these tiger landscapes.

2.2.1 Tiger Occupancy

Out of 5553 (10x10 km) grids within potential tiger habitat that were surveyed, tiger signs were detected in 464 grids giving a naive estimate of tiger occupancy at 8.36%. Of the total available tiger habitat covering 3,38,378 km² in these grids, 38,056 km² constituting 11.2% of the total habitat was occupied by tigers.

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After accounting for bias of imperfect detections (basic occupancy model) tiger occupancy was estimated at 10.8 (se 0.5)% with a detection probability of 34.4 (se 0.6)%. The best model in PRESENCE incorporated the following covariates for estimating occupancy (Table 2.1 and 2.2):

a) prey abundance indexed by large prey encounter rates on transects and wild ungulate dung density
b) landscape characteristics indexed by forested area and area of core habitat within a grid
c) human disturbance variables indexed by number of livestock trails, livestock dung density and distance to major roads, with a constant detection

Since the top two models explained tiger occupancy equally well (Delta AIC <2) we used model averaged coefficients to estimate tiger occupancy (Table 2.1).

Since the covariates were standardized, the sign and magnitude of their coefficients could be compared to infer their effect on tiger occupancy.

Table 2.1 Model selection results for estimating tiger occupancy within the Central Indian Landscape incorporating imperfect detections and covariates of landscape characteristics, prey abundance, and human disturbance

Model	AIC	Delta AIC	No. Par.	-2 x Log Likelihood
ψ (ChSamGr,RdDis,CatDng,WldDng, For, Trail),p(.)	11177.97	0	9	11159.97
ψ (ChSamGr, Lvstk,RdDen,CatDng,WldDng, For, Trail),p(.)	11179.5	1.53	10	11159.5
ψ (ChSamGr, Lvstk,RdDen,DEMcv,WldDng, For, Trail),p(.)	11199.46	21.49	10	11179.46
ψ (Ch+Sam+Gr,Lvstk,NitL,RdDen,For,DEMcv, NDVIPM),p(.)	11240.25	62.28	9	11222.25
ψ (ChSamGr, Lvstk,RdDen,NDVIM,WldDng, For, Trail),p(.)	11241.9	62.93	10	11221.9
ψ (ChSamGr, Lvstk,RdDen,NDVIPM,WldDng, Trail),p(.)	11245.25	67.28	10	11225.25
ψ (ChSamGr,Lvstk,NitL,RdDen,For,PAD,NDVIPM),p(.)	11272.91	94.94	9	11254.91
ψ (for,NitL,Wlddng),p(.)	11374.27	196.3	5	11364.27
ψ (for,rddis,wlddng),p(.)	11402.41	224.44	5	11392.41
ψ (ChSamGr, Lvstk,For, PAD,NitL, Rd.),p(TigSignAvg)	11542.63	364.66	8	11526.63
ψ (ChSsmGr,NitL,Lvstk,NDVIPM,For),p(TigSignAvg)	11546.12	368.15	7	11532.12
ψ (ChSamGr, Lvstk,For,NitL,Rd.),p(.)	11592.07	414.1	7	11578.07
ψ (for,rddis,Wlddng),p(TigSignAvg)	11652.8	474.83	5	11642.8
ψ (UngER),p(.)	11691.4	512.43	3	11685.4
ψ (NDVIPM),p(.)	11822.84	645.87	3	11817.84
ψ (.), p(Sur)	11830.48	652.51	31	11768.48
ψ (trails),p(.)	11832.44	654.47	3	11826.44
ψ (DEM),p(.)	11888.74	710.77	3	11882.74
ψ (.), p(.)	11900.07	722.1	2	11896.07

UngER- Ungulate prey encounter per km transect walk, Ch+Sam+Gr – Encounters of chital, sambar, gaur per km transect walk, NDVIM- Normalized differential vegetation index monsoon, NDVIPM- Normalized differential vegetation index pre-monsoon, DEMcv – CV of elevation, DEM- elevation, RdDen: Density of major metalled roads, PAD – Euclidian distance to nearest Protected Area , NitL- Euclidian distance to night lights, For – Area of forest cover, GrC – Signs of grass and bamboo cutting on 15m plots on transects, Trail – Presence of human-livestock trails on transects, Lvstk – Presence of livestock on transect plots, TigSignAvg – Average encounter rate of tiger sign, WldDng- Wild ungulate dung, rddis- Euclidian distance to road, tigsign- Tiger sign , Sur-Survey specific detection, TigSignAvg- Average encounter of tiger sign.

The major determinants of tiger occupancy in the landscape were (Table 2.2):
a) amount of undisturbed forest area (had positive coefficients),
b) encounters of large prey and wild dung density (had positive coefficients)
c) human disturbance indexed by distance to major roads, human and livestock trails and livestock dung density (negative effect on tiger occupancy)

Table 2.2
Coefficient estimates for the best model selected for estimating tiger occupancy in the Central Indian Landscape

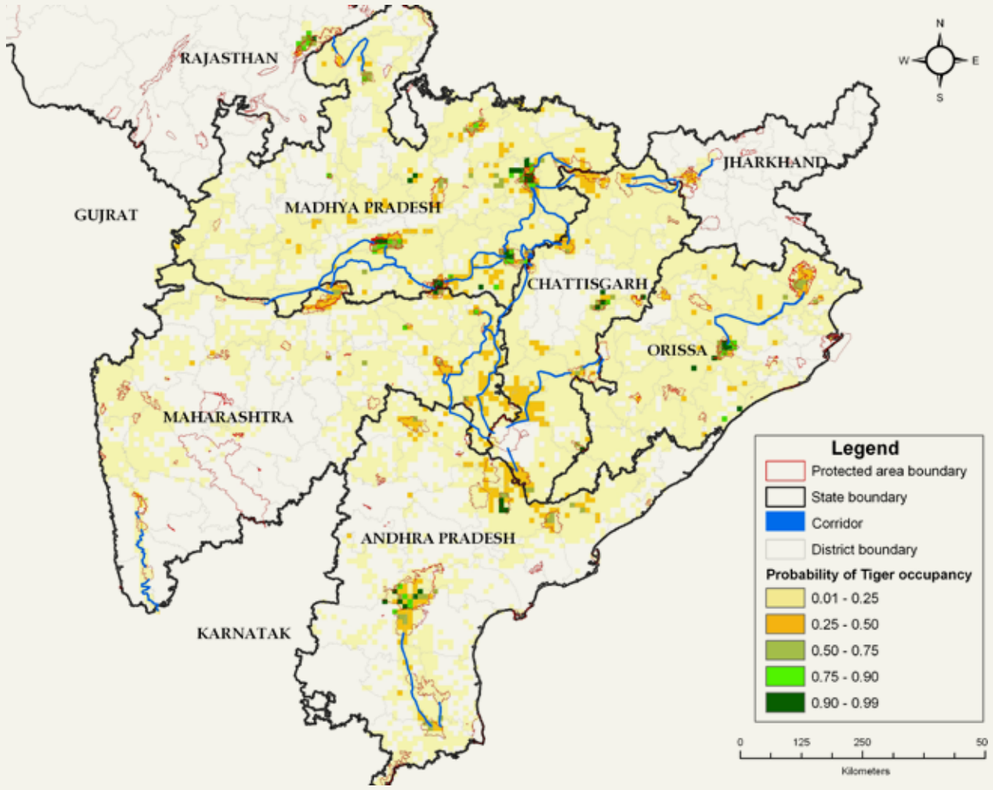
Covariates	Coeff. Estimate	SE
a1	-2.990615	0.086265
WildDng	0.454872	0.055197
Trails	-0.391184	0.081708
Chital+Sambar+Gaur+Wpig	0.572733	0.078048
Forest Area	0.832377	0.065739
Livestock Dung Den	-0.756348	0.110097
Forest Core	0.143628	0.055316
Dist to Roads	0.110243	0.05793
b1	-0.643573	0.025998

The delta AIC for the top two models was less than two. Therefore, we used the model averaged coefficients, based on AIC weights of these two models to estimate parameters.

The tiger occupancy estimate from the model averaged coefficients was 9.48 (se 0.17)%. With high detection probability (0.34) and number of surveys (5 kilometre spatially independent walks) ranging from 3 to 30 (proportional to the amount of tiger habitat in a grid) the increment in tiger occupancy (from 8.36 % naive estimate to 9.48 %) by incorporating imperfect detections and covariates was small. However, the coefficients of covariates used in the models provided good insight into factors that influence tiger occupancy in this landscape. The occupancy probability of a grid habitat was interpreted as a quantitative estimate of habitat suitability for tigers and was a useful tool for mapping source and corridor habitats (Fig. 2.1).

Figure 2.1

Tiger habitat in the Central Indian Landscape showing probability of tiger occupancy modelled by incorporating imperfect detections as well as covariates of landscape characteristics, human disturbance, and prey availability. Least cost corridor pathways re-aligned on high resolution satellite image are also shown.



2.2.2 Tiger Population Extents and Abundance across the Central Indian Landscape

Mark-recapture population and density estimates of tigers based on camera-trapping were obtained for Ranthambhore, Satpura, Pench, Kanha, Supkhar, Bandhavgarh, Achanakmar, Melghat, Tadoba and Srisailam Tiger Reserves. Tiger densities in this landscape ranged between 1 to 16 tigers per 100 km^2. Non-camera trapped grids with tiger occupancy were assigned to tiger density categories using ordinal logistic regression (see chapter on Phase III). Based on contiguous occupied grids, 23 separate tiger populations could be identified within the Central Indian Landscape with some scattered tiger presence also recorded in-between some major populations (Fig. 2.2). Eight major tiger populations with over 30 adult individuals (Table 2.3) and several smaller populations were identified in the landscape.

Figure 2.2

Tiger occupancy, population extent, size and habitat connectivity in the Central Indian Landscape

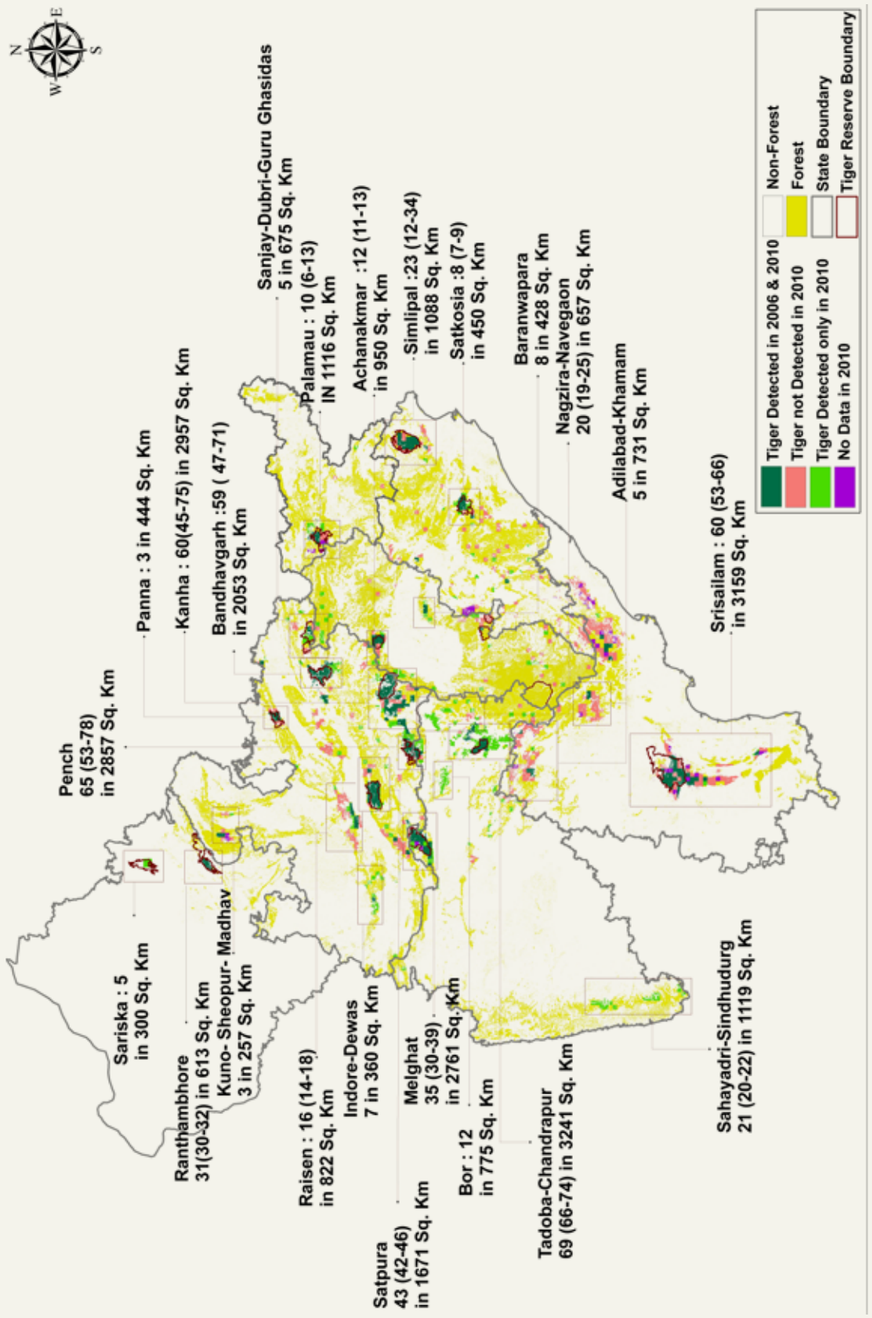


Table 2.3
Major tiger populations in the Central Indian Landscape

Location	Tiger population	Total area (km²)
Kanha landscape	45-75	2957
Pench landscape	53-78	2857
Tadoba-Chandrapur	66-74	3241
Bandhavgarh landscape	47-71	2053
Srisailam landscape	53-66	3159
Satpura landscape	42-46	1671
Melghat landscape	30-39	2761
Ranthambhore landscape	30-32	613

Smaller populations exist in Bor, Sahayadris, Nagzira-Navegaon, Achanakmar, Simlipal, Satkosia, Palamau, Sanjay-Dubri-Guru Ghasidas, and Raisen.

Sporadic occurrences of tigers were also recorded in the forests of Indore and Dewas, Jabalpur, Nauradehi and Damoh, Kuno-Sheopur and Madhav, Adilabad and Khammam, and within intervening forest corridors between Kanha and Pench, Kanha and Achanakmar, and within forested pockets across Odisha. Tiger populations that were exterminated from Sariska and Panna have been re-established by reintroductions. Two reintroduced tigresses have already littered within Panna. Indravati and parts of Chhattisgarh and Jharkhand could not be assessed due to Leftist insurgency within these States.

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2.2.3 Changes in Occupancy and Abundance from 2006 to 2010

Tiger occupancy in central India was recorded to be 38,590 km² in 2010 and was reduced by 21% from that estimated in 2006 (Fig. 2.2). Most of this loss in occupancy was recorded from northern Andhra Pradesh (Adilabad, Khamam, East Godavari, and Vishakhapatnam), and from the northern banks of the Narmada in Madhya Pradesh (Fig. 2.2). All of these areas from which tiger signs were not recorded were low tiger density areas (0.5 to 1 tiger per 100 km²). Loss of tigers from such low density areas did not result in a major decline in tiger population estimates but it signals loss of habitat quality and extent which further compromises connectivity and dispersal opportunity for genetic exchange between source populations. Such habitat connectivity and evidence of tiger usage of corridor habitats is essential for the long term survival of healthy tiger populations within larger landscapes.

2.2.4 Critical Corridors, Habitat Connectivity and Conservation

The Central Indian landscape currently has three functional metapopulations which include:
a) Pench-Kanha-Achanakmar
b) Satpura-Melghat
c) Tadoba-Chandrapur

Four more landscapes have the potential to harbour tiger metapopulations. However, their corridor connectivity has become fragile requiring intervention of policy and restoration for functioning as effective wildlife corridors. These include:

a) Pench–Satpura
b) Bandhavgarh–Sanjay–Dubri-Guru Ghasidas
c) Ranthambhore-Kailadevi–Kuno–Sheopur
d) Tadoba-Chandrapur-Gharcharoli-Adilabad-Indravati

Due to the small size of many source tiger populations in the Central Indian landscape, their long term future is bleak unless they are managed as functional metapopulations. Therefore, developing a policy to legally ensure that the habitat matrix within these corridors remains friendly for movement of wildlife is essential. Herein, using probability of tiger occupancy as a base layer along with tiger habitat connectivity defined at a high resolution, we have identified potential corridors using “least cost pathway” analysis and Circuitscape in a GIS domain (Figs. 2.1 and 2.3). Many of these corridors are known to be used by tigers and other wildlife such as the Kanha-Pench corridor. Others, such as the Satpura-Pench corridor, need further field verification to define their exact boundaries on the ground, so as to minimize impacts on local and national economies while maximizing wildlife values.

The loss of peripheral tiger occupancy is a major conservation concern within this landscape where tiger poaching had eliminated two populations (Sariska and Panna) in the recent past (Check 2006; Gopal *et al.* 2010). Good accessibility within tiger forests, prevalence of tribes known for their traditional hunting skills, combined with high poverty levels makes this landscape of conflicts vulnerable to commercial poaching.

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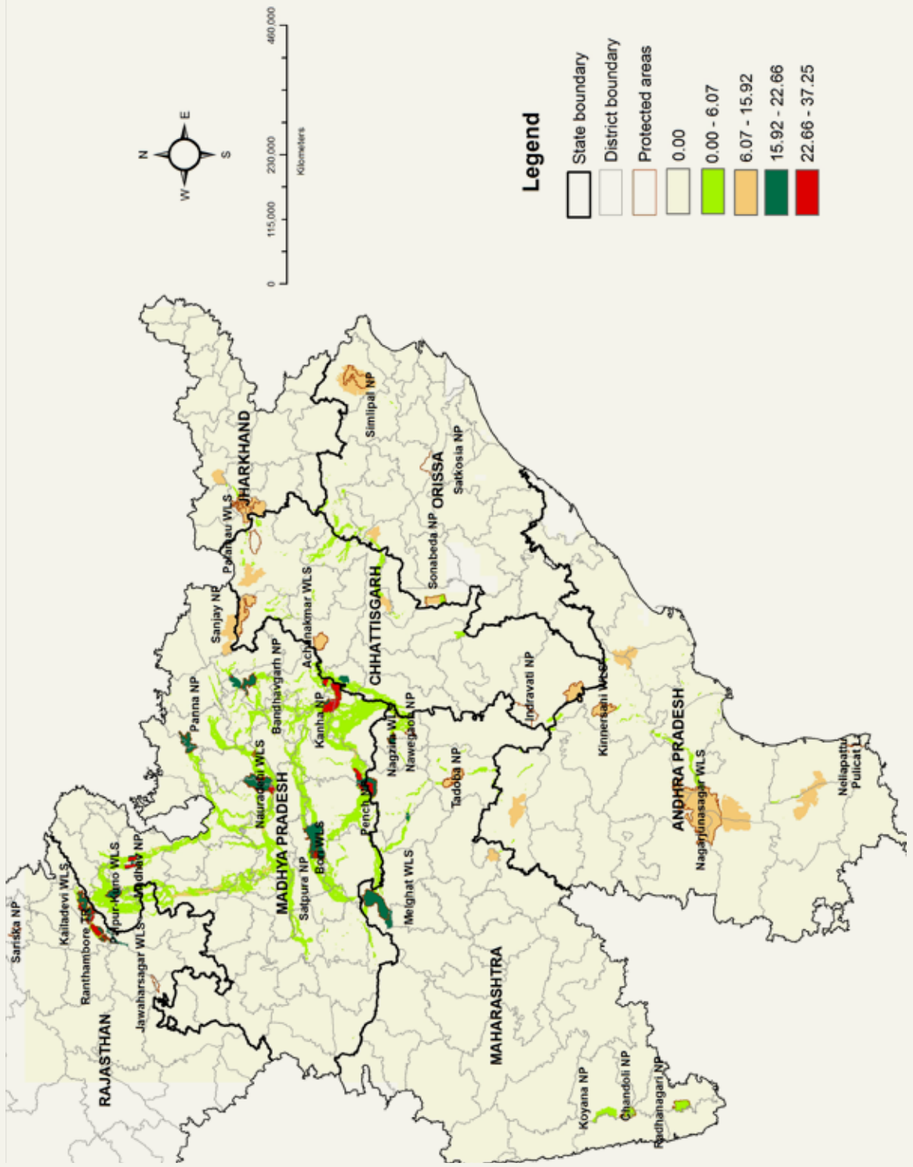
Figure 2.3

Least resistance pathways connecting potential tiger habitats and source populations within the Central Indian Landscape modelled in Arc GIS using CIRCUITSCAPE.



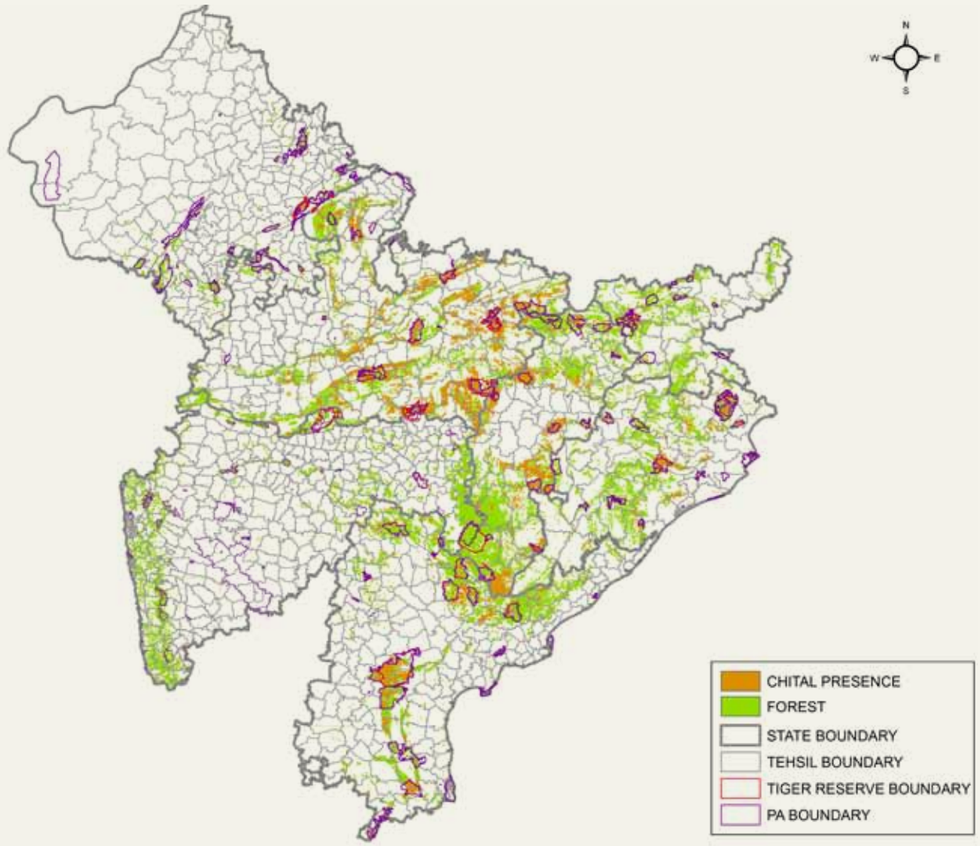
2.2.5 Distribution of ungulates in the landscape

a) **Chital** (*Axis axis*)

Chital occupancy was recorded from within 100,560 km² in the Central Indian landscape. Protected Areas of eastern Madhya Pradesh had the highest chital occupancy while the species was also recorded from most corridors connecting Tiger Reserves (Fig. 2.4.1) The Kanha-Achanakmar landscape had the largest area under chital occupancy in the central Indian landscape.

Figure 2.4.1

Occupancy of chital in the Central Indian landscape

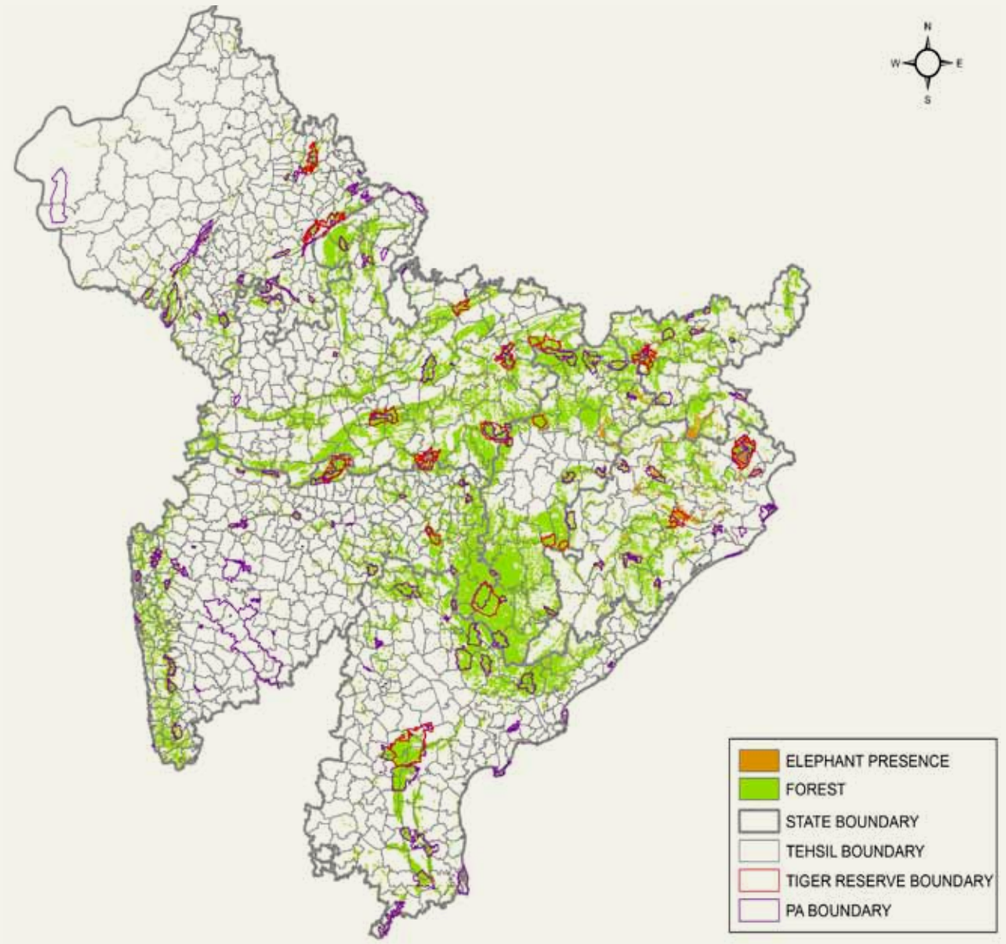


b) **Elephant** (*Elephas maximus*)

Elephant occupancy was recorded from 9,747 km² from the forests of Odisha and parts of eastern Chhattisgarh and Jharkhand (Fig. 2.4.2). Within Chhattisgarh elephant occupancy was recorded from the district of Jashpur and Raipur.

Figure 2.4.2

Occupancy of elephant in the Central Indian landscape

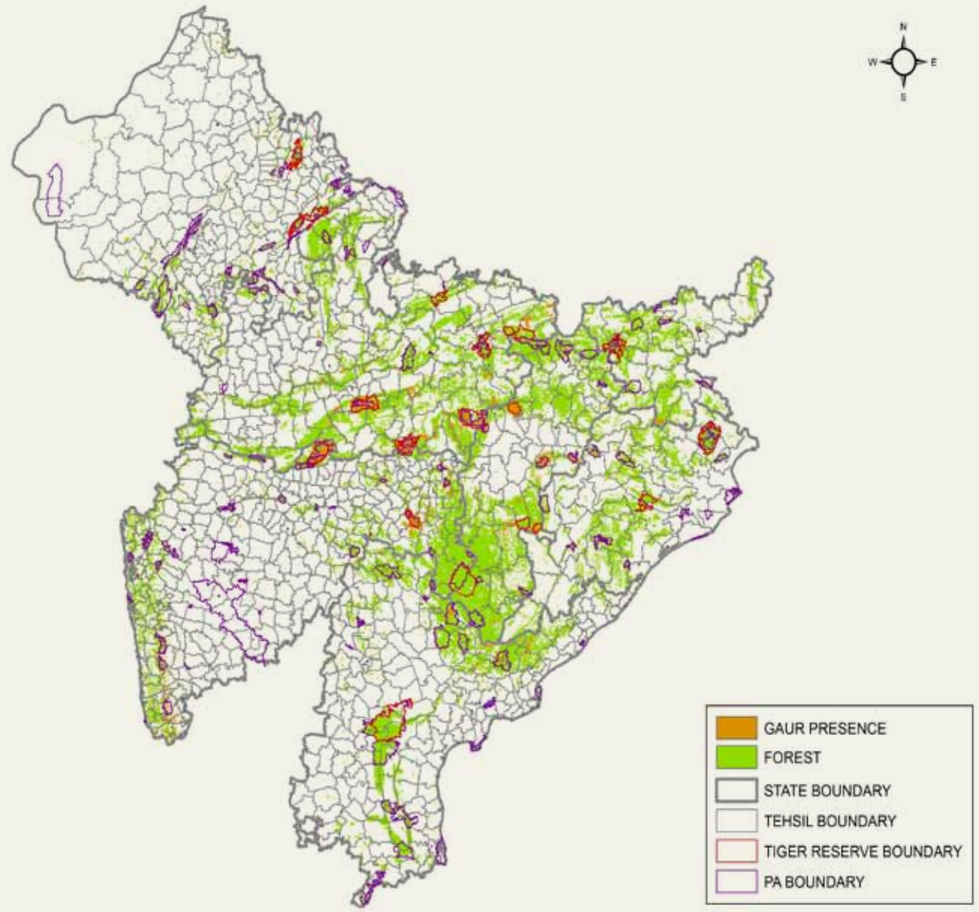


c) **Gaur** (*Bos gaurus*)

Gaur occupancy was recorded from 22,275 km² of the Central Indian landscape. Their populations were primarily restricted to Protected Areas with scattered records within connecting corridor habitats and surrounding forests of Protected Areas (Fig. 2.4.3). The species is known for its local migration patterns, for which landscape connectivity is an essential element for their persistence. Degradation of connectivity of Bandhavgarh National Park was one of the important factors responsible for the species becoming locally extinct and finally having to be reintroduced. Thus, gaurs are good indicators of large landscape connectivity. The landscape complexes that hold promise for metapopulation existence of gaur within the Central Indian landscape were Satpura-Melghat and Achanakmar-Kanha-Pench landscapes.

Figure 2.4.3

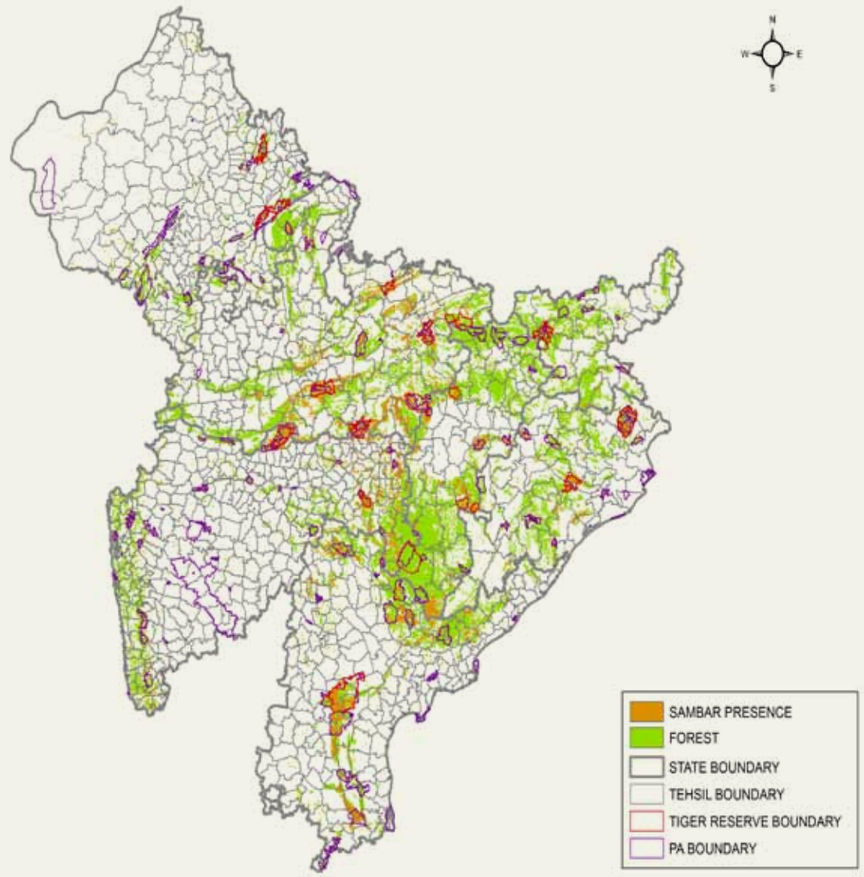
Occupancy of gaur in the Central Indian landscape



d) **Sambar** (*Rusa unicolor*)
Sambar occupancy was recorded from 77,672 km². Besides Protected Areas, sambar occupancy was recorded from the corridor habitats of Kanha-Pench, Kanha-Achanakmar, Satpura-Melghat, within the connectivity of eastern Maharashtra with Chhattisgarh and across the southern Eastern Ghats landscape (Fig. 2.4.4). Occurrence of prey like the sambar within these connecting forests is encouraging as this is suggestive of viability of these corridor habitats to large carnivore movement.

Figure 2.4.4

Occupancy of sambar in the Central Indian landscape



2.2.6 Distribution of co-predators in the landscape

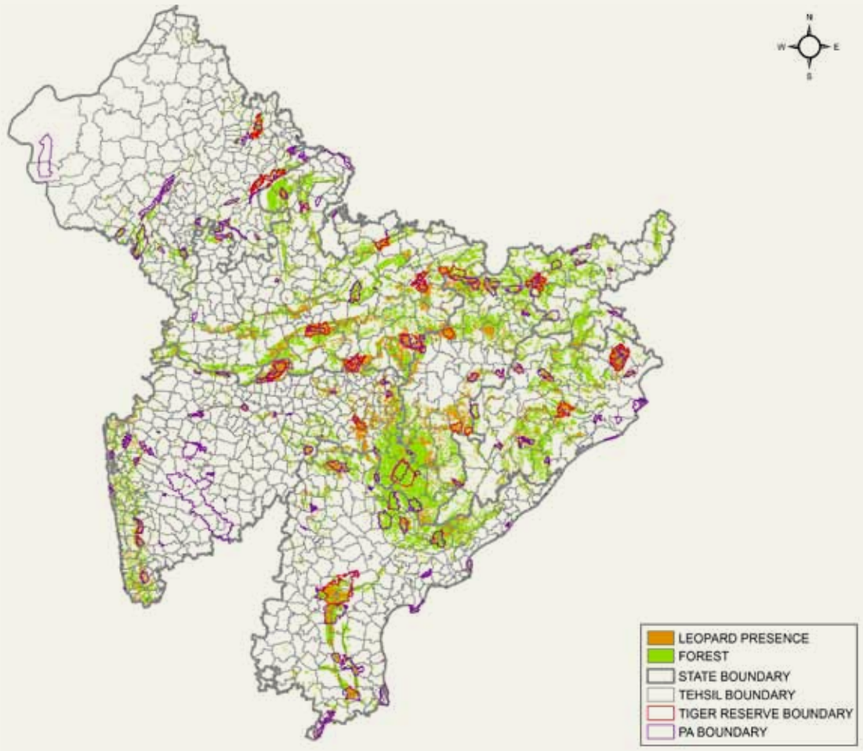
a) **Leopard** (*Panthera pardus*)
An almost contiguous leopard distribution is recorded across the forested landscapes of Central India (Fig. 2.5.1). Major source sites were observed to coincide with PAs. Most corridor connectivity identified by the least cost pathways had leopard occupancy. Four distinct leopard distributions were discerned. These were:

i) Rajasthan along with northern Madhya Pradesh (Ranthambhore Tiger Reserve, Kuno-Sheopuri-Madhav)
ii) Almost contiguous, large scale distribution across remaining Madhya Pradesh, eastern Maharashtra, Chhattisgarh, Jharkhand, Odisha, and northern Andhra Pradesh
iii) Nagarjunasagar-Srisailam block formed a distinct contiguous population with Sri Venkateshwara forests to the south
iv) The Western Ghats population in western Maharashtra was contiguous with that in Goa to the south and with the Dang forests in Gujarat. This population maintained continuity with leopards of Central India through the forests of Jhabua (Vindhya Range) and to the northern populations via the forests of the Aravallis

The total leopard occupied forests within the Central Indian landscape were 92,786 km²

Figure 2.5.1

Occupancy of leopard in the Central Indian landscape

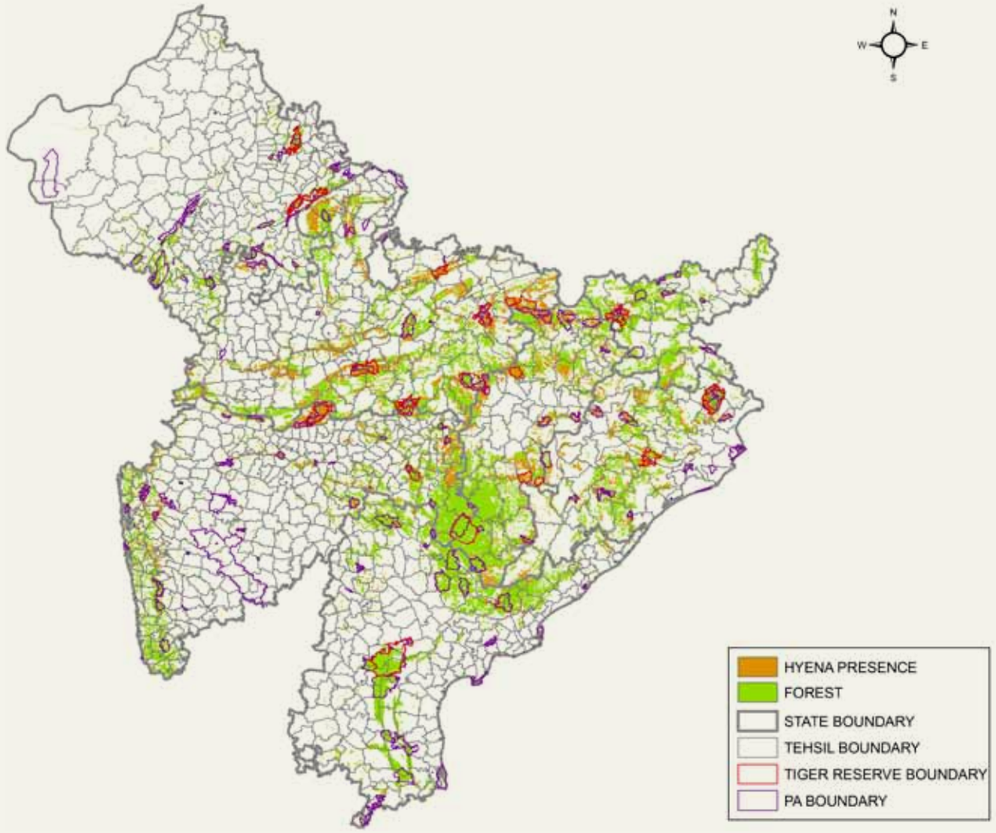


b) **Striped hyena** (*Hyaena hyaena*)

Forested areas of Central India recorded striped hyena occupancy in an area of 112,009 km² (Fig. 2.5.2). Since hyenas also occur outside of forests within agro-pastoral landscapes, this area is the minimal occupancy of the species. Interestingly, hyenas were not recorded from Nagarjunasagar-Srisailam Tiger Reserve and the contiguous forests of the southern Eastern Ghats.

Figure 2.5.2

Occupancy of striped hyena in the Central Indian landscape

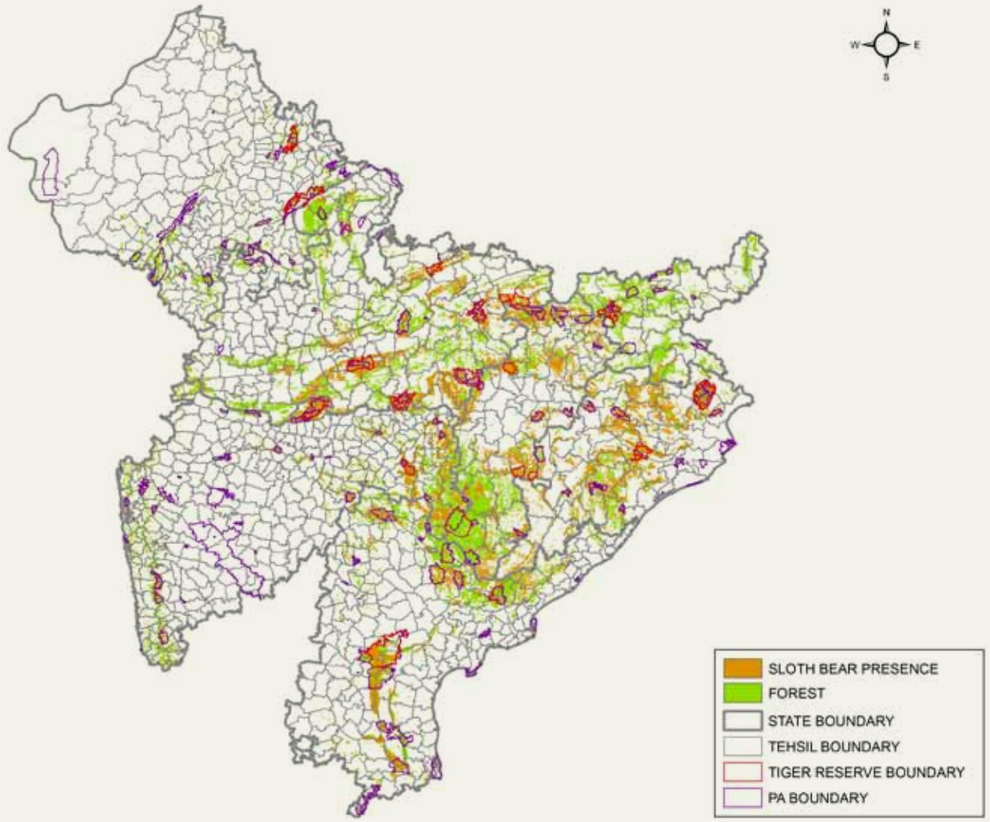


c) **Sloth bear** (*Melursus ursinus*)

Sloth bear had the most widely recorded distribution of any large carnivore in Central India with forested area coverage of 180,628 km² (Fig. 2.5.3). Its strong holds were the forests of Odisha, Chhattisgarh, Madhya Pradesh and eastern Maharashtra. The Nagarjunasagar-Srisailam block recorded a contiguous occupancy of sloth bear with Shri Venkateshwara forests.

Figure 2.5.3

Occupancy of sloth bear in the Central Indian landscape



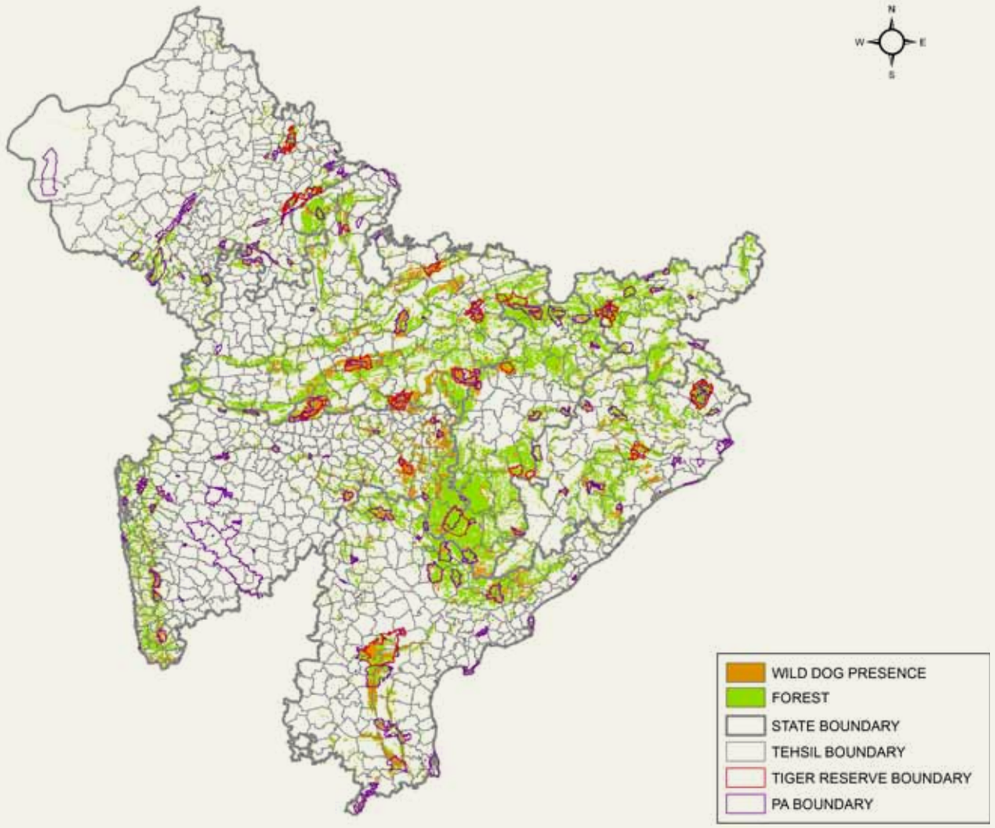
d) **Wild dog** (*Cuon alpinus*)

Occupancy of wild dogs in the landscape was 71,817 km² within forested areas (Fig. 2.5.4). Their populations were more restricted in comparison to leopard populations. Major strong holds of dhole populations were:

i) Satpura-Melghat landscape
ii) Kanha-Pench-Navegaon-Nagzira-Tadoba complex probably extending into Indravati landscape in Chhattisgarh
iii) Nagarjunasagar-Srisailam-Venkateshwara forest complex

Dhole populations were also recorded across the northern banks of the Narmada into Bandhavgarh TR and onto Guru Ghasidas National Park in Chhattisgarh.

Figure 2.5.4 Occupancy of wild dog (dhole) in the Central Indian landscape



RAJASTHAN

The State of Rajasthan has only 4.69% of its geographical area under forest cover (State of the Forest Report 2009). Of this, 26.7% of the State's forest cover is restricted to the districts of Sawai Madhopur and Alwar which also host the two highly publicised Tiger Reserves of the country, Ranthambhore and Sariska.

The Ranthambhore Tiger Reserve encompasses an area of 1,334.64 km² constituted by the Keladevi Wildlife Sanctuary (674 km²), Ranthambhore National Park (392.5 km²), Sawai Mansingh Wildlife Sanctuary (127.6 km²), the Qualji Closed Area (7.58 km²) and other forest area (132.96 km²). The Reserve spans across the districts of Karauli and Sawai Madhopur with the National Park restricted to the tehsils of Khandar and Sawai Madhopur. It is located at the junction of the Aravallis and the Vindhyas bounded to the north by River Banas and River Chambal in the east. At the time of declaration of the Ranthambhore National Park, 17 villages were located within this zone, of which all except viz., Padra, Katholi and Mordoongri were relocated.

The Keladevi Wildlife Sanctuary is separated from the Ranthambhore National Park by the Sawanta-Hadoti road and several villages in this zone. These villages along with the road and the sand mining from River Banas in this region are a constant threat to the only existing corridor between Keladevi and Ranthambhore National Park. Quarrying is another important threat to Ranthambhore National Park and some parts of Keladevi Wildlife Sanctuary. Similarly, the presence of 19 villages in the buffer zone of the Tiger Reserve in addition to 332 within a radius of five kilometres from the Reserve boundary exert high livestock grazing and poaching pressures on the park. The presence of religious sites within the National Park and close to Qualji Closed Area also attracts large number of pilgrims, which further aggravate disturbance levels in the area.

The other important Tiger Reserve in the State is the Sariska Tiger Reserve, infamous for the disappearance of its tigers. Sariska Tiger Reserve encompasses an area of 866 km² and is constituted by the 492 km² Sariska Wildlife Sanctuary (proposed National Park) and 374 km² of other forests (Reserved, unclassed and protected forests). It is located in the Aravalli Range of Alwar district and is known for the high levels of biotic pressures and disturbance. The Reserve has 24 villages in the core zone and 246 in the buffer zone, with predominantly a 'gujjar' population with high dependence on the Reserve for livestock grazing. Two State Highways, viz., Sariska-Kalighati-Tela and Alwar-Thanagazhi-Jaipur also traverse the Reserve covering a length of 44 kilometres within the Reserve precincts. Many small settlements have emerged along the highway, many of which are encroachments. The presence of a religious site within the park adds further challenges to park monitoring. Quarrying and frequent forest fires are other threats to this Reserve.

On recommendations of an expert committee, between July 2008 and June 2009, three tigers (two females and one male) were transferred from Ranthambhore Tiger Reserve to Sariska with the aim of re-establishing a population of wild tigers in the Reserve. A proposed supplementation of three tigers in every two years for a period of six years has been recommended by scientists to enable a self-sustaining viable population of tigers in the Reserve (Sankar *et al.* 2010). At present, two tigers and three tigresses continue to survive in Sariska, without having bred so far. Even though effort has been taken to reduce anthropogenic pressures in Sariska, human and livestock use and presence is recorded throughout the Sariska Tiger Reserve. Without availability of undisturbed areas for littering, tigresses are unlikely to

reproduce successfully. Substantial areas of Sariska need to be made inviolate with no anthropogenic disturbances for the reintroduction efforts to be successful.

In 2006, tiger occupancy was recorded in an area of 344 km² of Ranthambhore Tiger Reserve with a population of 32 (30-35) tigers (Jhala *et al.* 2008). In 2010, the recorded tiger occupancy was 613 km² with an estimated population of 30 to 32 tigers (Fig. 2.RJ.1).

Figure 2.RJ.1

Tiger occupancy, population extent, size and habitat connectivity in Rajasthan

Figure 2.RJ.1.1

Ranthambhore Tiger Reserve-Chambal-Kuno corridor

While the Sariska tiger population is isolated, Ranthambhore Tiger Reserve has the potential to act as a source for tigers to other neighbouring forested areas such as Kuno-Palpur Wildlife Sanctuary to the east (Fig. 2.RJ.1.1) and to forests of Kota and Bundi districts to the south. Potential connectivity exists between Ranthambhore Tiger Reserve and Kuno-Sheopur forests, across the Chambal, near the confluence of Kuno River (Fig. 2.RJ.1.1). This connectivity is impacted by agriculture and settlements but has forested patches and a fissured rugged terrain, conducive to movement of carnivores under the cover of darkness. Tigers occasionally cross into the Kuno landscape but have so far failed to establish a population there in spite of good prey recovery. This could probably be an outcome of poaching in the Kuno landscape.

The proposed Tiger Reserve in Mukundwara and Darra hill Ranges in Kota district, along with the adjoining forests of Jawahar Sagar Wildlife Sanctuary in Bundi district, along the banks of River Chambal could be connected with Ranthambhore Tiger Reserve by strengthening the existing corridors between the two areas. Darra has the potential to sustain tiger populations with restorative management and enhancement of prey base. However, due to its small size, liner shape and being surrounded by a predominantly human-dominated landscape, a sizable tiger population is likely to cause severe human-tiger conflict in the region. This aspect needs consideration before promoting tiger occupancy and density in this Protected Area. A better alternative is to consolidate Ranthambhore Tiger Reserve with restoration of Kailadevi through incentive driven relocation, reduction of livestock pressures, and recovery of wild prey populations. Revival of Kailadevi as good tiger habitat would have the added advantage of providing connectivity to the landscape of Kuno-Sheopur which together with Ranthambore Tiger Reserve could be managed as a metapopulation to ensure long term survival of tigers in this semiarid ecosystem.

MADHYA PRADESH

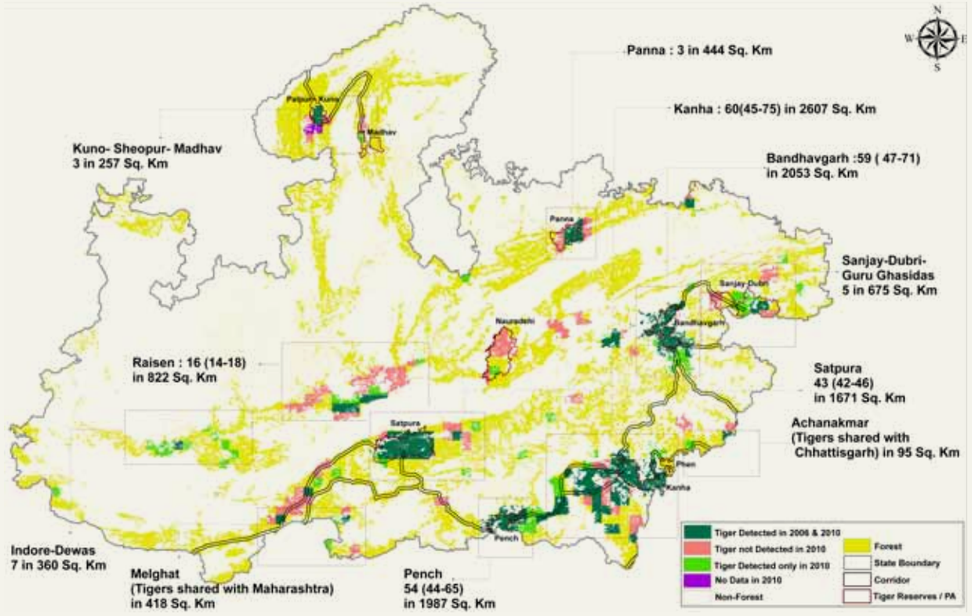
The State of Madhya Pradesh has an area of 76,429 km² under forest cover comprising of about 25% of the total geographical area of the State (State of the Forest Report 2003). The state has six Tiger Reserves, one proposed Tiger Reserve, viz. Ratapani, nine National Parks, 25 Wildlife Sanctuaries and 81 Forest Divisions all of which form a part of the Central Indian Tiger Landscape.

There were four major tiger populations whose status in 2010 was as follows:

a) Kanha having occupancy of 2607 km² and population of 60 (45-75).
b) Bandhavgarh having occupancy of 2053 km² and population of 59 (47-71). This population has recorded significant increase.
c) Satpura population is stable with 43 (42-46) tigers with recorded presence in 1671 km².
d) Pench population has recorded tiger presence in 1987 km² with tiger abundance of 54 (44-65) (Fig. 2.MP.1).

Figure 2.MP.1

Tiger occupancy, population extent, size and habitat connectivity in Madhya Pradesh



In Central Indian landscape Madhya Pradesh has the maximum numbers of tiger population, these are:

a) **Bandhavgarh Tiger Reserve** encompasses an area of 1,161.47 km² with the core area formed by Bandhavgarh National Park and Panpatha Wildlife Sanctuary covering 694.68 km². It is spread across Umaria and Katni districts and is surrounded by Forest Divisions of Umaria, Katni and North Shahdol. Around 62 villages are spread across this area with high livestock grazing and frequency of forest fires. Livestock depredation by carnivores and crop-raiding are frequent. Two PWD roads, Umaria-Rewa and Parasi Khitoli, pass through the Protected Area while over 25,000 tourists visit the Park each year, enhancing disturbance levels.

b) **Kanha Tiger Reserve** covers an area of 1,945 km² area with 940 km² categorised as the National Park and 1005 km² as the buffer zone stretching across the districts of Mandla, Balaghat and Dindori in Madhya Pradesh. When the park came under Project Tiger in 1974, 26 forest villages were relocated outside the park while 18 still continue to exist within the Protected Area. Also, 40% of the area in the buffer zone is forested while rest is revenue land with 145 forest and revenue villages. About 20 kilometres south-west of the park exists the Malajkhand copper complex and a cement plant.

c) **Satpura Tiger Reserve** comprises of the Bori and Pachmari Wildlife Sanctuaries and is located in Hoshangabad district covering 1501.72 km². On the western side of the Reserve is located the reservoir of Tawa while the Satpuras in this region form a catchment for River Narmada along with its tributaries. The region has low levels of disturbance with about 85% of its area under forest cover.

d) **Pench Tiger Reserve** is located in Seoni and Chhindwara districts of Madhya Pradesh and covers an area of 757.86 km² with 292.86 km² as the buffer. It lies along the border of Madhya Pradesh and Maharashtra, separated by a reservoir on the River Pench with more forested regions in the latter State. The area has a large tribal population comprising chiefly of Gonds.

e) **Panna Tiger Reserve** covers 542 km² of the Vindhyas in north-central Madhya Pradesh. The park is spread across parts of Panna and Gunor tehsil in Panna district and Bijawar and Chhatarpur tehsils in Chhatarpur district. River Ken passes through the park and provides water to people and wildlife. The region has some diamond mines for which it is famous. Like Sariska, Panna lost all of its tigers in 2009 (Gopal 2010) and currently three females and one male have been successfully reintroduced. Two of the reintroduced tigresses have subsequently bred and produced litters.

f) **Sanjay-Dubri Tiger Reserve** comprises of the Dubri Wildlife Sanctuary covering 364.6 km² and the Sanjay National Park covering 466.7 km², both of which are located in Sidhi district on the border with Chhattisgarh. Dubri Wildlife Sanctuary has 29 revenue villages within it while Sanjay National Park has 18, comprising chiefly of tribal population with primarily Gond, Yadav and Kol communities.

a) **Kuno-Sheopur-Madhav**
Currently few (2-4) dispersing tigers from Ranthambhore continue to survive within this large (> 4,000 km²) forest patch. Kuno has shown improvement in its prey base due to reduction in anthropogenic pressures by relocation of villages from its core done under the lion reintroduction project. Further investment under the new scheme of cheetah reintroduction project is likely to bring about better improvement for establishing a metapopulation of tigers with Ranthambhore as the source.

b) **Raisen tiger population**
This population has now become a relict with much loss of occupied habitat between 2006 and 2010. With no linkage to any major source population the future of this tiger population is bleak.

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c) **Indore-Dewas**
This tiger population has shown an increase in occupied area since 2006. The population was estimated to be around 7 tigers. Narrow forest connectivity exists between Raisen and Indore-Dewas population. If this corridor were restored then both the Dewas and Raisen tiger populations would benefit immensely.

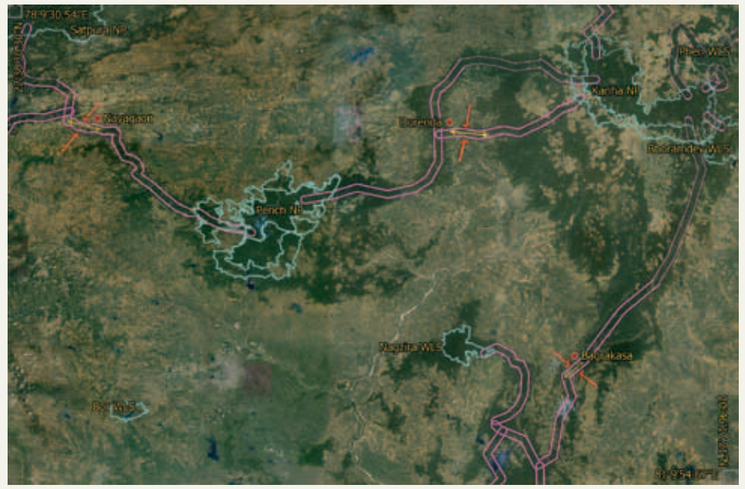
Most other tiger populations on the northern banks of the Narmada recorded sporadic tiger occurrences and have probably dwindled to last few individuals. These included the Nauradehi, Jabalpur, Damoh and Sagar populations. Tiger presence continues to be recorded from East Nimar and Betul, the connecting corridor forests between Satpura and Melghat (in Maharashtra); within the tehsil forests of Balaghat, Waraseoni, and Seoni which form the corridor forests between Kanha and Pench; and from the *talukas* of Dindori and Mandla that form the corridor between Kanha and Achanakmar. These occurrences were encouraging and suggestive of viable corridor connectivity between the important source populations (Fig.2 MP.1.1 & Fig.2.MP.1.2).

Fewer but encouraging occurrences of tigers were recorded from Beohari and Gopal Banas tehsil forests connecting Bandhavgarh with Sanjay-Dubri-Guru Ghasidas landscape (Fig.2.MP.1.1). Tiger occupancy in the forests of Sohagpur were spill overs from Bandhavgarh and are important for connecting Bandhavgarh with Kanha and Achanakmar (Fig.2.MP.1.1). Tiger occupancy of Jabalpur forests (Sihora and Murwara tehsils) was maintained by dispersers from Bandhavgarh which are important elements in maintaining tiger occupancy and connectivity with the northern Narmada bank populations.

The least cost corridor pathways shown herein identify the critical connectivity between important source populations to ensure long term viability of these populations (Fig. 2.3). Some other connectivity also exists in this landscape but need further ground data to delineate on a map.

a) **The Kanha-Pench corridor**
This corridor system has gained much public attention in recent times due to the issues related to the widening of National Highway No 7. Several other linear infrastructural development projects such as the widening of State Highways and construction of broad gauge railway lines along with increasing human pressure threatens this connectivity that ensures gene flow of tigers and other wildlife across the 16,000 km² of forested landscape (Fig.2 MP.1.1). The current viability of this corridor is highlighted by the distribution of tigers, other large carnivores, and prey species across the corridor habitat. Development projects need to ensure appropriate mitigation measures when implemented within corridors so as not to act as barriers to wildlife while being constructed as well as when completed.

Figure 2.MP.1.1
Kanha-Pench -Satpura corridor



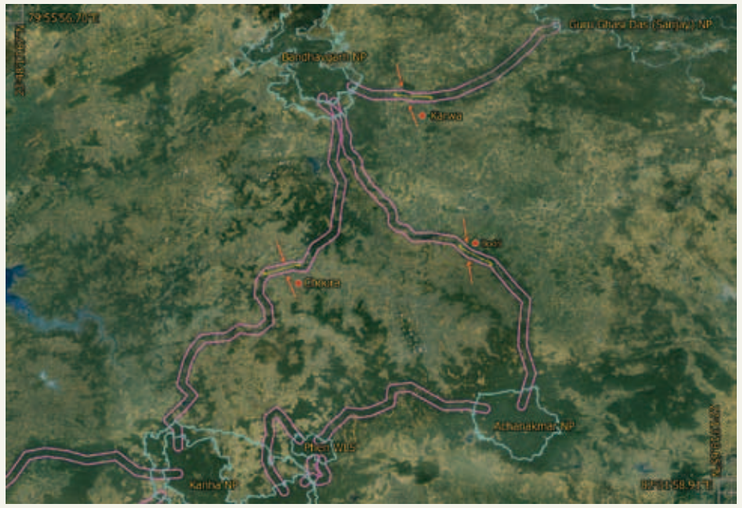
b) **Kanha-Achanakmar**
This corridor ensures the east-ward connectivity of the important Pench-Kanha-Achanakmar landscape through the forests of Phen Wildlife Sanctuary and then through the tehsils of Mandla and Dindori of Mandla district along the border of Chhattisgarh. Connectivity between Phen Wildlife Sanctuary and Kanha Tiger Reserve is maintained by two short but important corridors (Fig. 2.MP.1.2). These corridors are vital for sustenance of tigers within Achanakmar (which currently has a very small population) and maintain gene flow with Bandhavgarh population as well.

c) **Kanha-Navegaon-Nagzira**
A narrow forested strip southwards along the border of Chhattisgarh from the forests of Balaghat connects Kanha Tiger Reserve with tiger populations in Maharashtra. This corridor passes through degraded forests and would benefit immensely from restorative inputs. This corridor system forms a crucial linkage for the geneflow of tigers between east Maharashtra populations (Nagzira and Tadoba landscape), Indravati (Chhattisgarh) and those of northern Andhra Pradesh (Fig. 2.MP.1.1).

d) **Sheopur-Shivpuri-Ranthambhore**
This corridor connects the forests of Kuno-Sheopur with those of Ranthambhore Tiger Reserve (Rajasthan). The optimal connectivity is parallel to the River Kuno and crosses the Chambal near the confluence of River Kuno with the Chambal. The habitat matrix of this corridor consists of dry thorn forests, scrub, rain -fed agriculture and low density settlements. On the banks of the Chambal, due to fertile soils and water availability, agriculture flourishes. Yet, due to the fissured nature of the landscape, wildlife manages to cross between Ranthambhore Tiger Reserve and the Sheopur forests. Kuno is further connected through forest fragments and rugged landscape features with Shivpuri forests and Madhav National Park. Occasional records of tiger sightings from this region confirm that tigers are able to move between Ranthambhore and Madhav National Park (Fig. 2.RJ.1.1).

e) **Bandhavgarh-Sanjay-Dubri**
Bandhavgarh source population connects with that of Sanjay-Dubri and further eastwards to Palamau through Guru Ghasidas National Park (Fig.2.MP.1.2). These corridors are vital linkages to the major source of tigers (Bandhavgarh) to populate this vast landscape that can be home for a large population of tigers in the future. Corridors to the south connect Bandhavgarh with Achanakmar and Kanha (Fig. 2.MP.1.2). Connectivity to the west ensures tiger movement into the forests of Katni (Jabalpur) and through "stepping stone" forest patches onto the northern banks of the Narmada. These corridors need attention especially while sanctioning development activities within this region. Proper mitigation measures need to be ensured when activities that are likely to adversely affect the wildlife usage of these corridors are undertaken.

Figure 2.MP.1.2
Bandhavgarh-Kanha-Guru Ghasidas-Achanakmar corridors



f) **Satpura-Pench**
This corridor linkage is extremely precarious with forests intermittently disrupted by agriculture and habitations (Fig.2.MP.1.1). The Kanan coal block occupies parts of this corridor forests near Satpura Tiger Reserve. A severe bottleneck exists near Nayagaon, in Parasia tehsil of Chindwara where agriculture, habitation, highway and railway tracks traverse the corridor. Proper mitigation is required to make this corridor viable for regular movement of tigers and other wildlife.

g) **The Satpura-Melghat Corridor**
It connects the major source populations of Satpura in Madhya Pradesh with that of Melghat in Maharashtra (Fig. 2.MP.1.3). Tiger occupancy in the forests of Betul-Hoshangabad-East Nimar suggests a viable corridor connectivity. The corridor passes through degraded forests, agricultural areas, and some low density human settlement areas.

Figure 2.MP.1.3
Satpura-Melghat Corridor

After the declaration of the status assessment report in April 2011, the State of Madhya Pradesh has expressed its reservations regarding the reported tiger population and occupancy by Chief Wildlife Warden's Letter No. 153 Dated 31-03-2011. Madhya Pradesh has since resurveyed parts of the Kanha landscape and sent the data for reassessment to the Wildlife Institute of India. The Institute would be addressing this new dataset in a separate report to the State.

MAHARASHTRA

The State of Maharashtra has a forested area of 50,650 km² constituting 16.46% of the total geographic area of the State (State of the Forest Report 2009). The State has four Tiger Reserves, six National Parks and 35 Wildlife Sanctuaries administered by 14 Forest Divisions. Nagzira-Navegaon forests and Bor Wildlife Sanctuary in Vidarbha region have been proposed as Tiger Reserves and are awaiting State approval. The four Tiger Reserves in the State include:

a) **Melghat Tiger Reserve** covers an area of 1676.93 km² and is located in Chikhaldara and Dharni tehsils of Amaravati district. The Reserve is located within the Gawilgarh Hills, which also form its southern boundary while Rivers Tapi and Khandu form its northern boundary. The core area of the Reserve has no villages although 61 villages exist within the buffer zones and exert high pressure on the Park by grazing livestock in the Protected Area. Efforts to relocate three villages, viz., Pastalai, Churni and Vairat are in the process.

b) **Tadoba-Andhari Tiger Reserve** comprises of the Tadoba National Park covering an area of 116.55 km² and the Andhari Wildlife Sanctuary covering 508.85 km². The Tiger Reserve located within Chandrapur district, has witnessed amongst the highest levels of tiger poaching and cases of human-tiger conflict when compared to other Tiger Reserves in the country, in a span of five years. The six villages located within the Andhari Wildlife Sanctuary comprising of Botezari, Kolasa, Palasgaon, Rantalodi, Jamani and Navegaon along with 59 villages on the peripheries exert high pressures on the Reserve for sustenance requirements.

c) **Pench Tiger Reserve** is located in the Satpura-Maikal hills of Nagpur district in Ramtek tehsil and covers an area of 257 km². It is contiguous with Pench Tiger Reserve of Madhya Pradesh to the north and is bounded by the River Pench to the west. Fulzari village is located within the Reserve, while about nine villages are situated along the Park boundary. Encroachment, livestock grazing and forest fires are the major threats to the area.

d) **Sahyadri** was declared a Tiger Reserve in 2007, and comprises of the Koyna Wildlife Sanctuary in Satara district covering 426 km² along with Chandoli National Park (317.67 km²) to its south at the junction of Sangli, Kolhapur, Satara and Ratnagiri districts. Koyna Wildlife Sanctuary has the Shivsagar Lake formed by the Koyna Dam and Chandoli is located between Chandoli Dam and Radhangiri Wildlife Sanctuary. The Reserve is threatened by the proposed Karadi-Bhogiv hydro-electricity project. So far 32 villages have been relocated from the Reserve reducing anthropogenic activities in the Park considerably.

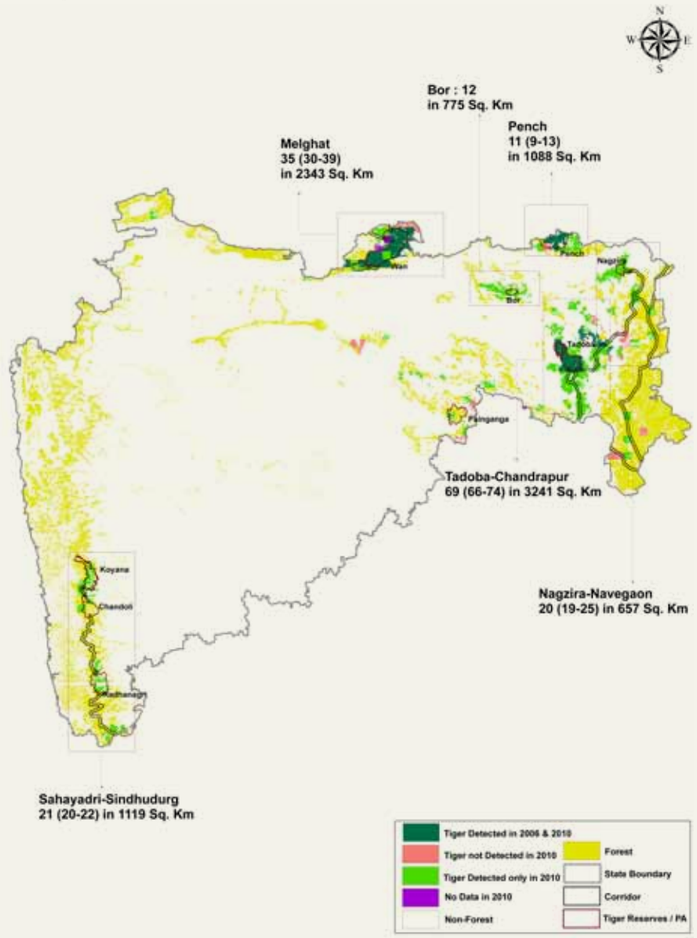
The major tiger populations identified in the State include:

a) **Melghat**: This is one of the most important tiger landscapes of Maharashtra since it forms a source within the larger Melghat-Satpura landscape of over 1,200 km². Melghat's connectivity with forests of Betul and East Nimar (Madhya Pradesh) need to be ensured by protection and restoration of forests in the tehsils of Melghat and Chikhaldhara in Amrawati District (Fig 2.MP.1.3). Tiger occupancy within the Melghat landscape was 2,343 km² with a population estimate between 30-39 tigers showing an improvement over estimates of 2006.

b) **Pench (Maharashtra)**: This Tiger Reserve is contiguous with the much larger Pench Tiger Reserve of Madhya Pradesh to the north and forms a part of the Maikal

Figure 2.MH.1

Tiger occupancy, population extent, size and habitat connectivity in Maharashtra



landscape. Tiger population within Pench Maharashtra was 1,088 km² with an estimated 9 to 13 tigers.

c) **Tadoba-Andhari:** This landscape connects the tiger population of Maharashtra to that of Indravati in Chhattisgarh through forests of Chandrapur and Gharchiroli Districts and to the north-east with Kanha through the Navegaon-Nagzira forests (Fig. 2.MH.1.1). The tiger occupancy within this landscape was estimated at 3,241 km² with a population of 66 to 74 tigers. The region has been facing high levels of human-tiger conflict, tiger poaching and is also severely threatened by developmental activities and mining pressures. Mining of coal within the corridor habitats near Lohara and Agarzari threaten these crucial corridor habitats. Similarly, the Human River Irrigation Project located three kilometers from the core zone

of the Tiger Reserve is expected to submerge parts of the buffer zone including an important corridor used by tigers between Palasgaon (Sirkada) to Shivni.

The proposed Tiger Reserves in the State include Nagzira-Navegaon forests separated by a distance of about 20 kilometers and the Bor Wildlife Sanctuary. Nagzira and Navegaon are located in Bhandara and Navegaon districts respectively while the Bor Wildlife Sanctuary is in Wardha district.

The status of the three important tiger landscapes in the State which include Melghat, Pench and Tadoba-Andhari (Fig. 2.MH.1).

Figure 2.MH.1.1
Indravati-Tadoba-Nagzira corridor

d) Sporadic tiger presence has also been reported from **forests of Bhrampuri, Garhchiroli, Nagbir, Chimur and Ahiri tehsils**, suggesting movement of tigers between Maharashtra, Chhattisgarh and parts of northern Andhra Pradesh.

e) **The Shayadri-Sindhudurg Landscape** of the Western Ghats portion within Maharashtra was assessed for the first time. Though belonging to the Western Ghats landscape this region is discussed here so as not to split Maharashtra State into two different chapters. The tiger population of the Sahyadris was connected with that of Goa through the Radhangiri Wildlife Sanctuary and further southwards with that of Anshi-Dandeli in Karnataka through the ridge-top forests of the Western Ghats. Tiger numbers estimated for the Sahyadris (20-22 tigers within 560 km²) seem to be over estimates. Field verification by camera trapping is needed to accurately assess the tiger numbers within this landscape.

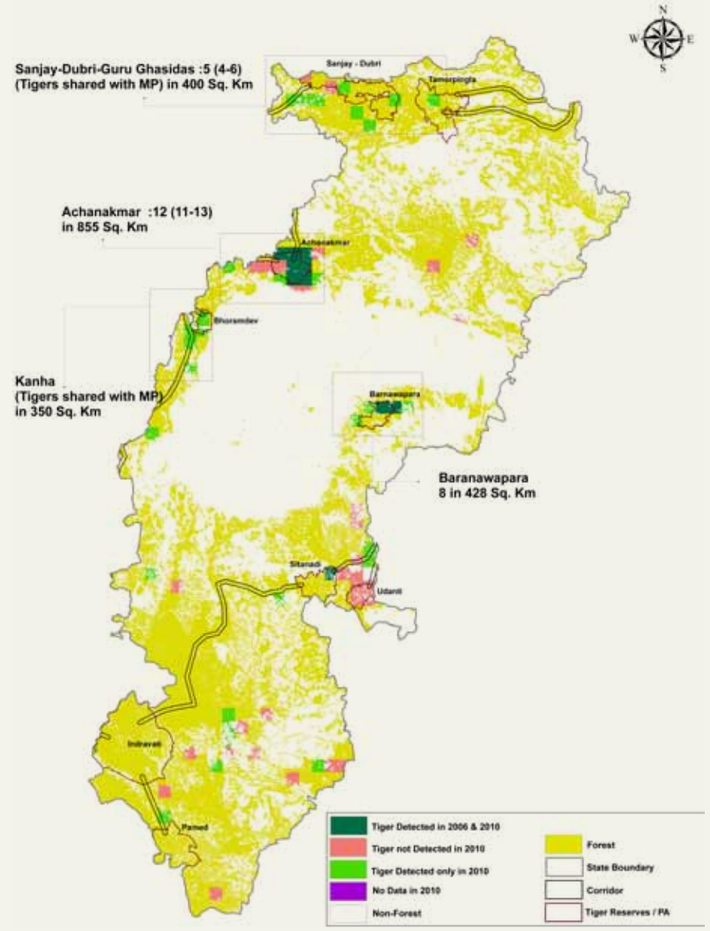
CHHATTISGARH

Chhattisgarh has an area of 59,772 km² under forest cover which constitutes 44.2% of the total geographical area of the State, having the highest proportion of area under forest cover for any State in central India. The State has three Tiger Reserves, three National Parks and 11 Wildlife Sanctuaries under 35 Forest Divisions.

The northern forests comprise of Guru Ghasidas National Park which covers 1,440 km² along the border of Madhya Pradesh, east of which are situated the Timor Pingla and Semarsot Wildlife Sanctuaries. This forest is almost contiguous from west to east through the districts of mostly Sarguja and Korea.

Figure 2.CH.1

Tiger occupancy, population extent, size and habitat connectivity in Chhattisgarh



In the central zone along the border of Madhya Pradesh are located Achanakmar Tiger Reserve and Bhoramdev Wildlife Sanctuary. Towards the central east of the State is Barnawapara Wildlife Sanctuary in Raipur district with reports of sporadic tiger presence.

The three Tiger Reserves in the State include (Fig. 2.CH.1):

a) Achanamkar Tiger Reserve is located within the Achanamkar-Amarkantak Biosphere Reserve and comprises of the Achanamkar Wildlife Sanctuary covering an area of 551.55 km² in Mungeli tehsil of Bilaspur district. It is connected to the tiger landscapes of Kanha-Pench in Madhya Pradesh on the west. However, the region has high levels of disturbance and subsistence level poaching. In 2006 about 19 (18-22) tigers were estimated to occupy 1,066 km². In 2010 a single tiger was camera trapped after an extensive effort. The total population was estimated between 11 to 13 occupying an area of 855 km².

b) Udanti-Sitanadi Tiger Reserve is located along the border of Odisha with contiguous tiger occupancy into Sonabeda Wildlife Sanctuary of Odisha. Udanti Wildlife Sanctuary covers an area of 247.59 km² in Bindra-Nawagarh tehsil of Raipur district while Sitanadi in Dhamtari district covers an area of 553.36 km². Sitanadi Wildlife Sanctuary along with Indravati is the last abode of the wild buffalo in central India with less than ten individuals of the species surviving. In 2006, six to eight tigers were estimated to occupy an area of 636 km², while in 2010, mere tiger presence was recorded and population was too small for a meaningful estimation.

c) Indravati Tiger Reserve is located in the Bastar region of south-eastern Chhattisgarh along the border with Maharashtra. It comprises of the 1,258.37 km² Indravati National Park situated in Bijapur taluka of Dantewada district along with a buffer zone of 1,540.71 km², in total covering an area of 2,799.08 km². Around 56 tribal villages are located in and around the Tiger Reserve exerting immense pressure on it. This area also has high levels of leftist extremism thus making it almost impossible to manage or monitor the biodiversity of the area. Indravati has high potential to serve as a source population within the large landscape of eastern Maharashtra, northern Andhra Pradesh, and forests within Chhattisgarh consisting of Indravati Tiger Reserve and up to Sitanadi-Udanti-Sonabeda complex. The decline in tiger numbers and occupancy observed in northern Andhra Pradesh suggests a decline in the source population of Indravati as well.

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The Guru Ghasidas National Park-Timor Pingla Wildlife Sanctuary-Semarsot Wildlife Sanctuary were a part of the tiger landscape extending from Bandhavgarh to Palamau. This contiguous forest connects large areas of Sanjay National Park and Dubri Wildlife Sanctuary in Madhya Pradesh that have been brought under the ambit of Tiger Reserves. Guru Ghasidas National Park has comparatively better forests and fewer human settlements that are cut off from mainstream socio-economic development. Bringing Guru Ghasidas National Park as well as the Tamor Pingla and Semarsot Wildlife Sanctuary under Project Tiger ambit would be extremely beneficial for tiger conservation and will provide much needed economic benefits to the local communities that eke out a meagre living in the area.

This landscape is rich in minerals, especially coal and is earmarked for mining. The least cost pathways shown herein provide guidelines for the minimal habitat required for maintaining corridor connectivity between the Protected Areas. These need to be secured before they are destroyed by developmental projects to ensure the continued value of these forested landscapes as repositories of biodiversity for future generations.

Bhoramdev Wildlife Sanctuary is contiguous with the forests of Kanha Tiger Reserve. It forms the staging ground for the dispersal of tigers southwards through the corridor along the border of Chhattisgarh and Madhya Pradesh (Kawardha and Raj Nandgoan Districts) to Nawegoan and Nagzira wildlife sanctuaries in Maharashtra. This connectivity continues further into Tadoba and Indravati landscape and therefore has far reaching implications to tiger gene flow (Fig.2.MH.1.1). Tiger sign records in this corridor and tiger occupancy of Nagzira and Nawegoan are suggestive of the viability and importance of this corridor, which spans across three States and is therefore a challenge to manage and conserve. Bhoramdev should also be managed as an integral part of the Pench-Kanha-Achanakmar landscape complex.

The corridor connectivity from Achanakmar connects this Tiger Reserve to the Kanha-Pench landscape in the west and to Bandhavgarh landscape in the north. These corridors are essential elements for the long term persistence of tigers in Achanakmar. The forests of Achanakmar in the Maikal Range of Chhattisgarh are contiguous with the Amarkantak forests and Kanha-Pench landscape in Madhya Pradesh.

Udanti-Sitanadi-Sonabeda landscape has continuous forest connectivity to Indravati and further south to the northern Andhra Pradesh tiger populations. The habitat matrix of this corridor was composed of forests, agricultural patches and some settlements with no major barriers to dispersing tigers. Tiger occupancy of Udanti and Sitanadi is contiguous with Sonabeda Wildlife Sanctuary of Odisha and comprises a part of the larger Indravati landscape.

Indravati landscape comprises of the Indravati Tiger Reserve and adjoining forested areas including Bhairamgarh Wildlife Sanctuary to the east. These forests are contiguous with forests of Kanha and Tadoba to the west in Madhya Pradesh and Maharashtra, and forests of northern Andhra Pradesh and western Odisha. Pameda Wildlife Sanctuary in Bastar is connected with northern Andhra forests providing a zone for tiger movement. Least cost pathways identify the minimal habitat corridors that potentially connect Indravati to the above mentioned tiger populations (Fig. 2.2). Indravati due to its sheer size has the potential to be a source of tigers across this landscape of over 30,000 km² but currently due to the presence of extremists groups the status of tigers and other wildlife could not be assessed.

ODISHA

The State of Odisha has 48,855 km² area under forest cover constituting 31.38% of the total geographical area of the State (State of the Forest Report 2009). The State has two Tiger Reserves, one proposed Tiger Reserve, viz., Sunabeda, two National Parks and 18 Wildlife Sanctuaries. It also has one Biosphere Reserve, viz., Simlipal landscape covers an area of 5,569 km² including the Simlipal Tiger Reserve and its surrounding forests.

The two Tiger Reserves in the State include:

a) Simlipal Tiger Reserve encompasses an area of 2,750 km² with a core area of 1,194.75 km². It is situated in the Mayurbhanj district of north-eastern Odisha and forms a part of the Simlipal Biosphere Reserve. The Tiger Reserve is known for the pioneering research initiatives taken by its Founder-Field Director, Saroj Raj Chaudhury, who collected field data on chital, sambar and Khairi the tigresses. The Tiger Reserve faces high levels of anthropogenic disturbance with the presence of three villages in the core zone along with the settlements of Bahaghar and Upper Barakamda and 65 villages in the buffer zone. The majority population of these villages is tribal and continues to indulge in customary activities such as Akhand Shikar or mass hunting within the Reserve boundaries. The Reserve also faces high levels of livestock grazing and encroachment. Such factors along with presence of extremist groups within the Protected Area are a challenge to long-term biodiversity monitoring and conservation initiatives in this region.

b) Satkosia Tiger Reserve covers an area of 964 km² constituted by the 745.52 km² Satkosia Wildlife Sanctuary and the 168.35 km² Baisipalli Wildlife Sanctuary. The Reserve is spread across the districts of Angul, Cuttack, Nayagarh and Boudh and is dissected into the north-eastern Satkoshia Wildlife Division and the south-western Mahanadi Wildlife Division by the gorge of River Mahanadi. It forms a part of the Mahanadi Elephant Reserve and is also known for the gharial project at Tikarpada. With about 35 villages within the Sanctuary and 80 in the buffer zone, the biotic pressures exerted on the Reserve in the form of timber extraction, NTFP collection, grazing for livestock and fishing is high. Similarly, the location of the Reserve close to the Talcher coal-fields and consequently in the industrial hub of the region comprising of industries such as NALCO, NTPC, TTPS, Bhushan Steels and Straps, Jindal Steels and many other smaller industries, exerts high pressure on the region.

Four important tiger populations in the State include Simlipal, Sonabeda-Udanti-Indravati, the southern population in Malkangiri and Koraput districts and the Satkosia tiger population.

The forests south of Satkosia in the districts of Phulabani, Ganjam, and Koraput had substantial tiger occupied area in 2006 but recorded significant decline in tiger signs in 2010 (Fig. 2.OD.1). However, sporadic tiger occurrences were recorded in the forests adjacent to the border with Andhra Pradesh (Vijaynagaram District).

A forest connectivity that is likely to be a viable tiger corridor exists between Simlipal Tiger Reserve and Satkosia Tiger Reserve (Fig. 2.OD.1.1). Tiger signs were recorded along this corridor in the tehsils of Anandapur in Kendujhar District and Angul.

The vast contiguous forest in Odisha holds the potential to sustain large populations of tigers. However, many parts of the State are affected by insurgency. With

Figure 2.OD.1
Tiger occupancy, population extent, size and habitat connectivity in Odisha

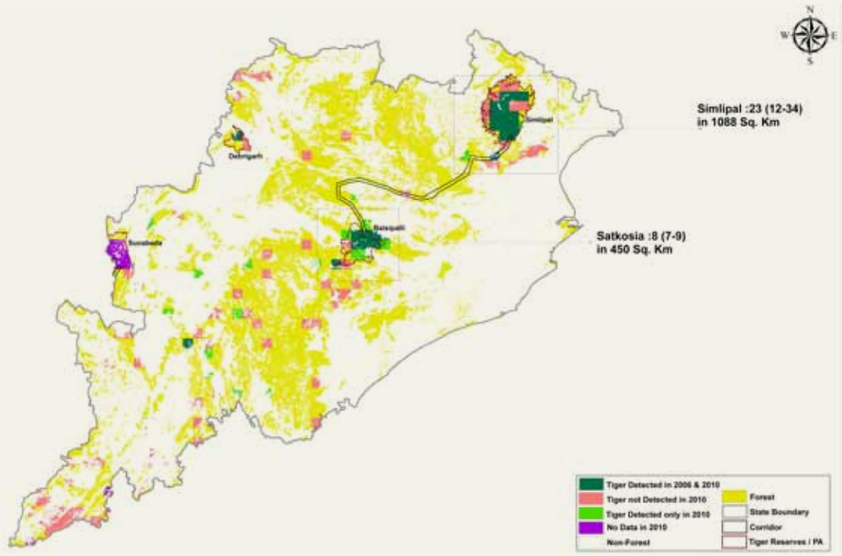
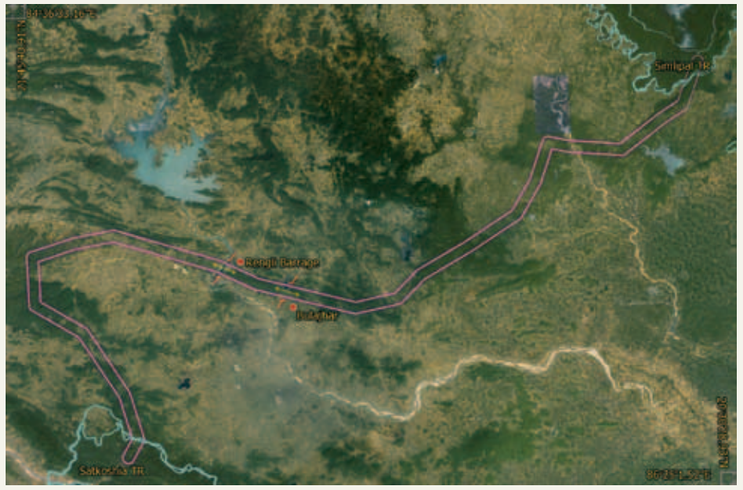


Figure 2.OD.1.1
Corridor connecting Simlipal and Satkosia



poverty ridden tribal communities that depend on the forests for their livelihoods, conservation is a challenging task in this landscape. in Dhenkanal District. Safeguarding this corridor would assist in ensuring tiger persistence within the larger landscape of Simlipal-Satkosia.

JHARKHAND

The State of Jharkhand has an area of 23,605 km² under forest cover constituting 29.61% of the total geographical area of the State (State of the Forest Report 2009). The only Tiger Reserve in the State is Palamau Tiger Reserve located on the western boundary of the State along the State border with Chhattisgarh. The State also has the Singhbhum Elephant Reserve, one National Park and 11 Wildlife Sanctuaries.

The Palamau Tiger Reserve located in the western part of the Chhotanagpur plateau covers an area of 1,026 km² spread over the districts of Latehar, Garhwa and Lohardagga. It comprises of the Palamau Wildlife Sanctuary covering an area of 979.97 km² and the Betla National Park covering 226.32 km². The Tiger Reserve is contiguous with the Sarguja Forest Division of Chhattisgarh to the west and is demarcated by Rivers Koel and Oranga on the west and north respectively for some distance. The Reserve faces high levels of anthropogenic pressure with three villages, viz., Ramandag, Latoo and Kujrum in the core zone and 72 villages in the buffer zone. Another 113 villages are located within a zone of five kilometres from the Reserve boundary, depending heavily on the area for forest products and livestock grazing. The Howrah-Mughalsarai Grand Chord Line passes through the Tiger Reserve with stops at Barwadih, Chipadohar and Kumandih. The Daltonganj-Ranchi State Highway also passes through northern fringes of the Reserve. From this highway emerges a PWD road that goes to Mahuaduar and Neterhat and passes through almost the middle of the Tiger Reserve. Apart from all these disturbances, the Reserve is affected by insurgency, thus making it difficult to implement tiger monitoring exercises.

During 2006 Phase-1 survey of the 'All India Tiger Monitoring' exercise, appropriate data to validate tiger signs could not be recorded from Palamau Tiger Reserve although subsequent questionnaire surveys and field visits conducted by the Forest Staff confirmed the presence of tigers in the Reserve. In 2010, Phase I data gathered from 16 grids of 10x10 km was obtained from Jharkhand and used for analysis.

To the north-east, Palamau is weakly connected to the Gautam Buddha and Koderma Wildlife Sanctuaries through Lawalong Wildlife Sanctuary in Chatra district and Hazaribagh Wildlife Sanctuary. Gautam Buddha and Koderma Wildlife Sanctuaries are both located in Koderma district along the border with Bihar. Similarly, to the south it is connected to Palkot Wildlife Sanctuary in Gumla district close to Jashpur region of Chhattisgarh.

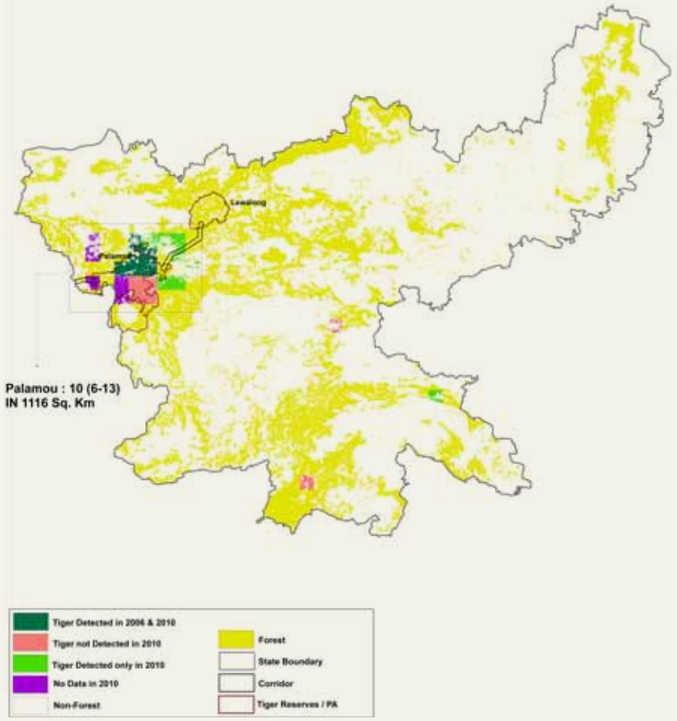
Palamau Tiger Reserve holds high potential to sustain tigers with the large forest connectivity it has to Tiger Reserves extending as far west as Bandhavgarh Tiger Reserve in Madhya Pradesh. The contiguous forest from Bandhavgarh to Palamau comprises of Sanjay-Dubri Tiger Reserve in Madhya Pradesh and the recently proposed Guru Ghasidas National Park in Chhattisgarh. The latter is further connected to forests of Timor Pingla and Semarsot Wildlife Sanctuaries in Chhattisgarh which eventually connect to Palamau. The entire forested landscape in this region covers an area of 12,580 km² and could form one of the largest contiguous tiger habitats in central India.

In 2006, sporadic presence of the tiger was also recorded from forests of Saranda and those of Ranchi tehsil within a contiguous forest patch of 7,448 km² extending further into northern Odisha. In 2010, tiger occupancy was recorded within 771 km² limited to the sampled landscape in and around Palamau Tiger Reserve with an estimated population between 6 to 13 tigers (Fig. 2.JR.1).

Palamau still has corridor connectivity both to the west and the east and can serve as a source population to revitalize this landscape with tigers and other endangered species in years to come. Until the ground situation improves for implementing restorative management, the best policy would be to ensure that the habitat of the core and crucial connectivity is not compromised since it is possible to bring back lost prey and tigers, but bringing back habitat is the most difficult if not an impossible task in high human density landscapes riddled with poverty. The least cost pathways defined here provide an indicative guidance as to where corridor connectivity's exist and need safeguarding especially from unplanned developmental activities (Fig.2.3). The areas in Chhattisgarh and Jharkhand in and around these habitat corridors are rich in minerals especially coal. It would be prudent to factor in wildlife (tiger) needs early on prior to opening up corridor habitats for development without mitigation plans or in critical habitats.

Figure 2.JR.1

Tiger occupancy, population extent, size and habitat connectivity in Jharkhand



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ANDHRA PRADESH

The State of Andhra Pradesh has 22 Wildlife Sanctuaries and four National Parks along with 58 Forest Divisions. Nagarjunasagar-Srisailam is the only Tiger Reserve in the State but covers an extensive area of 3568 km² spanning across the districts of Mahbubnagar, Nalgonda, Kurnool, Guntur and Prakasam.

A larger part of the Tiger Reserve is located in Achampet tehsil of Mahbubnagar district. Most of the Reserve is drained by the River Krishna which flows for over 130 kilometers through the park. The reservoirs of Srisailam and Nagarjunasagar are also located in this area and inundated large portions of it when constructed. Around 200 villages are located around the Tiger Reserve, with 120 within the Wildlife Sanctuary and 24 within the core zone. Two highways, viz. 140 kilometers of the Mannanur to Dornal in Prakasam and another covering almost 50 kilometers of the Tiger Reserve from Nallaguntala to Bairlutty traverse the Reserve. Only 76 km² of the Tiger Reserve has very dense forest while 1174 km² has open forest. NTFP collection, forest fires, livestock grazing and presence of leftist extremist are major problems in this area.

South of Nagarjunasagar-Srisailam is the Gundla Brahmeswaram Wildlife Sanctuary in the Nallamalai tracts of Kurnool district which also has sporadic tiger presence. Further south are the Sri Lankamaleshwar Wildlife Sanctuary in Cuddapah district and Sri Penusila Narasimha Wildlife Sanctuary in Nellore which did not report any tiger signs in 2006 and 2010.

Most of the 63,821 km² forested area of the State is restricted to the northern parts in the Godavari Basin landscape. In the extreme north-west of the State are located Kawal and Pranahita Wildlife Sanctuaries (proposed to be made Tiger Reserve) in Adilabad district, contiguous with the forests of Maharashtra. This zone also has the Sivaram Wildlife Sanctuary in Adilabad district. However, the largest forested block in the north is located in Warangal and Khammam districts connected to forests of Chhattisgarh (Indravati Tiger Reserve). Etunagaram and Pakhal Wildlife Sanctuaries are in Warangal while Kinnerasani Wildlife Sanctuary occupies parts of Khammam district. South of Odisha along the course of the Godavari is located Papikonda Wildlife Sanctuary with forest connectivity into Odisha.

Four distinct populations in the Godavari Basin landscape and the Eastern Ghats complex in south-central part of the State were identified in 2006 (Jhala *et al.* 2008). These were tiger populations in (i) Adilabad district, (ii) Karimnagar, Warangal and Khammam, (iii) East Godavari and Vishakapatnam and (iv) Nagarjunasagar-Srisailam.

Northern Andhra Pradesh Landscape has lost substantially in terms of tiger occupancy and population between 2006 and 2010 (Fig. 2.AP.1). This trend of northern Andhra Pradesh does not bode well for the major source population within this landscape located at Indravati Tiger Reserve in Chhattisgarh. Due to Naxal insurgency Indravati could not be assessed, however the northern Andhra Pradesh tiger populations were indicative of the tiger status in Indravati. Major investments in protection, community participation and livelihood options are needed along with restoration of habitat corridor connectivity and prey populations to revive tiger populations in northern Andhra Pradesh.

Figure 2.AP.1

Tiger occupancy, population extent, size and habitat connectivity in Andhra Pradesh

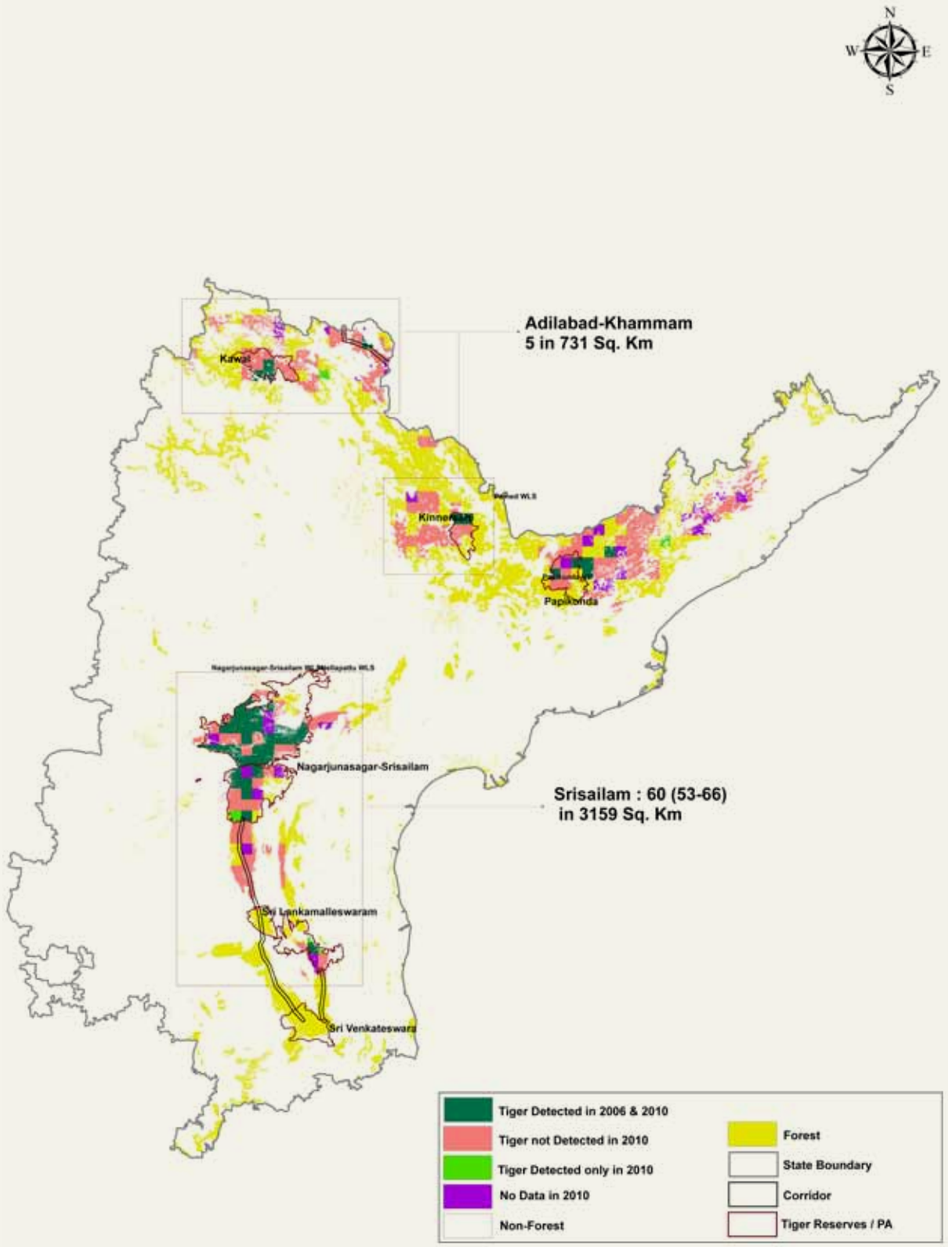
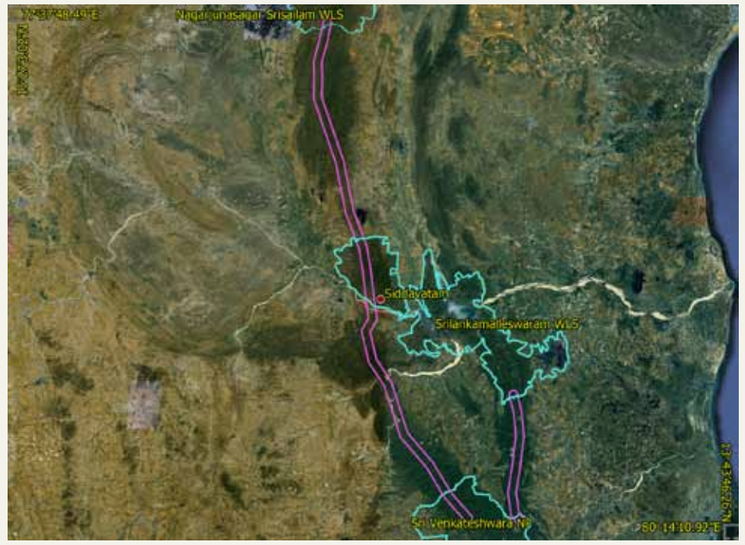


Figure 2.AP.1.1
Nagarjunsagar-Srilankamaleshwaram-Sri Venkateshwara corridor



Although Nagarjunasagar-Srisailam Tiger Reserve and its adjoining landscape recorded a drop in tiger occupied area, it showed an increase in tiger numbers. This is possibly due to a better assessment of tiger density by larger coverage in 2010. Control of extremism within Srisailam has assisted in its recovery, yet a lot needs to be done to control anthropogenic pressures especially livestock grazing by offering and subsidizing alternative livelihood options. Competition of wild prey with livestock and subsistence level poaching are major impediments to recovery of prey populations and subsequently those of tigers. Once Srisailam tiger populations increase and foster dispersing tigers, forest connectivity will ensure colonization and establishment of tiger populations in the southern Eastern Ghats landscape of Gundla Brahmeshwaram Wildlife Sanctuary, upto Sri Venkateshwara Wildlife Sanctuary (Fig.2.AP.1.1). A severe bottleneck exists within this connecting corridor near the township of Siddavatam where habitation, agriculture and roads disrupt this continuous forest connectivity for about 2 kilometer, but as yet, is not an insurmountable barrier to wildlife movement.

Tiger population status summary for the Central India landscape

State	Tiger Population			Tiger km²		
	2006	2010	Increase/ Decrease/ Stable	2006	2010	Increase/ Decrease/ Stable
Andhra Pradesh	95	72	Decrease	14126	4495	Decrease
Chhattisgarh	26	26	Stable	3609	3514	Stable
Madhya Pradesh	300	257	Decrease	15614	13833	Decrease
Maharashtra	103	168	Increase	4273	11960	Increase
Odisha	45	32	Decrease	9144	3398	Decrease
Rajasthan	32	36	Increase	356	637	Increase
Jharkhand	-	10	-	1488	1180	Decrease
Central India	601	601	Stable	48610	39017	Decrease

3.0
WESTERN GHATS LANDSCAPE COMPLEX

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The Western Ghats (also called Sahyadri Mountains) are located between 8˚ and 21˚ N and extend for about 1600 kilometres along the western coastline of India (Ranjit Daniels 1992). These pre-Cambrian remnants form the western escarpment of the peninsular plateau of India, a large part of which lies concealed under the northern plains and partly thrust beneath the Himalayas (Mani 1974).

The western coastal plains of Konkan in the north, Kanara in the centre and Malabar in the south bound the Western Ghats on the west. The coastline varies in width, from 30-60 kilometres, being the narrowest around 14-15˚ N (Ranjit Daniels 1992). In the north, the Ghats are bounded by the Satpura Range positioned in an east-west direction. This Range hosts several towns of Maharashtra such as Matheran, Lonavala, Khandala and Panchgani and also forms an important bio-geographical barrier between the Western Ghats and the remaining parts of India. The Vindhya and Ajanta Ranges in the north further strengthen this barrier.

The contiguity of the Western Ghats is disrupted at three locations. Around 16˚ N is the youngest Goa gap, then the 40 kilometre wide Palakkad Gap around 11˚ N, followed by the southernmost and the narrowest Shencottah gap at 9˚ N with a width of 7.5 kilometres. Recent studies indicate that such geographical barriers impact the population and genetic structure of populations across the gaps (Robin *et al.* 2010).

The Western Ghats mostly follow a south-south-eastern direction with about 60% of the range located within the State of Karnataka. The Kudremukh and Baba Budangiri Hills around Chikamagalur are located in the central zone while the Brahmagiri Hills situated towards the southern regions of the State form a barrier between Coorg and Wayanad.

South-east of Mysore, the Biligiri Ranganaswamy Hills link the Western and Eastern Ghats which extend further east as the Shevaroy and Tirumala hills. These hills are considered to be a 'dislocated' part of the Western Ghats owing to the north westerly movement of this area and are an important corridor for movement of bio-geographical affinities of flora and fauna between the two regions.

The Nilgiris (Blue Mountains) located between the Coimbatore plains and the Mysore plateau (900-1200 m) at the western-most part of Tamil Nadu and the junction of Kerala and Karnataka are separated from the Mysore plateau by the Moyar gorge (Mani 1974). The 2600 km² Nilgiri plateau is at an elevation of 1800-2500 m and rises abruptly on all sides and has several Protected Areas. This plateau has a precipitous drop of 1800 m on the east within three kilometres and is home to indigenous tribes such as the Todas, Kotas, Kurumbas and Badagas (Hockings 1989).

Between the Palakkad and the Shencottah Gaps is located the Anamalai Range along with the Nelliampathi Hills. This region has a large network of Protected Areas around the Valparai plateau which covers about 200 km² in the Anamalai Range. The region is home to several indigenous communities of different ethnic origins such as the Kadar, Muthuvar and Malai Malasar (Chandi 2008). The highest peak in peninsular India, Anaimudi (2695 m) is located in this region within Eravikulam National Park in Kerala.

East of the Anamalais is the Palni range (Kodaikanal Hills) in Tamil Nadu which extends further into the Sirumalai-Ammayanayakkanur-Ayyalur Hills and the Varshanad-Andippatti Range towards the Vaigai Valley.

South-west of the Palnis are the Cardamom Hills that partly shape the boundary of Kerala and Tamil Nadu. To the south of the hills lies the Periyar Tiger Reserve and

Major tiger populations, their status, political units and corridors in Western Ghats Landscape

Tiger Population	State/s	Tiger abundance in 2006	Tiger abundance in 2010	Increase/ Decrease/ Stable	Area occupied (sq. km.) in 2006	Area occupied (sq. km.) in 2010	Increase/ Decrease/ Stable	Connecting larger PA landscapes
Sharavathi Valley-Anshi-Dandeli	Karnataka	33(31-34)	39 (36-42)	Stable	7,309	4,756	Decrease	Mollem-Netravali-Anshi-Dandeli-Cotigaon-Haliyal FR-Kumbharwada FR-Karwar FR-Honavar FR-Gersoppa FR-Sharavathi
Kudremukh-Bhadra	Karnataka	58(52-65)	40 (38-42)	Decrease	3,816	4,258	Stable	Mookambika-Someshwara-Kudremukh Kudremukh-Masakali RF-Kuskal RF-Bhadra Bhadra-Shethihalli
Nagarahole-Mudumalai-Wayanad	Karnataka, Kerala, Tamil Nadu	267(207-327)	382 (354-411)	Stable	9,087	11,100	Increase	Bandipur-Nagarahole Wyanad-Nagarahole-Bandipur-Moyar-Segur-Sathyamangalam-BRT-Cauvery-Mudumalai
Parambikulum-Indira Gandhi WLS	Kerala, Tamil Nadu	14 (13-16)	34 (32-36)	Increase	2,744	3,253	Increase	Peechi-Vazhani-Chimmony-Parambikulum Indira Gandhi WLS-Chinnar-Anaimudi-Eravikulum
KMTR-Periyar	Kerala	32 (28-38)	38 (36-40)	Increase	3,288	3,812	Increase	Periyar-Shendurney-Peppara-KMTR

to its east in the rain-shadow region, is the Srivilliputtur Wildlife Sanctuary in Tamil Nadu. Watersheds of important rivers like the Periyar and Pamba are located within this region.

Towards the southern end of the Western Ghats, the range becomes narrow with steep slopes on both sides until about 20 kilometres from Kanyakumari. The Agasthyamalai Hills (Ashambu Hills) are located within this zone between the Cardamom Hills and the Aryankavu Pass with the Agastyamalai peak (1868 m) being the highest part of the region. Kanikkaran, one of the oldest hunter-gatherer tribes is known to live here.

3.1.1 Location

In this report, the Western Ghats landscape comprises of the Satpura Range in Maharashtra, the Western Ghats in the States of Karnataka, Tamil Nadu and Kerala and some lowland areas around the Mysore plateau comprising of Nagarahole and Bandipur Tiger Reserves in the state of Karnataka.

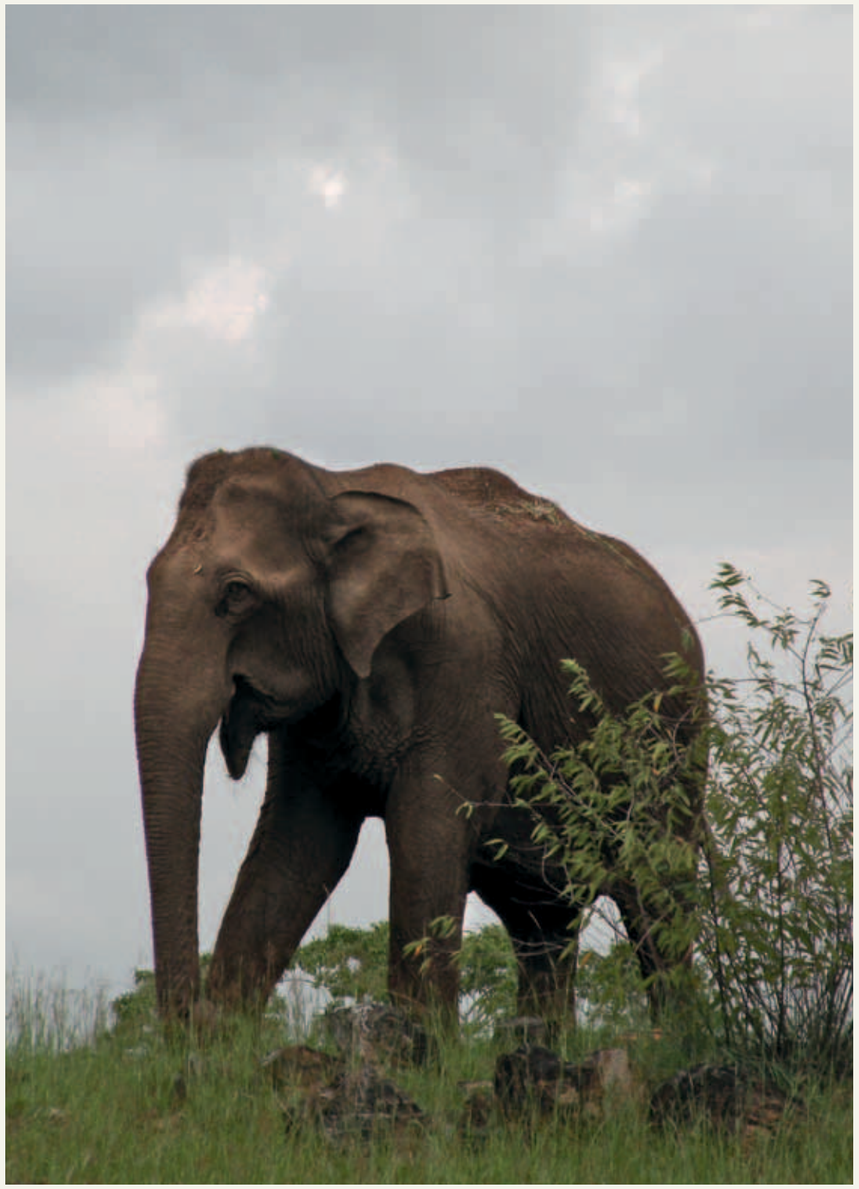
The major biogeographic zones of this region include the Western Ghats (Malabar Plains), The Western Ghats (Mountains), Deccan Peninsula (Central Plateau), Deccan Peninsula (Deccan South), Coasts (East Coast) and Coasts (West Coasts) with nine eco-regions as per Rodgers and Panwar's (1988) classification.

From an ecological perspective, this region with a total forested area of 1,01,467 km^2 (Qureshi *et al.* 2006) comprising of nine notified Tiger Reserves, three proposed Tiger Reserves`, viz., Sathyamangalam Tiger Reserve in Tamil Nadu and Kudremukh and Biligiri Rangaswamy Temple Hills (BRT) Wildlife Sanctuary in Karnataka; 20 National Parks and about 68 Wildlife Sanctuaries forms one of the largest Protected Area networks in India. The Nilgiri and Agasthiyar Malai Biosphere Reserves are also located within this zone in addition to several Reserved Forests and sacred groves, totalling to about 5.8% of the total forested area in the Western Ghats alone.

The Western Ghats landscape in Karnataka comprises of several Protected Areas of which some of the important ones include Nagarahole National Park, Bandipur Tiger Reserve, Bhadra Tiger Reserve, Anshi-Dandeli Tiger Reserve, BRT Wildlife Sanctuary, Kudremukh National Park, Sharavathy Valley Wildlife Sanctuary, Mookambika Wildlife Sanctuary, Someshwara Wildlife Sanctuary, Pushpagiri Wildlife Sanctuary, Talacauvery Wildlife Sanctuary, Gersoppa Reserved Forest, Kodachadri Reserved Forest, Balehalli Reserved Forest and Agumbe Reserved Forest.

Within the Nilgiris are located the Mudumalai Tiger Reserve and Mukurthi National Park, while on the lower slopes are the Silent Valley National Park and the new Amarambalam Reserved Forest. Wayanad Wildlife Sanctuary is at the junction of Karnataka and Kerala. The Anamalais comprise of a cluster of several protected areas such as the Anamalai Tiger Reserve (Indira Gandhi Wildlife Sanctuary and National Park, Grass Hills, Top Slip and Karian Shola), Eravikulum National Park, Chinnar Wildlife Sanctuary, Parambikulum Wildlife Sanctuary, Peechi-Vazhani Wildlife Sanctuary and Reserved Forests of Athirappaly and Vazachal.

The region around the Cardamom Hills comprises of Protected Areas of Periyar Tiger Reserve and the Reserved Forests of Ranni, Konni and Achankovil Forest Divisions while in the rain shadow region of Tamil Nadu is located the Srivilliputtur Wildlife Sanctuary.



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The southernmost part of the Ghats around the Agasthyamalai Hills comprises of Kalakad-Mundanthurai Tiger Reserve, Neyyar Wildlife Sanctuary, Peppara Wildlife Sanctuary and Shendurney Wildlife Sanctuary along with the Kulathupuza and Palode Reserved Forests.

While the entire landscape has a human density of 318.7 persons/ km² (Qureshi *et al.* 2006), it is distributed irregularly with Kerala state having amongst the highest human density in India. The high human populations of the three States exert enormous pressure on these fragile systems for hydro-electric power, timber and agricultural output from plantations.

3.1.2 Ecological Background

The edaphic and climactic conditions of the Western Ghats support high diversity of flora and fauna. However, prior to British accession of India, most of this region was occupied by indigenous groups that practised swidden cultivation and were primarily hunter-gatherers.

The British annexation of Malabar in 1792 opened this area to exploration with the Nilgiri plateau being amongst the first to become a British establishment due to its appealing climate. Thus, it became an important administrative and military base with missionaries and settlements in the 1820s (Hockings 1989). The arrival of the British also coincided with felling of large tracts of natural forests in the region and replacement of those with plantation species like wattle (introduced in 1832), eucalyptus (1842), conifers, fruit trees, alder and eventually leading to about 400 introduced or exotic species of plants (Hockings 1989). This was followed by plantations of tea around 1832-3 and by coffee after its initial success in Conoor in 1838 (Hockings 1989).

By mid 1800s, large tracts of Baba Budangiri Hills (incidentally also the first place where coffee was grown in 1670), Biligiri Rangan Hills, Wayanad plateau, Valparai plateau in the Anamalais, parts of Kerala and Madras Presidency were under intense tea or coffee plantations after the removal of natural forests. By 1866, Madras Presidency had over 200 coffee plantations covering an area of 14,613 acres with two-third plantations being owned by Europeans and the remaining by Indians from coastal towns (Tucker 1988). Since most native inhabitants either refused to work or were inefficient workers, labour for plantations was brought from the plains of Tamil Nadu to clear forests and grow coffee. Some parts of the forest were however reserved for timber. However, with foresters like BR Hugowood, while large areas around Top Slip came under teak plantations in early 1900s, protection of the Karian Sholas was also ensured (Johnsingh 2006a). In the same area in 1944, the Konalar Fishing Association introduced the rainbow trout and advocated its preservation (Johnsingh 2006a).

Parts of the Western Ghats under Bombay Presidency were exploited extensively for teak which was supplied to the Bombay dockyard for ship-building and later for railway sleepers. This region was occupied primarily by the pastoralist Gawlis in Haliyal and Yellapur taluks and the Havik Brahmins in Yellapur, Siddapur and Sirsi who owned areca nut and spice plantations (Buchy 1996). Siddis were brought as slaves from Africa and were also known to inhabit these regions. The regions around Supa and Bhatkal were occupied by Kumri Marathas that practised kumri or shifting cultivation (Cleghorn 1861; Buchy 1996). Further south, the regions around Kudremukh remained relatively less exploited and were sanatoriums from the heat of the plains.

Cardamom Hills in the southern part of the Western Ghats were amongst the last to come under extensive plantations between 1880s and the Second World War. However, by 1868-76, most coffee in the Malabar was destroyed by coffee blight and replaced by tea (Tucker 1988). With tea came higher work load and commercialization. Regions like the High Ranges became centres of landless migrants, land grabbers, labour unions and planter lobbies against the government. By 1874, the Peermade Planters Association was formed and at the United Planters Conference in 1893, local associations merged to form the United Planters Association of South India (UPASI) (Tucker 1988).

While the forests of the region underwent massive alterations due to altered land-use, the wildlife too suffered immensely. Apart from habitat loss, extensive uncontrolled hunting became a major problem. Areas around Wayanad and in parts of Mudumalai comprising of Karguli, Thepakkadu and Masinagudi were known for their big game shooting comprising of tiger, elephant and gaur while the Nilgiris were known for the tahr. In fact, around 1890s wildlife numbers dwindled to such an extent that a group of sports hunters formed the Nilgiri Game Association and enforced strict quotas for shooting animals (Rangarajan 2001). By 1879, the Nilgiri Game Act was initiated. It was due to this Act that the Nilgiri tahr population recovered in this area and continues to survive even today. In the Anamalais, the High Range Game Preservation Association (now High Range Wildlife and Environment Preservation Association) has been providing similar protection to the tahr since 1895 (Seshadri 1986; Johnsingh 2006a).

Around Mysore plains and plateau, the forests had large elephant and tiger populations. While in areas like Coorg bounties of rupees five were given for every tiger skin (Richter 1870), the Maharaja of Mysore zealously protected his shooting blocks in the 803 km² of the Venugopal Wildlife Park of which present day Bandipur Tiger Reserve forms the core (Seshadri 1986). No forestry practices or hunting by locals was permitted in this zone with shooting privileges restricted to the ruler and his guests. The princely state of Mysore was also known for its kheddah operations to capture elephants. The first successful kheddah in this region was attempted by Sanderson in 1837 in the foothills of Biligiri Rangan Hills. Prior to this attempt only Haidar Ali had tried capturing wild elephants using similar techniques. Captured elephants would be sent to the Hebballa camp on the banks of Lakshmanatirtha River which flows through Nagarahole National Park (Seshadri 1986).

In the contemporary era, while this landscape remains marked by large scale plantations that first attracted foreigners to this region, some of the old shooting preserves like Bandipur and Nagarahole are sources of tiger populations for the entire landscape.

3.1.3 Conservation Significance

The Western Ghats apart from being a store house of tropical biodiversity are also a source of 38 east flowing rivers and 27 flowing into the Arabian Sea (Dahanukar *et al.* 2004). These rivers act as important sources of hydro-electric power, water for agriculture and industrialisation downstream and add impetus to the development of large cities in the plains of Karnataka, Tamil Nadu and Kerala.

These hills also structure rainfall and climatic patterns of this region, allowing vast scale plantations of commercial crops while supporting amongst the highest abundances of endangered species of floral and faunal elements in India. Despite sustaining the high diversity of flora and fauna, the region is also susceptible to high levels of anthropogenic disturbances and thus was amongst the first 18 global biodiversity hotspots identified (Myers *et al.* 2000).

Due to its ecological significance, the Nilgiri Biosphere Reserve was included in the United Nations Educational, Scientific and Cultural Organisation's (UNESCO) Man and Biosphere Programme (MAB) in 2000. The aim of this programme is primarily to promote interdisciplinary research and capacity building with the aim of reducing biodiversity loss by addressing ecological, social and economic complexes.

The south Western Ghats moist deciduous forests and the South Western Ghats montane rain forests also constitute two of WWF's 200 global terrestrial ecoregions due to their unique biodiversity with high levels of endemism (Olson and Dinerstein 1998; Olson *et al.* 2001).

In 2006, the Nature Conservation foundation (NCF), Mysore and the Ashoka Trust for Research in Ecology and the Environment (ATREE), Bangalore submitted a proposal to the UNESCO to include the Western Ghats sub-cluster comprising of the region between the Sahyadris and the Agasthyamalai Hills on the World Heritage List. The proposal is under review.

Wikramanayake *et al.* (1998) recognised two important level one tiger conservation units (TCUs) within this landscape comprising of Dandeli-Bandipur and Periyar-Kalakad regions while Parambikulum National Park was included in level II TCUs based on their importance in tiger conservation. Johnsingh and Goyal (2005) improvised upon this framework and added more details and national level conservation rankings to these landscapes. They also identified breeding habitats and potential threats to each of these TCUs.

3.1.4 Vegetation

The Malabar Coast of this region was recognised in the pre-colonial era for its importance as a trading zone for spices like pepper, ginger and cardamom, thus plant studies were initiated in this region by the Dutch and the Portuguese as early as 1565 when Garcia de Orta prepared a list of medicinal plants. The region also hosted one of the first comprehensive botanical treatise (not following binomial nomenclature system) from the pre-Linnean era of the modern world, Hortus *Malabaricus* (The Garden of Malabar), written by Heinrich Van Rheede Tot Draakenstein between 1678-1703. It was in 12 volumes and later inspired Carl Linnaeus to write his *Species Plantarum*. Thereafter, myriad botanical surveys have been conducted in this region and much information exists on its floral diversity.

The levels of endemism are remarkably high not just in higher level of plants with 1500 endemic angiosperms (Nayar 1996), 118 endemic orchids (Sathish Kumar *et al.* 2001), 25 species of endemic rattans (Renuka 1992), 23 species of *Calamus* (Manohara *et al.* 2007), 12 species of Dipterocarpus and 76 species of *Impatiens* but also amongst lower levels of vegetation. This landscape has 121 species of endemic liverworts of the 280 growing here, 190 species of mosses from the 682 known and 2 species of hornworts from the 14 known from this region (Gunawardene *et al.* 2007).

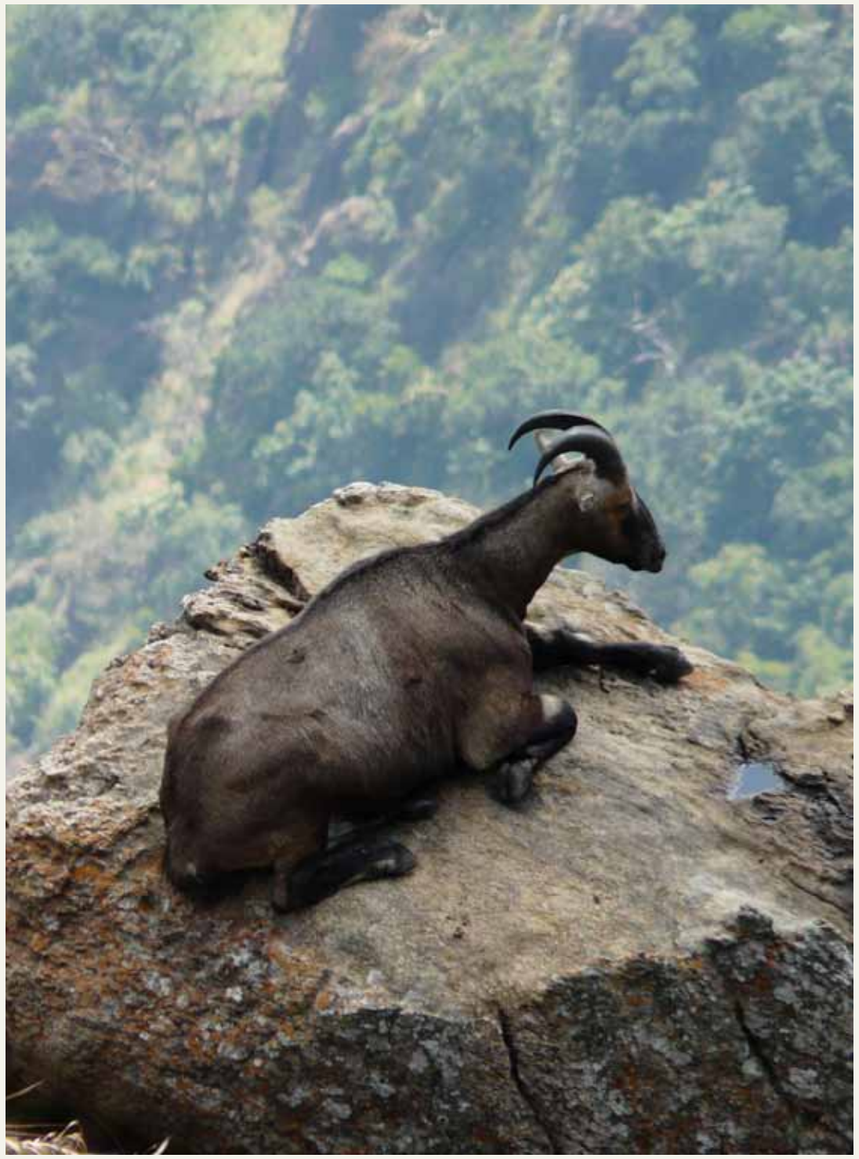
The dominant families in this region are Poaceae, Fabaceae, Acanthaceae, Orchidaceae, Asteraceae, Euphorbiaceae, Rubiaceae, Apocynaceae, Geraniaceae and Lamiaceae while the most dominant genera include *Crotalaria, Impatiens, Diospyros, Ipomoea, Eugenia, Strobilanthes, Ficus, Desmodium, Habenaria, Grewia* and *Osbeckia*. The endemic genera include *Poeciloneuron (CR), Adenoon, Willisia, Meineckia, Pseudoglochidion, Baeolepis, Nanothamnus, Wagatea* and *Otonephelium*. The only gymnosperm in this landscape is *Nageia wallichiana* which grows in the Anamalai, Palni and Cardamom Hills regions.

Subramanyam and Nayar (1974) divided the Western Ghats into four phylogeographical regions: From River Tapti to Goa, River Kali to Coorg, the Nilgiris, and the Anamalai, Palni and Cardamom Hills.

Up to Goa, scrub and dry semi-deciduous species occur on the foothills on the eastern side of the Ghats. The dominant species include *Diospyros montana, Eriolena quinquelocularis, Sterculia urens, Canthium dicoccum, Solanum surattense, Argemone mexicana, Barleria prionitis, Eranthemum roseum, Hemigraphis latebrosa* and *Justicia diffusa*. Valleys and ravines have *Terminalia chebula, Albizia procera, Erinocarpus nimmonii, Turraea villosa, Lavallea ceylanica, Xantolis tomentosa* and *Pavetta indica* along with *Lantana camara*.

Moist deciduous forests on the windward side at elevations between 500 and 833 meters include *Terminalia crenulata, Dalbergia latifolia, Anogeissus latifolia, Lagerstroemia lanceolata, Pterygota alata, Schleichera oleosa, Grewia tiliifolia* and *Pterocarpus marsupium*. Several species of Bamboo like, *Bambusa arundinacea, Zingiberaceae like Kaempferia scaposa, Hitchenia caulina, Curcuma pseudomontana, Zingiber cernuum, Cheilocostus speciosus* and species of Araceae like *Cryptocoryne spiralis, Pothos scandens and Colocasia esculenta* are also found. Montane subtropical evergreen forests have species such as *Amoora lawi, Toona ciliata and Alstonia scholaris*. Orchids are represented by several genera, most dominant being *Habenaria* with about 21 species.

The region from Karwar to Coorg comprises of some of the best teak forests in the upper evergreen zones and the taller trees (30-45 m) in the rain forests comprise of *Tetrameles nudiflora, Elaeocarpus tuberculatus, Dipterocarpus indicus* and *Dysoxylum malabaricum*. The next layer (15-23 m) has *Alstonia scholaris, Strychnos nux-vomica, Xylia xylocarpa* and *Artocarpus lakoocha*. The third layer comprises of *Callicarpa tomentosa, Flacourtia montana* and *Leea indica*. The deciduous forest



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species are found between 666-1000 m with areas receiving about 150-200 cm rain. These areas have *Haldina cordifolia, Albizia sp., Bauhinia* sp.*, Bridelia squamosa, Butea monosperma, Dalbergia latifolia, Diospyros Montana, Emblica officinalis, Ficus* sp.*, Grewia tiliifolia, Lagerstroemia lanceolata, Lannea coromandelica, Mallotus philippensis, Tectona grandis and Terminalia* spp. Areas on eastern sides with scrub vegetation have *Acacia catechu, Balanites aegyptiaca, Capparis* sp.*, Carissa spinarum, Rhus mysorensis, Gardenia* sp., etc.

The Nilgiris are interspersed with plantations, woods and Shola forests. The grassy areas have distinct vegetation comprising of *Strobilanthus* sp.*, Berberis* sp.*, Hypericum* sp.*, Rubus* sp. *and Gaultheria* sp. The Sholas are found above 1666 m, dominated by Lauraceae family and comprise of evergreen forests with thick undergrowth with species such as *Hydnocarpus alpina, Michelia nilgirica, Berberis tinctoria, Mahonia napaulensis, Garcinia gummi-gutta, Gordonia obtusa, Ilex* spp.*, Meliosma* spp.*, Cinnamomum wightii, Ternstroemia japonica, Clematis hirsuta, Viola serpens* and *Polygala arillata*. Insectivorous plants like *Drosera* and *Utricularia* can also be found at elevations over 2000 m along with grasses, sedges and mosses in the peat bogs. *Eriochrysis rangachari* is an endemic grass that grows in this region and is extensively used by the Todas (Gunawardene *et al.* 2007). The flora of this region bears a strong similarity to that of the Khasi-Naga hills and the Eastern Himalayas.

Deciduous vegetation in the Anamalai, Palni, and Cardamom Hills region is similar to that of the Karwar belt with some additional species like *Santalum album*. On the leeward side of these hills rainfall is low (between 45-53 cms), thus, species such as *Commiphora berryi, Dichrostachys cinerea, Acacia horrida, Euphorbia* spp. and *Jatropha villosa* occur. The wet evergreen forests from 500-2500 m with high rainfall (between 250-500 cms) have *Mesua ferrea, Vitex altissima, Aglaia elaeagnoidea, Polyalthia fragrans, Diospyros buxifolia, Syzygium gardneri, Canarium strictum, Artocarpus* spp.*, Bischofia javanica, Calophyllum tomentosum, Palaquium ellipticum* and *Diospyros ebenum*. The evergreen forests over 2500 m have species such as *Rhododendron arboreum, Gaultheria fragrantissima, Rhodomyrtus tomentosa, Microtropis* sp., etc.

The vegetation in the Western Ghats is particularly unique in areas south of Mysore. Species like *Mesua ferrea, Dipterocarpus indicus, Vateria indica, Myristica malabarica* and *Hopea utilis* occur only south of this region.

Besides, discovery of new species continues with the recently discovered *Semecarpus kathalekanensis* from the *Myristica* swamps of Uttar Kannada and *Kunstleira keralensis* from the sacred groves of Kerala.

3.1.5 Fauna

High levels of endemism in this region are not restricted to plants. The tropical climate and high rainfall along with high levels of humidity through most parts of the year create an ideal environment for herpetofauna. Thus, herpetofaunal studies in this zone probably outnumber those conducted anywhere else in the country. Of the 131 species of amphibians found here, 7 genera and 96 species are endemic with 42% species belonging to Ranidae and 25% to Rhacophoridae (Gunawardene *et al.* 2007). The endemic genera include *Micrixalus, Indotyphlus, Melanobatrachus, Nannobatrachus, Nyctibatrachus, Ranixalus,* and *Uraeotyphlus*. Amongst caecilians too, of the 20 species found here, 16 are endemic (Gunawardene *et al.* 2007).

Similarly, of the 197 species of reptiles from the region, 130 are endemic making it a mega hotspot for reptilian fauna. Eight endemic genera of reptiles found here include *Brachyophidium, Dravidogecko, Melanophidium, Plectrurus, Ristella, Salea, Teretrurus* and *Xylophis*.

Amongst birds, about 500 species have been recorded from this landscape of which 22 are endemic (Gunawardene *et al.* 2007) and include species like the Nilgiri pipi (*Anthus nilghiriensis*), Nilgiri flycatcher (*Eumyias aplbicaudata*), Malabar grey hornbill (*Ocyceros griseus*), Malabar parakeet (*Psittacula columboides*), Sri Lankan frogmouth (*Batrachostomus moniliger*), white-bellied treepie (*Dendrocitta leucogastra*), Nilgiri wood pigeon (*Columba elphinstonii*) and the white-bellied shortwing (*Brachypteryx major*).

The region has 135 mammalian species (Nameer *et al.* 2001) with 16 endemic (Kaveriappa and Shetty 2001) species. Together, Chiroptera, Insectivora and Rodentia constitute 66.5% of all mammalian species in the region (Nameer *et al.* 2001). Endemic species that are critically endangered as per the IUCN Red List (1994) include the Malabar civet (*Viverra civettina*) and the Wroughton's free tailed bat (*Otomops wroughtoni*), while the Nilgiri tahr (*Nilgiritragus hylocrius*), Salim Ali's fruit bat (*Latidens salimali*), Lion-tailed macaque (*Macaca silenus*) and Bonhote's rat (*Mus famulus*) are categorised endangered. This region has a high diversity of Sciuridae (squirrels) which includes nine species, viz., Layard's striped squirrel (*Funambulus layardi*), three-striped palm squirrel (*F. palmarum*), five-striped palm squirrel (*F. pennantii*), jungle striped squirrel (*F. tristraitus*), Travancore flying squirrel (*Petinomys fuscocapillus*), Elliot's giant flying squirrel (*Petaurista philippensis*), Indian giant squirrel (*Ratufa indica*) and the grizzled giant squirrel (*R. macroura*). The only large carnivores in the region are the tiger (*Panthera tigris*), leopard (*P. pardus*), dhole (*Cuon alpines*) and sloth bear (*Melursus ursinus*). The striped hyena (*Hyaena hyaena*) may also be found albeit with a very restricted distribution and in low abundances. The main prey of large carnivores in the region comprises of wild pig (*Sus scrofa*), Indian chevrotain (*Moschiola indica*), chital (*Axis axis*), sambar (*Rusa unicolor*), Indian muntjac (*Muntiacus muntjak*), gaur (*Bos gaurus*), Nilgiri tahr (*Nilgiritragus hylocrius*) and four-horned antelope (*Tetracerus quadricornis*).

This region also has about 288 species of fish of which 118 are endemic (Dahanukar *et al.* 2004). Many fish found in this region show similarities to those of the north-east, supporting the Satpura hypothesis (Hora 1944). Some endemic forms like the blind catfish (*Horaglanis krishnai*) besides being endemic to Kerala show unique behaviour, moving between some wells through a subterranean network of channels.

The invertebrate fauna of this region is also diverse with about 76% of the 269 species of land snails in the region being endemic (Aravind *et al.* 2005). With respect to butterflies, the Nilgiris alone host about 299 species while the entire region has about 330 species.

Apart from this vast diversity of fauna, discoveries of new species continue, though restricted primarily to herpeto-fauna. Within the last few months, this region has seen rediscovery of four species of frogs, viz., Chalazodes bubble-nest frog (*Raorchestes chalazodes*) rediscovered after 137 years in Kodayar, Anamalai dot-frog (*Ramanella anamalaiensis*) rediscovered from Parambikulum Wildlife Sanctuary, Silent Valley tropical frog (*Micrixalus thampii*) last seen 31 years ago and the elegant tropical frog (*Micrixalus elegans*) known from a specimen collected in 1937, rediscovered from Kempholey in Karnataka. Prior to this *Nasikabatrachus sahyadrensis, Nyctibatrachus minimus* (Biju *et al.* 2007) and *Philautus nerostagona* were also discovered from this region in recent times.

3.1.6 Ecological Studies

The Western Ghats, from times immemorial, have been subjected to high levels of exploration and research. However, in recent times this area has seen amongst the highest levels of ecological research and monitoring anywhere in the country owing to its high biodiversity and the extensive levels of potential threats to it.

Several institutions are located in this zone and conduct intensive scientific monitoring and research and thus could be responsible for the extensive information available on biodiversity and the high levels of conservation initiatives from this landscape. Some of these institutes are the French Institute of Pondicherry, Wildlife Conservation Society (WCS), Centre for Wildlife Studies (CWS), National Centre for Biological Sciences (NCBS), ATREE, NCF, Centre for Ecological Studies (CES) at the Indian Institute of Science, University of Agricultural Sciences at Dharwad, Salim Ali Centre for Ornithology and Natural History (SACON), Forestry college in Sirsi, Agumbe Rainforest Research Station (ARRS), Tropical Institute of Ecological Sciences in Kottayam, Kerala Forest Research Institute (KFRI) and Zoo Outreach Organisation (ZOO).

Pioneering scientific research in tiger ecology in India has been an outcome of field studies conducted by CWS in collaboration with the WCS. Most of these studies were first conducted at the Nagarahole National Park and Bandipur Tiger Reserve. Karanth and Sunquist (1992) used line transect method to estimate large herbivore densities in Nagarahole in 1986-87, initiating an era that would use scientific techniques to estimate animal populations against the then existing ad-hoc methods. This was followed by usage of capture-recapture methods to estimate tiger populations from camera trapped photographs in Nagarahole in 1991-92 (Karanth 1995). While the tiger and its prey estimation project initiated in late 1980s still continues, the areas under its operations have increased to include other Protected Areas such as Bandipur Tiger Reserve, Bhadra Tiger Reserve, Anshi-Dandeli Tiger Reserve, Kudremukh National Park and most recently Biligiri Rangaswamy Hills Wildlife Sanctuary and Kaveri Wildlife Sanctuary.

Further, Karanth and Sunquist (1995) examined the differences in prey selection by tiger, dhole and leopard with their principal prey. A spatially extensive study conducted by Karanth *et al.* (2004) identified the relationship between tigers and their prey, deducing that the dependence of tigers on their prey resulted in densities of tigers being determined by their prey. Tiger abundance data of Nagarahole from 1991-2000 was used by Karanth *et al.* (2006) to assess population dynamics of the species using non-invasive tools. This study showed that tiger populations can have high fluctuation due to natural processes of mortality and dispersal. CWS in collaboration with WCS continues to improvise its existing population methods by incorporating new concepts like developing software to identify individual tigers (Hiby *et al.* 2009), usage of occupancy and spatially explicit likelihood methods for abundance estimation (Royle *et al.* 2009) and the usage of non-invasive tools like genetic based individual identification of tigers from scats (Andheria 2006; Mukherjee 2006; Mukherjee *et al.* 2007; Mondol *et al.* 2009a, b). The same organisation with allied conservation groups has also been studying human dimensions of tiger conservation (Karanth 2007).

Jhala *et al.* (2008) conducted a large scale study incorporating areas from all three

states of the Western Ghats and concluded that while tiger distribution from 17% of districts within this landscape has been lost, about 51,000 km² of potential tiger habitat still exists here with 366 (297-434) tigers.

3.1.7 Conservation Status

The major impediments to tiger conservation in this zone are the existence of hydro-electric projects, hunting (Madhusudan and Karanth 2002) and deforestation of large areas for commercial plantations.

Johnsingh and Goyal (2005) recognised TCU 55 which covers the tiger landscape between Silent Valley-Mudumalai-Bandipur and Dandeli (with 7500 km² under protection and about 2000 km² of inviolate area) as the most important area for the persistence of the species. They also identified five breeding habitats in this zone capable of sustaining upto 600 tigers and suggested strengthening the connectivity between Mukurthi-Nadugani-Mudumalai to link populations between areas north and south of the Nilgiris. The second important landscape (ranked 8th in the country) was Megamalai-Periyar-Kalakad with 1800 km² area under protection and capable of holding as many as 100 tigers with a breeding habitat in Periyar. Anamalai unit was recognised as the 9th best landscape with 1600 km² of protected area with a carrying capacity of 100 tigers.

Jhala *et al.* (2008) estimated the single largest contiguous population of tigers in India (and probably in the world) within Nagarahole-Mudumalai-Bandipur-Wayanad landscape with occupancy of 10,800 km² and an estimated tiger population of 280 individuals.

However, despite the conservation impediments, a strong lobby of conservationists in this zone have enabled the creation of inviolate zones in parts of Nagarahole NP and Bhadra Tiger Reserve (Karanth 2007) by relocating villages from both these Protected Areas and making them partially or fully inviolate. Further, they have ensured closure of mining operations in Protected Areas such as Kudremukh National Park (Krishnaswamy *et al.* 2006) and prohibited the creation of dams which would submerge large biodiversity rich areas in Silent Valley National Park, while, organisations such as the NCF work in plantation forest mosaics and restore the natural vegetation in those regions (Shankar Raman and Mudappa 2003).

The existence of strong conservation organisations like Kerala Shastra Sahitya Parishad in this zone along with large groups of individuals willing to protect biodiversity assures the persistence of wildlife including flagship species such as the tiger and the elephant here.

3.3.1 Tiger Occupancy

In this landscape, 861 (10x10 km) grids having potential tiger habitat were surveyed. Tiger signs were detected in 295 of these grids, resulting in a naïve occupancy estimate of 34.26%.

The forested area (tiger habitat) within these occupied grids summed to 20,800 km² out of a total of 49,900 km² of available habitat i.e. 41.7% of the available habitat was occupied by tigers. The basic model of occupancy (corrected for imperfect detections,

with no covariates) provided an estimate of occupancy at 34.6 (se 1.6) % with a detection probability of 39.2 (se 0.82) %.

The best model incorporated the following covariates:

a) Prey availability, indexed by encounter rates of major prey (chital, sambar and gaur);
b) Landscape habitat features, indexed by average rainfall, elevation, forested area, amount of core habitat, and distance of the grid from a Protected Area;
c) Human disturbance variables indexed by presence of human/livestock trails, and livestock seen on transects as covariates of occupancy.

The best model also had detection probability modelled with a covariate of tiger abundance indexed by the average intensity of tiger sign encounter (Table 3.1 and 3.2). The AIC support for models incorporating covariates for modelling detection probability was high (Delta AIC of 46). The detection probability modelled with the covariate of average tiger sign intensity was 0.533 (0.001 se). This best model estimated tiger occupancy at 34.7 (1 SE).

The delta AIC for the top two models was less than two. We therefore used the model averaged coefficients based on AIC weights of these two models to estimate parameters. With high detection probability and number of surveys (5 kilometre spatially independent walks) ranging from 3 to 30 (proportional to the amount of tiger habitat in a grid), the increment in tiger occupancy (from 34.26 % naive estimate to 34.7 (se 1) best model estimate) by incorporating imperfect detections and covariates was marginal. However, the coefficients of covariates used in the models provided good insight into factors that influence tiger occupancy in the Western Ghats landscape. The occupancy probability of a grid habitat was interpreted as a quantitative estimate of habitat suitability for tigers and was used for mapping source and corridor habitats (Fig. 3.1).

Table 3.1
Model selection results for estimating tiger occupancy within the Western Ghats landscape incorporating imperfect detections and covariates of landscape characteristics, prey abundance, and human disturbance

Model	AICc	Delta AICc	No. Par	-2 x Log Likelihood
ψ (Ch+Sam+Gr,Trail,Lvstk,For,PAD,DEM,Cor, Precp),p(AvgTigSgn.)	5616.77	0	10	5596.32
ψ (Ch+Sam+Gr, Trail, LvStkSn, For, PAD, DEM,Cor, Precp, Rug),p(AvgTigSgn.)	5618.79	3.02	11	5596.25
ψ (Ch+Sam+Gr, Trail, LvStkSn, For, PAD, DEM,Cor, Precp),p(.)	5664.77	48	10	5644.32
ψ (Ch+Sam+Gr, Trail, LvStkSn, For, PAD, DEM,Cor, Precp, Rug),p(.)	5666.79	50.02	11	5644.25
ψ (Ch+Sam+Gr, Trail, LvStkSn, For, PAD, DEM,Cor, Precp, Lop,GrC,NitL,PatSz),p(.)	5667.03	50.26	14	5638.16
ψ (UngER, Trail, LvStkSn, For, PAD, DEM,Cor, Precp),p(.)	5696.53	79.76	10	5676.08
ψ (Ch+Sam+Gr, Trail, LvStkSn, For, PAD, DEM,Cor, Precp),p(Sur sp.)	5743.59	125.82	10	5723.14
ψ (NitL,Rug,RdDis,For,PAD,DEM,Cor,Precp) ,p(.)	5763.67	145.9	10	5743.22
ψ (Ch+Sam+Gr),p(.)	5808.64	191.87	3	5803.59
ψ (Trail,WdC,Lop,PeopSn,GrC,LvStkSn,LvstkE R,PreyER),p(.)	5870.25	253.48	10	5849.8
ψ (.),p(Sur sp.)	5879.98	263.21	31	5813.74
ψ (PAD),p(.)	5880.95	264.18	3	5874.9
ψ (for),p(.)	5889.36	273.59	3	5883.31
ψ (DEM),p(.)	5921.01	304.24	3	5914.96
ψ (NDVIM,NDVIMcv,NDVIPM,NDVIPMcv,rd den),p(.)	5924.41	307.64	7	5910.18
ψ (.),p(TigSignAvg.)	5938.59	321.82	2	5934.57
ψ (trails),p(.)	5964.41	347.64	3	5958.36
ψ (cor),p(.)	5967.29	350.52	3	5961.24
ψ (Precp),p(.)	5976.98	360.21	3	5970.93
ψ (LvStkSn),p(.)	5978.72	361.95	3	5973.67
ψ (.),p(.)	5988.16	371.39	2	5984.14

UngER- Ungulate Prey encounter per km transect walk, Ch+Sam+Gr – Encounters of Chital, Sambar, Gaur per km transect walk, NDVIM- Normalized differential vegetation index monsoon, NDVIPM- Normalized differential vegetation index pre-monsoon, NDVIcv- Coefficient of variation in NDVI value, DEM - Elevation, RdDen: Density of major metalled roads, PAD – Euclidian distance to nearest Protected Area , NitL-Euclidian distance to Night Lights, For – Area of Forest Cover, Cor – Area of Forest Core, Rug- Ruggedness of the terrain measured by CV of Digital elevation model, , LvStkER – Livestock encounters per km transect walk, WdC – Number of wood cutting signs on 15m plots along transects, Lop- Number of trees lopped on 15m plots on transects, GrC – Signs of grass and bamboo cutting on 15m plots on transects, Trail – Presence of human-livestock trails on transects, Hum- Presence of humans on line transect plots, LvstkSn – Presence of livestock on transect plots, TigSignAvg – Average encounter rate of tiger sign, GrC – Signs of grass and bamboo cutting on 15m plots on transects, Cor – Area of Forest Core, Precp- Precipitation, Patsz- Patch size, Sur sp.- Survey specific, RdDis- Euclidian distance to road, PeopSn- People seen, PreyER- Prey encounter, NDVIPMcv- Coefficient of variation in pre-monsoon NDVI value

Table 3.2
Coefficient Estimates for the best model selected for estimating tiger occupancy in the Western Ghats landscape

Covariates	Coeff. estimate	SE
a1	-0.812702	0.104214
Chital+Sambar+Gaur	3.013354	0.302964
Human Trails	-0.308664	0.102971
Cattle seen	-0.251749	0.105847
Forest Area	0.533918	0.112168
Dist to Protected Area	-0.713781	0.120529
Elevation	0.372733	0.101806
Core Area	0.350489	0.108812
Precipitation	-0.34831	0.113176
b1(Avg. Tiger Sign)	0.379125	0.027644

3.3.2 Tiger Population Extents and Abundance across the Western Ghats landscape

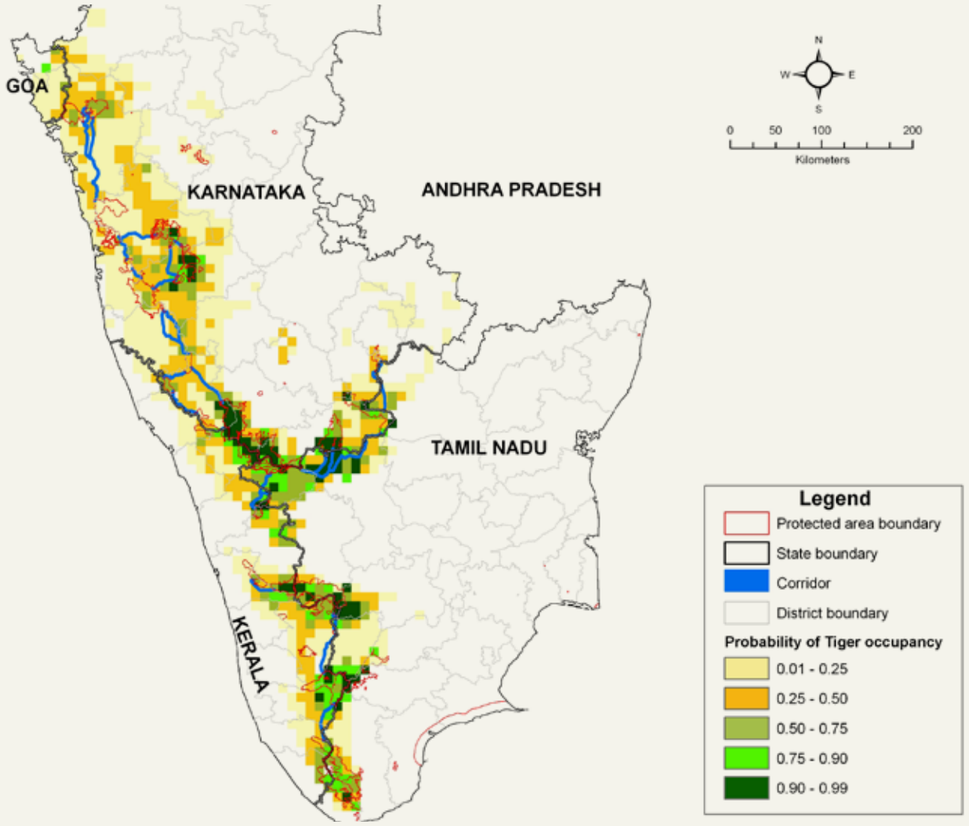
Mark-recapture population and density estimates of tigers based on camera-trapping were obtained for Bandipur Tiger Reserve, Mudumalai Tiger Reserve, Segur Plateau, Moyar Gorge, Sathyamangalam Forest Division, Periyar Tiger Reserve, Parambikulum Tiger Reserve, Eravikulam National Park and Kalakad-Mundanthurai Tiger Reserve. Tiger densities in the Western Ghats landscape ranged between 3 to 13 tigers per 100 km² and were assigned to tiger density categories of no, low, medium and high number of tigers per 100 km².

Tiger sign encounter rates, prey abundances, landscape characteristics and human pressure indices explained variability in tiger density categories quite well (see Phase III result). A ordinal logistic regression was then used to predict tiger density categories for areas where tiger density was not estimated by camera traps. Based on the probability value of assigning tiger density category to a particular grid, tiger density value (see Phase III result) was assigned to that grid. After joining contiguous grids with tiger presence, five tiger populations were identified within the Western Ghats (south of Goa) (Fig. 3.2). These include:

a) The southern-most population of tigers in Kalakad-Mundanthurai-Periyar complex having tiger occupancy of about 3,812 km² with an estimated population of 36 to 40 individuals;
b) Parambikulum-Indira Gandhi complex, with tiger occupancy of about 3,253 km² with an estimated population of 32 to 36 individuals;
3) Nagarahole-Mudumalai-Wayanad complex having tiger occupancy of about 11,100 km² with the largest single population in India numbering between 354 to 411 individuals;
4) The Kudremukh-Bhadra population having tiger occupancy of about 4,258 km² with an estimated tiger population of between 38 to 42 individuals;
5) Sharavathi Valley-Anshi-Dandeli complex with tiger occupancy of about 4,756 km² with an estimated 36 to 42 individuals.

Figure 3.1

Tiger habitat in the Western Ghats landscape showing probability of tiger occupancy modelled by incorporating imperfect detections as well as covariates of landscape characteristics, human disturbance, and prey availability

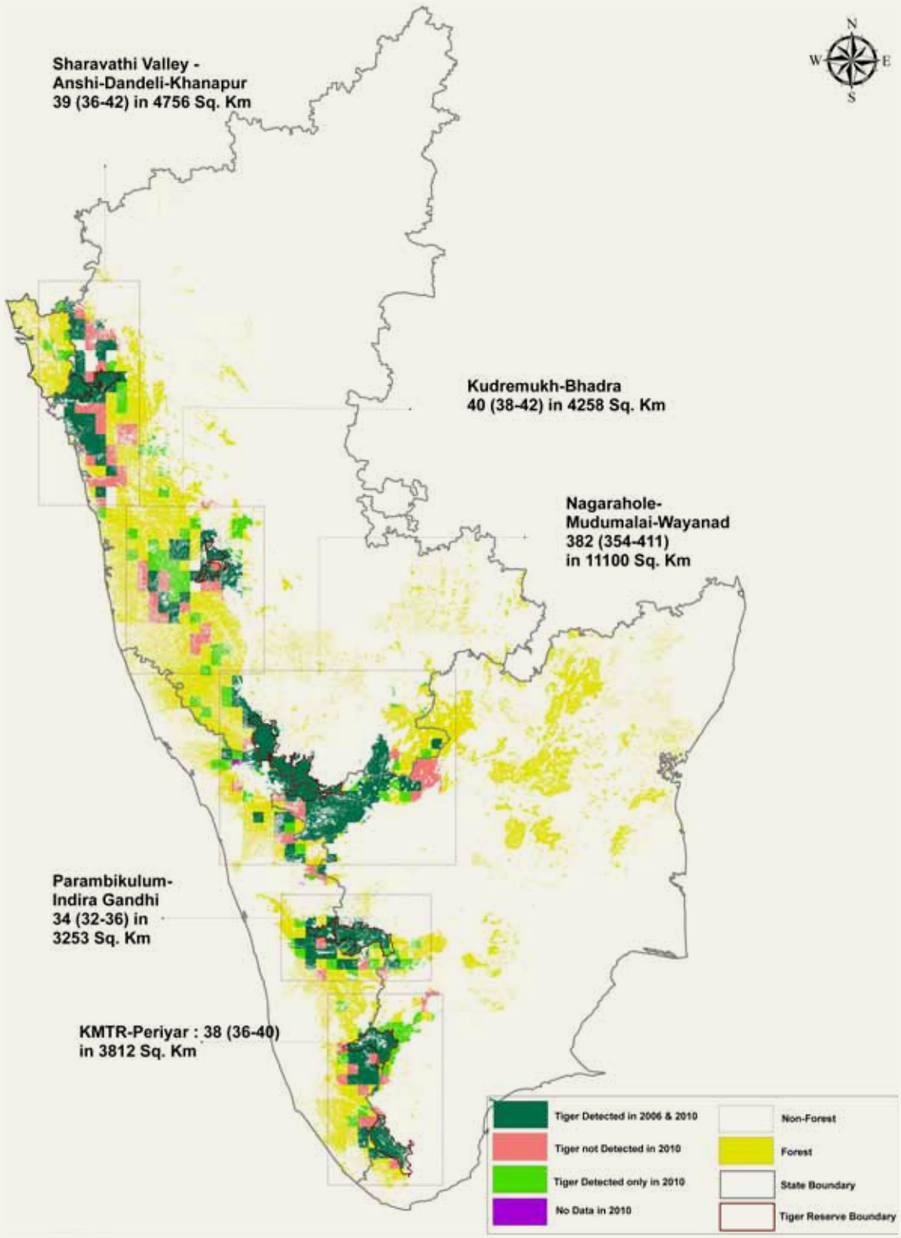


3.3.3 Change in Occupancy and Abundance from 2006 to 2010

Tiger occupancy in the Western Ghats landscape was recorded to be around 34,094 km² in 2006, and decreased to 29,607 km² in 2010, (Fig. 3.2). Loss in tiger occupied areas for the period between 2006 and 2010 was observed in the forests in southern Kerala connecting Periyar to Kalakad-Mundanthurai in Tamil Nadu; eastern parts of Bhavani tehsil in Periyar district of Tamil Nadu; western forests of Chikmagalur district, and in some forests of Supa and Ankola tehsils of Uttara Kannada in Karnataka. All these areas were low tiger density areas, but important for their role as corridors for maintaining tiger presence in the larger landscape.

Figure 3.2

Tiger occupancy, population extent, size and habitat connectivity in Western Ghats Landscape



3.3.4 Critical Corridors, Habitat connectivity, and Conservation

This landscape has the potential to have contiguous tiger occupancy from the Dang forests in Gujarat up to the Palakkad Gap in Kerala and then again from Parambikulum-Indira Gandhi complex upto Kalakad-Mundanthurai Tiger Reserve.

Within this landscape the most important source population is the Nagarahole-Mudumalai-Wayanad population which spans the three States of Karnataka, Tamil Nadu and Kerala with a high density (average density of over 4 tigers per 100 km²) tiger population occupying a large area (over 11,000 km²) (Fig. 3.2).

The other sources though occupying sufficiently large patches of habitat are of low tiger density (1-2 tigers per 100 km²) and their nuclei are centred within Protected Area complexes. These source populations are Kalakad-Mundanthurai, Periyar and the Parambikulum-Indira Gandhi complex south of the Palakkad Gap, while Kudremukh, Bhadra, Anshi and Dandeli are north of the Palakkad Gap. Few tigers are also recorded from the forests in Goa and from the Sayahadri Tiger Reserve in Maharashtra. The populations in Goa and Maharashtra depend significantly on the narrow forest connectivity of the Western Ghat ridge.

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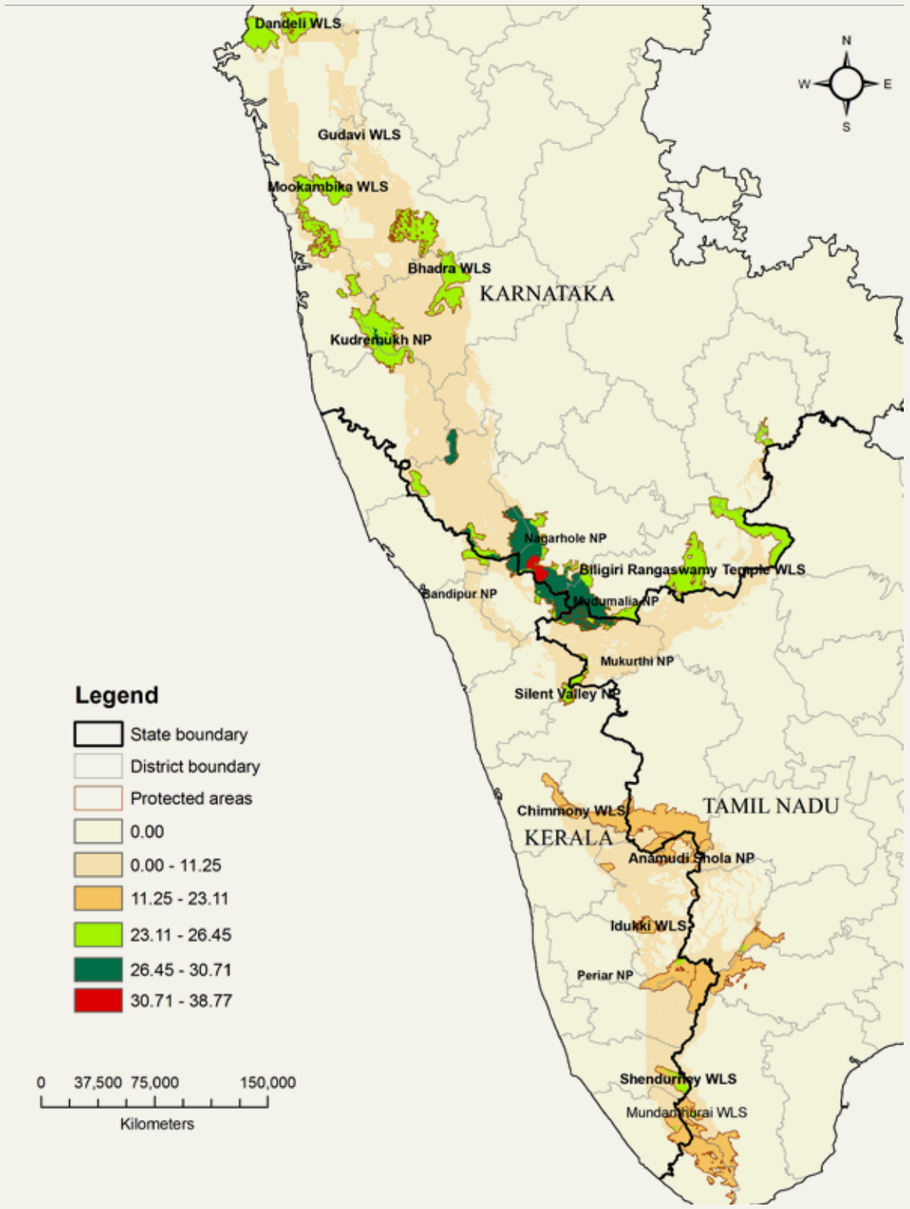
The Western Ghat tiger populations are more connected with each other when compared to tiger populations in Central India and the Shivalik-Gangetic Plains landscapes. The habitat matrix in the Western Ghats was more conducive for tiger occupancy (Fig. 3.1). However, the habitat connectivity is threatened by plantations, agriculture, industrial and infrastructural development. It would be prudent to timely identify and legitimize the minimal corridors needed for the conservation objective of ensuring gene flow between the Western Ghats tiger populations in times to come. Phase-I data collection has revealed occupancy of tigers in Goa, which acts as a corridor between Anshi-Dandeli in Karnataka and Sahyadris in Maharashtra.

The Least Cost Path analysis (Fig. 3.3) provides the optimal corridor between Protected Areas. The minimal corridors defined here need to be safeguarded through policy and formal legislation. A designation of "ecosensitive areas" to these minimal habitat corridors would ensure that land uses within these corridors are not altered to such drastic levels that the corridors become non-functional and loose their conservation significance. Bottlenecks within each of the corridors that may require restoration or acquisition of habitat is detailed in the section on each State. Currently, this least cost corridor analysis considers only the biological aspects to design. However, if in conflict with national priority development projects, alternative, less optimal corridors may be considered in some situations (Fig. 3.3). These corridors have been designed based on the habitat potential for supporting tigers (occupancy probability), however, they would also suffice for the needs of most other wildlife species.

Figure 3.3

Least resistance pathways connecting potential tiger habitats and source populations within the Western Ghats landscape modelled in Arc GIS using CIRCUITSCAPE.



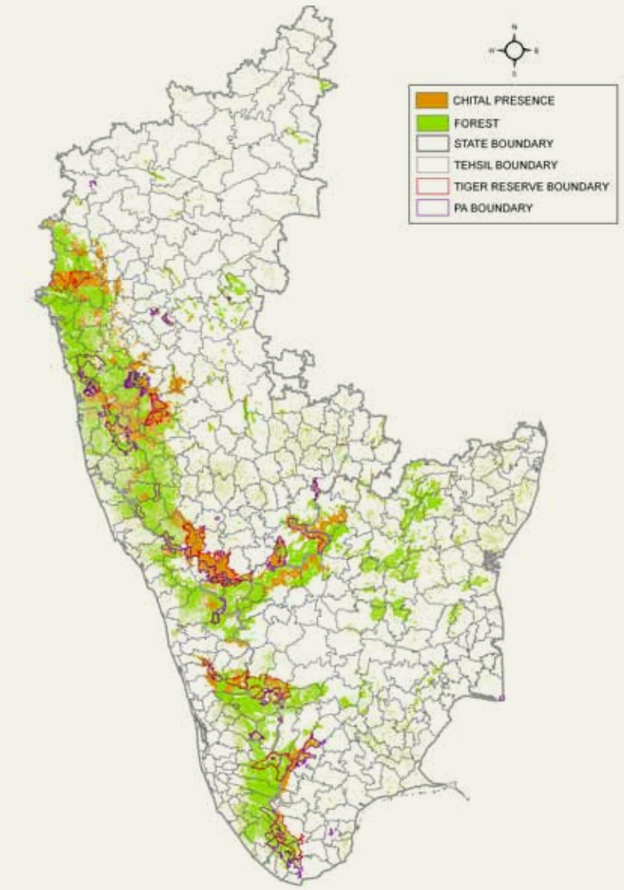
3.2.5 Distribution of ungulates in the landscape

a) **Chital** (*Axis axis*)
Chital occupancy was recorded from within 20,760 km² in the Western Ghats landscape. The species occurred as three large populations north of the Palakkad Gap:
a) Anshi-Dandeli complex,
b) Bhadra-Kudremukh complex and
c) Nagarahole to Cauvery complex

Chital occurrence was low south of the Palakkad Gap and restricted to open canopy forests, although the species was recorded from within Periyar and Kalakad-Mundanthurai Tiger Reserves. High density tiger populations are associated with high abundance pockets of chital within the Western Ghats landscape (Fig. 3.4.1).

Figure 3.4.1

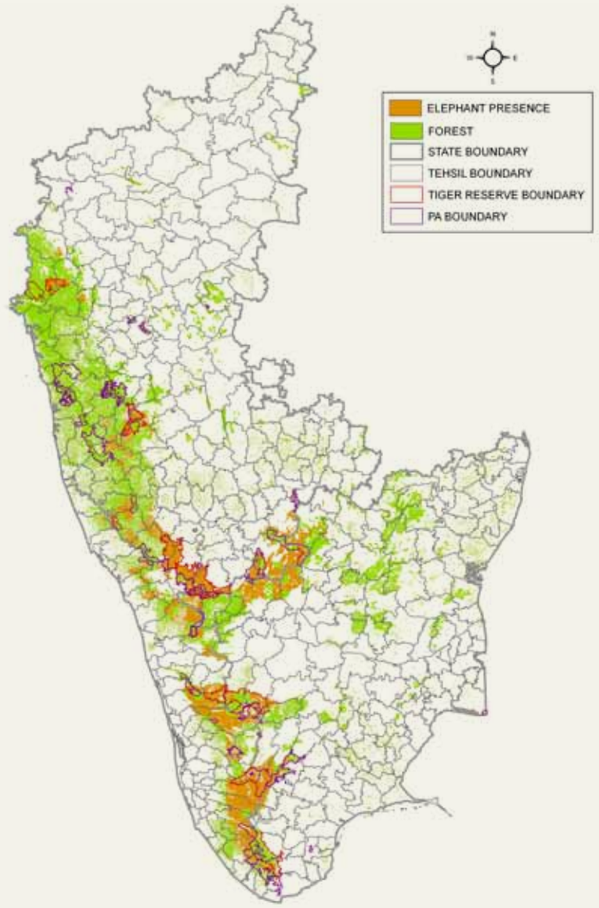
Occupancy of chital in the Western Ghats landscape



b) **Elephant** (*Elephas maximus*)
Elephant occupancy was recorded from 23,543 km² of the Western Ghats landscape. Three major populations (one to the north of the Palakkad Gap and the two to the south of it) in this landscape include:
a) The northern population extends through the Protected Areas of Pushpagiri-Talakaveri-Brahmagiri-Nagarahole-Bandipur-Mudumalai-Wayanad-BRT and Cauvery Wildlife Sanctuary and their intervening forests, extending up to the Eastern Ghats.
b) The two southern populations south of the Palakkad Gap were those extending across Protected Areas of i) Peechi-Vazhani-Parambikulum-Indira Gandhi Wildlife Sanctuary-Idukki and ii) Periyar-Srivilliputhur-Shendurney-Peppara to KMTR. Elephant signs were also recorded from parts of Anshi and Bhadra Protected Areas and from the forests of Mudigere tehsil of Chikmagalur district (Fig. 3.4.2).

Figure 3.4.2

Occupancy of elephant in the Western Ghats landscape



c) **Gaur** (*Bos gaurus*)

Gaur occupancy was recorded in 23,225 km². Presence of the species was observed throughout the landscape as scattered occurrences in the northern parts of the landscape (mostly within Protected Areas) and as contiguous populations in:

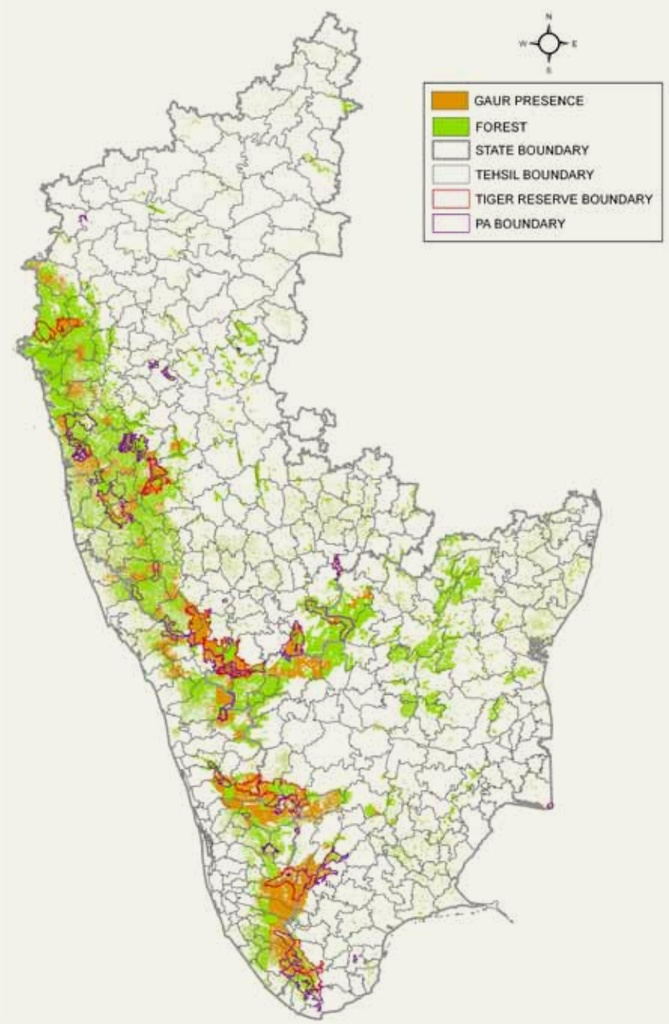
a) Nagarahole-Mudumalai-Wayanad-BRT Wildlife Sanctuary,

b) Peechi-Vazhani-Parambikulum-Indira Gandhi Wildlife Sanctuary

c) Periyar-Srivilliputhur-Shendurney-Peppara to Kalakad-Mundanthurai landscapes (Fig. 3.4.3).

Figure 3.4.3

Occupancy of gaur in the Western Ghats landscape

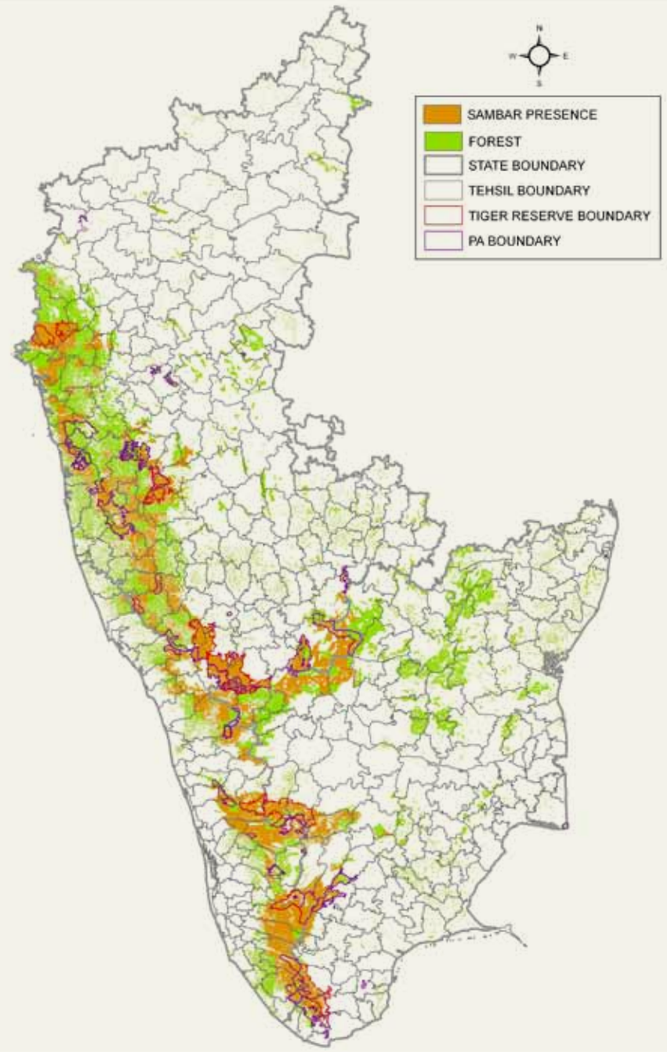


d) **Sambar** (*Rusa unicolor*)

Sambar occupancy was recorded from 37,899 km² in the Western Ghats. A contiguous occupancy of sambar was recorded from Anshi-Dandeli upto the Palakkad Gap in the south and eastwards into Cauvery Wildlife Sanctuary and beyond. Occupancy was also recorded throughout the forests of Peechi, Vazhani, Parambikulum, Indira Gandhi Wildlife Sanctuary, Idukki, Periyar, Srivilliputhur, Shendurney, Peppara to Kalakad-Mundanthurai in southern Tamil Nadu (Fig. 3.4.4).

Figure 3.4.4

Occupancy of sambar in the Western Ghats landscape



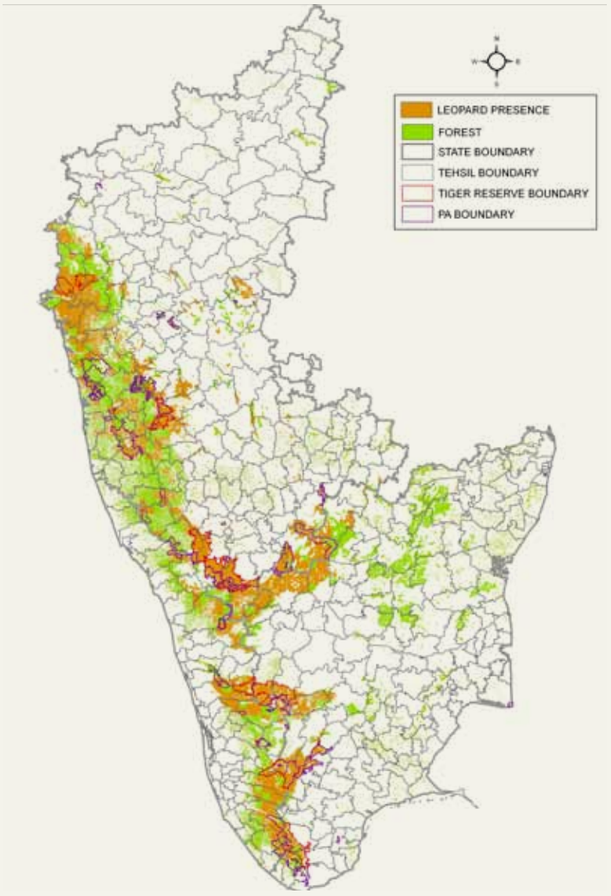
3.2.6 Distribution of co-predators in the landscape

a) **Leopard** (*Panthera pardus*)
Five major populations of leopards are present in the Western Ghats landscape occupying a total forested area of 40,660 km². These populations include the Protected Areas of:
a) Anshi-Dandeli,
b) Sharavathi Valley-Kudremukh-Bhadra,
c) Nagarahole-Mudumalai-Wayanad-BRT-Cauvery Wildlife Sanctuary,
d) Peechi-Vazhani-Parambikulum-Indira Gandhi Wildlife Sanctuaries and
e) Periyar-Srivilliputhur-Kalakad-Mundanthurai

The populations north of the Palakkad Gap are connected from the Dang forests in Gujarat to Silent Valley NP, while those to the south of the Palakkad Gap are connected between themselves. Sporadic leopard occurrences were recorded across forest patches in Karnataka and Tamil Nadu (Fig. 3.5.1).

Figure 3.5.1

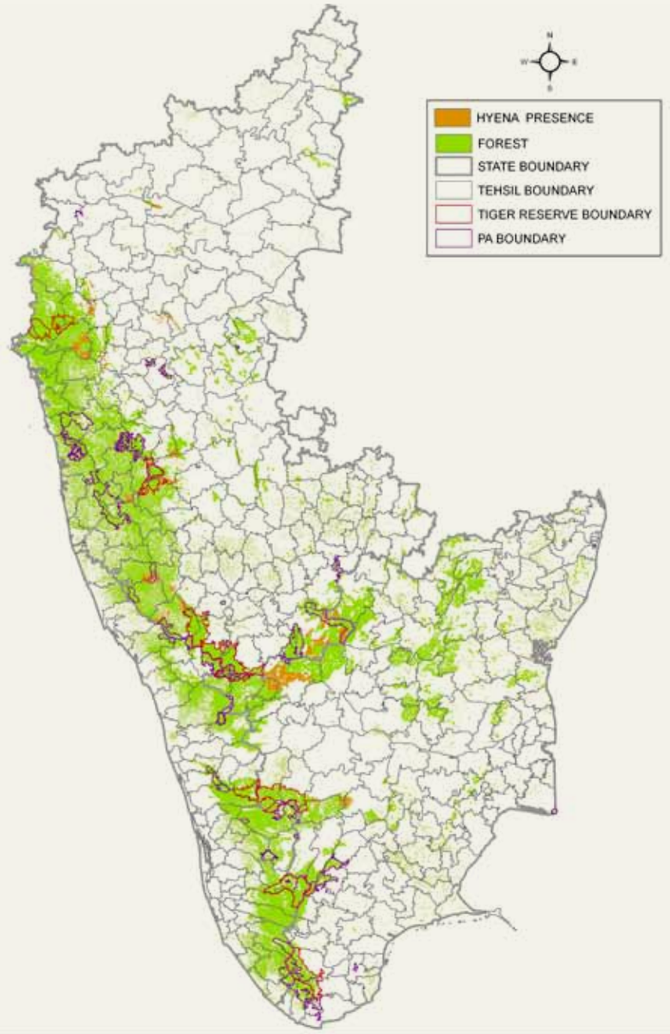
Occupancy of leopard in the Western Ghats landscape



b) **Striped hyena** (*Hyaena hyaena*)
Hyena distribution was primarily restricted to the drier forests of Tamil Nadu and Karnataka in an area of 4,376 km² (Fig. 3.5.2). Sporadic occurrences were also recorded from wetter forests of Pushpagiri Wildlife Sanctuary and from the forests of Yellapur tehsil in Uttara Kannada, and Narsimharajapura tehsil of Chikmagalur. Major occurrence was recorded from Sathyamangalam tehsil in Periyar District, Cauvery Wildlife Sanctuary and Kollegal forests in Chamrajnagar district of Karnataka.

Figure 3.5.2

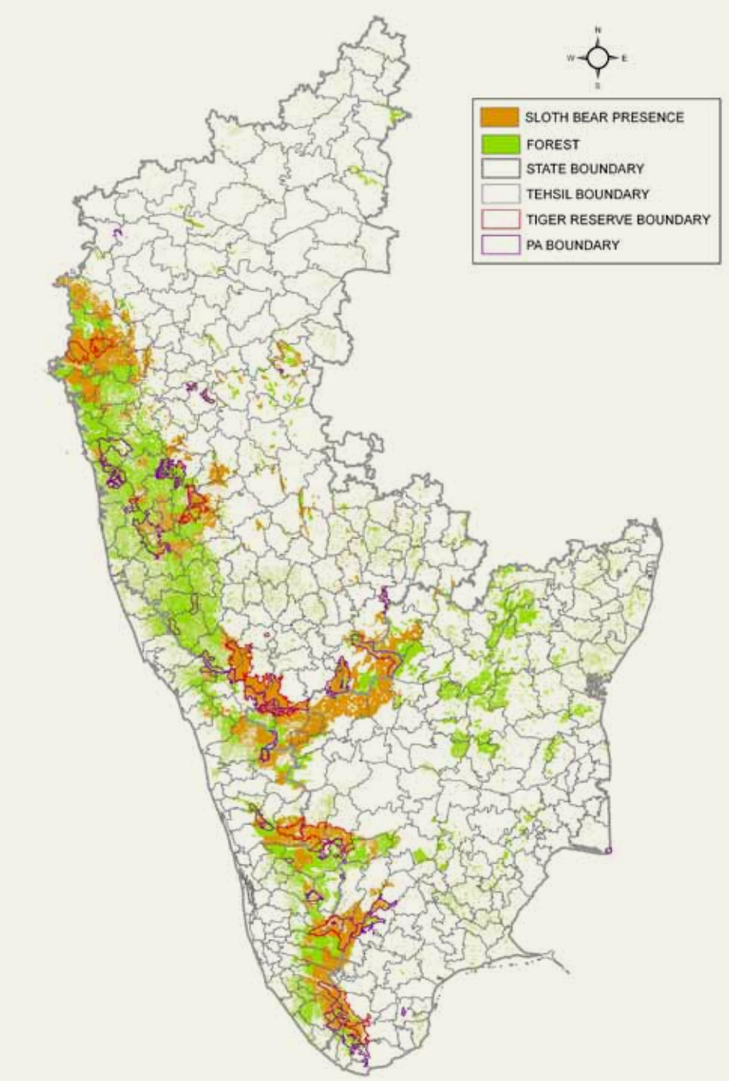
Occupancy of hyena in the Western Ghats landscape



c) **Sloth bear** (*Melursus ursinus*)
Sloth bear populations too had the same distribution pattern as that observed for leopards and wild dogs, but with occupancy of 34,440 km^3. Bear occurrences were recorded across several small forest patches in drier regions of Karnataka as well as of Tamil Nadu (Fig. 3.5.3).

Figure 3.5.3

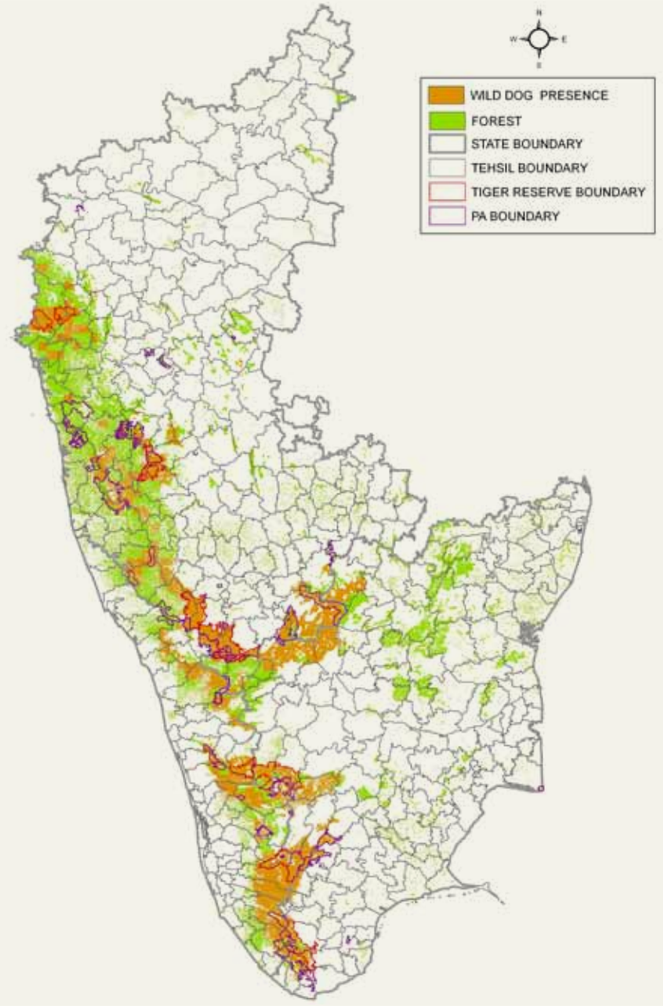
Occupancy of sloth bear in the Western Ghats landscape



d) **Wild dog** (*Cuon alpinus*)
Dhole occupancy was recorded in 35,389 km^2 of forested landscape. They are distributed in almost the same areas as the leopard, although the northern regions of Anshi-Dandeli and Saravathi Valley-Kudremukh-Bhadra have lower occupancy of dhole in comparison to leopards while the southern populations of Periyar-KMTR were observed to have wider distribution of dhole (Fig. 3.5.4). Most of these populations were primarily restricted to large forest patches and were not recorded from small scattered forested areas.

Figure 3.5.4

Occupancy of wild dog in the Western Ghats landscape



KARNATAKA

The State of Karnataka has an area of 36,190 km² under forest cover of which 28,182 km² has been recognised as priority I and II areas for tiger conservation. The State has four Tiger Reserves, one proposed Tiger Reserve, viz., Biligiri Rangaswamy Temple (BRT) Wildlife Sanctuary while the National Tiger Conservation Authority (NTCA) is awaiting a proposal from the State government to designate Kudremukh National Park as a Tiger Reserve. Apart from the Tiger Reserves, there exist five National Parks and 22 Wildlife Sanctuaries across diverse habitat types of the State. Parts of the Nilgiri Biosphere Reserve also span across the State and include Chamrajanagar, Bandipur and Hunsur Forest Divisions.

The four Tiger Reserves in the State include:

a) **Nagarahole Tiger Reserve** covers an area of 643.39 km2 in the Virajpet taluka of Kodagu district and Heggadadevankote and Hunsur *talukas* of Mysore district. The Reserve is contiguous with Bandipur to the south-east, separated by the backwaters of Kabini reservoir. About 6000-7000 tribals (mostly Kuruba) live within the Park with some having chosen to be a part of the 'voluntary relocation' schemes initiated by the Forest Division and local conservation organisations. The Park is also an important site for the India Eco-development Project scheme.

b) **Bandipur Tiger Reserve** is one of the earliest Tiger Reserves in the country covering an area of 870.36 km2 at the junction of the Western Ghats, the Nilgiris and the Deccan plateau in Heggadadevankote, Nanjangud and Gundlupet *talukas* of Mysore district. The Reserve is bounded by Wayanad Wildlife Sanctuaries to the west, Nagarahole to the north-west and the River Moyar to the south which forms a political boundary between Karnataka and Tamil Nadu and separates Bandipur from Mudumalai Tiger Reserve. Human pressures on the Park such as livestock grazing and fuel wood collection is high with about 200 villages located within five kilometres of the Reserve boundary. Two highways, viz., the Mysore-Ooty highway and Gundulpet-Sultan Bathery highway are a disturbance to wildlife in the area.

c) **Bhadra Tiger Reserve** was constituted in 1972 by joining Jagara Valley and Lakkavalli forests in the Malnad region. The 493.46 km2 Reserve is spread across the *talukas* of Tarikere, Narasimharajapura and Chikmagalur in Chikmagalur district. Small parts of the Reserve are also located in Shimoga district. This Reserve is often cited as the best example of successful 'voluntary relocation' of people from Protected Areas with 11 villages having volunteered to move out of the Reserve by 2003. Presence of magnetite ore in the Baba Budangiri Hills and the plans of damming River Somvahini could be major threats to this area.

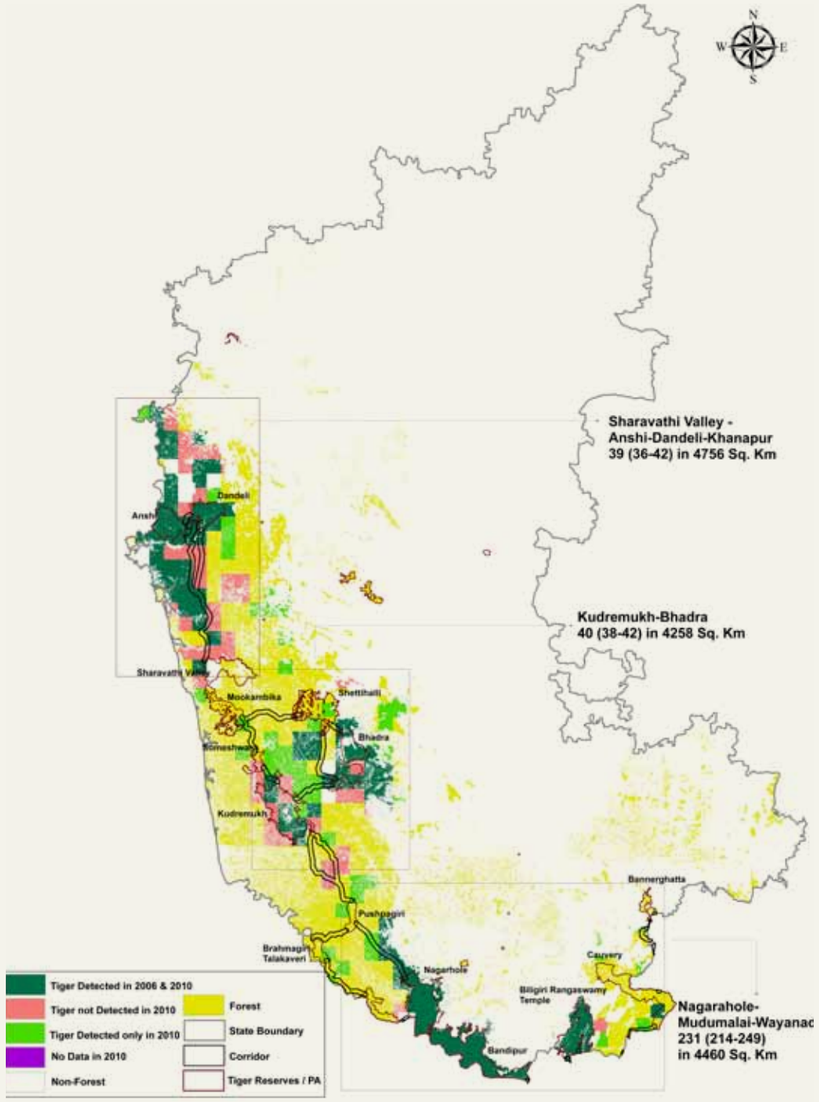
d) **Anshi-Dandeli Tiger Reserve** in Uttar Kannada district of north Karnataka comprises of 339.8 km2 Anshi National Park in Supa and Karwar *talukas* and 475.02 km2 Dandeli Wildlife Sanctuary in Supa, Haliyal and Yellapur *talukas*. Together, the two Protected Areas, along with the adjoining forests, form a contiguous forest patch of about 2200 km2 which further links to six Protected Areas of Goa and Maharashtra. Anshi National Park to the west of Dandeli shares a border with Goa and receives high rainfall supporting evergreen forests while Dandeli Wildlife Sanctuary faces intense human pressures from the surrounding villages as well as from the paper and plywood industries in Dandeli town.

In 2010, tiger occupancy was recorded within 13,474 km² of the State with an estimated population of 288 to 333 tigers, suggesting a decline in the area occupied by the species in the State (Fig. 3.KT.1).

Most Tiger Reserves of Karnataka have been sites for long-term tiger monitoring and intensive conservation activities such as 'voluntary relocation' of villages from Tiger Reserves (in Nagarahole and Bhadra (Karanth 2007)), lobbying to prohibit night-time vehicular traffic through Protected Areas (Mysore-Ooty Highway in Bandipur), prevention of lease extension to mining companies (e.g. Kudremukh Iron Ore Company Ltd. (KIOCL)) and initiation of Eco-development projects (in Nagarahole). It is thus no surprise that tiger population in this zone is the highest known than from any other part of the world.

Figure 3.KT.1

Tiger occupancy, population extent, size and habitat connectivity in Karnataka



Jhala *et al.* (2008) identified three important tiger landscapes in this region. These include:

a) **Anshi-Dandeli-Sharavathi Valley population**
This complex consists of the protected areas of Mollam-Netravali, Anshi-Dandeli, Sharavathi Valley-Mookambika along with Reserved Forests of Haliyal and Yellapur. To the north, this complex is connected to the forests of Goa which continue to the Sahayadri Tiger Reserve in Maharashtra with sporadic records of tiger occupancy. While the forest connectivity between this complex and the southern Kudremukh-Bhadra complex is weak, interspersed by plantation and agricultural mosaics, evidence exists through camera trapped pictures to confirm movement of tigers between the two areas (Ullas Karanth, Pers. Com.). Tiger population in 2010 within this region was estimated to be between 36 and 42 tigers with occupancy in an area of 4,756 km^2, indicating a decline in tiger occupied area since 2006 (Fig. 3.KT.1). This decline was observed in the forests connecting Anshi-Dandeli to forests of Goa in the north and to forests of Sharavathi Valley in the south.

Anshi and Dandeli are connected through contiguous forests, the least cost pathways (north of Ulavi settlement) formalizing this connectivity (Fig. 3.KT.1.1). The corridor connectivity between Anshi-Dandeli and Sharavathi Valley is long and traverses through plantations and agriculture mosaics. However, the least cost pathway and Circuitscape flows minimizes passage through private lands and suggests the ideal corridor to connect the two major tiger landscapes of Karnataka. Two corridors, one from Anshi and another from Dandeli, emerge from either side of the Kodasalli Reservoir and meet north of the Benne Hole falls. The bottlenecks for this corridor were at Jog Falls where a narrow strip of forest (1.5 km) remains as connectivity. This connectivity, if formally established and restored would promote gene flow across major populations of the Western Ghats from Pune to Palghat.

Figure 3.KT.1.1
Anshi-Dandeli-Sharavathi Valley corridor

b) **Kudremukh-Bhadra population**
This complex comprises of the central part of the Western Ghats in Karnataka and includes Kudremukh National Park and Bhadra Tiger Reserve. Kudremukh National Park is a potential Tiger Reserve site and occupies parts of Karkala taluka in Udupi, Belthangadi taluka in Dakshin Kannada and Mudigere, Sringeri and Koppa taluka in Chikmagalur district. Immediately north of Kudremukh is Someshwara Wildlife Sanctuary while Shettihalli Wildlife Sanctuary is located north of Bhadra Tiger Reserve. While this region has relatively low abundance of tigers, the area holds good potential for tiger persistence. The tiger population in 2010 within this complex was estimated to be between 38 and 42 tigers with occupancy in an area of 4,258 km^3. The area occupied by tigers and the estimated tiger population within this landscape showed a decline in 2010 compared to 2006 (Fig. 3.KT.1). The loss in tiger occupancy was observed in the forests south of Bhadra (Chikmagalur taluka), and south-west of Kudremukh (Belthangadi taluka).

To the south of this tiger complex is the Nagarahole-Mudumalai-Wayanad complex, with small Protected Areas in-between such as Pushpagiri Wildlife Sanctuary and Talakaveri Wildlife Sanctuary separated from Brahmagiri Wildlife Sanctuary by Padinalknad and Kerti Reserved Forests. The intervening habitat matrix between the Protected Area complexes consist of plantations, agriculture and some scattered habitation along with other Reserved Forests such as Kabbinale, Kagneri and Kiribag (Fig. 3.KT.1.2).

Figure 3.KT.1.2
Kudremukh-Pushpagiri corridor

The corridor linkages identified within this landscape and between this landscape and tiger landscapes to the north and south by least cost pathways and Circuitscape flows are essential elements to ensure long term tiger persistence. Connectivity between the Protected Areas within the Kudremukh-Bhadra complex was patchy (Fig. 3.KT.1.3).

Figure 3.KT.1.3
Kudremukh-Bhadra corridor

Mookambika Wildlife Sanctuary is connected to Someshwara Wildlife Sanctuary in the south through Reserved Forests of Hulikal, Varahi and Tombattu; which is further connected to Kudremukh National Park through contiguous forest (Fig. 3.KT.1.4 and 3.KT.1.5).

Figure 3.KT.1.4
Someshwara-Kudremukh corridor

On the east, Mookambika Wildlife Sanctuary is poorly connected to Shettihali Wildlife Sanctuary through narrow ridge-top forests, the last part (8-10 km) of which traverses habitation and agriculture, with small patches of forests providing “stepping stone” connectivity (Fig.3.KT.1.5).

Figure 3.KT.1.5
Someshwara-Mookambika corridor

The Reserved Forests of Northern Cardamom Hills, Choranayedahalli, Kakanhosudi and Tamadihalli connect Shettihalli Wildlife Sanctuary to the northern parts of Bhadra Tiger Reserve (Fig. 3.KT.1.6). While this habitat matrix is permeable for wildlife movement, it is dotted with a few agricultural developments which could grow into barriers at a later date. Connectivity to the southern portion of Bhadra with Shetthalli was only through ridge top forests and at risk of being broken at some places by agriculture development. Habitat matrix intervening Bhadra Tiger Reserve and Kudremukh National Park was conducive for movement of tigers and their prey, but designating a formal corridor within this matrix would ensure this connectivity for the future.

Figure 3.KT.1.6
Shettihalli-Bhadra corridor

The connectivity to the south from Kudremukh National Park to Pushpagiri Wildlife Sanctuary, and then directly onto Nagarahole National Park and to Wayanad Tiger Reserve (Kerala) via Talakaveri Wildlife Sanctuary and Brahmagiri Wildlife Sanctuary is one of the most precarious corridor systems within the Western Ghats. The connectivity of Kudremukh-Bhadra complex to the Nagarahole-Bandipur-Mudumalai-Wayanad complex via the western corridor system (Pushpagiri-Talakaveri-Brahmagiri) as well as the direct connectivity to Nagarahole (Fig. 3.KT.1.7) showed tiger presence suggestive of viable corridors systems. The western corridor is along the steep western slopes of the Ghats and therefore not an easy

passage for species like elephants, while the eastern corridor is along moderate gradients but traverses more human impacted habitats. There are two bottlenecks on the eastern corridor; one along the banks of the Cauvery where agricultural development disrupts forest contiguity and another is near Nagarahole, where the corridor passes through an agriculture-forest matrix for the last 8-10 kilometres. Immigration of tigers from the Nagarahole-Mudumalai-Wayanad landscape to Kudremukh-Bhadra complex is likely to be an important component for tiger population dynamics in this low density landscape. Formal recognition and protection of these least cost pathways as corridors would help ensure long term tiger persistence within this landscape system.

Figure 3.KT.1.7
Talacauvery-Brahmagiri-Nagarahole corridor

c) **Nagarahole-Bandipur-Mudumalai-Wayanad Population**: This tiger population stretches across three states, viz., Karnataka (Nagarahole-Bandipur), Tamil Nadu (Mudumalai-Segur plateau-Moyar gorge-Sathyamangalam) and Kerala (Wayanad). In 2010, tigers were also camera-trapped in the Segur plateau-Moyar gorge-Sathyamangalam region in Tamil Nadu, providing evidence of resident tiger population as well as possible movement of individuals between this region and BRT Wildlife Sanctuary and onwards to Cauvery Wildlife Sanctuary. This landscape showed an overall increase in tiger occupancy in 2010 when compared to 2006. The tiger population on the Karnataka side (Nagarahole, Bandipur, BRT, Cauvery Wildlife Sanctuary and adjoining forests) was estimated at 231(214-249) tigers covering an area of 4,460 km^3. Since this tiger population is contiguous with Mudumalai (Tamil Nadu) and Wayanad (Kerala) and tigers move across State boundaries this number is not unique to Karnataka and the numbers are indicative for the State. The total tiger population for this landscape inclusive of Karnataka, Tamil Nadu and Kerala (Nagarahole, Bandipur, Wayanad, Mudumalai, Brahmagiri, Sathyamangalam, BRT, and Cauvery Wildlife Sanctuary) is probably the largest contiguous single population in the world with 354 to 411 tigers. This complex also boasts of being home to the single largest Asian elephant population in the world (Varma *et al*. 2005). Both tigers and elephants serve as flagship and umbrella species for the conservation of all biota that these ecosystems represent. The status of their populations indicate the well being of all ecosystem processes within this landscape which should be of global priority and importance.

Figure 3.KT.1.8
Bandipur-Cauvery corridor

Figure 3.KT.1.9
Cauvery-Bannerghatta corridor

Connectivity between Bandipur, BRT and on to Cauvery Wildlife Sanctuary through the Moyar-Segur-Sathyamangalam forests (Tamil Nadu) shown by the least cost pathways needs to be ensured through inter-state cooperation between Karnataka and Tamil Nadu (Fig. 3.KT.1.8). Connectivity from BRT to Cauvery Wildlife Sanctuary though intact, is threatened by growing settlements and agriculture, while connectivity from Cauvery to Bannerghatta Wildlife Sanctuary is through narrow forest strips and "stepping stone" forest patches in a human-dominated landscape (Fig. 3.KT.1.9).

After communicating the results of this study through a press conference in March 2011 the Chief Wildlife Warden of Karnataka has communicated vide his letter No. C1(F)/Wl/Tiger Estimation/09-10 Dated 12-05-2011 that parts of the territorial divisions of the State may have provided incorrect GPS coordinates resulting in under estimation of tiger occupancy. He has requested that fresh data from concerned regions be reanalysed.

TAMIL NADU

The State of Tamil Nadu has a forested area of 23,338 km² constituting 18% of the total area of the State of which an area of 8,400 km² is occupied by priority I and II areas for tiger conservation. The State has three Tiger Reserves while a proposal is awaited from the State for one Tiger Reserve, viz., Sathyamangalam. There also exist five National Parks, 21 Wildlife Sanctuaries and one Conservation Reserve. Large parts of the State also fall under the Nilgiri Biosphere Reserve, Agasthiyar Malai Biosphere Reserve and the Gulf of Mannar Biosphere Reserve.

The three Tiger Reserves in the State include:

a) **Indira Gandhi (Anamalai) Tiger Reserve** covers an area of 959 km² in Pollachi, Valparai and Udumalpet *talukas* of Coimbatore district. It comprises of the Indira Gandhi Wildlife Sanctuary and the National Park with a core area of 126 km². Several rivers originate in the Reserve providing water to reservoirs such as Parambikulam, Aliyar, Sholayar and Amaravathi. It has unique Shola habitats at Karian Shola, Grass Hills and Manjampatty.

b) **Mudumalai Tiger Reserve** covers an area of 321 km² and is located in Gudalur and Udhagamandalam *talukas* of the Nilgiri district. It is connected to Wayanad Wildlife Sanctuary of Kerala and Bandipur Tiger Reserve of Karnataka. River Moyar traverses the Reserve from south to north, parallel to which runs the Udhagamandalam-Mysore Highway, for some distance. The region has high livestock grazing pressure and human disturbance levels.

c) **Kalakad-Mundanthurai Tiger Reserve** covers an area of 895 km² of which 550 km² forms the core and is a part of the Agasthiar Malai Biosphere Reserve. It is located in Nanguneri and Ambasamudram *talukas* of Tirunelveli district and Thovalai and Vilavancodu *talukas* of Kanyakumari districts. The western border of the Reserve coincides with the crest line of the Western Ghats. About 14 rivers originate from this area and support three dams which provide hydro-electric power and irrigation facilities to the district of Kanyakumari. The Reserve has several settlements which include religious enclaves, private forests, dams, PWD land and

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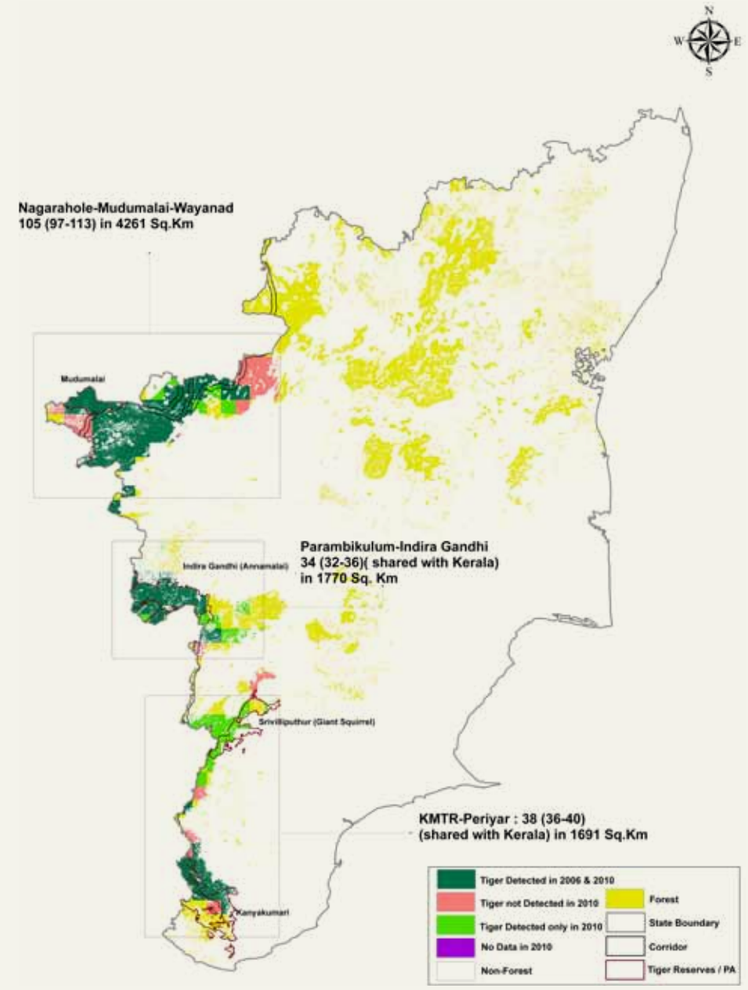
Figure 3.TN.1

Tiger occupancy, population extent, size and habitat connectivity in Tamil Nadu



encroachments. Fire during the dry season along with grazing and NTFP collection are among the numerous pressures exerted on the Reserve by the 145 hamlets within five kilometres of the eastern boundary. The Tiger Reserve has demonstrated successful implementation of local community participation in conservation efforts through eco-development projects.

The tiger occupancy and estimated population within the State has shown an increase from that estimated in 2006. The current (2010) occupancy was estimated at 7,722 km² with a tiger population between 165 to 189 tigers (Fig. 3.TN.1). Tiger occupancy within parts of Bhavani tehsil of Erode district which forms the connectivity between

Cauvery and BRT Wildlife Sanctuary (Karnataka) was not recorded in 2010. Jhala *et al.* (2008) identified three major tiger populations in the State. These include:

a) **Nagarahole-Mudumalai-Wayanad Population**

This landscape has the highest tiger population in India within a network of Protected Areas such as Wayanad in Kerala, Nagarahole-Bandipur in Karnataka along the northern border with Mudumalai in Tamil Nadu and BRT and Cauvery Wildlife Sanctuary along Karnataka-Tamil Nadu border. Tiger densities within the Mudumalai Tiger Reserve were high 11.06 (3.04) per 100 km². Surprisingly, camera trapping also revealed that Reserved Forests (Moyar gorge-Segur plateau region) surrounding the Tiger Reserve had high abundance of tigers 7.65 (0.93 per 100 km². The tiger occupancy within the Tamil Nadu part of this landscape was 4,261 km² with an estimated 97 to 113 tigers.

The Mudumalai landscape is connected through the forested slopes of the Nilgiris to the Mukurthi National Park in the south which is further connected to Silent Valley. Due to the rugged and steep nature of this connectivity, elephants are unlikely to use it, but it would serve as a viable corridor for tigers and other fauna (Fig. 3.TN.1.1). Towards the east, Sathyamangalam Wildlife Sanctuary connects with the corridor formed by the Moyar River valley connecting the Bandipur-Mudumalai complex with BRT Wildlife Sanctuary and on to Cauvery Wildlife Sanctuary (see Fig. 3.KT.1.8).

Figure 3.TN.1.1
Silent Valley-Mudumalai landscape corridor

Within the southern buffer of Mudumalai and its surroundings, the habitat is fragmented by large and small settlements like Masinagudi and Moyar colony. Many of these private lands are being developed into tourist resorts with elephant proof power fencing. Linear infrastructure like the power channel from Masinagudi to Moyar and the water pipeline from Glenmorgan to Singara further prevent free movement of species like elephants across these forests. Restrictions on non-eco friendly developments and mitigation of existing linear infrastructure are needed for full utilization of this landscape by wildlife. Addressing the above issues and legitimizing the two corridors defined by the least cost pathways would enhance the conservation potential of this important reserve complex further.

b) **Parambikulam-Eravikulam-Indira Gandhi Population**

This tiger population is spread over Parambikulam Tiger Reserve, Eravikulam National Park and Chinnar Wildlife Sanctuary in Kerala; and Indira Gandhi (Anamalai) Tiger Reserve in Tamil Nadu. The region has tiger occupancy in about 3,253 km², with 1,770 km² on the Tamil Nadu side of this landscape. In this landscape, Tamil Nadu has between 32 and 36 tigers. The landscape has shown good recovery due to good management of the several reserves constituting the complex, lower human pressures due to the difficult terrain and contiguous nature of the tiger habitat.

c) **Kalakad-Mundanthurai-Periyar Population**

This complex extends from Periyar Tiger Reserve and is contiguous with Peppara, Shendurney and Neyyar Wildlife Sanctuaries of Kerala extending into forests of Mundanthurai-Kalakad-Kanyakumari in Tamil Nadu (Fig. 3.KR.1.3). Tiger occupancy within this landscape was recorded at 3,812 km² with an estimated tiger population of between 36 to 40 tigers. On the Tamil Nadu side, occupancy was 1,691 km² with an estimated 38 (36-40) number of tigers.

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KERALA

The State of Kerala has an area of 17,324 km² under forest cover constituting 45% of the geographical area of the State. Of this 13,367 km² is categorised as Tiger Conservation Priority I and II area.

The State has two Tiger Reserves, six National Parks, 15 Wildlife Sanctuaries and two Biosphere Reserves, viz., the Nilgiri Biosphere Reserve and the Agasthyamala Biosphere Reserve. Altogether, these Protected Areas encompass an area of 5,991 km² of the State. The two Tiger Reserves in the State include:

a) **Parambikulam Tiger Reserve** which covers an area of 285 km² and is located within Chittur taluka of Palghat district. It is located between the Nelliampathy Hills of Kerala and the Anamalai Range of Tamil Nadu within a cluster of Protected Areas. The Reserve has six colonies with indigenous tribes such as the Kadar, Malasar, Muduvar and Malamalasars living in them. There is also a colony in the Reserve which came up in the 1950's and 60's during the construction of the Parambikulam-Aliyar Project.

b) **Periyar Tiger Reserve** which covers an area of 777 km² within Pirmed taluka of Idukki district with a small portion in Rani taluka of Pathanamthitta district. To the east of the Reserve are the Srivilliputhur Grizzled Giant Squirrel Wildlife Sanctuary and Thirunelveli Forest Division of Tamil Nadu. The Mullaperiyar dam constructed in 1895 resulted in a lake which covers 26 km² of the Reserve. Over five million pilgrims visit the Sabrimala Temple in the Reserve each year; most of these pilgrims reach the temple through Rani Forest Division by road, disturbing the habitat severely and polluting River Pamba. Only four small settlements exist within the Park at Labbakkandam near Kumily, Mannakudy, Paliyakudi and Vanchivayal.

Tiger occupancy within Kerala was recorded at 5,991 km with a population estimated between 105 to 119 tigers a substantial increase in tiger occupied area as well as numbers in comparison to the 2006 estimates (Fig.3.KR.1).

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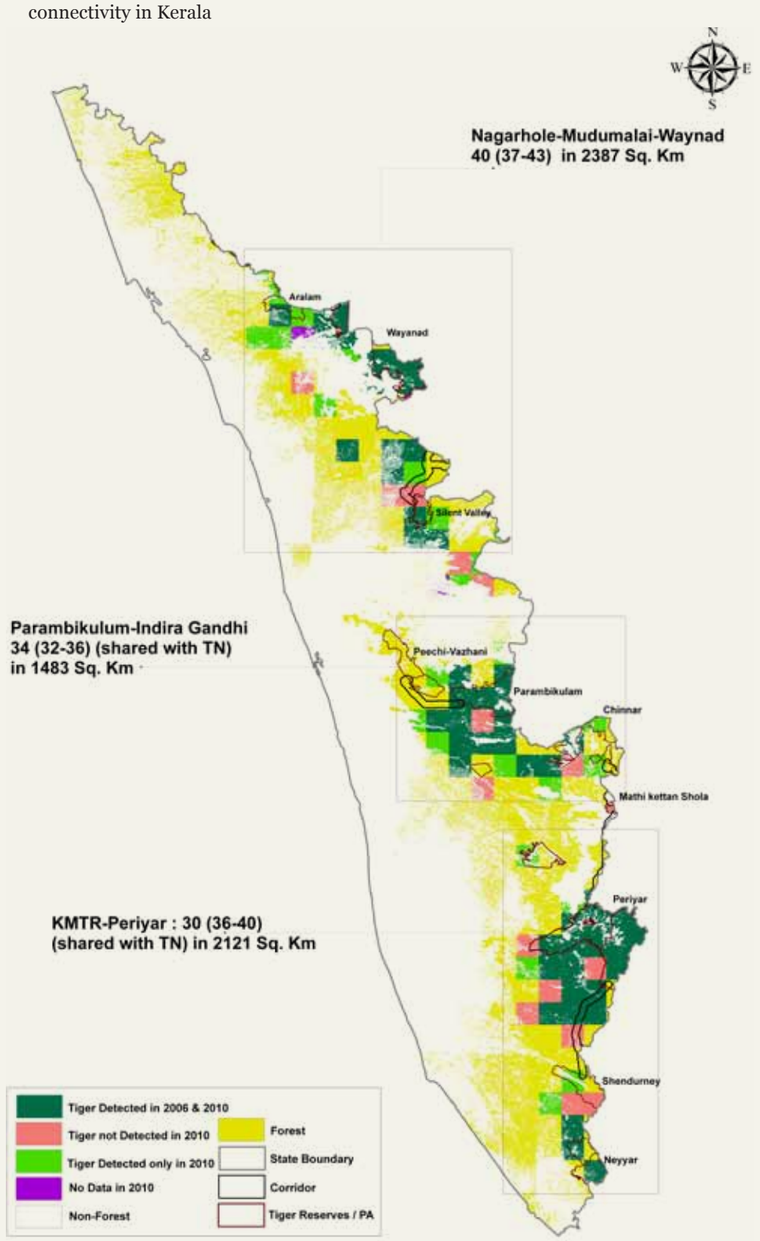
Figure 3.KR.1

Tiger occupancy, population extent, size and habitat connectivity in Kerala



The State has three major tiger populations (Jhala *et al.* 2008):

a) **Nagarahole-Mudumalai-Wayanad population**
Wayanad Wildlife Sanctuary shares its north-eastern border with Karnataka and is contiguous with parts of Bandipur and Nagarahole in Karnataka and Mudumalai in Tamil Nadu. The Tholpetty Range of Wayanad in Manantoddy taluka is contiguous with Nagarahole while Kurichiat, Sultan's Battery and Muthanga Ranges are contiguous with Bandipur and Mudumalai Tiger Reserve. This landscape (Nagarahole-Wayanad-Mudumalai) hosts the largest contiguous population of tigers and elephants. Wayanad is connected to the Silent Valley National Park in Kerala through Mudumalai and Mukurti in Tamil Nadu. Tiger occupancy within Kerala in this landscape was 2,387 km² with an estimated population of 40 (37-43) tigers (Fig. 3.KR.1).

b) **Parambikulam-Eravikulum-Indira Gandhi population**
This is the first major tiger population south of the Palghat Gap, which is a major barrier to geneflow from the northern Western Ghats to the southern Western Ghats for most wildlife species including tigers, due to its high human density and habitation.

Within Kerala, this zone comprises of several Protected Areas which include Peechi-Vazhani Wildlife Sanctuary, Chimmony Wildlife Sanctuary, Eravikulum National Park, Chinnar Wildlife Sanctuary and Parambikulam Tiger Reserves in Kerala. The tiger habitat in this zone is contiguous with the Indira Gandhi (Anamalai) Tiger Reserves in Tamil Nadu and with, Anaimudi and Pambadum Shola National Park which are located within Devikulam taluka of Idukki district in Kerala. All of these Protected Areas are connected through forested habitats interspersed with plantations, agriculture, and settlements, consisting of a habitat matrix that is permeable for movement of wildlife. However, two formal corridor systems are required: one connecting Peechi-Chimmony to Parambikulam (Fig. 3.KR.1.1) and second, connecting Anaimudi Shola National Parks to Pambadum Shola, which further extends into Mathikettan Shola National Park (Fig. 3.KR.1.2). This connectivity extends further south along the border of Kerala and Tamil Nadu as narrow ridge top forests of the Ghats, through plantations and agriculture west of the Ghat ridge, connecting the population of this landscape with that of Periyar-Kalakad-Mundanthurai. This connectivity is very precarious and as the least cost pathways traverse lot of privately owned lands and distinguishing between plantations and forests through remotely sensed data was difficult. Ground verification is required urgently and conservation action is needed to secure this connectivity. Tiger occupancy on the Kerala side of this landscape was 1,483 km² with an estimated population of 32 to 36 tigers. This area showed a significant increase in both, the area occupied by tigers since 2006 and their abundance.

Figure 3.KR.1.1
Chimmony-Parambikulam corridor

Figure 3.KR.1.2
Anaimudi-Pambadum-Mathikettan and Mattikettan-Kalakad-Mundunthurai-Periyar

c) **Kalakad-Mundanthurai-Periyar population**
This complex extends from Periyar Tiger Reserve in Kerala and is contiguous with Peppara Wildlife Sanctuary in Nedumangad taluka of Trivandrum and Neyyar Wildlife Sanctuary in Neyyattinkara taluka of Trivandrum district. Shendurney Wildlife Sanctuary is located in Pathanapuram district of Kollam. All three of these Protected Areas are contiguous with Kanyakumari Wildlife Sanctuary and Kalakad-Mundanthurai Tiger Reserve in Tamil Nadu (Fig. 3.KR1.3). This landscape has tiger occupancy in about 2,121 km² with an estimated tiger population between 36 and 40. The connectivity between Periyar complex and the Protected Areas to the south of Periyar are an essential element for long term tiger persistence within this landscape complex. The corridor identified by the least cost pathway traverses hilly forested terrain, interspersed by plantations and habitation (Fig. 3.KR.1.3). It meets major barriers to wildlife movement near the township of Aryankavu in the form of high human densities, road and rail traffic. Mitigation measures need to be implemented here to maintain the wildlife value of this corridor for the future.

Figure 3.KR.1.3
Periyar-Shendurney-Mundunthurai corridor

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GOA

The State of Goa has an area of 2,151 km² under forest cover, constituting 58% of the State's total geographical area. The State had one National Park, viz. Mollem and six Wildlife Sanctuaries with 20.4% of the State's is under Protected Area network.

The Mhadei Wildlife Sanctuary covers an area of 208.48 km² in Sattari taluka of north-eastern Goa. It is connected to the larger tiger landscape of Karnataka around Anshi-Dandeli Tiger Reserve through the Bhimgad Forest in the east and through Bhagwan Mahavir Wildlife Sanctuary in the west. The latter Protected Area is connected to Mollem National Park and Netravali Wildlife Sanctuary in south Goa which in turn form a contiguous forested landscape with Anshi-Dandeli Tiger Reserve in the Western Ghats of Karnataka.

Mhadei, along with Netravali and Bhagwan Mahavir Wildlife Sanctuaries are located within the iron ore mining zone of Goa and are under intense mining pressure. At the behest of a non-governmental organisation, Goa Foundation, around 80 mining leases were stopped in Protected Areas of Goa by a petition to the Supreme Court, in recent times. Restoring the link between Bhagwan Mahavir and Mhadei Wildlife Sanctuary would be essential to allow movement of tigers from Anshi to Mhadei via Protected Areas of Netaravli and Mollem.

The Phase I exercise recorded tiger presence in Mollem Wildlife Sanctuary and in the forests of Ponda and Sanguem Tehsils. Tiger occupancy within the state was low about 322 km² but is encouraging as these forests form part of the corridor connecting Anshi-Dandeli in Karnataka to Sahayadri Tiger Reserve in Maharashtra. Goa can potentially be home to a small breeding population of tigers which would be sustained by immigrants from Anshi-Dandeli as well as Sahayadri. It would therefore benefit from being incorporated as part of tiger reserve complex.

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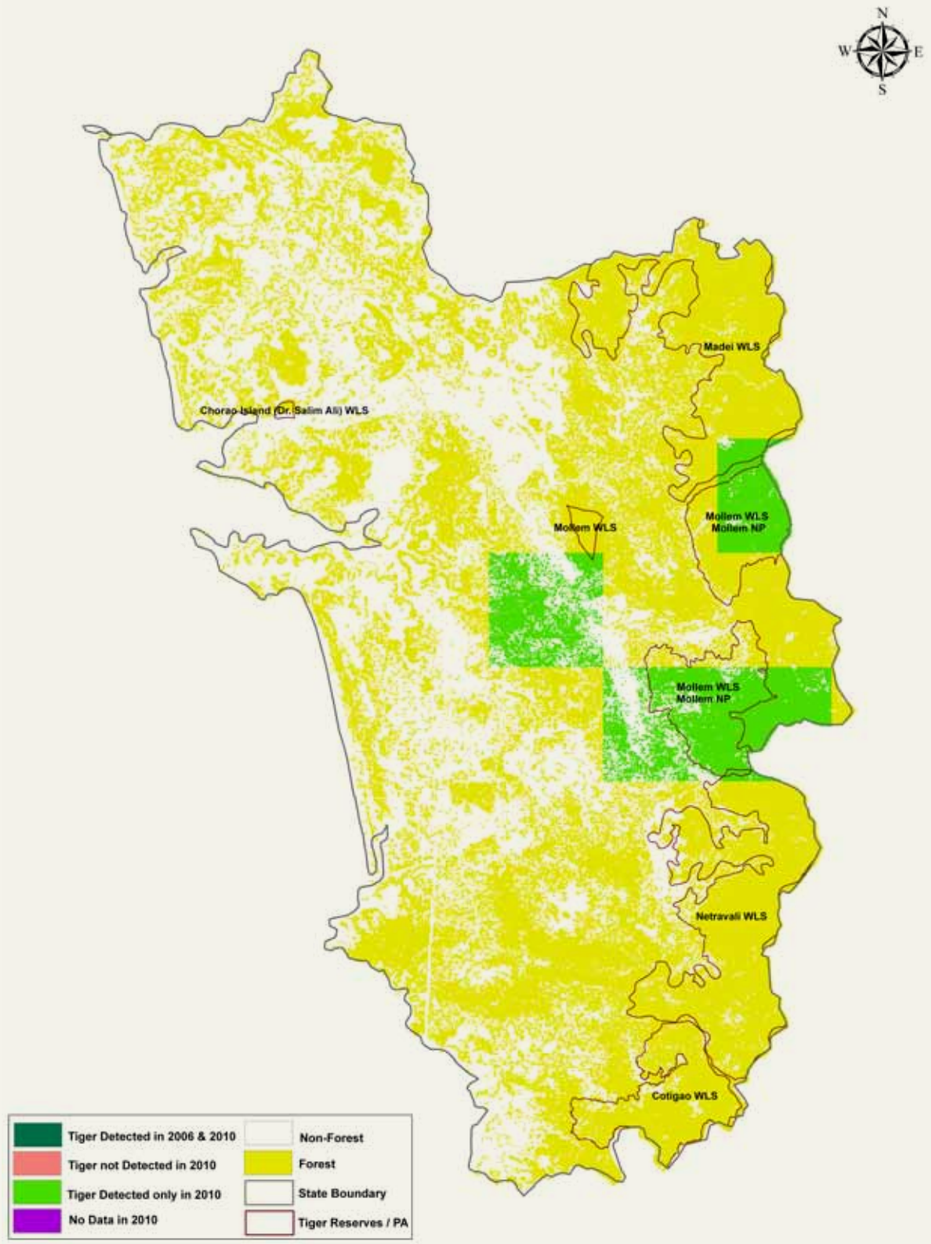
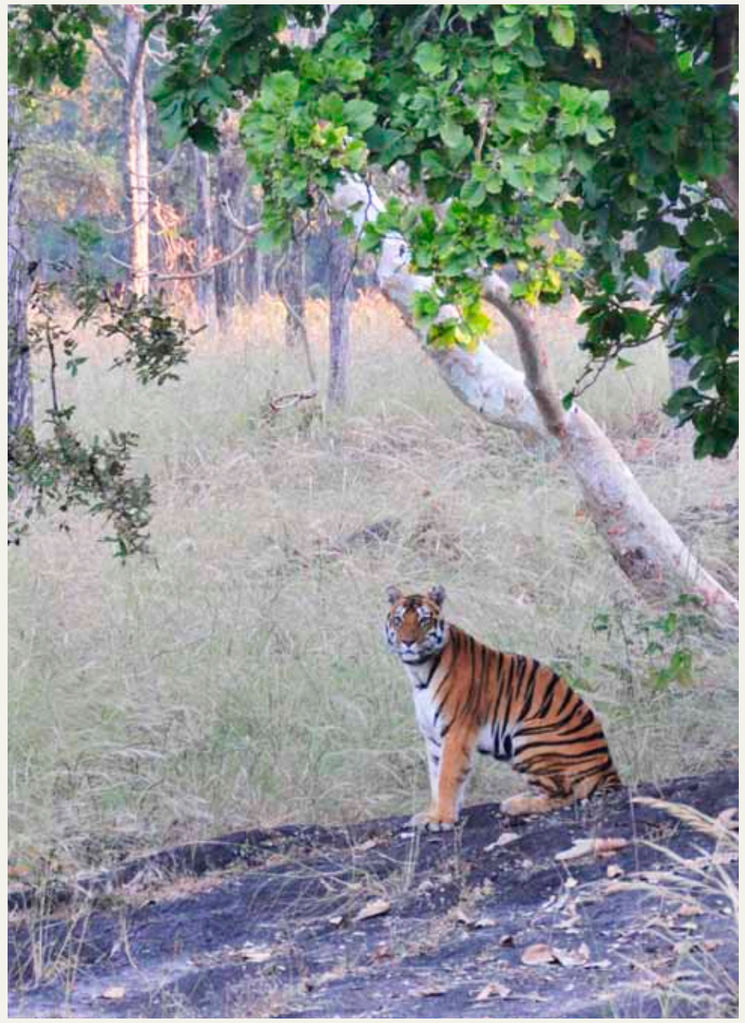
Figure 3.G.1

Tiger occupancy in Goa



Tiger population status summary for the Western Ghats landscape

State	Tiger Population			Tiger km²		
	2006	2010	Increase/ Decrease/ Stable	2006	2010	Increase/ Decrease/ Stable
Karnataka	290	300	Stable	18715	14414	Decrease
Kerala	46	71	Increase	6168	6804	Stable
Tamil Nadu	76	163	Increase	9211	8389	Stable
Western Ghats	402	534	Increase	34094	29607	Decrease



4.0 THE NORTH-EAST HILLS AND BRAHMAPUTRA FLOOD PLAINS LANDSCAPE

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This landscape can be divided into three zones: the Upper Bengal Dooars, the Brahmaputra flood plains and the north-eastern hill region. These zones are connected to the Indian mainland through the 'Siliguri Corridor or chicken's neck', which is about 20 kilometres wide (Datta 1995) and is located in the northern part of West Bengal. The Bengal Dooars are fertile plains in the foothills of the Himalayas, to which several mountain passes open, providing accessibility to parts of Bhutan. The river Sankosh forms the political boundary between Assam and West Bengal and also demarcates the Bengal Dooars from those of Assam. Most of this region today, is under intense tea cultivation with small isolated remnants of forests.

The Brahmaputra flood plains in the Brahmaputra valley are about 750 kilometres long and 80 kilometres wide with hills rising on all sides except the west (Rao 1974). Most of these flood plains are characterised by many islands and alluvial fertile soils. Thus the region is under intense cultivation with high human densities. On the southern side of Assam plains flows the Barak, which originates from the Barail Range along Assam-Nagaland border and flows into Bangladesh as Surma structuring the Surma valley enroute (Rao 1974).

The north-eastern region comprises of several hill ranges which can be categorised as the Eastern Borderlands and the Eastern Himalayas. The Easter Borderlands comprise of the Assam-Burma hills, which are essentially a conglomerate of the Meghalaya, Mizoram, Nagaland, Tripura, Manipur, and Assam hills. The Meghalaya hills (Garo-Khasi-Jaintia hills) are at right angle to the Burmese system of meridional mountains along with other hills in this zone. The southern and central part of the Meghalaya hills forms the Shillong plateau with elevation ranging between 1200 to 1930 meters (Rao 1974). The plateau rises steeply on the western side to an elevation of 1500 meters within 16-20 kilometres, precipitously overlooking the Bangladesh floodplains (Rao 1974). Further south-east are located the Lushai hills. These hills rise to an elevation of 1600 meters in the east and lie mostly in Mizoram with a smaller portion in Tripura. The Naga Hills are narrowly laid out along the India-Myanmar border while the Barail Range, Karbi-Anglong hills and the Cachar hills are located in the state of Assam.

The northern boundary of this landscape is located in the Eastern Himalayan region, which traverses parts of West Bengal, Sikkim and Arunachal Pradesh. This region includes areas between Rivers Tamur and Teesta along with the Singalila Ridge on which is located the Singalila National Park. On the eastern side, this section of the Himalayas includes the Abor, Dafla, Mikir and Mishmi hills and the valleys of rivers Subansiri, Dihang and Dibang.

4.1.1 Location

This landscape stretches across the flood plains of River Torsa in West Bengal, to the peaks of Khangchendzonga in Sikkim, includes the Brahmaputra flood plains and the hills of Assam and Myanmar along with the Eastern Himalayas. It covers an area of 2,71,129 km² of which 1,56,896 km² is forested area (Qureshi *et al.* 2006) in the states of northern West Bengal, Sikkim, Assam, Arunachal Pradesh, Manipur, Mizoram, Nagaland, Tripura and Meghalaya. The region includes seven Tiger Reserves, viz., Buxa in northern West Bengal, Manas, Kaziranga and Nameri in Assam, Pakke and Namdapha in Arunachal Pradesh and Dampa in Mizoram. Several National Parks, Wildlife Sanctuaries, Reserved Forests and sacred groves are scattered across the landscape making it the largest connected forest landscape in India. The region shares political boundaries with Nepal, Bhutan, Tibet Autonomous Region of China,

Tiger population status summary for the North-East hills and Brahmaputra flood plains

Tiger Population	State/s	Tiger abundance in 2006	Tiger abundance in 2010	Area occupied (km²) in 2006	Area occupied (km²) in 2010	Increase/ Decrease/Stable	Connecting larger PA landscapes
Manas Buxa	Assam/WestBengal	Not Estimated	9 (7-10)	1,051	1,349	Increase	Manas-Buxa
Kaziranga	Assam	Not Estimated	106 (81-131)	766	800	Stable	Kaziranga-Karbi Anglong
Kaziranga -Nameri							
Orang	Assam	Not Estimated	13 (10-15)	NE	74	NE	Kaziranga
Pakke-Nameri	Arunachal Pradesh -Assam	Not Estimated	9 (7-11)	1,100	371	Decrease	Kaziranga- Nameri
Karbi Anglong	Assam	Not Estimated	6 (4-7)	NE	590	NE	Kaziranga-Karbi Anglong
Namdapha	Arunachal Pradesh	Not Estimated	Not Estimated	540	NE	NE	Kamlang-Mehao WLS Myanmar
Dampa	Mizoram	Not Estimated	Not Estimated	482	416	Decrease	Bangladesh

NE : Not Estimated

Myanmar and Bangladesh making conservation a challenging task and the need for trans-boundary international cooperation an essential requirement for conservation success.

While the Brahmaputra plains comprise chiefly of parts of northern West Bengal and Assam encompassing some of the last remaining alluvial grasslands of India, the Eastern borderlands and the Eastern Himalayas encompasses a diversity of bio-geographic realms like the Trans Himalaya- Tibetan Plateau, Himalaya (Central Himalaya and East Himalaya) and North-East (Brahmaputra Valley and North-east Hills) (Rodgers and Panwar 1988).

4.1.2 Ecological Background

The Dooars and terai region of Bengal due to their proximity to the capital of British India, Calcutta, were subjugated to amongst the highest intensity of hunting. The Maharaja of Cooch Behar often organised large hunts for the British aristocracy and royalty from all over the world. Most of these hunts were for the tiger, elephant or the rhinoceros in parts of Patlakhawa, Takoamari, Gorpad, Bhalka Shalbari and later Manas in Assam (Rai Barma 1988). Between 1871 and 1907, 207 rhinos were hunted in the forests of Cooch Behar and Buxa by the Maharaja of Cooch Behar (Bahuguna and Mallick 2004). Eventually, the Bengal Rhinoceros Preservation Act of 1932 was initiated to provide protection to the species. The rhino that once was found throughout the Brahmaputra valley, the Torsa region, through the forests of Buxa and Cooch Behar upto the Sundarbans and Rajmahal hills of Bangladesh (Bahuguna and Mallick 2004) is today restricted to small pockets in the northern and eastern parts of this landscape.

The fertile lands of the Brahmaputra flood plains and the discovery of good tea growing areas in Assam made this region amongst the first to undergo extensive land-use changes with large areas being cleared out for tea cultivation on the banks of the Brahmaputra. Also, the discovery of oil in this belt led to the construction of the first oil refinery in India at Digboi in upper Assam in 1891. This region also became a favourite hunting ground of the British once they exhausted most big game in the lower Dooars

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and terai of Bengal. It was this reason, which led to the near extermination of the rhinoceros from Kaziranga with only 12 animals left in 1905 (Vasu 2002). Similarly, the extinction of the Sumatran rhinoceros (*Dicerorhinus sumatrensis*) was also an outcome of extensive hunting in this region.

Prior to the advent of the colonial rule, most of the hill area of the north-east was under the control of tribal chieftains and different tribes. Each tribe had its own political system to manage resources. Even today, the six eastern most states of the north-east are a home to 209 major tribes (Datta 1995). Almost all hill tribes historically practiced shifting cultivation and were hunter-gatherers. Some tribes in Arunachal Pradesh (former North East Frontier Agency) also indulged in some trade. However, consolidation of this landmass under the colonial rule (starting from Assam-1826 to Lushai hills in 1890) brought Christian missionaries to these remote areas bringing about large scale changes to the subsistence level economy and changing it to a market oriented one along with a new political system (Datta 1995).

In recent years, most north-eastern states have been sites of intense political unrest resulting in differential development between states and within different regions of individual States. Sites such as the Manas Tiger Reserve are located in areas with high levels of political disturbance since 1989 with incidents of forest department employees being killed, burning down of anti-poaching camps, rhinoceros poaching (Vigne and Martin 1994) and research staff being kidnapped for ransom.

4.1.3 Conservation significance

Apart from being located at the meeting place of the Himalayas and the peninsular India, this region also incorporates the transition zones of the Indian, Indo-Malayan and Indo-Chinese bio-geographic realms (Mani 1974). The biological importance of this area is reiterated through its declaration as a 'Global Biodiversity Hotspot' by Conservation International (Myers *et al.* 2000), its recognition as an 'Endemic Bird Area (EBA)' by BirdLife International (Stattersfield *et al.* 1998) and it harbouring three of the 200 global 'Terrestrial Eco-regions of the World' of the WWF (Olson and Dinerstein 1998). A common feature to all these accolades is the recognition of this area as a region with high species diversity, high levels of endemism, taxonomic uniqueness of species, serious habitat loss and threatened status of the floral and faunal diversity of the area.

With 6.8% of its total land area under the protected area network, this zone incorporates amongst the highest diversity of species known from India, albeit the faunal abundances are low due to a high dependence of the local communities on bush-meat for subsistence and cultural reasons. In this lowland-highland transition zone the highest diversity of biomes and ecological communities can be found and thus species diversity is very high with most of the lowland fauna being Indo-Malayan while at higher elevation it changes to Palearctic species.

An average human density of 114 persons/ km^2 (Qureshi *et al.* 2006), along with the isolated and rugged nature of terrain makes this one of the least explored areas of the country with many species of flora and fauna still undocumented. Thus, the region also boasts of the largest number of mammalian discoveries in the last decade. These include, one primate- the Arunachal macaque (*Macaca munzala*) in 2004 (Sinha *et al.* 2005), one ungulate (range extension in India, albeit not a species new to science) the leaf deer (*Mutiacus putaoensis*) in 2002 (Datta *et al.* 2003) and one avian species, Bugun liocichla

(*Liocichla bugunorum*) in 2006 (Athreya 2006). Apart from discovery of new mammalian species, the region also lost out on one large mammal, the Sumatran rhinoceros.

From the perspective of the tiger, this region has two important Tiger Conservation Units (TCUs), one comprising of the Manas Tiger Reserve, stretching across Bhutan to Arunachal Pradesh in the north-east, while the other includes the Kaziranga Tiger Reserve in Assam and stretches upto Meghalaya. While the former is suppose to be the only landscape in south-Asia sustaining the phenomenon of tigers living close to the timber line and predating upon mountain ungulates, the latter encompasses the best preserved grassland habitat in the global tiger range (Wikramanayake *et al.* 1998).

Much of the prey is depleted in these forests as the hunter-gather tribes are efficient hunters and depend a lot on wild game for subsistence (Aiyadurai 2007).

4.1.4 Vegetation

The floral diversity of the north-eastern India is unmatched with that of any other landscape. This region has about 7500 species of angiosperms belonging to over 200 families, 700 species of orchids of the 1300 known from India, 70 species of rhododendrons, which are confined to the Himalayas of this region, 63 species of bamboo of 136 known from India along with many saprophytic plants, ferns, palms and conifers (Ramakantha, unpubl.). Monogeneric families like Coriariaceae, Nepenthaceae, Turneraceae, Illiciaceae, Ruppiaceae, Siphonodontaceae and Tetracentraceae have representatives in this zone while primitive flowering plants like *Magnolia pealiana, Tetracentron sinense, Holboellia latifolia, Exbucklandia populnea, Manglietia sp., Myrica esculenta* and *Corylopsis himalayana* are known to occur in some areas (Ramakantha, unpubl.).

As per the classification by Champion and Seth (1968) classification this region has a high diversity of ecoregions which include the Brahmaputra Valley semi-evergreen forests, Eastern Himalayan broadleaf forests, Eastern Himalayan subalpine conifer forests, Himalayan sub-tropical pine forests, Himalayan sub-tropical broadleaf forests, Lower Gangetic Plains moist deciduous forests, Meghalaya subtropical forests, Mizoram-Manipur-Kachin rain forests, Northeastern Himalayan subalpine conifer forests and the Terai-Duar savanna and grasslands.

Rao (1974) classified the vegetation of this region broadly into three major types: the tropical, the temperate and the alpine.

The tropical forests encompass evergreen, semi-evergreen, moist deciduous, dry deciduous, grasslands, riparian forests and swamps upto an elevation of 900 meters. Most of the tropical forests are located in the Assam valley, foothills of the Eastern Himalayas, parts of Naga Hills and Manipur hills. The common species amongst such forests are: tall trees- *Dipterocarpus turbinatus, Canarium resiniferum, Artocarpus chaplasha, Ailanthus grandis, Tetrameles nudiflora, Euphoria longana, , Kayea assamica, Terminalia chebula, Mesua ferrea and Dysoxylum binectariferum;* lower trees-*Amoora wallichii, Lagerstroemia parviflora* and *Terminalia myriocarpa; lianas-Bauhinia, Acacia, Derris, Vitis, Unona, Gnetum;* plams- *Caryota, Licuala, Arenga, Pinanga, Didymosperma,* shrubs- *Saurauja roxburghii, Antidesma* spp., *Pavetta indica, Holarrhena antidysenterica,* epiphytic climbers- *Rhaphidophora* spp., *Pothos, Scindapsus officinalis* and *Hoya* spp. *Apart from these, several species of Calamus, Pandanus, stem parasites of Loranthaceae, Musa* spp. , orchids, ferns and fern allies are common.

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The deciduous forests are dominated by *Shorea robusta* in areas with less than 80 inches of rainfall. Thus, they are found predominantly in the districts of Goalpara, Kamrup, on lower slopes of Garo-Khasi hills and some in north Cachar hills. The associated species in these regions are *Careya arborea, Kydia calycina, Sterculia villosa, Bombax ceiba, Grewia* spp.*, Acacia* spp.*, Terminalia* spp.*, Albizia* spp.*, Adina cordifolia* and *Gmelina arborea* along with climbers, herbaceous plants, grasses and sedges.

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The grasslands occur mainly in the riparian belts with species of *Saccharum, Arundo donax, Erianthus ravannae* (Ekra) and *Phragmites communis*. Around marshes members of *Nymphaeaceae, Lemnaceae, Araceae, Cyperaceae* and *Eriocaulaceae* are common.

Subtropical mixed forests occur primarily in parts of Arunachal at elevations upto 1500 meters. In such places associations of *Castanopsis, Schima, Engelhardtia, Terminalia, Ficus, Michelia, Albizia, Bridelia, Cinnamon, Garcinia, Lindera,* and *Musa* spp. may be found along with *Quercus spp., Acer* spp. and palms.

The temperate vegetation is found at elevations from 1300-2500 meters in Shillong plateau, Naga Hills, Lushai hills, Mikir hills and parts of Arunachal. These include associations of *Albizia, Acer, Juglans, Quercus, Magnolia, Michelia, Rhododendron* and *Rubus* spp. Higher up, rhododendron dominates with *Pyrus, Prunus, Spiraea* and *Eriobotrya* finally ending in coniferous vegetation with *Tsuga-Picea-Abies* associations. Beyond elevations of 4500 meters alpine vegetation predominates with several species of rhododendron and meadows.

4.1.5 Fauna

The fauna of the region is extremely diverse with 13 species of primates, viz., slow loris (*Nycticebus bengalensis*), the hoolock gibbon (*Bunopithecus hoolock*), Hanuman or common langur (*Semnopithecus entellus*), Nepal langur (*Semnopethicus schistaceus*), capped langur (*Trachypithecus pileatus*), golden langur (*Trachypithecus geei*), the Phayre's leaf-macaque (*Trachypithecus phayeri*), rhesus macaque (*Macaca mulatta*), stump-tailed macaque (*M. arctoides*), northern pig tailed macaque (*M. leonina*), Assamese macaque (*M. assamensis*), Pere David's or Tibetan macaque (*M. thibetana*), and the newly discovered Arunachal macaque (*M. munzala*); four large cats, viz., tiger, leopard, snow leopard, clouded leopard along with three species of ursidae, the Asiatic black bear (*U. thibetanus*), sloth bear (*M. ursinus*) and the Malayan sun bear (*Helarctos malayanus*) along with two canid species, the jackal (*Canis aureus*) and the wild dog (*C. alpinus*).

The region also has the largest diversity of small carnivores known which includes five species of small cats, viz., the marbled cat (*Pardofelis marmorata*), Asiatic golden cat (*Catopuma temmincki*) , leopard cat (*Prionailurus bengalensis*), fishing cat (*Prionailurus viverrinus*) and the jungle cat (*Felis chaus*) and several species of viverrids and mustelids, viz., yellow-throated marten (*Martes flavigula*), Chinese ferret-badger (*Melogale moschata*), Burmese ferret-badger (Melogale personata), hog badger (*Arctonyx collaris*), small Indian civet (*Viverricula indica*), large Indian civet (*Viverra zibetha*), common palm civet (*Paradoxurus hermaphrodites*), Himalayan palm civet (*Paguma larvata*), binturong (*Arctictis binturong*) and spotted linsang (*Prionodon pardicolor*), smooth coated otter (*Lutrogale perspicillata*), small clawed otter (*Amblonyx cinereus*) and Eurasian otter (*Lutra lutra*).

This is also the area with the highest number of squirrel species which include the rare, endemic Namdapha flying squirrel (*Biswamayopterus biswasi*), hairy-footed flying squirrel (*Belomys pearsoni*), parti-coloured flying squirrel (*Hylopetes alboniger*), orange-bellied Himalayan squirrel (*Dremomys lokriah*), Malayan giant squirrel (*Ratufa bicolor*), hoary- bellied Squirrel (*Callosciurus pygerythrus*) and Himalayan striped squirrel (*Tamiops macclellandi*) along with over 65 species of bats.

This region also has probably the highest diversity of ungulates in the world ranging from species of the lowlands like the elephant (*Elephas maximus*), one-horned rhinoceros (*Rhinoceros unicornis*), wild buffalo (*Bubalus bubalis*), brow-antlered deer (*Cervus eldi eldi*), swamp deer (*Rucervus duvaucelii*), leaf deer (*Muntiacus putaoensis*), hog deer (*Axis porcinus*), sambar (*Rusa unicolor*), barking deer (*Muntiacus muntjak*), chital (*Axis axis*) (in the Bengal dooars), wild pig (*Sus scrofa*) and pygmy hog (*Porcula salvania*). The mountain ungulates comprise of Himalayan serow (*Capricornis thar*), Himalayan goral (*Naemorhedus goral*), red goral (*Naemorhedus baileyi*), Tibetan wild ass (*Equus hemionus kiang*), markhor (*Capra falconeri*), ibex (*Capra ibex*), great Tibetan sheep (*Ovis ammon hodgsoni*) and blue sheep (*Pseudois nayaur*) to name a few.

The only species of Ailuropodidae, the red panda (*Ailurus fulgens*) is also endemic to this region along with the endangered hispid hare (*Caprolagus hispidus*) and the rare Chinese pangolin (*Manis pentadactyla*) and Indian or thick-tailed pangolins (*Manis crassicaudata*).

Like the mammalian fauna, this region also supports high number of avian species with Arunachal Pradesh alone having 665 species (Ramakantha, unpubl.) with discoveries of new species like the Bugun liocichla still in process (Athreya 2006).

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

4.1.6 Ecological Studies

The remoteness and inhospitable terrain along with insurgency in most parts of this landscape has isolated the region from most large scale and long term scientific studies. The first attempt using scientifically robust methodology to estimate tiger and its prey densities in Kaziranga and Namdapha Tiger Reserves was made by Karanth and Nichols in 1998. The study estimated 16.8 ± 2.96 tigers/ 100 km² in Kaziranga National Park with densities of prey being 58.1 animals/ km². This was the highest number of tigers and large prey estimated from any part of the country. However, due to inadequate data on tigers and their prey in Namdapha, density estimates could not be derived. In 2006-07, Datta *et al.* (2008) conducted a study in Namdapha National Park and detected direct evidences of only one large carnivore, the clouded leopard in this region. Based on prey availability, they estimated a potential tiger density of 1 tiger/ 1000 km². As part of a larger study, Jhala *et al.* (2008) estimated tiger occupancy of 4,230 km² in this landscape and identified important tiger landscapes in this zone.

In recent times, few endeavours have been made by Ahmed *et al.* (2009) from Aaranyak, a local organisation, to monitor tiger populations in the Orang National Park and the Kaziranga Tiger Reserve (2010) in collaboration with the Assam Forest Department. The same group also conducted a study in 2009 to determine the usage of the Brahmaputra river islands by tigers moving between the Kaziranga Tiger Reserve and Orang National Parks. Ahmed *et al.* (2010) estimated 32.64 ± 7.8 tigers/ 100 km² in an effectively sampled area of 144 km² of Kaziranga National Park in 2010.

The other noteworthy studies from the region have been those on the wild buffalo in Kaziranga National Park to determine levels of hybridization, conducted by the Wildlife Institute of India and in more recent times, experiments with captive breeding and re-introduction of the pygmy hog in the Nameri and Manas Tiger Reserves, being conducted by the Durrell Wildlife Conservation Trust, UK in association with the Assam Forest Department.

Apart from the scientific studies, faunal aspects of this region have been well-documented by naturalists such as E.P. Gee (also known for the discovery of the golden langur) and the prolific writer, Anwaruddin Chowdhury.

The floristic and faunal elements of the north-eastern parts of India and its adjoining areas have always fascinated naturalists. Evidence of which exists in the extensive surveys carried out in the last decade by Rabinowitz *et al.* (1995) of the Wildlife Conservation Society in the politically disturbed neighbouring country of Myanmar in search of the Sumatran rhinoceros.

Apart from the studies on the tiger and its prey, this region in recent times has also become the focus of intensive long term ecological monitoring and a zone for surveys and explorations. While Aaranyak has carried out several studies on the hispid hare, rhinoceros, elephant, swamp deer, tiger, leopard and the Gangetic dolphin, almost restricting its work to the State of Assam, the Nature Conservation Foundation, Mysore, has focussed extensively on ecological monitoring in Arunachal Pradesh. The Centre for Ecological Studies (Indian Institute of Science, Bangalore) has been working in this region for almost a decade, conducting studies to better understand ecology and behaviour of the elephant while simultaneously experimenting with methods to reduce human-elephant conflict. A long term project to monitor biodiversity of Sikkim has also been initiated in the State of Sikkim by the National Centre for Biological Sciences, Bangalore with a grant from the Department of Science and Technology, Government of India.

4.1.7 Conservation Status

Currently tiger occupancy was recorded from an area of 4,565 km² of forests within the Brahmaputra Valley and the North East Hills landscape, with an estimated population of about 143 (113 to 172) tigers. The important tiger populations in this landscape include:

a) The largest contiguous forested region in this landscape is over 136,000 km². This landscape unit commences in the north-west from Pakke Tiger Reserve through the forests of Palia, Tale Valley Wildlife Sanctuary, Mouling National Park and Daying Ering Wildlife Sanctuary into Dibang Wildlife Sanctuary and upto the Namdapha Tiger Reserve in the east. The landscape continues south through some degraded areas into the Intanki National Park, and further south to the Dampa Tiger Reserve and Blue Mountain National Park. The Kaziranga National Park in the Brahmaputra 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 almost lost its connectivity to the north (to Pakke) due to intensive agriculture on northern banks of the River Brahmaputra. Intanki National Park is also connected westwards through priority III forests upto the 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, Mokokchung, Tuensang, Zuheboto, Wokha, and Phek in the east. The landscape between the 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 population of tigers in this landscape are in Kaziranga and Pakke in India and dispersing tigers from Bhutan and Myanmar. This landscape holds the largest tiger population in the North-Eastern region consisting of about 125 tigers. It is connected to the southern parts of the North East Landscape via the Karbi-Anglong Hills, for which it acts as a major source. The Kaziranga population connects to the tiger population of Nameri-Pakke through riverine corridors (Fig. 4.1).

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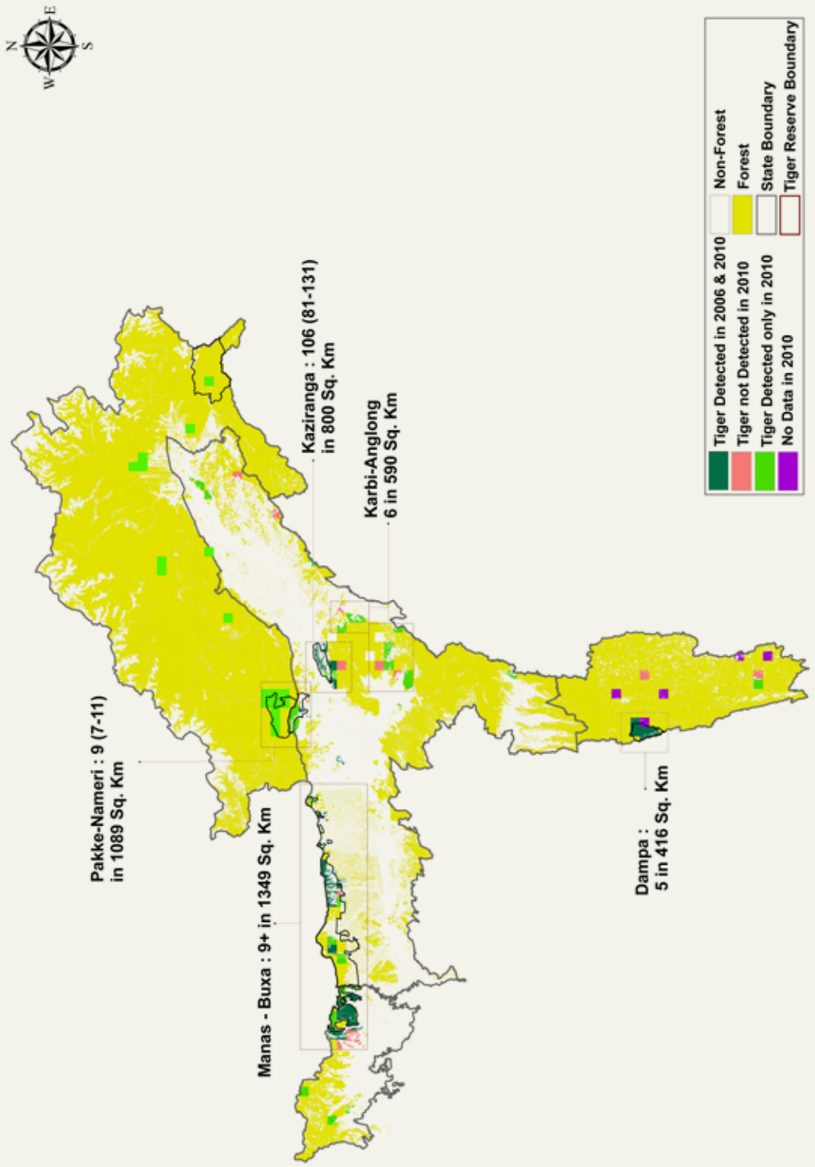
b) Manas-Ripu Chirang-Buxa/Jaldapara-Gorumara-Singhalila landscape unit is about 7,200 km² with a single block of 5,000 km² from northern West Bengal (Gorumara) to the coniferous forests of Sikkim (Singhalila). The forest connectivity in the Brahmaputra plains is patchy and fragmented, but the landscape is connected through the forests of Bhutan. On the Indian side, “stepping stone” connectivity exists between Gorumara, Jaldapara, Buxa, and Ripu Chirang through the district of Jalpaiguri. Connectivity between Ripu Chirang and Manas is degraded on the Indian side. This landscape needs to be managed through transboundary international cooperation with the Government of Bhutan.

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

Figure 4.1

Tiger occupancy, population extent, size and habitat connectivity in the North Eastern Hills and Bramhaputra Flood Plains Landscape

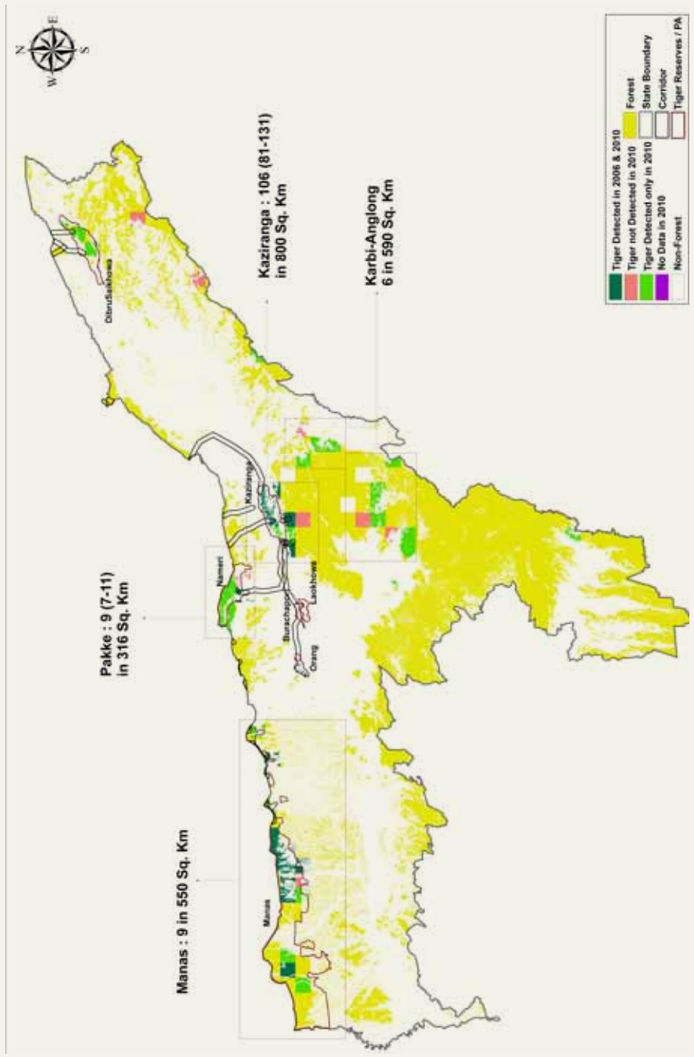


ASSAM

Until 1900, Assam had about 142,854 km² forested area of which about 54,000 km² was under government control. This was the largest area under state control at that time in India (Tucker 1988). However, as per the Forest Survey Report (2009), only 27,692 km² forested area remains in the State, constituting about 35% of the geographical area of the state. Several reasons can be attributed to this reduction of forests in Assam. These include expansion of areas under tea cultivation, the global depression of 1930s that struck the tea industry in Assam and forced much labour at tea estates to start practicing shifting cultivation, large scale demand for timber and in more recent times, an uncontrolled expansion of human population.

Figure 4.AS.1

Tiger occupancy, population extends, size and habitat connectivity in Assam



Of the total forested area in the state, 20,359 km² is categorised as Tiger Conservation Priority Area with significance levels of I and II. In 2006 the state reported tiger occupancy in 1,164 km² (Jhala *et al.* 2008). In 2010 the tiger occupancy was recorded within 2,381 km² showing an increase of almost 76% in recorded area occupied by tigers since 2006. This increase in occupied area is likely due to better coverage and sampling in 2010. The total tiger population for the state of Assam was estimated at 143 (113 to 173) (Fig. 4.AS.1).

The state has three Tiger Reserves, five National Parks and 17 Wildlife Sanctuaries and three proposed Wildlife Sanctuaries. The three Tiger Reserves of the state include:

a) The Kaziranga Tiger Reserve covers an area of 1,033 km² and includes the 859 km² Kaziranga National Park, 44 km² Burachapori and 70 km² Laokhowa Wildlife Sanctuaries. The National Park is located in Nagaon, Golaghat and Sonitpur districts, bounded in the north by the Brahmaputra and to the south, by the Karbi-Anglong Hills. National Highway 37 separates it from the Karbi-Anglong hills while about 150 villages are located along this road, within the zone of influence of the

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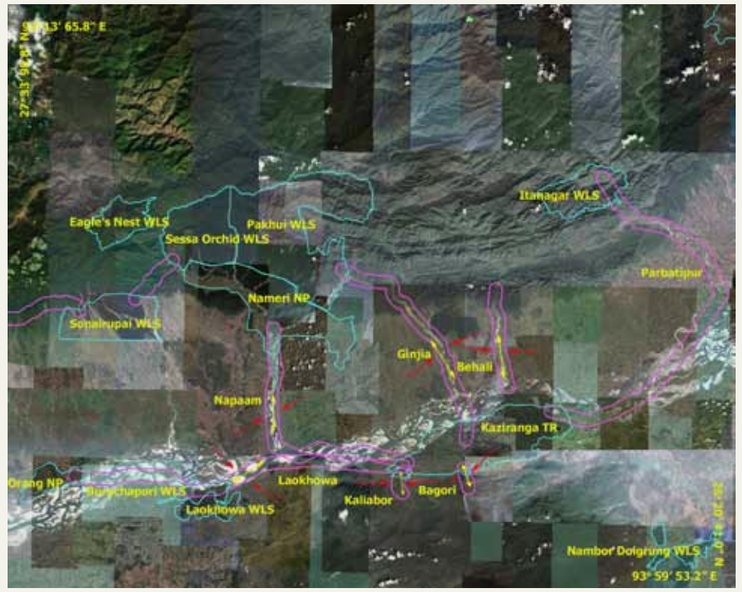
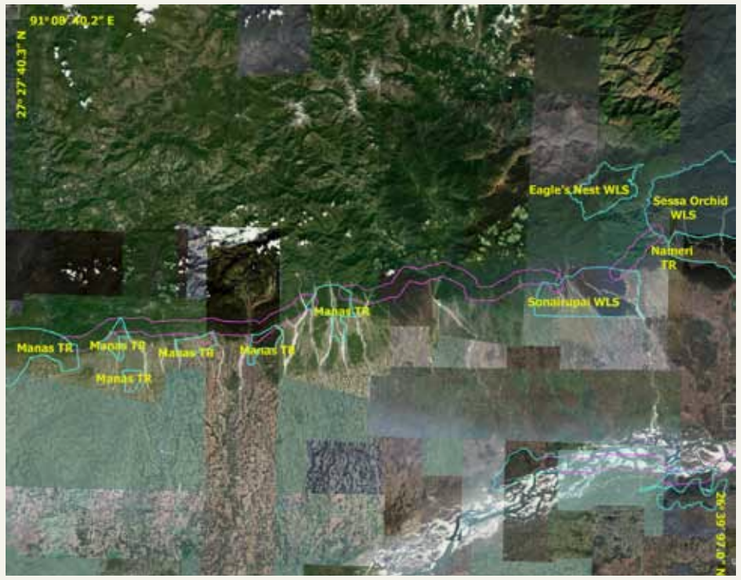
Reserve. The Kaziranga tiger population is contiguous with that of the Rajiv Gandhi Orang National Park connected through island systems of the Brahmaputra. This is the single largest population in this Landscape consisting of about 125 tigers. The Kaziranga population connects with Nameri through riverine corridors (Fig. 4.AS.1.1), which is an important connectivity maintaining gene flow between the plains and the hill population of tigers (in Arunachal). This region being extremely fertile is in demand for agriculture and the Protected Areas are increasingly becoming isolated islands. In light of this the connectivity with Nameri in the north, Karbi Anglong in the south as well as the riverine islands, "stepping stones" through Laokhowa and Burachapori Wildlife Sanctuaries to Orang form the crucial elements for targeting conservation efforts (Fig. 4.AS.1.1). Large mammals from Kaziranga are also known to move between Karbi-Anglong hills and the Tiger Reserve, although protection levels to these dispersing and migrating individuals cannot be ascertained with the existence of political unrest in the Karbi region.

Figure 4.AS.1.1
Kaziranga-Orang-Nameri-Pakke Corridor



b) Manas Tiger Reserve spans across the districts of Kokrajhar, Bongaigaon, Barpeta, Nalbari, Kamrup and Darrang in north-west Assam, covering an area of 2,837 km² of which 470 km² is designated as the core area. To the north, it is separated from the Royal Manas National Park of Bhutan by the River Manas and its tributaries-Beki and Hakua; while to the west, it is separated from the Buxa Tiger Reserve of West Bengal by the River Sankosh. Around 62 villages are located within two kilometres of the Reserve boundary between Rivers Sankosh and Dhansiri. The region is affected by high levels of extremist activities, thus making conservation and scientific monitoring in the area a challenge till date. The Reserve shares the area with the Ripu Chirang Elephant Reserve and further westwards continues with the forests of Buxa in West Bengal. The entire area inclusive of the Bornadi Wildlife Sanctuary in Assam covers an area of 7,200 km². The Manas Tiger Reserve was camera trapped with almost a total coverage and its current tiger density is estimated to be 1.8 tiger per 100 km². However, the region has high potential and is on its path to recovery. With control of poaching of prey, tiger densities are likely to increase substantially, especially in the southern parts of Manas. (Fig. 4.AS.1.2).

Figure 4.AS.1.2
Manas-Sonairupai-Nameri corridor



c) The Nameri Tiger Reserve is located in the Sonitpur districts of north-east Assam. It is contiguous with the Pakke Tiger Reserve of Arunachal Pradesh to its north and covers an area of 344 km² of which 200 km² forms the core demarcated by the Rivers Bhorali and Bordikarai. Within the Reserve are located 13 villages of which eight are forest villages with predominantly tribal population. The population of tigers is small (about 9) and is shared with Pakke. Though the area has potential for higher densities and ability to sustain a larger population of tigers, the depletion of prey by subsistence poaching as well as other anthropogenic disturbances is responsible for the current situation. Its connectivity with Kaziranga is important and needs policy and managerial inputs for its continued viability (Fig.4.AS.1.1). This complex may further be connected to the Sonai Rupai Wildlife Sanctuary in Assam and the greater forest complex of Arunachal, that provides connectivity, although with high hunting pressures and insurgency problems, to the forests further east into Namdapha, Intanki and maybe even Myanmar.

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ARUNACHAL PRADESH

The largest tract of forest in the north-east of India is located in Arunachal Pradesh covering 67,353 km² which constitutes 80.4% of the total geographical area of the state (State of the Forest Report 2009). The state is a biodiversity hotspot with two Tiger Reserves, two National Parks, nine Wildlife Sanctuaries, one Orchid Sanctuary, the Dihang-Dibang Biosphere Reserve and the Kameng Elephant Reserve that covers parts of Papumpare, East Kameng and West Kameng (Fig. 4.AP.1).

The two Tiger Reserves include:

a) The Namdapha Tiger Reserve covers an area of 1,985 km² in the Changlang district of eastern Arunachal Pradesh. While most of the area is free of human presence, about six small patches of cultivation still exist within the Reserve covering about 25 hectares. On the peripheries of the Tiger Reserve are settlements such as Gandhigram, Deban and M'pen with mostly Lisu population. The Miao-Gandhigram road traverses 105 kilometers of the Reserve and 13 kilometers of the Miao-Vijaynagar road cuts across the buffer zone of the Reseve. Hunting for cultural and subsistence reasons appears to be the greatest threat to biodiversity in this area. Namdapha Tiger Reserve is connected to the forests of Kamlang Wildlife Sanctuary and further eastwards to the forests of Myanmar which is a contiguous forest patch of 1,36,000 km².

b) The Pakke Tiger Reserve covers an area of 862 km² in the East Kameng district along the boundary with Assam. Around 27 villages are located on the fringes of the Reserve and several conservation initiatives such as formation of Self Help Groups (SHGs), Village Forest Development Councils (VFDCs) and implementation of eco-development schemes have been undertaken to increase the awareness of biodiversity and reduce the dependence of people on the park. The Pakke-Nameri landscape includes parts of the Sessa Orchid Sanctuary in the West Kameng district, Eagle's Nest Wildlife Sanctuary, Pakke Tiger Reserve, parts of Nameri Tiger Reserve

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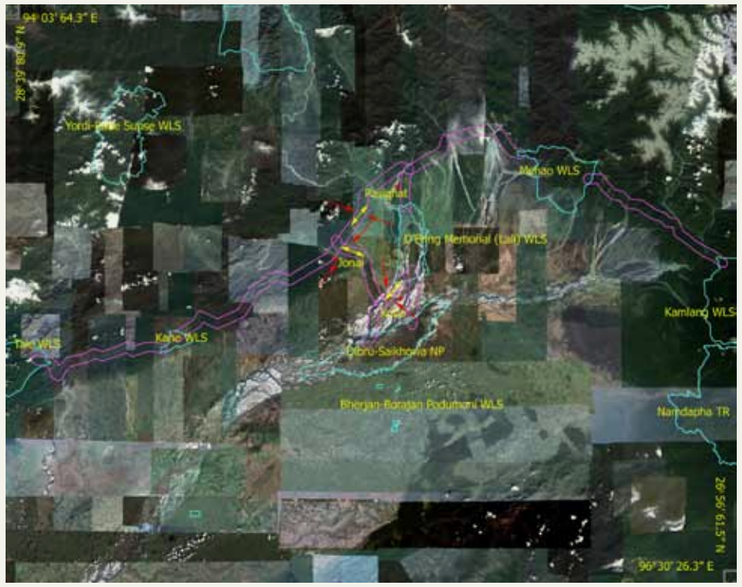
Figure 4.AP.1
Tale-Mehao-Namdapha corridor



in Assam and continues via the forests of Tale Valley into lower Subansiri to Daying Ering Wildlife Sanctuary in East Siang upto the Namdapha Tiger Reserve. The largest tiger population of Arunachal is within pockets of this landscape (Fig.4.1). The tiger population of Pakke is shared with that of Nameri Tiger Reserve (Assam) and was estimated to be around 9 tigers.

The presence of dipterocarpus forests in this region along with the high levels of hunting, result in low abundances of prey which subsequently affect tiger abundances. Thus, despite the availability of vast forested areas in this zone, tiger abundances are low. The low land forest and hill forest are connected within Arunachal and with Assam (Fig. 4.AP.1.1)

The Namdapha region was not surveyed systematically but targeted areas were sampled by the WWF-India, Aaranyak and the Wildlife Trust of India. Population estimate for the state could not be derived due to the nature of the data recorded which was limited to tiger sign coordinates. The current distribution of tigers in Arunachal Pradesh is the reflection of this limited survey effort which has resulted in recorded tiger occupancy of 1,304 km^2.

MIZORAM

The State of Mizoram has an area of 19,240 km^2 under forest cover which constitutes over 91% of the total geographical area of the state as per the State of the Forest Report (2009). Of this, 9,084 km^2 is categorised as the Tiger Conservation Priority I and II area. The state has one Tiger Reserve, two National Parks and six Wildlife Sanctuaries under the jurisdiction of 14 Forest Divisions.

The Dampa Tiger Reserve is located in the Mamit district and covers an area of 500 km^2 of which 340 km^2 is categorised as the core area. To the west, it is separated from Bangladesh by River Saza, while metalled roads demarcate it on the east and north. About 20 villages are located on the peripheries of the Reserve and exert high pressure on the Reserve. In 2006 tiger occupancy was recorded to be 482 km^2 in this area while in 2010 the recorded tiger occupancy was 416 km^2 with a population estimate of about 5 tigers (Fig.4.1). Sporadic tiger occurrences have also been reported from the Ngengpui Wildlife Sanctuary which covers an area of 110 km^2 close to Indo-Myanmar and Indo-Bangladesh borders.

The high hunting levels in the region primarily for subsistence and cultural reasons along with the nature of forests; do not support high tiger presence in this landscape. However, with larger areas being brought under high levels of protection, this region could support a viable tiger population if managed as a trans-boundary population with Myanmar. The current policy of fencing the international borders to prevent infiltration can be a major barrier to sharing the gene pool of tigers across the larger landscape.

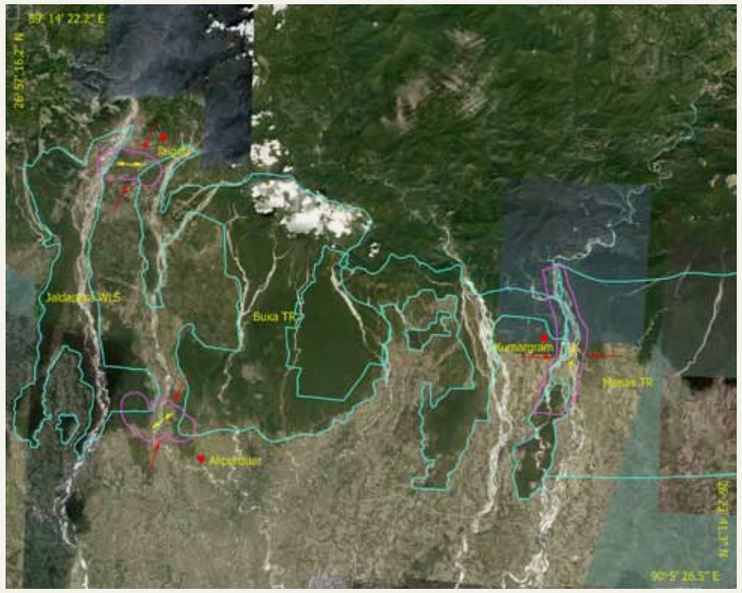
NORTHERN WEST BENGAL

The total forested region in the northern districts of West Bengal comprising of Darjeeling, Jalpaiguri, West Dinajpur and Coochbehar districts is 4,904 km². Other than the Sundarbans, this is the only forested region in the state and comprises of several Protected Areas, most of which are restricted to the 'Siliguri Corridor or chicken's neck' section of the Dooars and include the Singhalila National Park, Senchal Wildlife Sanctuary, Mahananda Wildlife Sanctuary and Neora Valley National Park in Darjeeling district. The Gorumara National Park, Chapramari Wildlife Sanctuary, and Buxa Tiger Reserve are located in Jalpaiguri district along with the Jaldapara Wildlife Sanctuary located in Jalpaiguri and Coochbehar districts in the terai belt, further south.

The only Tiger Reserve in this region, Buxa, is located in the Alipurduar sub-division of Jalpaiguri district and covers an area of 760.87 km². To the east, it is separated from the Manas Tiger Reserve of Assam by River Sankosh while on the west; tea estates and the Joygaon-Nimti State Highway demarcate its boundaries. To the north of it is the international boundary with Bhutan while on the south a mosaic of agricultural land, tea estates and the National Highway 31C are located. The Reserve has 37 forest villages while 7000-8000 pilgrims visit the Mahakal Temple, located within the Reserve, in March each year. The other factors adding to existing disturbance levels in the area include existence of a number of PWD roads, a National Highway and a meter gauge railway line from Damanpur to Hasimara. Until 1996, the area was also mined for dolomite, post which a stay order was passed on mining activities within the Park by the State High Court.

Buxa Tiger Reserve has a weak connectivity to the Jaldapara Wildlife Sanctuary and Gorumara National Park (Fig. 4.NWB.1.1). While both these latter areas are small with high levels of disturbance (with about 32 Toto villages around Jaldapara and 9 villages around Gorumara), they still provide some connectivity to tigers dispersing in this landscape. To the east, Buxa has a good connectivity with a much larger tiger landscape of Manas Tiger Reserve and Bornadi Wildlife Sanctuary in Assam and Royal Manas National Park in Bhutan (Fig. 4.NWB.1.1) with tiger occupancy of 1,051 km² of which 596 km² exists in the northern part of West Bengal as estimated in 2006 (Jhala *et al.* 2008). In 2010 the tiger occupancy in northern West Bengal was recorded to be 799 km² (Fig. 4.1) while the population of tigers in Buxa was estimated from fecal DNA by Aaranyak (a non-governmental organisation) to be a minimum of 15 individuals (Borthakur *et al.* 2010).

Figure 4.NBW.1.1
Buxa-Manas and Buxa-Jaldapara corridors



Tiger population status summary for the Brahmaputra Valley and the North East hills

State	Tiger Population			Tiger km²		
	2006	2010	Increase/ Decrease/ Stable	2006	2010	Increase/ Decrease/ Stable
Assam	70	143	Increase	1164	2381	Increase
Arunachal Pradesh	14	-	-	1685	1304	Decrease
Mizoram	6	5	Stable	785	416	Decrease
Northern West Bengal	10	-	-	596	799	Increase
North East Hills, and Brahmaputra	100	148	Increase	4230	4900	Increase

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5.0
THE SUNDARBANS

Principal Investigators: Y.V.Jhala and Qamar Qureshi
Researchers: Dipanjan Naha, Manjari Roy, Anant Pande, Manas Manjrekar, Charles Leo Prabhu

Sundarbans is the world's largest contiguous mangrove forest created at the confluence of the deltas of the Rivers Brahmaputra, Ganga and Meghna. The delta spreads across the countries of India and Bangladesh covering 80,000 km² (Chakrabarti 1992) with 38% (Mitra 2000) of it in India and the remaining in Bangladesh. It is comprised of mudflats, creeks, tidal channels and an archipelago of about 102 islands of which 54 are inhabited by human population (Bera and Sahay 2010).

To the north of Sundarbans are the Himalayas, Rajmahal Hills to the west and the Meghalaya plateau and Chittagong Hills to the east (Chakrabarti 1992). Geologically, this area was carved out in recent times by tidal action and silt deposition and is still under formation. As a result of neotectonic changes the Bengal basin has been tilting eastwards resulting in changes in the flow of River Ganga and subsequently the structure of this vast delta.

The mangrove forests of Sundarbans are considered an important barrier to the frequent cyclones emerging from the Bay of Bengal. Some of these can be of an intense nature like the cyclone of 1585 which killed about 2,00,000 people while another one in 1688 killed 60,000 people on the island of Sagar alone (Chakrabarti 1992). The conservation of these mangroves thus becomes essential for not just biodiversity of the region but also as a barrier to reduce the impact of such cyclones, which could affect the lives of people living onshore.

5.1.1 Location

The Indian part of Sundarbans covers about 4,266 km² (Sen and Naskar 2003) in the 24 Parganas district of West Bengal, with parts of the region submerged under water. It lies in the biogeographic zone 'Coasts' in the province of 'East Coast' as per Rodgers and Panwar's (1988) classification.

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The Protected Area of Sundarbans is comprised of 2,585 km² with a unique ecosystem of which 1,330 km² has been designated as the core zone of the Sundarbans National Park. The River Vidya Malta divides the forest into two Ranges, the western Namkhana Range and the eastern Bashirhat Range. The salinity levels vary spatially and temporally in this region with the westward (Namkhana) area having higher salinity compared to the Bashirhat Range (Chakrabarti 1992). This in turn affects the structure and composition of the flora and fauna in these areas.

The human population density of this region is amongst the highest in the country with 1437.4 persons/ km² (Qureshi *et al.* 2006) making biodiversity conservation a challenge, although the Tiger Reserve is free of human settlements.

5.1.2 Ecological Background

Human colonisation of this region happened relatively late due to the inhospitable conditions though some people did occupy the area even in the 6th century (Chakrabarti 1992). The present day district of the 24 Parganas was ceded to the East India Company as part of the treaty of 1737 and thereafter became the jagir of Lord Clive (Chaudhuri 1989). However, it was only in 1770 that serious efforts were made to reclaim land in this area for agriculture by Claude Russell, the then Collector-General of the district (Bera and Sahay 2010). By 1878-79, 4856 km² of this area was designated a Reserved Forest (Bera and Sahay 2010). In 1903, Sir Daniel Mackinnon Hamilton, a Scotsman, bought 40 km² of land which included the islands of Rangabelia, Satjelia and Gosaba where he established religious centres, dispensaries and co-operative societies for tribals from the Chotta Nagpur region belonging to tribes like the Bhumij and the Mundas (Chakrabarti 1992; Bera *et al.* 2010).

In 1978, many partition refugees from Bangladesh escaped from the Dandakaranya government resettlement camp in central India and decided to establish themselves at Marichjhanpi in Sundarbans, an area that was until then free of human presence and categorised as a Reserved Forest. This act led to violent clashes between the new settlers and the Left government and resulted in mass deaths, brutality and disease in the region (Ghosh 2004).

In 1973-74, India declared 2,585 km² of this area as a Tiger Reserve with Bangladesh following suit, declaring 23.5% of the remaining Sundarbans as a Reserved Forest in 1977 by carving out three sanctuaries, viz., Sundarbans West, Sundarbans East and Sundarbans South under the Bangladesh Wildlife (Preservation) (Amendment) Act, 1974 (Barlow *et al.* 2008).

5.1.3 Conservation Significance

The United Nations Educational, Scientific and Cultural Organisation (UNESCO) in 1987 placed the Indian Sundarbans on the World Heritage List for it being an outstanding example of ecological and biological processes in the evolution and development of coastal communities of plants and animals and for the importance of this region for biodiversity conservation. A decade later the Bangladesh part of Sundarbans was also added to the same list.

With respect to the tiger, this area is a tiger conservation unit (TCU) of level 1 importance and the only one in a mangrove habitat (Dinerstein *et al.* 1997). However, Sundarbans tigers of India and Bangladesh form a single population, which is isolated from other tiger populations.

5.1.4 Vegetation

The vegetation of this region is structured by several factors which include salinity levels, soil composition and structure, silt deposition rates and rates of humus formation. This area is the most important tidal forest in India with around 35 mangrove species and 117 other halophytic mangrove associates (Qureshi *et al.* 2006). Altogether, about 350 vascular plant species belonging to 254 genera are found here (Chakrabarti 1992). Most plants have unique adaptations like pneumatophores to breath and viviparous germination. Species like *Ceriops, Sonneratia apetala,*

Xylocarpus, Hertiera, Lumnitzera, Excoecaria and *Avicennia* have pnematophores while vivipary is found in *Rhizophora, Bruguiera, Ceriops, Kandelia* (Chaudhuri and Chakrabarti 1989). The dominant plant families of the region are *Rhizophoraceae, Verbenaceae* and *Sonneratiaceae*.

Champion and Seth (1968) describe five vegetation types from this region: mangrove scrub, mangrove forest, saltwater mixed forest (*Heritiera*), brackish water mixed forest (*Heritiera*) and palm swamp.

Low mangrove areas have species like *Ceriops, Avicennia, Excoecaria agallocha, Kandelia candel, Bruguiera cylindrica, Rhizophora* sp., *Sonneratia* sp., *Tamarix* sp., *Aegilops* spp., while tree mangrove forests have primarily *Rhizophora* sp., *Sonneratia* sp., *Bruguiera* sp., *Xylocarpus* sp., *and Kandelia candel* (Chaudhuri and Chakrabarti 1989). Saltwater Heritiera forests mainly have *Ceriops, Heritiera fomes, Excoecaria agallocha* while fresh water Heritiera forests are dominated by *Heritiera* and *Xylocarpus*.

On river islands and fresh silt, *Oryza coarctata* is a dominant herbaceous species. Poor soils have species like *Aegialitis rotundifolia* and *Acanthus llicifolius* while common palm species are *Phoenix paludosa* and *Nepa* sp..

Heritiera fomes or 'Sundari' is the most dominant species in the eastern region and thus gives the name 'Sundarbans' to this landscape.

5.1.5 Fauna

A mixture of fresh and salt water along with the spatial and temporal variations in water levels due to tidal action produce a unique environment for life in this zone with most species being amphibious or aquatic in nature. While estimates of species diversity vary, this region has about 165 species of fish (Dinda 2010), around 163 species of birds (Sen and Naskar 2003), 23 species of molluscs (Dinda 2010), 56 species of reptiles (Dinda 2010), amphibians, phytoplankton, benthic invertebrates and zooplankton. Mangroves provide most of the organic matter on which many of these aquatic species survive, bulk of which comprises of crustaceans (crabs, lobsters, shrimps and prawns). Some *Periophthalmus* and *Boleophthalmus* (mud-skippers) species in the region are also adapted to climbing trees in order to deal with the fluctuating water levels (Chakrabarti 1992).

Amongst the larger fauna, estuarine crocodile (*Crocodylus porosus*), water monitor (*Varanus salvator*), and three species of terrapin and turtles: northern river terrapin (*Batagur baska*), softshell turtle (*Pelochelys bibroni*), green sea turtle (*Chelonia mydas*), along with the Irrawaddy (*Orcaella brevirostris*) and Gangetic dolphins (*Platanista gangetica gangetica*) are rare and endangered.

However, the flagship species of the Sundarbans is the tiger (*Panthera tigris*). This is the only such habitat in which tigers are known to survive and lead a more amphibious life than their counterparts in other parts of the world. The tiger is an integral part of Sundarbans and partly responsible for the great publicity obtained by this area for two reasons, first, the highest concentration of tigers in the world was believed to exist here and second, for the highest concentration of man-eating tigers in the world. While the former claim is under scientific deliberation, the latter remains a mystery. Local legends mention that about 100 years ago 4,218 people were eaten by tigers in just six years (Montgomery 2008) while historical records indicate that 800 human lives were lost in a span of 20 years in the undivided Sundarbans (Chakrabarti 1992). More recent estimates proclaim that on an average 36 lives are lost to tigers on the Indian side of Sundarbans each year with only 28.5% of bodies recovered (Chakrabarti 1992). The intensity of human lives lost to tigers is further reiterated through the existence of 'vaidaba pallis' or tiger widow villages where every woman in the village has lost a son, father or husband to tigers (Montgomery 2008). Thus, local belief is that the "unofficial" figures of those killed by tigers can be far higher than the official figures provided by the administration as all deaths are not reported (Montgomery 2008). It is the existence of the tiger that has greatly influenced the local culture of the area with people wearing double faced masks and worshipping deities such as Dakshin Ray, Bara Thakur (Mundu) and Bon Bibi for protection from the tiger and other forest animals.

While mangrove habitats are amongst the most productive ecosystems, most of the productivity is confined to aquatic systems with terrestrial species being low in numbers. Thus, the ability of this region to sustain large mammals is restricted. The main prey of tiger in the region comprises of chital (*Axis axis*), wild pig (*Sus scrofa*) and rhesus macaque (*Macaca mulatta*) and lesser adjutant (*Leptoptilos javanicus*) (Khan 2008). Most other native fauna of the region which included Javan rhinoceros (*Rhinoceros sondaicus*), swamp deer (*Rucervus duvaucelii*), water buffalo (*Bubalus bubalis*), gaur (*Bos frontalis*) and hog deer (*Axis porcinus*) are now extinct from this area (Chakrabarti 1992). The marsh crocodile (*Crocodilus palustris*) also no longer exists in this region.

5.1.6 Ecological Studies

While several studies have been conducted in this region to study structure and composition of mangroves (Prain 1903; Champion 1936; Bhattacharyya 2002), dependence of local communities on such systems (Naskar, Guha & Bakshi 1987), pollutant levels (Sarkara *et al.* 2002; Guzzella *et al.* 2005) effects of climate change and sea level on Sundarbans (Naskar and Guha & Bakshi 1987; Mukherjee 2002; Hazra 2002) and geology of the area (Bhattacharya and Das 1994; Bhattacharya 1999;

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Sanyal 1999 (in Sen and Naskar 2003), few studies have been conducted to assess status of tigers and their prey in the Indian Sundarbans.

Most studies on tigers and their prey have been conducted on the Bangladesh side of Sundarbans. In 1971, Hubert Hendrichs conducted a three month study to identify reasons for man-eating by Sundarbans tigers. However, the project could not be completed but the initial data indicated an association between man-eating behaviour amongst tigers with increasing salinity levels. In more recent times, a long term study was initiated in February 2005 by the Bangladesh Wildlife Department from a funding by Save the Tiger Fund and the US Fish and Wildlife Service to study tiger ecology and prey availability. Some other studies to assess prey density have also been conducted in this landscape by Reza *et al.* (2002). However, the most important contribution to information on tiger ecology in this region is an outcome of studies conducted by Adam Barlow in Bangladesh Sundarbans, which includes monitoring tiger populations in mangrove landscapes (Barlow *et al.* 2008), designing conservation framework to reduce human-tiger conflict (Barlow *et al.* 2010) and studying the impact of sea-level rise on Sundarbans (Loucks *et al.* 2010).

However, on the Indian side, while several books have been published on this region and man-eating tigers, scientific studies on the tiger are lacking. Until recent times tiger numbers were determined using traditional methods like pug mark census, which have been considered error prone by scientific communities. Tiger census figures based on such methods produced estimates as high as 205 tigers in 1979 and 269 in 1989 (Chakrabarti 1992).

The inaccessible terrain of these habitats makes scientific research a challenge thus few such endeavours have been attempted in this zone. The first effort to assess tigers and their prey numbers in this region using more reliable scientific methods was made by Karanth and Nichols in mid 1990s followed by a more recent attempt at understanding tiger ecology using radio-telemetry by Jhala et. al. (current report and on-going).

5.1.7 Conservation Status

This region is under intense human pressure with around 3.5 million people living within 20 kilometres of its northern and eastern borders and depending upon the forests for livelihood resources. Annually, around 35,330 people enter the forests of Sundarbans to collect timber, fish, honey and other products (Chakrabarti 1992).

Most of the unique flora and fauna of this region is anyway being affected by the increasing levels of salinity and sedimentation which is a consequence of reduced inflow of freshwater into the delta due to construction of dams and barrages (e.g. Farakka) upstream. *Heritiera* fomes, the plant that lends its name to the Sundarbans is most threatened along with other species like *Nypha fruticans* and *Phoenix paludosa*.

The increasing sea level in the event of global climate change is also predicted to affect this region negatively with continuous submergence of pneumatophores of plants that would lead to asphyxiation and sand deposition. The increasing level of toxins and pesticides in the waters of rivers entering this area is also alarming with adverse effects on the biodiversity of the region. Other threats to the region exist in the form of mangrove conversion to paddy fields and shrimp farms and presence of oil and gas exploratory activities in the area.

Apart from all the above indirect threats to the tiger in this region, poaching of the

species may also be prevalent with at least 17 seizures of tiger skins and body parts in areas around Sundarbans in the last decade alone (data obtained from TRAFFIC Report 2010 (Verheij *et al.* 2010)).

All these factors, along with the isolated tiger population in this zone, makes this an important tiger conservation unit with a high degree of threat requiring continuous monitoring and management inputs.

5.1.8. Monitoring Methodology

Due to the unique and hostile habitat of the Sundarbans the methodology used across India (Phase I) for monitoring tigers and their prey could not be applied. We adapted the methodology to suit the environment of the Sundarbans. Since it was not possible to walk in the mangrove forests for recording tiger sign encounter rates due to lack of proper animal trails as well as the ever present threat of tiger attack, we used tidal channel searches across the Sundarbans to record sign and animal encounter rates. One hundred and twenty-six boat transects with an effort of 1163 kms were sampled across the entire tiger reserve. A similar approach has also been used in the Bangladesh Sundarbans as well (Barlow *et al.* 2008). The sign intensity data across the Sundarbans constituted the Phase I data set.
We then used a combination of satellite-telemetry and camera traps to estimate home range size, population and density of tigers (Phase III).

5.1.9.Collaring of Tigers

A total of five tigers, 2 adult females and 3 adult males were tagged with satellite radio collars as a part of an on-going study on the Sundarbans tigers. The tigers were trapped in cages using bait and were anesthetized using 3 mg/kg Ketamine and 1.5 mg/kg Xylazene (Kreeger, 1996) administered intra muscularly using a blowpipe. The satellite collars (VECTRONIX GPS Plus) weighed less than 1.5 % of the body weight of the tigers. The collars were programmed to provide GPS fixes every 30 minutes during phases of intensive sampling and later remotely reprogrammed to provide five GPS fixes per day to conserve battery power. Locations of tigers were analysed with ArcView v3.3 software (ESRI, Redlands, California) and Animal Movement extension v1.1 (Hooge and Eichenlaub 1997), to construct Minimum Convex Polygon (MCP) (Mohr and Stumpf 1966) and Fixed Kernel (FK) (Worton 1989) home ranges. Activity time periods, frequency of crossing water channels of various widths, and distances moved within a day were also computed.

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Figure 5.1
A camera trapped picture of a radio-collared tiger in the Sundarbans. Note: the bait attractant and the use of nylon netting to orient the tiger for obtaining pictures of both flanks.

Table 5.1
Home Ranges of Radio-collared Tigers (n = 4)

Individuals	Total Fixes	95% Fixed kernel (km²)	100% MCP (km²)
Sonaga Female	454	474.9	335.8
Netidhopani Male	680	116	207.1
Dhubni Male	122	75.3	92.9
Khatuajhuri Male	929	156.3	120.5
Average		205.6	189.1
SE		45.6	54.6

Figure 5.2
Home ranges of collared tigers (n=4) in the Sundarbans. Note: the Khatajuri tiger moved into Bangladesh and it's home range covered the entire Island of Talpati. It was possible to track this tiger due to the satellite link of its collar.

Due to the difficulty of walking in the mangrove forests and locating game trails for setting camera traps, we could not deploy camera traps in a systemetic grid based approach used across India. Instead, we set up camera traps at strategic locations, near fresh and brakish water ponds, using attractrants to lure tigers to our camera stations. We also used fishing nets to orient the approaching tigers to get proper flank photographs for uniquely identifying each tiger from its stripe patterns. We estimated the tiger population in a mark re-capture framework with closed population estimators in an area of about 200 km². This setup allowed us to estimate population size reliably. But due to the small number of camera stations (12) and uneven geographical spread of camera traps, it was not possible to obtain a reliable estimate of mean maximum distance (MMDM) moved by recaptured tigers nor use the spatially explict models (Efford *et al.* 2009) effectively. Models estimating effective trapping area attempt to estimate home range radius either by estimating MMDM or through centers of activity, in the case of the Sundarbans we had direct estimates of home ranges based on telemetry data. We therefore used home range radius from 95% fixed kernel area estimates of tiger home ranges as a buffer to the camera trap polygon for estimating effectively trapped area. Our telemetry data suggests that though tigers do cross wide channels, crossing of channels >1 km in width was rare. We therefore used a habitat mask wherein channels >1km in width were considered barriers to movement over the short term duration of the camera trapping exercise.

We photo-captured ten adult tigers and two cubs. The best model selected by CAPTURE was model Mh (incorporating individual heterogeneity) and the population estimate was 11 (se 3) tigers. The home range radius of four satellite-radio tagged tigers was 6 km and was used to calculate the buffer width around the camera trapped polygon, giving an area of 438 km². After applying a habitat mask bounded by channels >1 km the effectively camera trapped area was 257 km². Tiger density was computed to be 4.3 (se 0.3) tiger per 100 km².

Figure 5.3

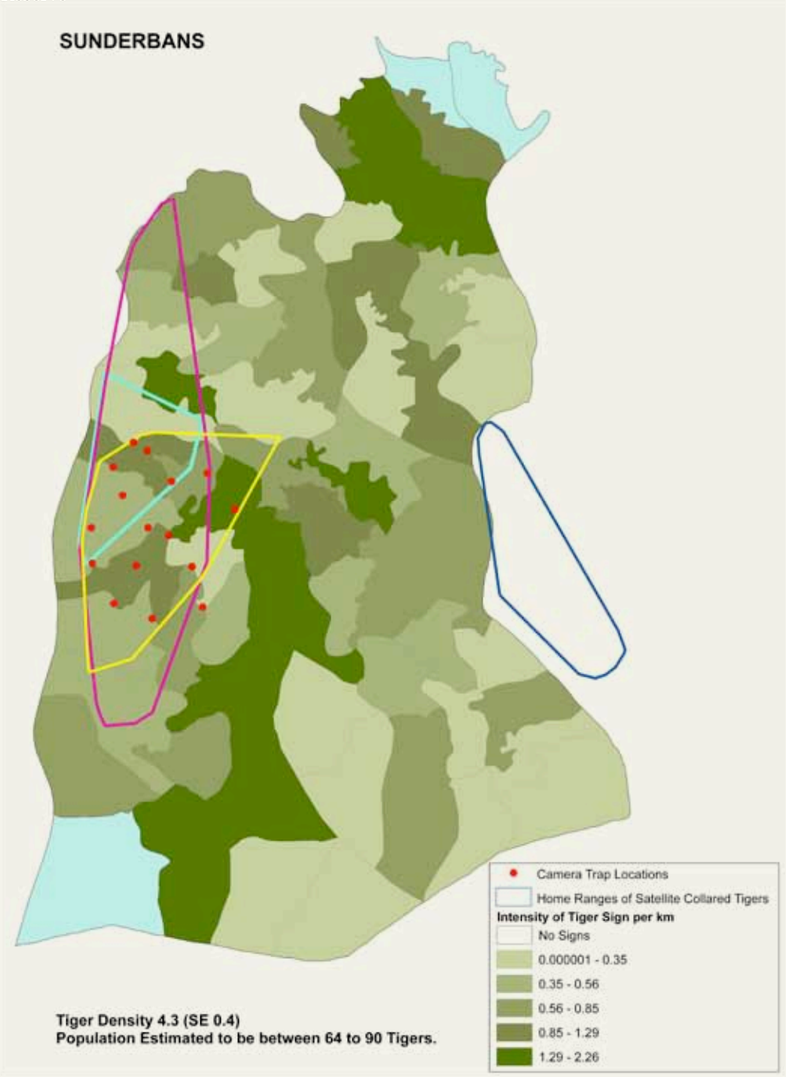
Map showing the camera trapped study area with (A) Camera Trapped area buffered by the Home Range Radius; (B) Habitat mask defined by channels > 1km width; (C) Effectively camera trapped area (257 km²)

Since tiger occupied area of the Sundarbans Tiger Reserve was 1645 km² (Fig 4) and the tiger signs were found throughout this area with a similar variation across the Tiger Reserve as found within the camera trapped area, it would be possible to extrapolate this tiger density across the reserve without much loss of accuracy. Ideally, 2-4 additional camera trap replicate areas need to be sampled and additional data from radio collared tigers are needed to provide more accurate and precise estimates of tiger density. But till these are obtained, this first quantitative assessment estimates the number of tigers to be around 70 (64 to 90) tigers for the Sundarbans Tiger Reserve (in 1645 km²).

The Principal Chief Conservator of Forests has communicated to NTCA through their letter No. DO No. 12119/CS/2M-22/09(Pt.II) Dated 30-03-2011, that they were not satisfied with the methodology used for population estimation of the Sunderbans tigers. Further refinement in methodology, involvement of other institutions is needed and mention must be made that the 2010 estimate is subject to further study and by better methodology.

Figure 5.3

Tiger occupancy, home ranges of radio-collared tigers and camera trapped area in the Sundarbans Tiger Reserve



PHASE III RESULTS

Authors: Qamar Qureshi, Yadvendradev Jhala,
Joseph Vattakaven, K.Sankar, Anil Singh, M. Firoz Ahmed.

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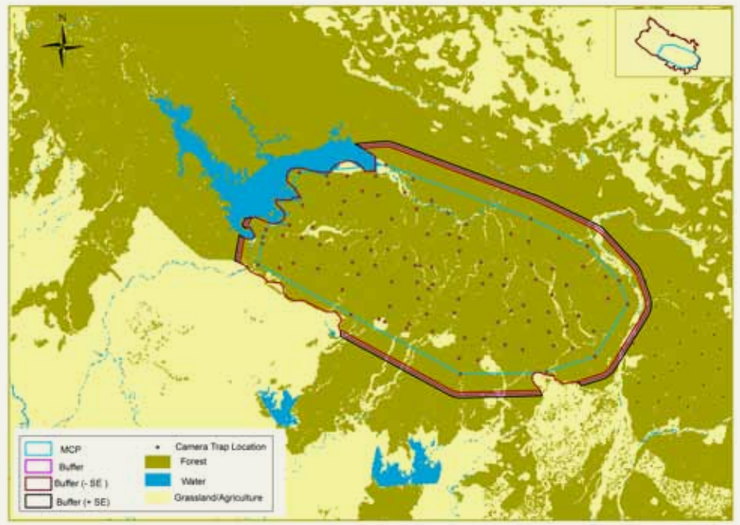
Teams of trained wildlife biologists collected information on the actual population and density of tigers and their prey from 29 different sites from across the tiger bearing forests of India by using statistically rigorous methods like camera trap based mark-recapture. The results of this exercise (Phase III) were then used to calibrate against the Phase I and Phase II data sets, which consist of indices and covariates of tiger abundance.

Tiger abundance was estimated from areas ranging between 74 (Orang) to 894 km² (Achanakmar) based on available tiger occupied habitats at various sites (Figures 6.1 to 6.31). The effort exerted ranged between 713 (Orang) to 12,400 (Pench) trap nights. The total area camera trapped was 11,192 km² across 29 sites with a total effort of 81,409 trap nights. Tiger (>1.5 years of age) captures ranged between 1 (Achanakmar) to 101 (Corbett) individuals. The total number of tigers photo-captured was 635 (table 6.1, Appendix 3). The minimum density (ETA estimated by half MMDM) of 0.11 tigers per 100 km2 was estimated for Achanakmar while the maximum was 17.8 (se 1.4) tigers per 100 km² in Corbett. Tiger densities of more than 10 tigers per 100 km² were recorded from seven sites (table 6.1). For comparison with earlier studies the density estimates were obtained from effective trapping area estimated by half mean maximum distance moved by recaptured tigers. Density was also estimated by spatially explicit likelihood models (table 6.1).

Figure 6.1

Corbett Tiger Reserve



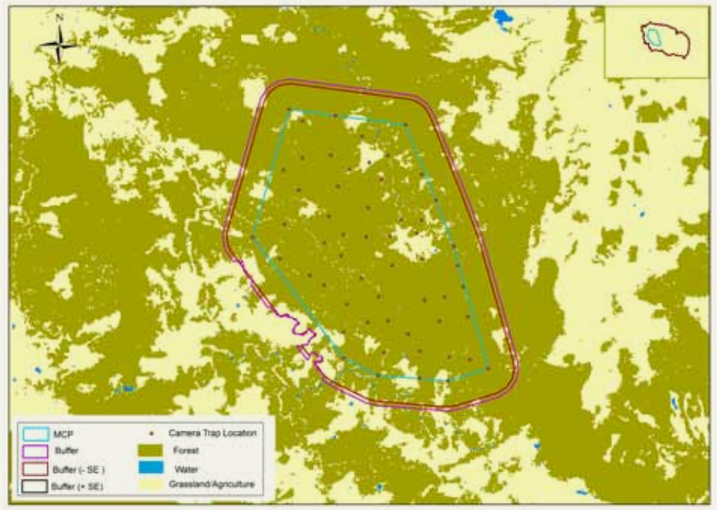
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	611	(594– 629)*
CAMERA POINTS	103	-
NO. OF TRAP NIGHTS	9064	-
UNIQUE INDIVIDUAL (Mt+1))	101	-
POPULATION ESTIMATE ($\widehat{N}$)	109	5.4
$\overline{D}$ DENSITY ESTIMATE	17.83	1.40
$\overline{D}$ MLSECR	16.23	1.63

• Standard Error Range *
• ($\widehat{N}$) The best fit model is Mh
• $\overline{D}$ is based on ETA by ½ MMDM
• $\overline{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Shikha Bisht, Debmalya Roy Chowdhury, Sudip Banerjee, Neha Awasthi, Rubi Kumari Sharma, Anant Pande, Devlin Leishangthem, Pushkal Bagchie, Abhinash Parida, Preeti Virkar, Subhasis Mahato, Ayan Sadhu, Priyanka Runwal.

Figure 6.2

Kanha-Mukki(Kanha Tiger Reserve) 2010



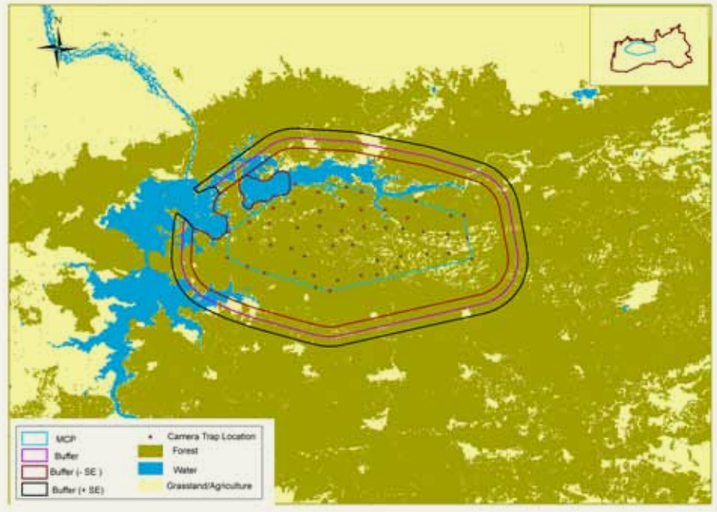
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	410	(387 – 432)*
CAMERA POINTS	56	-
NO. OF TRAP NIGHTS	1736	-
UNIQUE INDIVIDUAL (Mt+1))	27	-
POPULATION ESTIMATE ($\bar{N}$)	28	0.9
$\bar{D}$ DENSITY ESTIMATE	6.83	0.60
$\bar{D}$ MLSECR	5.61	1.11

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Ujjwal Kumar Sinha, Anup Kumar Pradhan, Geetanjali Kanwar, Zaara Kidwai, Arka Pratap Ghosh, Khreiketouzo K.

Figure 6.3

Satpura Tiger Reserve



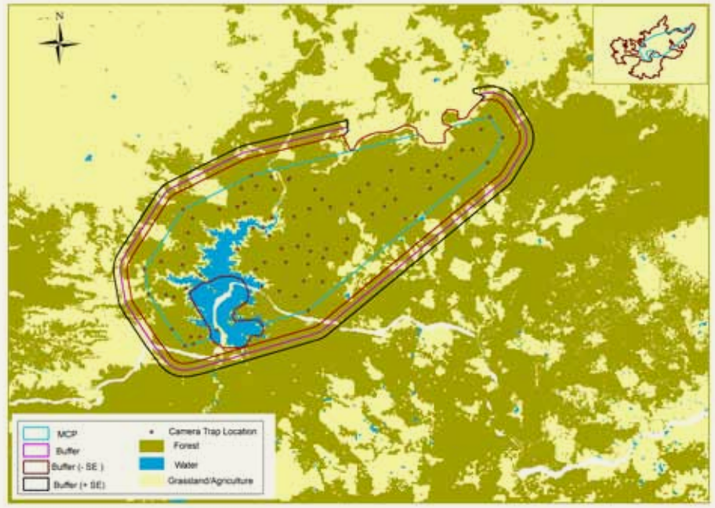
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	488	(412 – 571)*
CAMERA POINTS	48	-
NO. OF TRAP NIGHTS	2256	-
UNIQUE INDIVIDUAL (Mt+1))	11	-
POPULATION ESTIMATE ($\bar{N}$)	13	3.74
$\bar{D}$ DENSITY ESTIMATE	2.66	1.22
$\bar{D}$ MLSECR	1.57	0.5

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Anup Kumar Pradhan, Gaurang Patwardhan, Amol Kumbhar, Monika Kumari, Daya Thakur, Anant Pande, Raju Lal Gurjar and Dipankar Lahkar.

Figure 6.4

Pench Tiger Reserve (MP)



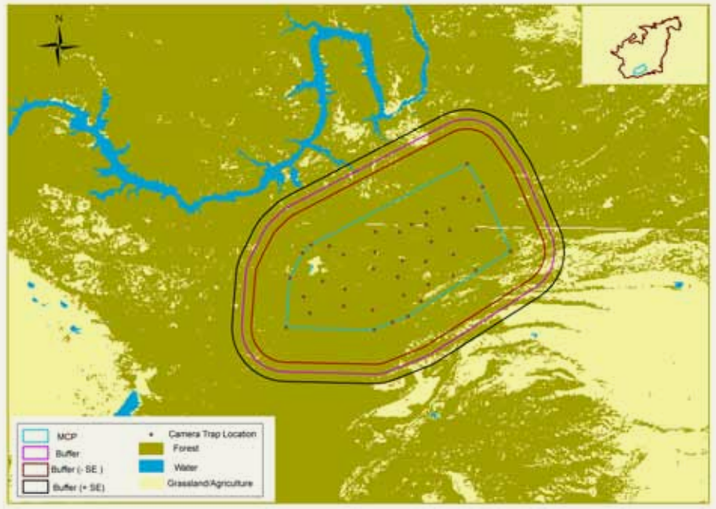
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	635	(569 – 704)*
CAMERA POINTS	80	-
NO. OF TRAP NIGHTS	12400	-
UNIQUE INDIVIDUAL (Mt+1))	23	-
POPULATION ESTIMATE ($\overline{N}$)	23	0.77
$\overline{D}$ DENSITY ESTIMATE	3.62	0.51
$\overline{D}$ MLSECR	3.86	0.92

• Standard Error Range *
• ($\overline{N}$) The best fit model is Mh
• $\overline{D}$ is based on ETA by ½ MMDM
• $\overline{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Anirudha Majumdar, Gaurang Patwardhan, Abhinash Parida, Shrinivas Yellapu, Monika Kumari, Preeti Virkar, Suneet Das.

Figure 6.5

Nagarjunsagar-Srisailam Tiger Reserve



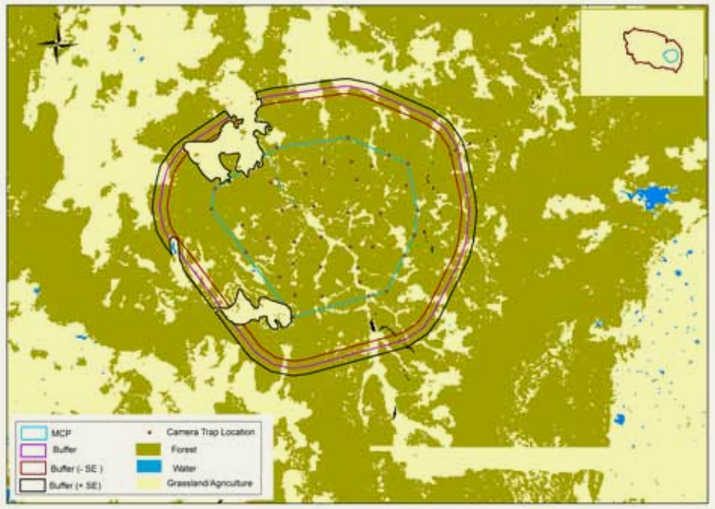
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	401	(341 – 466)*
CAMERA POINTS	40	-
NO. OF TRAP NIGHTS	2400	-
UNIQUE INDIVIDUAL (Mt+1))	6	-
POPULATION ESTIMATE ($\overline{N}$)	6	0.12
$\overline{D}$ DENSITY ESTIMATE	1.50	0.27
$\overline{D}$ MLSECR	0.85	0.38

• Standard Error Range *
• ($\overline{N}$) The best fit model is Mh
• $\overline{D}$ is based on ETA by ½ MMDM
• $\overline{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Sudip Banerjee, Devlin Leishangthem, Ashok Kumar, Bubesh Gupta, Rubi Kumari Sharma, Farhat Masood.

Figure 6.6

Supkhar-(Kanha Tiger Reserve)



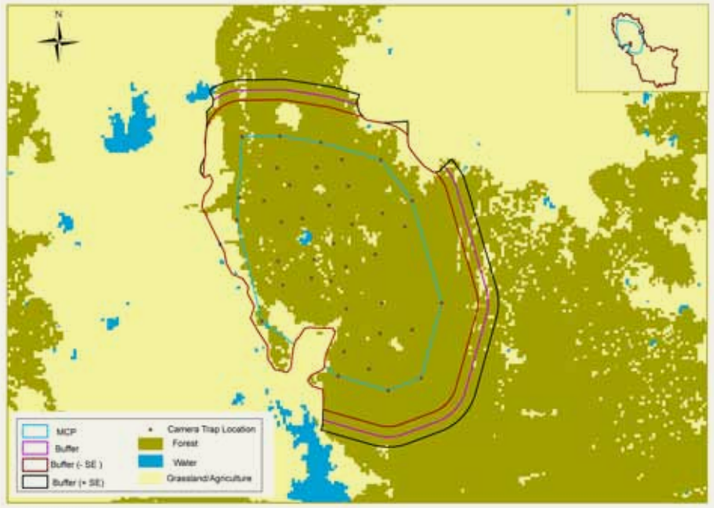
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	363	(327 – 402)*
CAMERA POINTS	38	-
NO. OF TRAP NIGHTS	1368	-
UNIQUE INDIVIDUAL (Mt+1))	10	-
POPULATION ESTIMATE ($\bar{N}$)	10	1.70
$\bar{D}$ DENSITY ESTIMATE	2.75	0.76
$\bar{D}$ MLSECR	2.08	0.68

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Ujjwal Kumar Sinha, Madhura Davate, Neha Awasthi, Pradeep Kumar Sahu.

Figure 6.7

Tadoba-Andheri Tiger Reserve



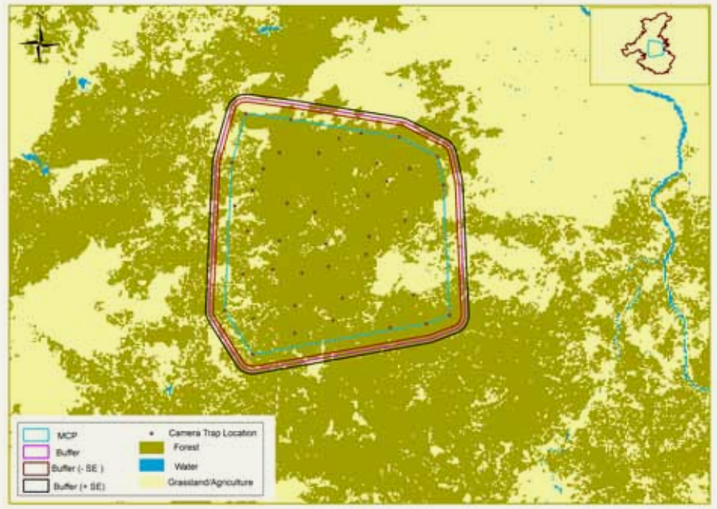
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	321	(294 – 347)*
CAMERA POINTS	37	-
NO. OF TRAP NIGHTS	5624	-
UNIQUE INDIVIDUAL (Mt+1))	15	-
POPULATION ESTIMATE ($\bar{N}$)	17	2.15
$\bar{D}$ DENSITY ESTIMATE	5.29	1.12
$\bar{D}$ MLSECR	4.45	1.14

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Bidyut Barman, Bubhesh Gupta, Avaneesh Rai, Tamma Ajay Kumar, Madhura Davate, Daya Thakur, Pradeep Sahu, Amol Kumbhar, Anil Dashere, Lalthanpuia.

Figure 6.8

Bandhavgarh Tiger Reserve



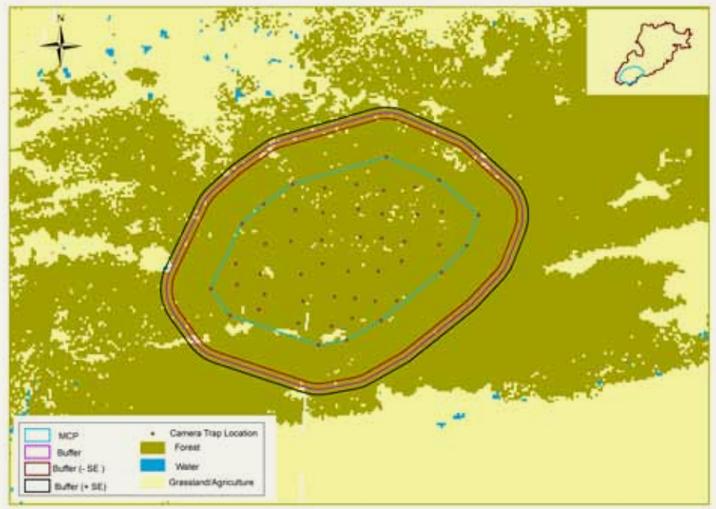
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	228	(215 - 241)*
CAMERA POINTS	40	-
NO. OF TRAP NIGHTS	3000	-
UNIQUE INDIVIDUAL (Mt+1))	30	-
POPULATION ESTIMATE ($\overline{N}$)	37	5.7
$\overline{D}$ DENSITY ESTIMATE	16.25	3.45
$\overline{D}$ MLSECR	13.97	2.7

• Standard Error Range *
• ($\overline{N}$) The best fit model is Mh
• $\overline{D}$ is based on ETA by ½ MMDM
• $\overline{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Subhasis Mahato, Yogesh J., Sanskruti Marathe, Richa Kesarwani, Navneethan N., Deepak Sawant.

Figure 6.9

Melghat Tiger Reserve



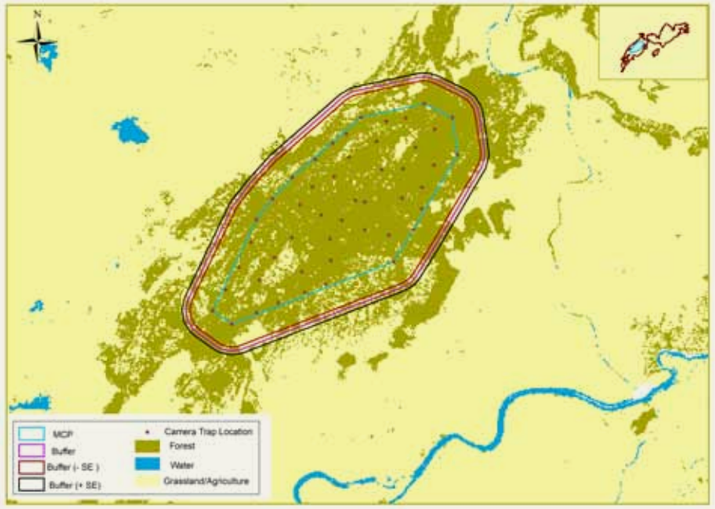
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	427	(394 – 461)*
CAMERA POINTS	48	-
NO. OF TRAP NIGHTS	2544	-
UNIQUE INDIVIDUAL (Mt+1))	12	-
POPULATION ESTIMATE ($\overline{N}$)	13	2.16
$\overline{D}$ DENSITY ESTIMATE	3.04	0.75
$\overline{D}$ MLSECR	2.29	0.68

• Standard Error Range *
• ($\overline{N}$) The best fit model is Mh
• $\overline{D}$ is based on ETA by ½ MMDM
• $\overline{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Narsimmharajan, Abhinash Parida, Bidyut Barman, Subhasish Mahato, Lalthanpuia, Anirudha Vasava.

Figure 6.10

Ranthambore Tiger Reserve



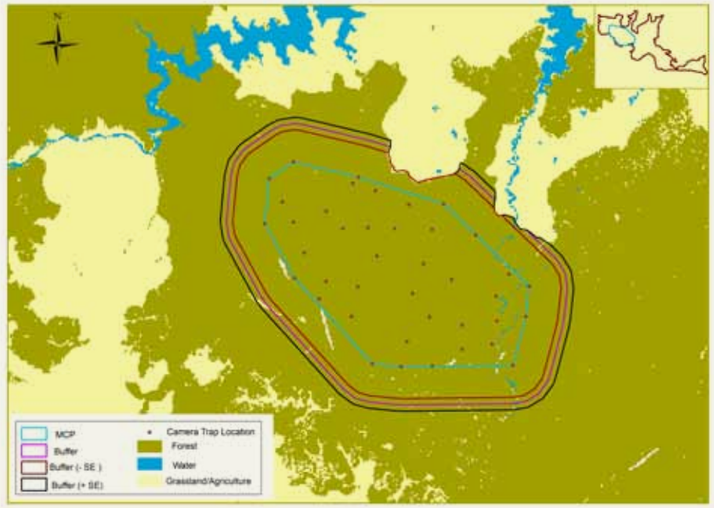
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	277	(257 – 297)*
CAMERA POINTS	48	-
NO. OF TRAP NIGHTS	1344	-
UNIQUE INDIVIDUAL (Mt+1))	25	-
POPULATION ESTIMATE ($\bar{N}$)	27	1.80
$\bar{D}$ DENSITY ESTIMATE	9.75	1.35
$\bar{D}$ MLSECR	8.09	1.66

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Peter Prem Chakravarthi J ., Farhat Masood, Dipankar Lahkar.

Figure 6.11

Bandipur Tiger Reserve



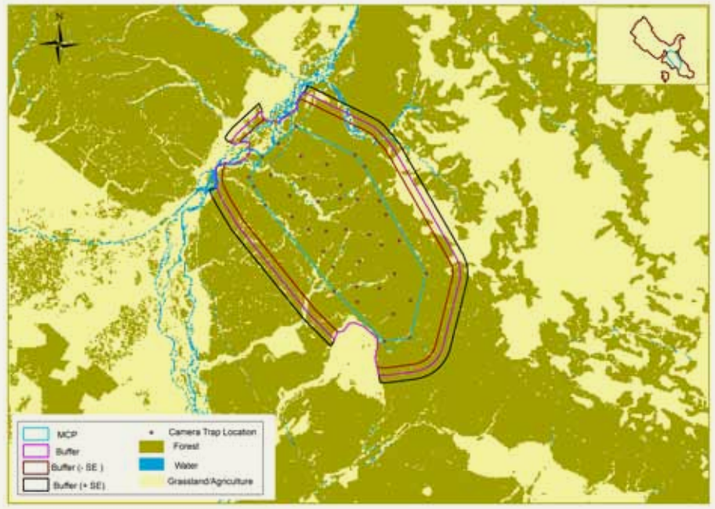
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	278	(255 – 300)*
CAMERA POINTS	40	-
NO. OF TRAP NIGHTS	2400	-
UNIQUE INDIVIDUAL (Mt+1))	33	-
POPULATION ESTIMATE ($\bar{N}$)	39	2.61
$\bar{D}$ DENSITY ESTIMATE	14.04	2.08
$\bar{D}$ MLSECR	8.24	1.47

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: N. Sridharan, Francis P., Gokulkannan N., Charles Leo Prabhau, Yogesh J.

Figure 6.12

Rajaji National Park



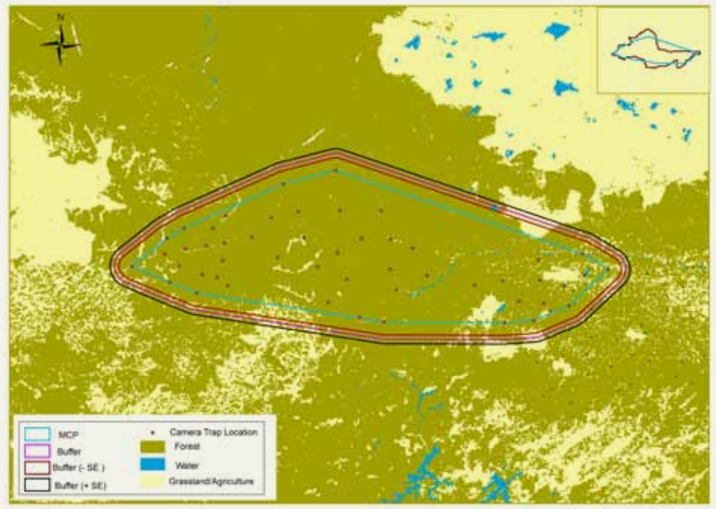
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	229	(201 – 256)*
CAMERA POINTS	40	-
NO. OF TRAP NIGHTS	1520	-
UNIQUE INDIVIDUAL (Mt+1))	6	-
POPULATION ESTIMATE ($\bar{N}$)	7	1.51
$\bar{D}$ DENSITY ESTIMATE	3.06	1.04
$\bar{D}$ MLSECR	2.25	1.1

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Suneet Das, Sanskruti Marathe, Neelanjan Kundu, Richa Kesarwani, Anil Dashere.

Figure 6.13

Mudumalai Tiger Reserve



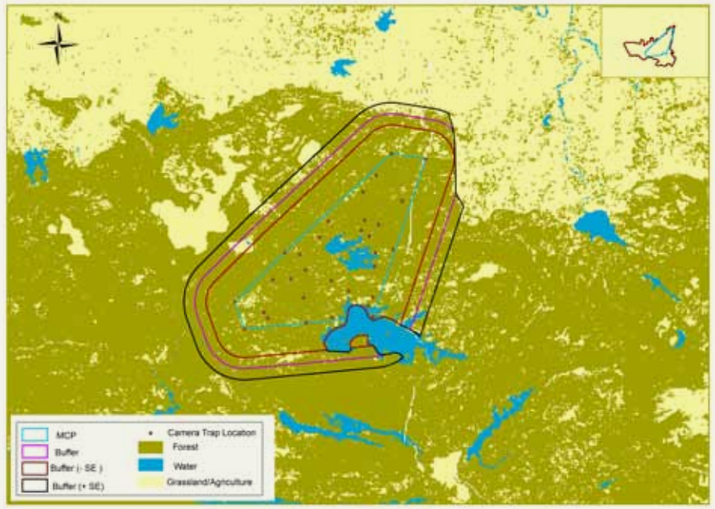
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	461	(425 – 498)*
CAMERA POINTS	50	-
NO. OF TRAP NIGHTS	2000	-
UNIQUE INDIVIDUAL (Mt+1))	32	-
POPULATION ESTIMATE ($\bar{N}$)	51	9.94
$\bar{D}$ DENSITY ESTIMATE	11.06	3.04
$\bar{D}$ MLSECR	9.42	2.08

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: T.Ramesh, Ridhika Kale, Ashok Kumar, Kamalakannan, Anirudh Vasava, Gokulakannan, Naveen M., Francis P., Narsimmharajan., N.Sridharan

Figure 6.14

Parambikulam Tiger Reserve (2009)



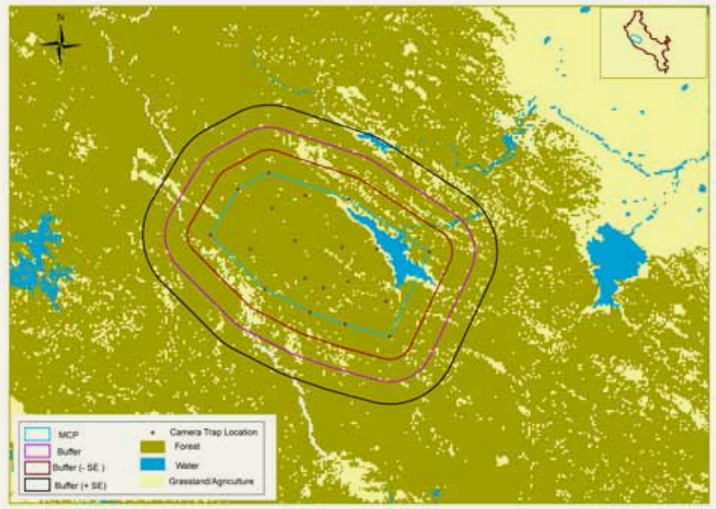
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	302	(245 – 362)*
CAMERA POINTS	31	-
NO. OF TRAP NIGHTS	1364	-
UNIQUE INDIVIDUAL (Mt+1))	7	-
POPULATION ESTIMATE ($\overline{N}$)	8	1.49
$\overline{D}$ DENSITY ESTIMATE	2.65	1.04
$\overline{D}$ MLSECR	1.49	0.62

• Standard Error Range *
• ($\overline{N}$) The best fit model is Mh
• $\overline{D}$ is based on ETA by ½ MMDM
• $\overline{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Deepanjan Naha, Pushkal Bagchie, Anirudh Vasava, Francis P., N. Gokulakannan, Naveen M.

Figure 6.15

Kalakkad Mundanthurai Tiger Reserve



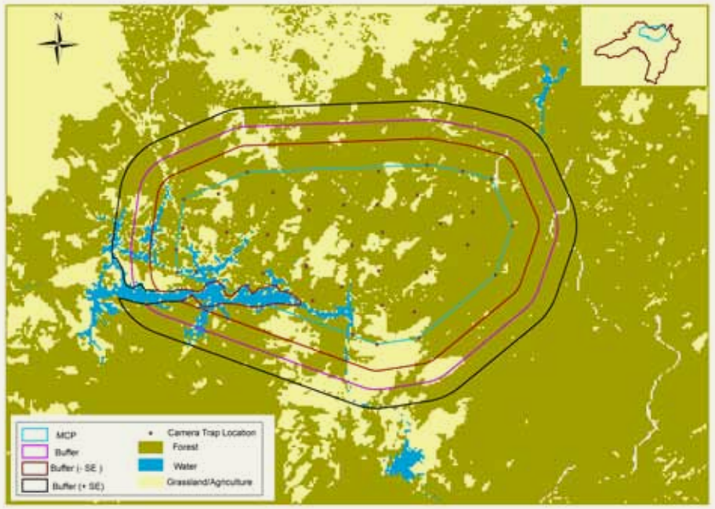
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	130	(87-180)*
CAMERA POINTS	19	-
NO. OF TRAP NIGHTS	1520	-
UNIQUE INDIVIDUAL (Mt+1))	6	-
POPULATION ESTIMATE ($\overline{N}$)	6	3.02
$\overline{D}$ DENSITY ESTIMATE	4.62	1.39
$\overline{D}$ MLSECR	2.62	0.84

• Standard Error Range *
• ($\overline{N}$) The best fit model is Mh
• $\overline{D}$ is based on ETA by ½ MMDM
• $\overline{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: N. Gokulakannan, Francis P., K. Narsimmharajan., N.Sreedharan

Figure 6.16

Periyar Tiger Reserve



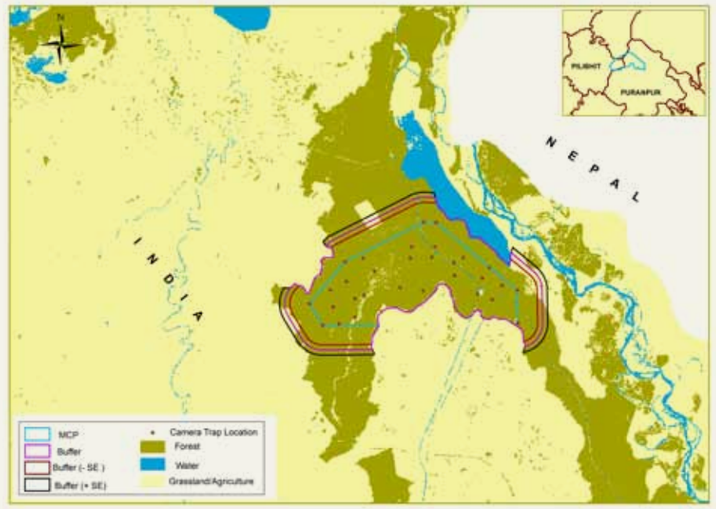
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	222	(171 – 277)*
CAMERA POINTS	37	-
NO. OF TRAP NIGHTS	2331	-
UNIQUE INDIVIDUAL (Mt+1))	10	-
POPULATION ESTIMATE ($\bar{N}$)	12	3.23
$\bar{D}$ DENSITY ESTIMATE	5.41	2.86
$\bar{D}$ MLSECR	2.91	0.95

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Francis P, N. Gokulakannan, Charles Leo Prabhau, Yogesh J., Amol Kumbhar.

Figure 6.17

Pilibhit Forest Division



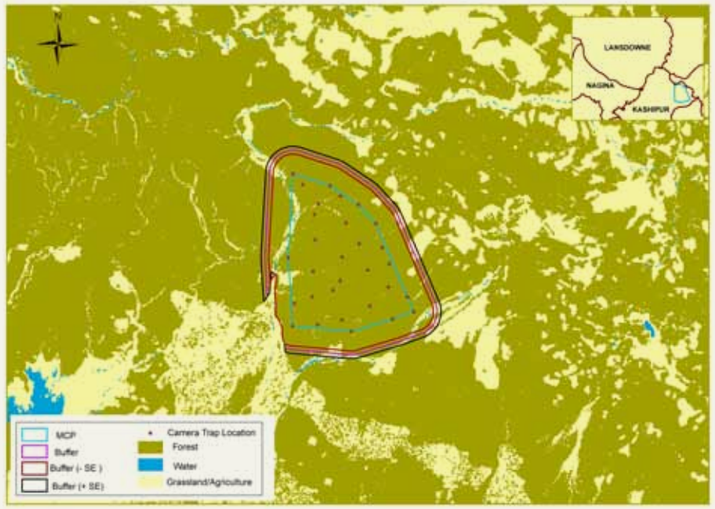
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	258	(236 – 280)*
CAMERA POINTS	30	-
NO. OF TRAP NIGHTS	1200	-
UNIQUE INDIVIDUAL (Mt+1))	11	-
POPULATION ESTIMATE ($\bar{N}$)	12	0.17
$\bar{D}$ DENSITY ESTIMATE	4.66	0.46
$\bar{D}$ MLSECR	3.78	1.17

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Deepankar Lahkar, Manas Manjrekar, Awanish Rai, Wasi A.
WWF-INDIA: Meraj Anwar.

Figure 6.18

Ramnagar Forest Division



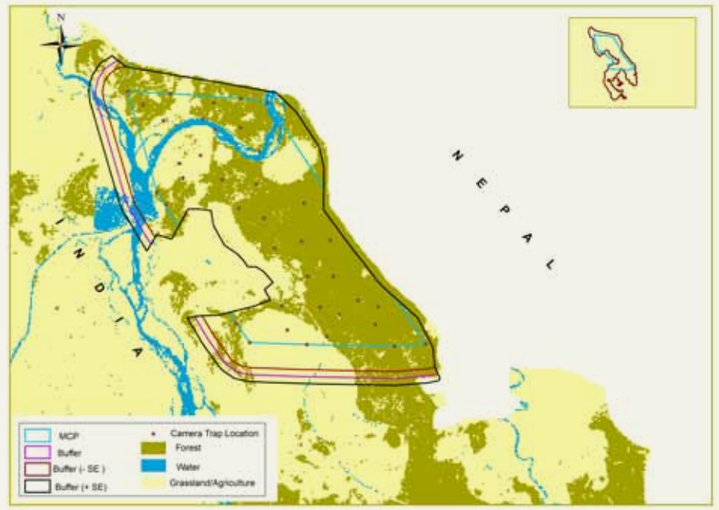
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	177	(163 – 192)*
CAMERA POINTS	30	-
NO. OF TRAP NIGHTS	1470	-
UNIQUE INDIVIDUAL (Mt+1))	26	-
POPULATION ESTIMATE ($\bar{N}$)	27	1.50
$\bar{D}$ DENSITY ESTIMATE	15.18	2.10
$\bar{D}$ MLSECR	13.8	2.74

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WWF-INDIA: Meraj Anwar.

Figure 6.19

Katarniaghat (Dudhwa Tiger Reserve)



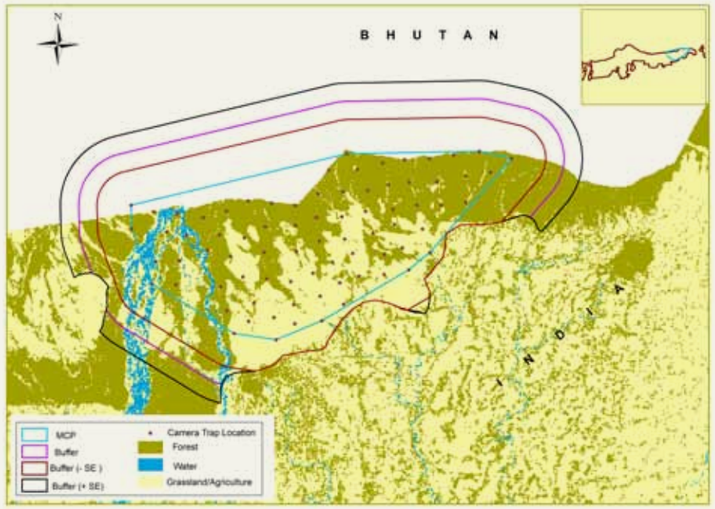
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	306	(288-326)*
CAMERA POINTS	40	-
NO. OF TRAP NIGHTS	1800	-
UNIQUE INDIVIDUAL (Mt+1))	17	-
POPULATION ESTIMATE ($\bar{N}$)	20	2.61
$\bar{D}$ DENSITY ESTIMATE	6.53	1.26
$\bar{D}$ MLSECR	4.82	1.19

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WWF-INDIA: Meraj Anwar, Dabeer Hasan.

Figure 6.20

Manas Tiger Reserve



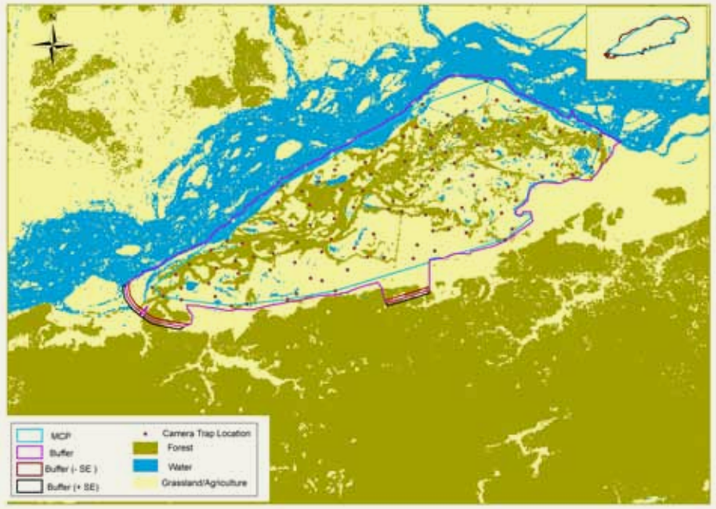
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	615	(510– 725)*
CAMERA POINTS	77	-
NO. OF TRAP NIGHTS	4389	-
UNIQUE INDIVIDUAL (Mt+1))	9	-
POPULATION ESTIMATE ($\bar{N}$)	11	4.91
$\bar{D}$ DENSITY ESTIMATE	1.79	1.14
$\bar{D}$ MLSECR	0.80	0.27

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WWF-INDIA: Jimmy Borah, Tridip Sharma.
ATREE: Dhritiman Das, Nilmani Rabha, Niraj Kakati.
AARANYAK: Ajit Basumatri , M Firoz Ahmed .

Figure 6.21

Kaziranga Tiger Reserve



VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	433	(430 – 436)*
CAMERA POINTS	107	-
NO. OF TRAP NIGHTS	4815	-
UNIQUE INDIVIDUAL (Mt+1))	69	-
POPULATION ESTIMATE ($\bar{N}$)	69	0.48
$\bar{D}$ DENSITY ESTIMATE	15.92	0.21
$\bar{D}$ MLSECR	12.63	1.51

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WII: Debmalya Roy Chowdhury, Anant Pande, Gitanjali Katlam, Monideepa Mitra and Priya Singh.

ARANYAK: M Firoz Ahmed, Kamal Azad, Ajit Basumatary .

WWF-INDIA: Jimmy Borah, Lalthanpuia .

Figure 6.22

Orang National Park

VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	74	(61 – 87)*
CAMERA POINTS	31	-
NO. OF TRAP NIGHTS	713	-
UNIQUE INDIVIDUAL (Mt+1))	13	-
POPULATION ESTIMATE ($\bar{N}$)	13	0.24
$\bar{D}$ DENSITY ESTIMATE	17.68	3.56
$\bar{D}$ MLSECR	17.08	4.83

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: ARANYAK: Kamal Azad, M Firoz Ahmed.

Figure 6.23

Pakke and Nameri Tiger Reserve

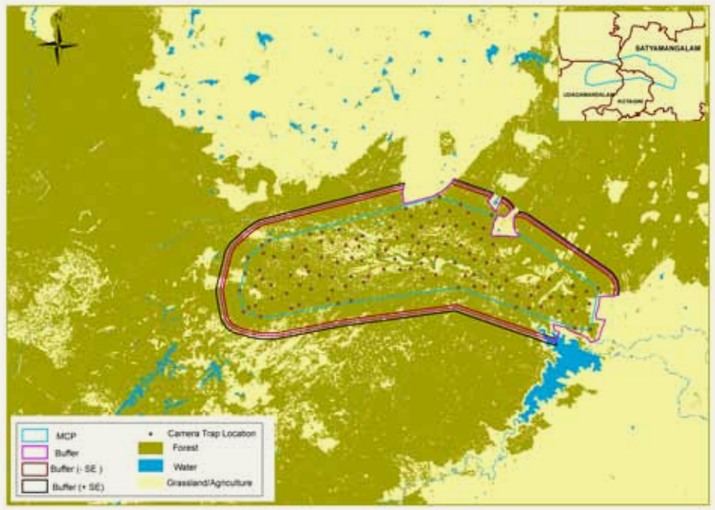
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	182	(117 – 255)*
CAMERA POINTS	25	-
NO. OF TRAP NIGHTS	1425	-
UNIQUE INDIVIDUAL (Mt+1))	10	-
POPULATION ESTIMATE ($\bar{N}$)	13	3.56
$\bar{D}$ DENSITY ESTIMATE	7.13	5.26
$\bar{D}$ MLSECR	3.28	1.13

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WWF-INDIA: Jimmy Borah, Tridip Sharma, Sanjay Gogoi.

Figure 6.24

Moyar-Satyamanaglam Reserve Forest



VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	758	(718-800)*
CAMERA POINTS	122	-
NO. OF TRAP NIGHTS	4270	-
UNIQUE INDIVIDUAL (Mt+1))	52	-
POPULATION ESTIMATE ($\bar{N}$)	58	3.86
$\bar{D}$ DENSITY ESTIMATE	7.65	0.93
$\bar{D}$ MLSECR	6.14	0.87

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WWF-INDIA: Vijayakumar K, Krishnakumar N, Ravikumar N, Sudhagar S, Peter Prem Chakravarthi J, Mohanraj N.

Figure 6.25

Eravikulam National Park

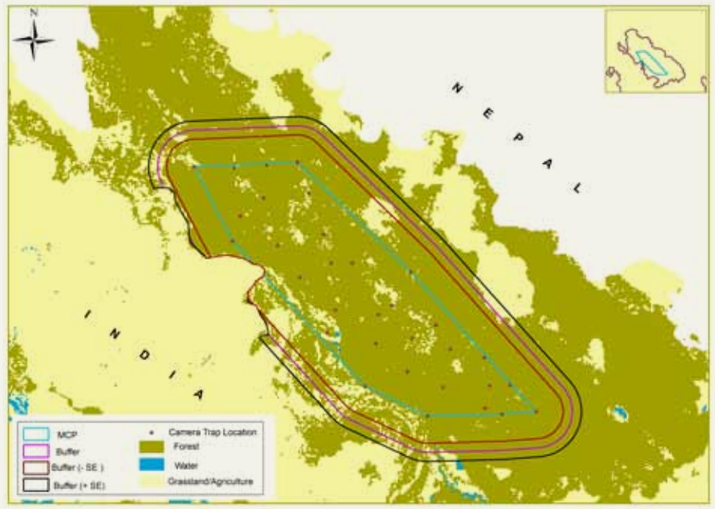
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	499	(493 – 506)*
CAMERA POINTS	32	-
NO. OF TRAP NIGHTS	960	-
UNIQUE INDIVIDUAL (Mt+1))	3	-
POPULATION ESTIMATE ($\bar{N}$)	3	0.04
$\bar{D}$ DENSITY ESTIMATE	0.60	0.02
$\bar{D}$ MLSECR	0.32	0.2

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WWF-INDIA: Krishnakumar N, Sudhagar S, Peter Prem Chakravarthi J, Mohanraj N.

Figure 6.26

Dudhwa National Park (Dudhwa TR)



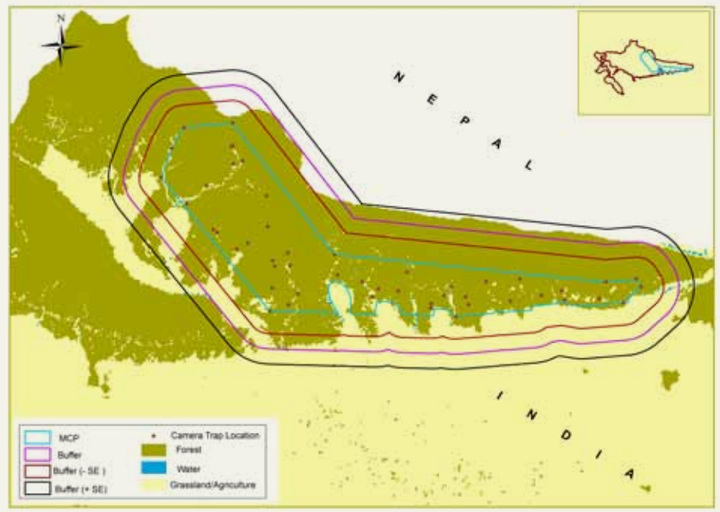
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	265	(231 – 299)*
CAMERA POINTS	32	-
NO. OF TRAP NIGHTS	1088	-
UNIQUE INDIVIDUAL (Mt+1))	15	-
POPULATION ESTIMATE ($\bar{N}$)	21	5.47
$\bar{D}$ DENSITY ESTIMATE	7.91	3.13
$\bar{D}$ MLSECR	4.79	1.28

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WTI: Dr. Anil Kumar Singh, Millind Pariwakam, Asim Rahul Singh, Siraz Uddin Majumdar, Shashank Kasare, Alkesh Thakre, Nikhil Simon.

Figure 6.27

Valmiki Tiger Reserve



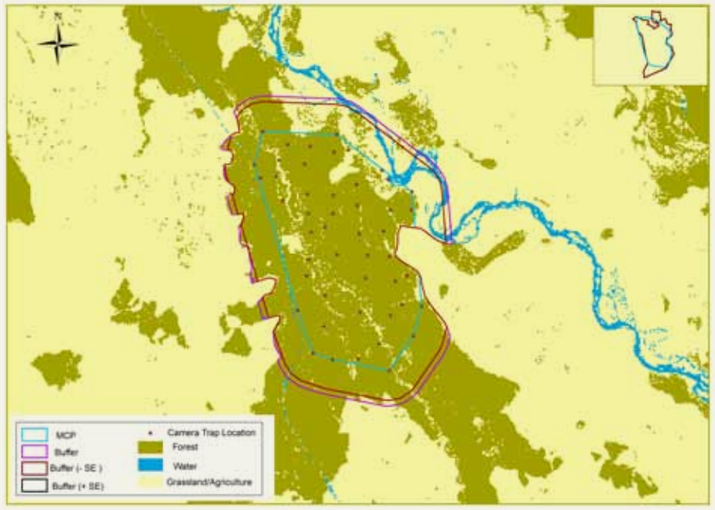
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	444	(568 – 329)*
CAMERA POINTS	49	-
NO. OF TRAP NIGHTS	1470	-
UNIQUE INDIVIDUAL (Mt+1))	8	-
POPULATION ESTIMATE ($\bar{N}$)	8	2.06
$\bar{D}$ DENSITY ESTIMATE	1.80	1.00
$\bar{D}$ MLSECR	1.12	0.52

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WTI: N. Karthik Murty, Ramendra Kumar, Dr. Samir Sinha.

Figure 6.28

Kishanpur (Dudhwa Tiger Reserve)



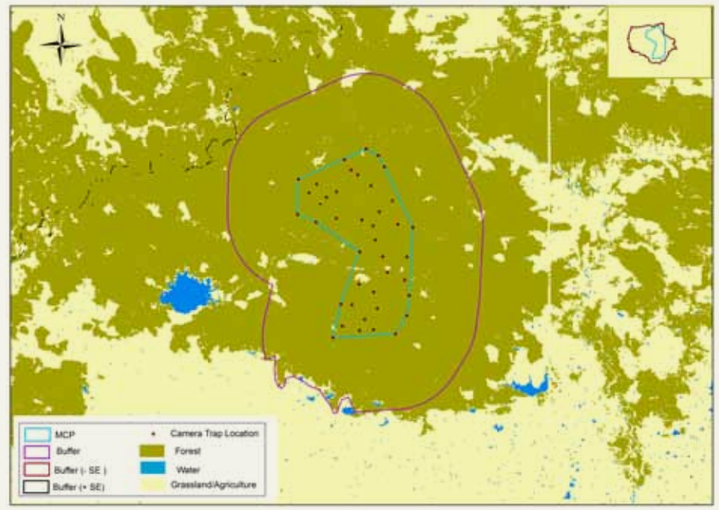
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	306	(284 – 384)*
CAMERA POINTS	48	-
NO. OF TRAP NIGHTS	1920	-
UNIQUE INDIVIDUAL (Mt+1))	18	-
POPULATION ESTIMATE ($\bar{N}$)	19	7.31
$\bar{D}$ DENSITY ESTIMATE	6.22	3.10
$\bar{D}$ MLSECR	4.64	1.11

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WTI: Dr. Anil Kumar Singh, Devna Arora, Dibyendu Kumar Mandal, Krishnendu Basak, Millind Pariwakam, Ramendra Kumar, Sanjay Babu, Shashank Kasare.

Figure 6.29

Achanakmar Tiger Reserve



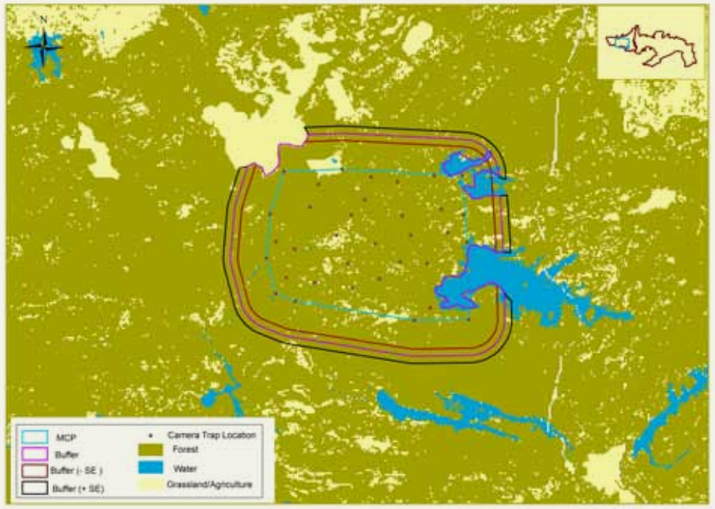
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	894	-
CAMERA POINTS	40	-
NO. OF TRAP NIGHTS	1760	-
UNIQUE INDIVIDUAL (Mt+1))	1	-
POPULATION ESTIMATE ($\bar{N}$)	1	-
$\bar{D}$ DENSITY ESTIMATE	0.1	-
$\bar{D}$ MLSECR	-	-

• Standard Error Range *
• ($\bar{N}$) The best fit model is Mh
• $\bar{D}$ is based on ETA by ½ MMDM
• $\bar{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WTI: Debobroto Sircar, Mahi Puri, Dibyendu Kumar Mandal, Krishnendu Basak, Millind Pariwakam, Rathna Kumar, Dr. R. P. Mishra and Moiz Ahmed, Prabal Sarkar.

Figure 6.30

Parambikulam Tiger Reserve (2011)



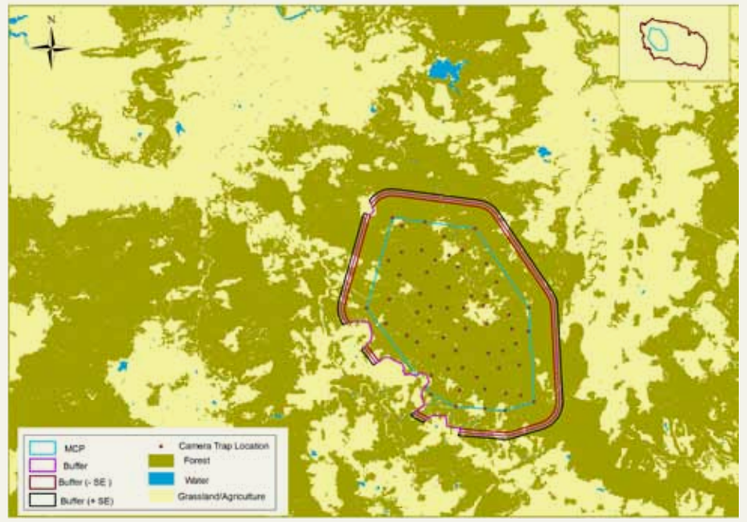
VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	197	(177-218)*
CAMERA POINTS	34	-
NO. OF TRAP NIGHTS	1258	-
UNIQUE INDIVIDUAL (Mt+1))	12	-
POPULATION ESTIMATE ($\overline{N}$)	13	1.49
$\overline{D}$ DENSITY ESTIMATE	6.61	1.51
$\overline{D}$ MLSECR	4.03	1.21

• Standard Error Range *
• ($\overline{N}$) The best fit model is Mh
• $\overline{D}$ is based on ETA by ½ MMDM
• $\overline{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team: WWF-India: Vijayakumar K, Krishna Kumar N, Sudhagar S, Mohanraj N.

Figure 6.31

Kanha Tiger Reserve (2011)



VARIABLES	ESTIMATION	STANDARD ERROR
EFFECTIVE TRAPPING AREA (ETA) km2	433	(410-457)*
CAMERA POINTS	58	-
NO. OF TRAP NIGHTS	2900	-
UNIQUE INDIVIDUAL (Mt+1))	34	-
POPULATION ESTIMATE ($\overline{N}$)	38	4.67
$\overline{D}$ DENSITY ESTIMATE	8.7	1.1
$\overline{D}$ MLSECR	5.9	1.04

• Standard Error Range *
• ($\overline{N}$) The best fit model is Mh
• $\overline{D}$ is based on ETA by ½ MMDM
• $\overline{D}$ MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) based on Half Normal model.

Research Team WII: Ujjwal Kumar Sinha, Madhura Davate, Neha Awasthi, Rahul Rana, AshishT.Prasad, Partha Sarathi Mishra, Malemleima Ningombi.

Table 6.1
Tiger abundance and density estimates using traditional ½ MMDM and Spatially explicit likelihood based estimators across India.

SL No.	SITES	TRAP NIGHTS	Mt+1	BEST MODEL	ETA (Km²)	$\bar{N}$	$\bar{N}$ (SE)	$\bar{D}$/(100 km²)	$\bar{D}$ SE	ML SECR ($\bar{D}$)	ML SECR $\bar{D}$ (SE)
	Shivalik-Gangetic Flood Plains										
1	Corbett Tiger Reserve	9064	101	Mh	611	109	5.40	17.83	1.40	16.23	1.63
2	Rajaji National Park	1520	6	Mh	229	7	1.51	3.06	1.04	2.25	1.1
3	Ramnagar Forest Division	1470	26	Mh	177	27	1.50	15.18	2.10	13.8	2.74
4	Pilibhit Forest Division	1200	11	Mh	258	12	0.17	4.66	0.46	3.78	1.17
5	Dudhwa National Park (Dudhwa TR)	1088	15	Mh	265	21	5.47	7.91	3.13	4.79	1.28
6	Katerniaghat (Dudhwa TR)	1800	17	Mh	306	20	2.61	6.53	1.26	4.82	1.19
7	Kishanpur (Dudhwa TR)	1920	18	Mh	306	19	7.31	6.22	3.10	4.64	1.11
8	Valmiki Tiger Reserve	1470	8	Mh	444	8	2.06	1.80	1.00	1.12	0.52
	Central Indian And Eastern Ghats Landscape										
9	Ranthambore Tiger Reserve	1344	25	Mth	277	27	1.80	9.75	1.35	8.09	1.66
10	Bandhavgarh Tiger Reserve	3000	30	Mh	228	37	5.72	16.25	3.45	13.97	2.7
11	Satpura Tiger Reserve	2256	11	Mh	488	13	3.74	2.66	1.22	1.57	0.5
12	Kanha-Mukki (Kanha TR)-2010	1736	27	Mh	410	28	0.90	6.83	0.60	5.61	1.11
12	Kanha-Mukki (Kanha TR)-2011	2900	34	Mh	430	38	4.67	8.70	1.10	5.9	1.02
13	Supkhar (Kanha TR)	1368	10	Mh	363	10	1.70	2.75	0.76	2.08	0.68
14	Pench Tiger Reserve (MP)	12400	23	Mbh	635	23	0.77	3.62	0.51	3.86	0.92
15	Tadoba Andheri Tiger Reserve	5624	15	Mh	321	17	2.15	5.29	1.12	4.45	1.14
16	Melghat Tiger Reserve	2544	12	Mh	427	13	2.16	3.04	0.75	2.29	0.68
17	Achanakmar Tiger Reserve	1760	1		894	1	_	0.11	_	_	_
18	Nagarjunsagar-Srisailam Tiger Reserve	2400	6	Mh	401	6	0.12	1.50	0.27	0.85	0.38
19	Bandipur Tiger Reserve	2400	33	Mb	278	39	2.61	14.04	2.08	8.24	1.47
20	Mudumalai Tiger Reserve	2000	32	Mh	461	51	9.94	11.06	3.04	9.42	2.08
21	Moyar Satyamangalam Reserve Forest	4270	52	Mth	758	58	3.86	7.65	0.93	6.14	0.87
22	Parambikulam Tiger Reserve-2009	1364	7	Mh	302	8	1.49	2.65	1.04	1.49	0.62
22	Parambikulam Tiger Reserve-2011	1258	12	Mh	197	13	1.59	6.61	1.51	4.03	1.21
23	Eravikulum National Park	960	3	Mo	499	3	0.04	0.60	0.02	0.32	0.23
24	Periyar Tiger Reserve	2331	10	Mh	222	12	3.23	5.41	2.86	2.91	0.95
25	Kalakkad Mundanthurai Tiger Reserve	1520	6	Mh	130	6	3.02	4.62	1.39	2.62	0.84
	North-Eastern Hills And Brahmaputra Flood Plains										
26	Manas Tiger Reserve	4389	9	Mh	615	11	4.91	1.79	1.14	0.80	0.27
27	Orang National Park	713	13	Mth	74	13	0.24	17.68	3.56	17.08	4.83
28	Pakke & Nameri Tiger Reserves	1425	10	Mh	182	13	3.56	7.13	5.26	3.28	1.13
29	Kaziranga Tiger Reserve	4815	69	Mb	433	69	0.48	15.92	0.21	12.63	1.51

Tiger Abundance

Tiger density categories were found to increase with increasing magnitude of tiger sign encounters, prey abundance (ungulate encounters on line transects and wild ungulate dung density, normalized differential vegetation index, forested area, and distance to night lights. Tiger density decreased with increase in human disturbance indices (human and livestock trails, livestock seen on transects, and distance to Protected Area (Figures 6.2-e, f, i).

Figures 6.2a to 6.2m. Distribution of indices of tiger abundance, prey abundance, human disturbance, and landscape characteristics plotted for increasing tiger density (ranging between 1.2 to 14 tigers per 100 km2) classes (Figures 6.2a to 6.2m). Values of indices and covariates are standardized with a Z transformation.

Fig. 6.2a

Distribution of tiger pugmark encounters per km walk recorded for different tiger density classes.

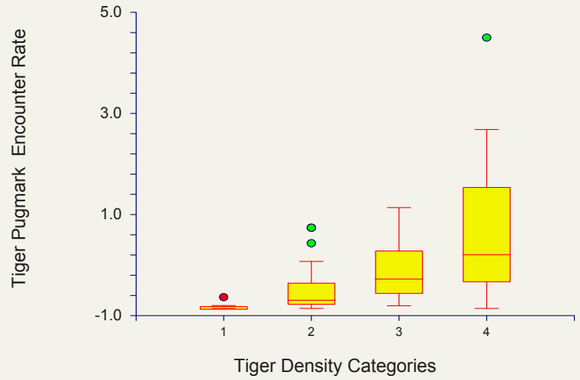


Fig. 6.2b.

Distribution of tiger pugmark and scat encounters per km walk recorded for different tiger density classes.

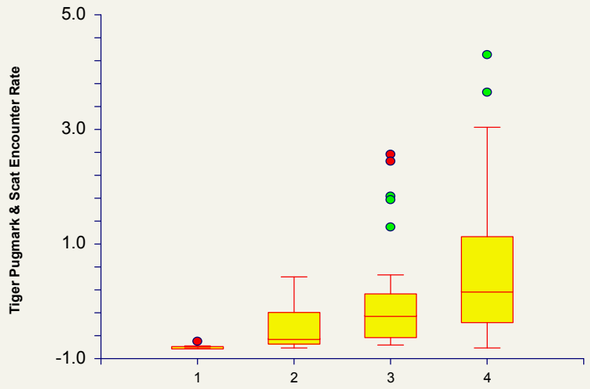


Fig. 6.2c.

Distribution of ungulate prey encounters per km walk within areas of different tiger density classes.

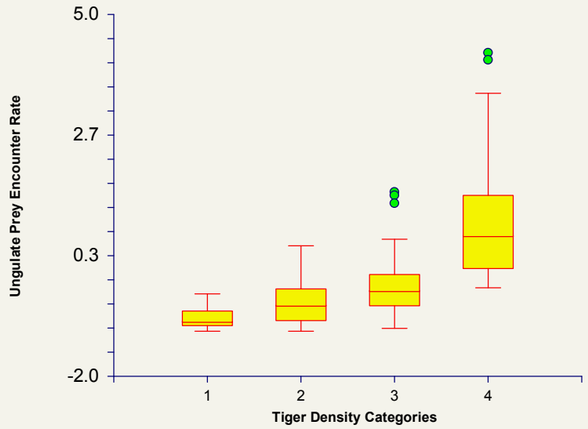


Fig. 6.2d.

Distribution of large ungulate prey encounters per km walk recorded for areas of different tiger density classes.

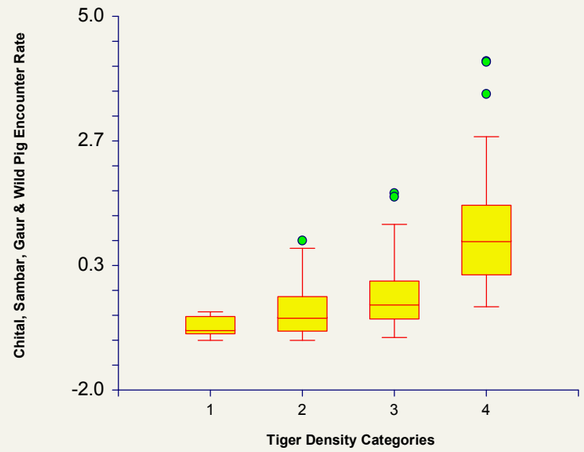


Fig. 6.2e.

Distribution of human and livestock trails on transects recorded within areas of different tiger density classes.

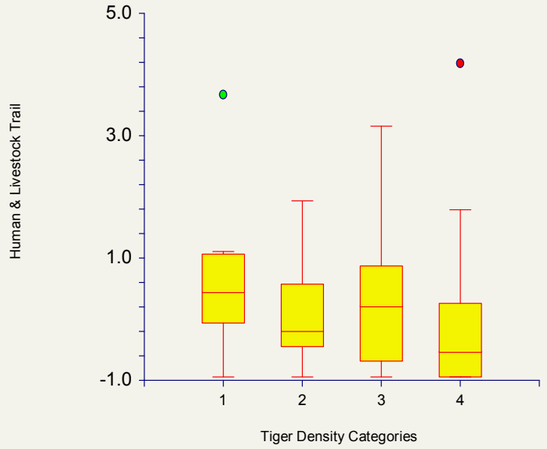


Fig. 6.2f.

Distribution of livestock seen on transects within areas of different tiger density classes.

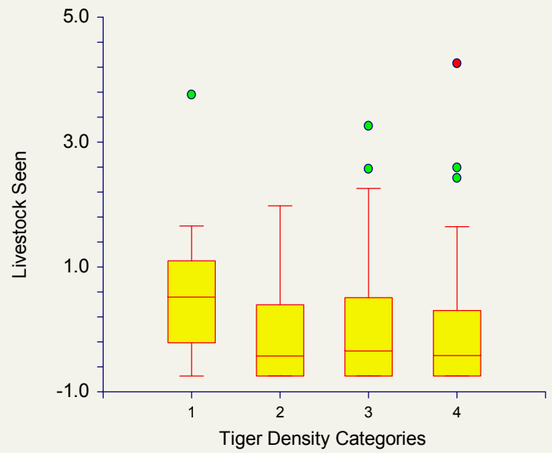


Fig. 6.2g.

Distribution of coefficient of variation in NDVI within areas of different tiger density classes.

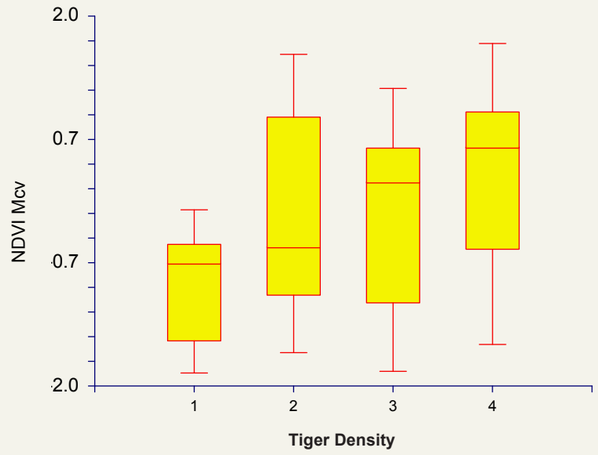


Fig. 6.2h.

Distribution of wild ungulate dung recorded for different tiger density classes.

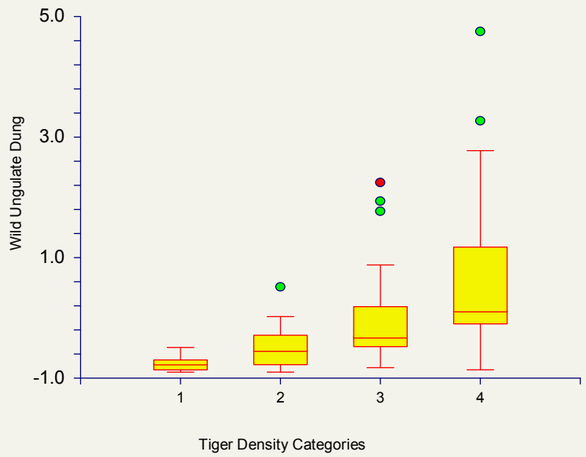


Fig. 6.2i.

Distribution of distance to protected area of tiger occupied grids across different tiger density classes.

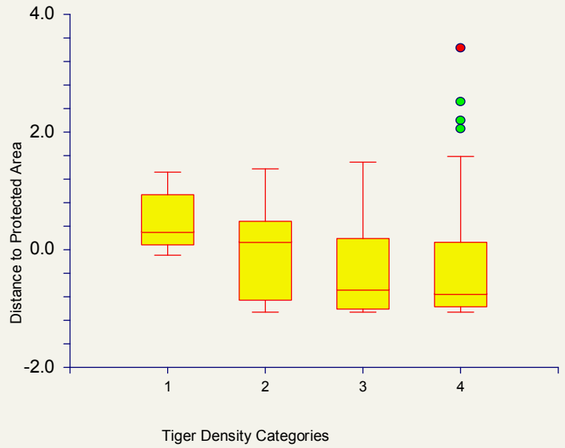


Fig. 6.2j.

Distribution of Principal Component scores having maximum loading from people and livestock along trails across different tiger density classes.

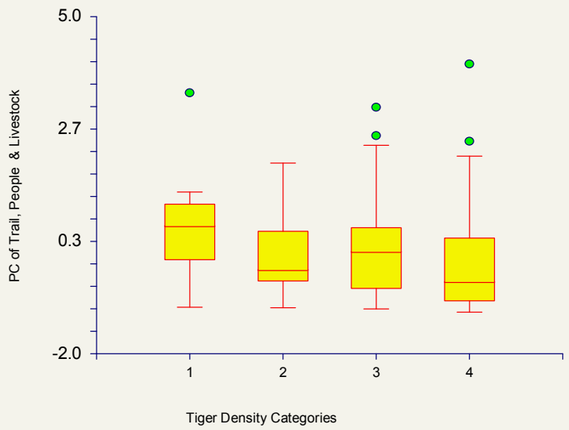


Fig. 6.2k.

Distribution of distance to nightlights across different tiger density classes.

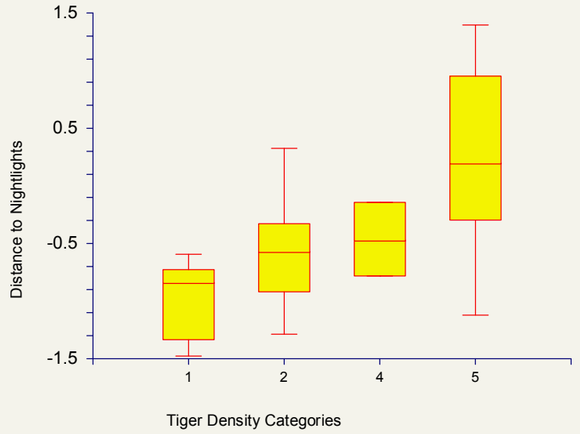


Fig. 6.2l.

Distribution of area under forest across different tiger density classes.

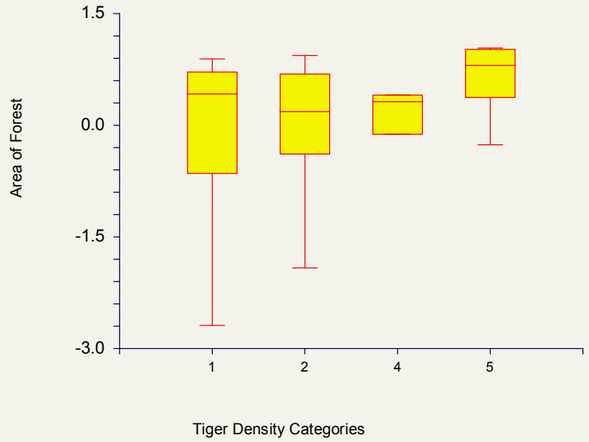
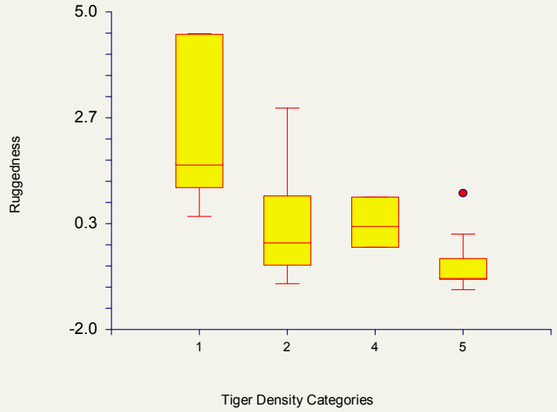


Fig. 6.2m.

Distribution of ruggedness of terrain across different tiger density classes.



The details of the model selection based on AIC and the coefficients of the best ordinal logistic regression model are provided in tables 6.2a to 6.4b. These models were used to estimate tiger density for tiger occupied grids that were not camera trapped.

Table 6.2a. Model selection for ordinal logistic regression of tiger density against covariates and indices of abundance for the Shivalik Hills and Gangetic Plains Landscape.

Variables	AIC	Deviance	Sig P
Pug&Scat, Ung ER, Wild dung,WoodCut, EucPA,NDVIMcv	213.7	195.7	
Pug&Scat, Ung ER, Wild dung,WoodCut, EucPA	213.8	197.8	
Pug&Scat, Ung ER	214.8	204.8	
Pug&Scat, Ung ER, Wdung,WoodCut	214.8	200.8	
Pug&Scat, Ung ER, Wdung,WoodCut, EucPA,NDVIMcv,DEM	215	195.5	
Pug Mark	219.5	211.5	***
Ungulate ER	225.7	217.7	****
Chital+Sambar+Gaur	229.2	221.2	***
Chital+Sambar+Gaur+Wpig	233.6	225.6	***
Wild Dung	239.8	231.8	
Wood cut	261.5	253.5	*
Euc PA	261.6	253.6	**
NDVIMcv	261.8	253.9	*
DEM	262.1	254.1	**
Lopping	263.6	255.6	*
Scat	264.8	256.8	**
H Trails	265.1	257.1	*
DEMcv	265.1	257.1	NS
Livestock on Transect	265.6	257.6	NS
People seen	265.7	257.7	NS
Livestock seen from Plots	265.8	257.7	*
Grass	265.9	257.9	NS
Forest Area	265.9	257.9	NS

Table 6.2b. Coefficients of the best Ordinal Logistic Regression model for estimating tiger density across the Shivalik hills and Gangetic Plains Landscape.

Coefficients	Value	Std. Error	t value
Pugmark & scat ER	1.22195	0.4155	2.9406
UngPrey	1.26517	0.3386	3.7365
WildDng	0.52555	0.3514	1.4955
Wood Cutting	-0.07678	0.1919	-0.4001
Dist P.A.	-0.42734	0.2418	-1.7673
NDVICv	0.37194	0.2563	1.451
Intercepts			
a|b	-1.5638	0.3442	-4.5426
b|c	0.0703	0.3174	0.2214
c|d	1.9734	0.3935	5.0156

Table 6.3a.
Model selection for ordinal logistic regression of tiger density against covariates and indices of abundance for the Central Indian Landscape.

Variables	AIC	Deviance	Sig P
Ungulate ER,Pmark,Wild dung,NDVIMcv,EUPA,Htrail,WdCut,Livestock	187.5	165.5	
Ungulate ER,Pmark,Wild dung,NDVIMcv,EUPA,Htrail,WdCut,Livestock,Forest Area	188.5	164.5	
Ungulate ER,Pmark,Wdng,NDVIMcv,EUPA,Htrail,WdCut	195.2	175.2	
Ungulate ER,Pmark,Wdng,NDVIMcv,EUPA,Htrail	197.6	179.6	
Ungulate ER,Pmark,Wdng,NDVIMcv,EUPA,Htrail,WdCu, Livstk on plt,For Ar,NDVIPM	198.5	163.5	
Ungulate ER,Pmark,Wdng,NDVIMcv,EUPA	198.9	182.9	
Ungulate ER,Pmark,Wdng,NDVIMcv,DEM,EUPA	200.2	182.2	
Ungulate ER,Pmark,Wdng,NDVIMcv	200.5	186.5	
Ungulate ER,Pmark,Wdng,NDVIMcv,DEM	201.5	185.5	
Ungulate ER,Pmark,Wdng,Scat,NDVIMcv	201.8	185.8	
Ungulate ER,Pmark,	203.1	191.1	
Ungulate ER,Pmark,Wdng	204.9	194.9	
Ungulate ER,Pmark,Wdng,Scat	204.9	190.9	
Ungulate ER	239.7	231.7	***
Chital+Sambar+Gaur+Wpig	254	246	***
Chital+Sambar+Gaur	264.3	256.3	***
Pug Mark	268.1	260.1	***
Wild Dung	274.7	266.7	***
Occ	287	279	***
Pug Mark & Scat	289.6	281.6	***
Scat	313.8	305.8	**
NDVIMcv	317	309	**
DEM	321	313	**
Euc PA	321.6	313.6	**
DEMcv	322.8	314.8	*
H Trails	323.9	315.9	*
NDVIPM	326	318	*
Livestock on Transect	326.2	318.2	*
Wood cut	326.7	318	*
Livestock seen from Plots	326.8	318.8	*
Forest Area	326.8	318.8	*
NDVIM	327	319	*
Cattle Dung	327	319	*
People seen	327.5	319.5	*
Grass	327.8	319.8	NS
NDVIPMcv	327.9	319.9	NS

Table 6.3b.
Coefficients of the best Ordinal Logistic Regression model for estimating tiger density across the Central Indian Landscape.

Coefficient	Value	SE	Tvalue
UngER	2.8554	0.5057	5.647
Pugmark ER	1.9996	0.4211	4.749
Wild DungDensity	1.2111	0.4529	2.674
NDVIcv	0.3722	0.2183	1.705
Dist PA	-0.3278	0.264	-1.242
Trail Human	1.5593	0.6735	2.315
Wood Cuting	0.3046	0.1984	1.536
Livestk seen	-2.1475	0.7169	-2.996
Intercepts			
a|b	-5.5149	0.6942	-7.9439
b|c	-1.8157	0.3887	-4.6706
c|d	1.0222	0.3431	2.9795

Table 6.4a.
Model selection for ordinal logistic regression of tiger density against covariates and indices of abundance for the Western Ghats Landscape

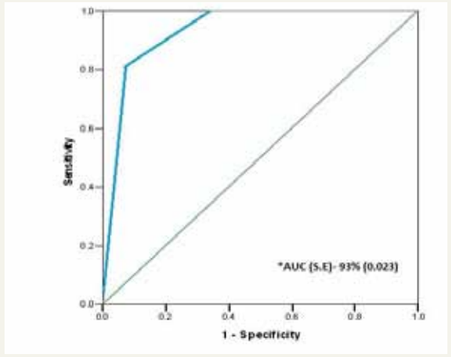
Variables	AIC	Deviance	Sig P
Pug+Sct, Core, Chit+Sam+gaur, NDVIM, Dist Night light	111.8	97.8	
Pug+Sct, Core, Chit+Sam+gaur, NDVIM, Dist Night light, Wild Dung	113.57	97.57	
Pug+Sct, Core, Chit+Sam+gaur, NDVIM, Dist Night light, Human Trails	113.8	97.8	
Pug+Sct, Core, Chit+Sam+gaur, NDVIM, Dist Night light, Human Trails, Wild Dung	115.5	97.5	
Pug+Sct, Core, Chit+Sam+gaur, NDVIM	130.9	118.9	
Pug+Sct, Core, Chit+Sam+gaur	136.9	126.9	
Pug+Sct, Core	137.6	129.6	
Pug Mark	145.8	139.8	***
Pug & Scat	148.1	142.1	***
Core	159.6	153.6	***
Scat	163.9	157.9	**
Chital+Sambar+Gaur	166.5	160.5	***
NDVIM	167.2	161.2	**
Forest	168.5	162.5	**
Chital+Sambar+Gaur+Wpig	169	163	***
Ung Prey	169.2	163.2	***
NDVIPM	169.6	163.6	**
Dist to Night Lights	172.8	166.8	*
Wild Dung	173.1	167.1	***
Lopping	174.2	168.2	*
Cattle Dung	174.8	168.8	NS
NDVIMcv	174.9	168.9	**
Rd Density	175	169	*
Human trails	175.2	169.2	*
Livestock seen from Plots	175.5	169.5	*
People seen	175.6	169.6	*
Wood cut	175.6	169.6	*
Grass	175.9	169.9	NS
DEM	176	170	*
Livestock on Transect	176.2	170.2	NS

Table 6.4b.
Coefficients of the best Ordinal Logistic Regression model for estimating tiger density across the Western Ghats Landscape.

Coefficients:	Value	Std. Error	t value
Pugmark & Scat	4.676	1.4978	3.122
Forest Core	1.219	0.301	4.049
Chital+Sambar+Gaur ER	0.874	0.3715	2.352
NDVI	0.95	0.2804	3.388
Dist. Night Light	1.424	0.3504	4.064
Intercepts:			
a|b	-5.34	1.0104	-5.2833
b|c	-2.206	0.7575	-2.9119

Fig. 6.3

Receiver Operator Curve for evaluating the performance of ordinal regression model in estimating tiger density classes.



**AUC (S.E)-Area Under the Curve (Standard Error)*

Comparing Tiger Population Estimates between 2006 and 2010

Density estimates rely on estimation of an additional parameter i.e. effectively trapped area which adds to the variability of the estimates and therefore loss in precision. In this section we compare the population estimates of the exact same area camera trapped in 2006 and 2010, thereby negating the need for estimating density and allowing for detection of small changes in tiger abundance. Most sites showed stable tiger populations, increases were observed for Bandhavgarh, Tadoba, and Supkhar (Fig. 6.4). The Kanha population showed a decline between 2006 and 2010, but the ongoing Phase IV monitoring by camera trapping, has revealed that the population is recovering.

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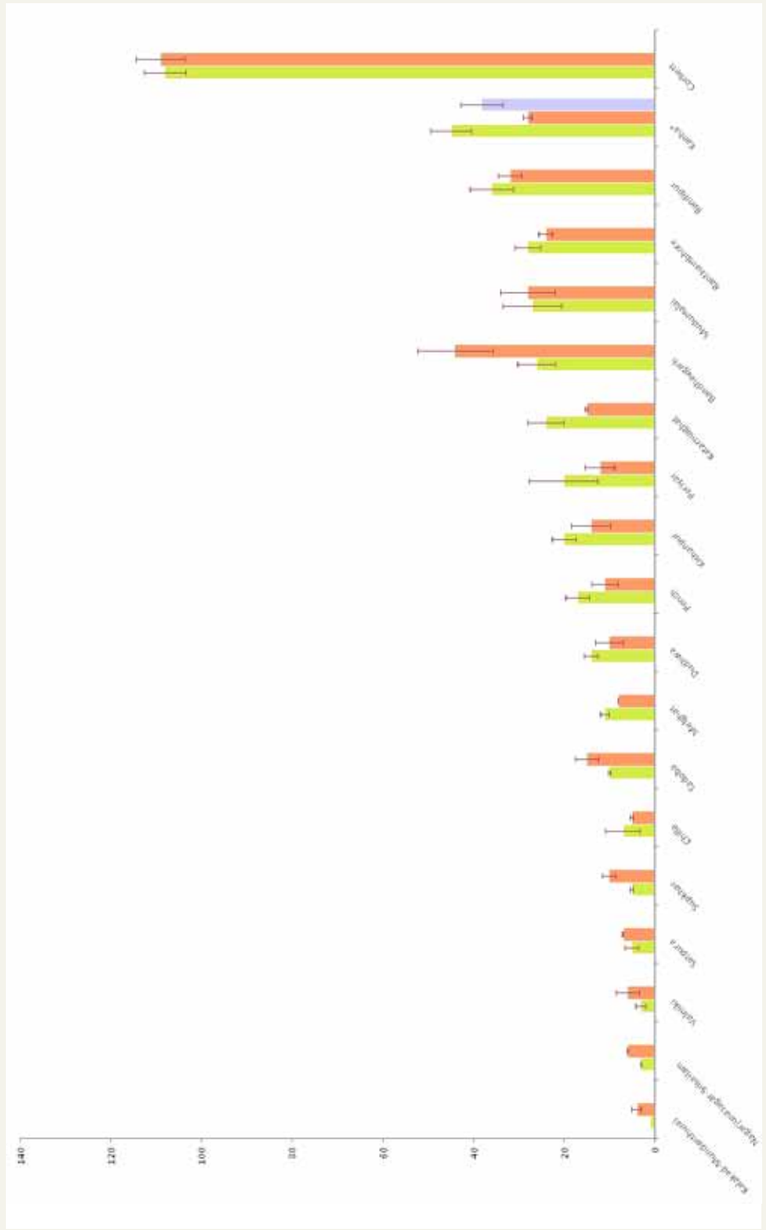
Fig. 6.4

Comparing tiger population estimates between 2006 and 2010 for the same sites. * Estimate also obtained by phase IV in 2011.



Prey Density Estimates

Tiger prey densities were computed for individual species where detections exceed 30 in a habitat type. However, density estimates of all prey combined (constituted by all ungulates, langur and peafowl) and ungulate prey (all ungulate sightings pooled) provide a comparative account of relative prey abundances in different habitat types of the tiger. The overall results suggest that open habitats supported higher ungulate densities in all the landscapes (Tables 6.5a to 6.5i) (Fig. 6.5a to 6.5i). The highest ungulate densities were recorded for thorn forest habitats while the poorest densities were observed in the dry deciduous forests of the Eastern Ghats (Srisailam Tiger Reserve). This was likely due to severe competition with livestock.

Table 6.5a . Density per km^2, effective strip width in meters (ESW), group density, and detection probability (p) estimates for the Sal and Miscellaneous forests of the Shivalik Forests sampled in Rajaji and Corbett sites with 32 spatial replicates and 185 km effort.

Species/ Category	ER	seER	Density	seDen	ESW	seESW	GrpDen	seGrpDen	p
All Prey	1.88	0.31	72.43	13.04	40.99	1.56	22.97	3.91	0.26
Ungulates	1.46	0.26	58.04	11.39	40.28	1.82	18.21	3.36	0.26
Cervids	1.26	0.26	54.51	12.1	37.43	1.79	16.86	3.52	0.27
Chital	0.86	0.21	46.71	13.25	40.63	4.11	10.62	2.85	0.24
Sambar	0.33	0.07	7.49	1.78	34.22	3.37	4.88	1.12	0.62
Nilgai	0.1	0.05	2.22	1.13	52.73	10.28	0.97	0.47	0.66

Fig. 6.5.a. Results of models fitted in DISTANCE to estimate detection probability and effective strip width for Sal and Miscellenous forests of Shivaliks from Rajaji and Corbett sites.

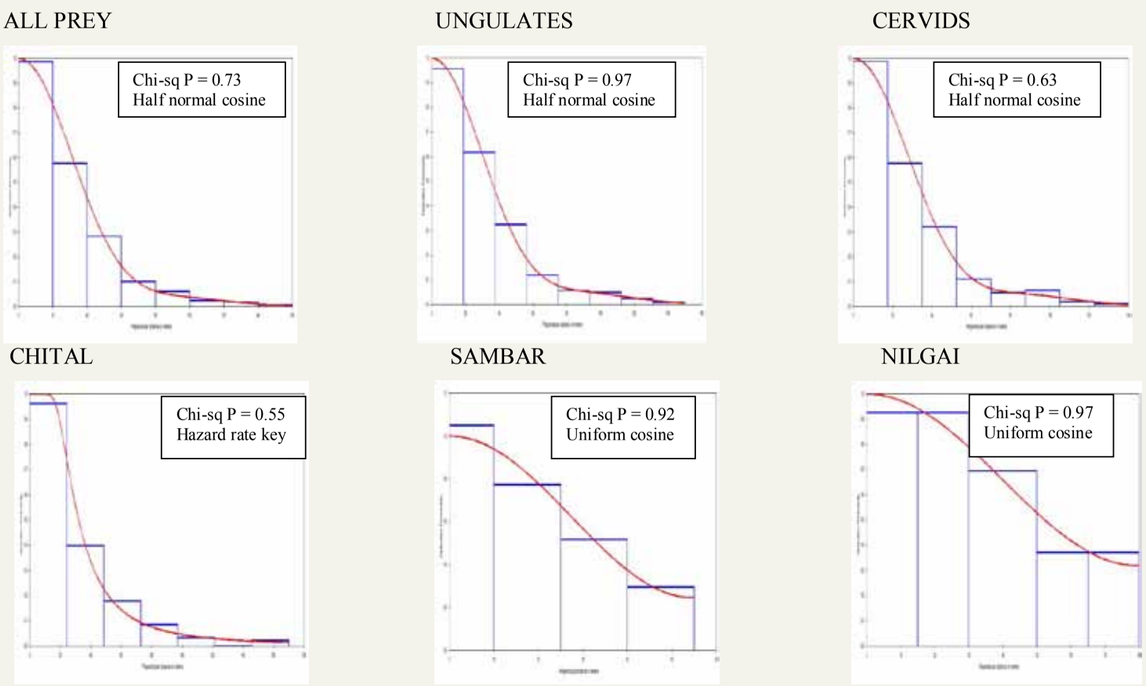


Table 6.5b . Density per km^2, effective strip width in meters (ESW), group density, and detection probability (p) estimates for the Sal forests and Grasslands of the Terai Forests sampled in Dudhwa, Kishanpur, Pilibhit, Valmiki and Katerniaghat sites with 93 spatial replicates and 742 km effort.

Species/ Category	ER	seER	Den	seDen	ESW	seESW	GrpDen	seGrpDen	p
All Prey	0.65	0.06	24.92	2.75	46.33	1.73	7.07	0.69	0.27
Ungulates	0.54	0.05	19.11	2.30	49.11	2.06	5.49	0.59	0.27
Cervids	0.39	0.04	13.12	1.87	54.20	3.16	3.67	0.46	0.22
Chital	0.31	0.04	13.00	2.17	54.01	3.98	2.86	0.42	0.39
Sambar	0.12	0.01	0.14	0.10	52.02	21.36	0.12	0.08	0.87
Hog deer	0.02	0.01	0.41	0.17	61.24	10.58	0.22	0.07	0.44
Barking deer	0.04	0.01	0.72	0.23	36.67	5.05	0.59	0.19	0.46
Nilgai	0.08	0.18	3.02	0.81	58.89	5.98	0.71	0.17	0.49
Wild pig	0.54	0.10	1.99	0.55	41.10	5.18	0.65	0.15	0.45
Peafowl	0.03	0.01	0.47	0.21	45.53	8.62	0.28	0.12	0.51

Fig. 6.5.b.

Results of models fitted in DISTANCE to estimate detection probability and effective strip width for Sal forests and Tall Grassland of Terai from Dudhwa, Kishanpur, Pilibhit, Valmiki and Katerniaghat sites.

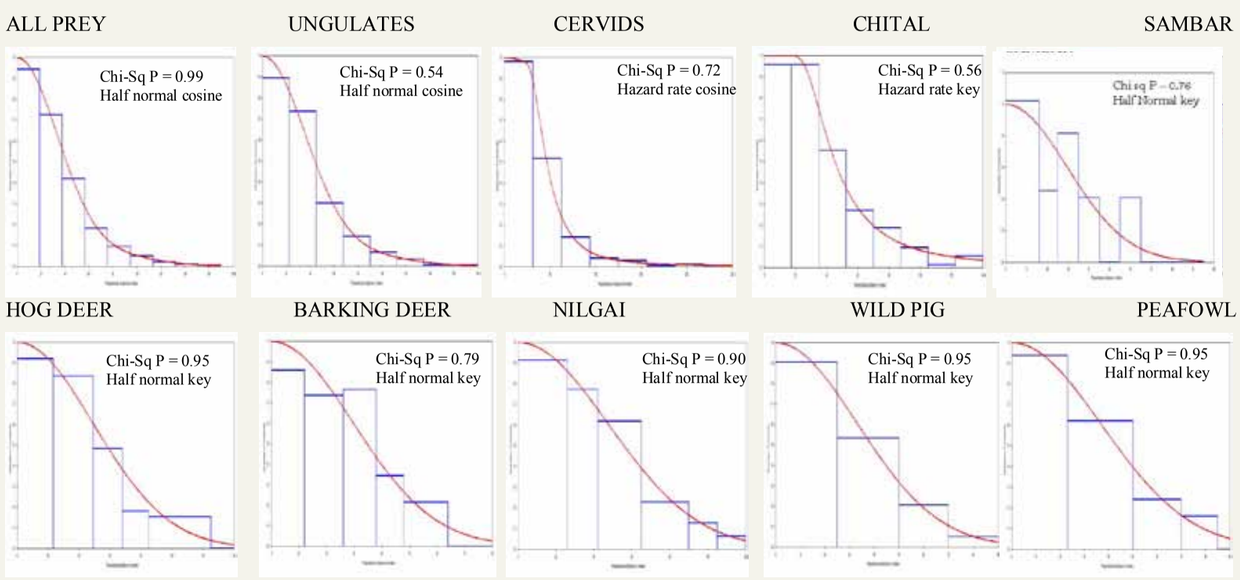


Table 6.5c. Density per km^2, effective strip width in meters (ESW), group density, and detection probability (p) estimates for the Sal and Miscellaneous forests of the Central Indian landscape sampled in Achanakmar, Bandhavgarh, Kanha and Satpuda sites with 106 spatial replicates and 962 km effort.

Species/ category	ER	seER	GrpDen	seGrpDen	Den	seDen	ESW	Se ESW	p
All Prey	1.78	0.25	17.22	2.57	83.64	12.70	51.75	2.54	0.22
Ungulates	1.15	0.22	10.20	1.98	47.19	9.32	59.69	2.23	0.21
Cervids	0.96	0.21	8.30	1.86	39.97	9.09	57.56	3.67	0.21
Gaur	0.07	0.01	0.74	0.17	3.47	0.92	59.17	4.53	0.28
Chital	0.70	0.19	6.22	1.73	36.93	10.42	59.27	3.06	0.20
Sambar	0.20	0.03	1.71	0.32	3.85	0.74	59.14	7.50	0.22
Nilgai	0.02	0.01	0.17	0.08	0.27	0.14	61.43	11.79	0.51
Wildpig	0.09	0.02	1.08	0.27	4.27	1.18	43.01	6.02	0.22
Peafowl	0.08	0.01	0.92	0.22	1.43	0.36	39.77	6.67	0.27

Fig. 6.5.c.

Results of models fitted in DISTANCE to estimate detection probability and effective strip width for Sal and miscellaneous forests of Central Indian landscape from Achanakmar, Bandhavgarh, Kanha and Satpuda sites.

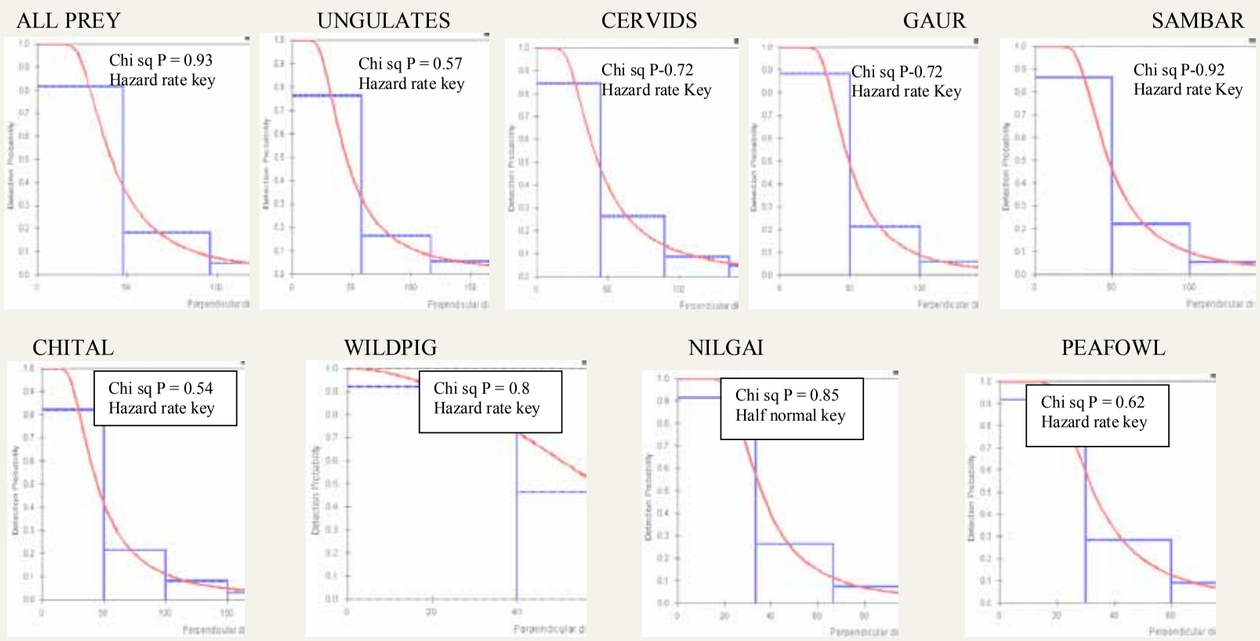


Table 6.5d. Density per km², effective strip width in meters (ESW), group density, and detection probability (p) estimates for the Teak and Miscellaneous forests of the Central Indian landscape sampled in Melghat, Pench and Tadoba sites with 103 spatial replicates and 1340 km effort.

Species/ category	ER	seER	Den	Se Den	ESW	Se ESW	GrpDen	seGrpDen	p
All Prey	1.83	0.16	107.74	9.95	44.20	0.79	20.66	1.85	0.26
Ungulates	1.08	0.11	51.24	5.68	48.82	1.47	11.10	1.18	0.33
Cervids	0.93	0.10	42.31	4.87	52.42	1.54	8.82	0.97	0.35
Gaur	0.05	0.01	2.55	0.63	43.79	3.48	0.56	0.11	0.58
Sambar	0.24	0.02	5.34	0.57	49.59	2.13	2.45	0.25	0.41
Chital	0.59	0.09	37.00	6.06	55.27	1.44	5.36	0.85	0.37
Nilgai	0.07	0.01	1.38	0.30	50.85	5.92	0.70	0.14	0.36
Barking deer	0.04	0.01	0.61	0.15	38.18	4.21	0.49	0.11	0.39
Wildpig	0.08	0.01	5.83	1.11	40.11	1.32	1.02	0.15	0.50
Peafowl	0.12	0.02	3.42	0.58	37.38	2.76	1.58	0.26	0.29

Fig. 6.5.d.

Results of models fitted in DISTANCE to estimate detection probability and effective strip width for Teak and miscellaneous forests of Central Indian landscape from Melghat, Pench and Tadoba sites.

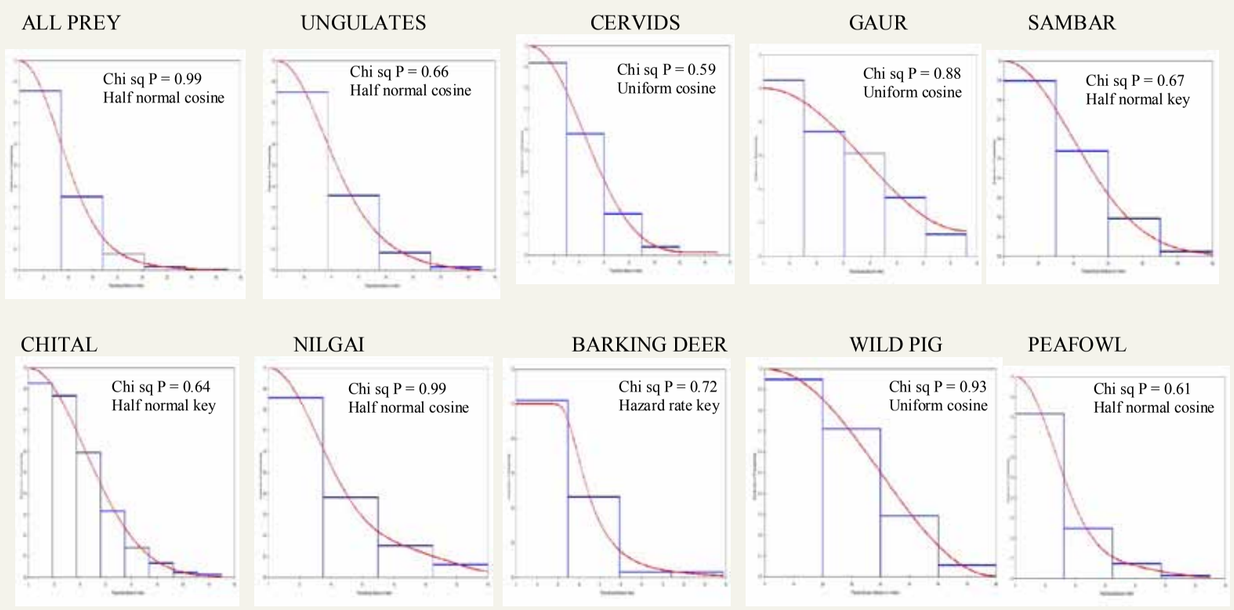


Table 6.5c. Density per km^2, effective strip width in meters (ESW), group density, and detection probability (p) estimates for the Dry Deciduous and Thorn forests of the Central Indian landscape sampled in Ranthambore and Sariska sites with 35 spatial replicates and 360 km effort.

Species/ category	ER	seER	Den	Se Den	ESW	Se ESW	Grp Den	Se GrpDen	p
Ungulates	0.89	0.19	51.97	10.20	44.09	1.5	15.09	2.89	0.25
Cervids	0.39	0.1	38.46	9.76	43.81	2.12	9.96	2.46	0.28
Sambar	0.21	0.07	8.24	1.82	41.21	3.55	3.44	0.72	0.27
Chital	0.18	0.06	31.62	10.38	47.72	3.22	6.17	1.97	0.32
Nilgai	0.4	0.11	11.17	2.69	44.2	2.81	4.24	0.98	0.29
Wild pig	0.07	0.04	4.86	7.68	17.21	25.41	1.53	2.39	0.16

Fig. 6.5.e.

Results of models fitted in DISTANCE to estimate detection probability and effective strip width for Dry Deciduous and Thorn forests of Central Indian landscape from Ranthambore and Sariska sites.

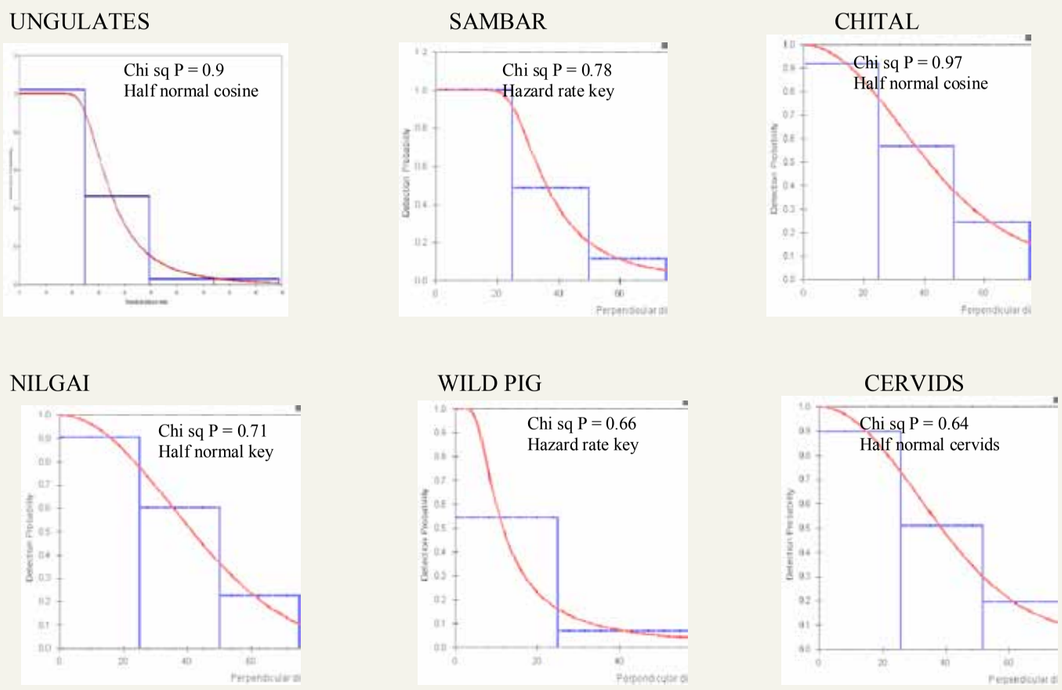


Table 6.5.f. Density per km^2, effective strip width in meters (ESW), group density, and detection probability (p) estimates for the Dry Mixed Deciduous forests of the Eastern Ghats landscape sampled in Nagarjunsagar Srisailam sites with 24 spatial replicates and 190 km effort.

Species/ category	ER	seER	Den	Se Den	ESW	Se ESW	Grp Den	Se GrpDen	p
All Prey	0.14	0.06	10.83	3.07	29.88	3.96	6.40	1.75	0.37
Ungulates	0.11	0.06	5.46	1.69	32.28	4.2	3.33	0.98	0.43
Cervids	0.11	0.06	4.78	1.47	31.96	4.21	3.12	0.91	0.43
Sambar	0.06	0.03	3.34	1.09	27.39	4.62	2.20	0.69	0.39
Chital	0.05	0.04	1.84	0.97	41.2	4.09	0.95	0.47	0.55
Pea fowl	0.02	0.02	3.35	1.32	22.25	3.94	2.25	0.84	0.4

Fig. 6.5.f.

Results of models fitted in DISTANCE to estimate detection probability and effective strip width for Dry Mixed Deciduous forests of Central Indian landscape from Nagarjunsagar Srisailam sites.

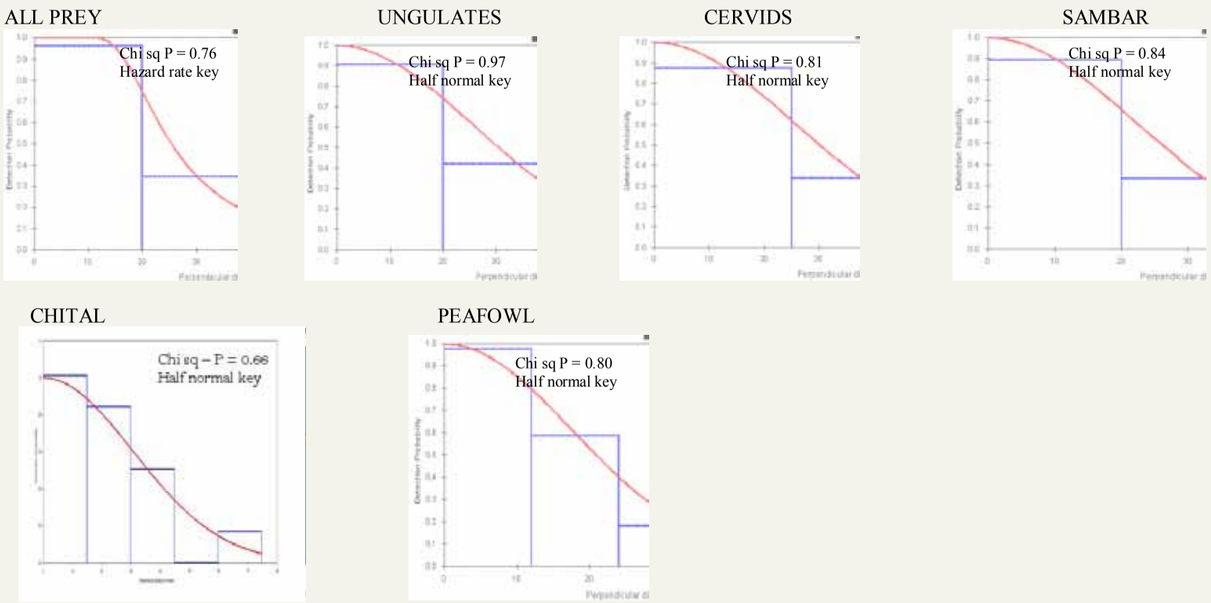


Table 6.5g . Density per km^2, effective strip width in meters (ESW), group density, and detection probability (p) estimates for the Deciduous and Teak forests of the Western Ghats landscape sampled in Bandipur, Parambikulam, Mudumalai and Kalakkad-Mundanthurai sites with 53 spatial replicates and 554 km effort.

Species/ category	ER	seER	Den	seDen	ESW	ESW SE	Grp Den	seGrp Den	p
All prey	1.18	0.13	59.75	7.40	41.13	1.37	14.32	1.62	0.27
Ungulates	0.82	0.09	43.54	5.85	40.33	1.91	10.13	1.18	0.20
Cervids	0.63	0.07	37.80	5.63	34.25	1.77	9.19	1.16	0.19
Chital	0.30	0.05	31.36	6.93	48.14	2.87	3.17	0.57	0.44
Sambar	0.28	0.04	7.69	1.18	30.74	1.60	4.49	0.66	0.28
Gaur	0.15	0.04	7.60	2.22	57.87	4.86	1.29	0.33	0.36
Elephant	0.14	0.03	5.63	1.53	61.24	5.32	1.15	0.29	0.38
Wild Pig	0.04	0.02	2.51	1.40	31.39	5.63	0.57	0.26	0.39

Fig. 6.5.g.

Results of models fitted in DISTANCE to estimate detection probability and effective strip width for Deciduous and Teak forests of Western Ghats landscape from Bandipur, Parambikulam, Mudumalai and Kalakkad-Mundanthurai sites.

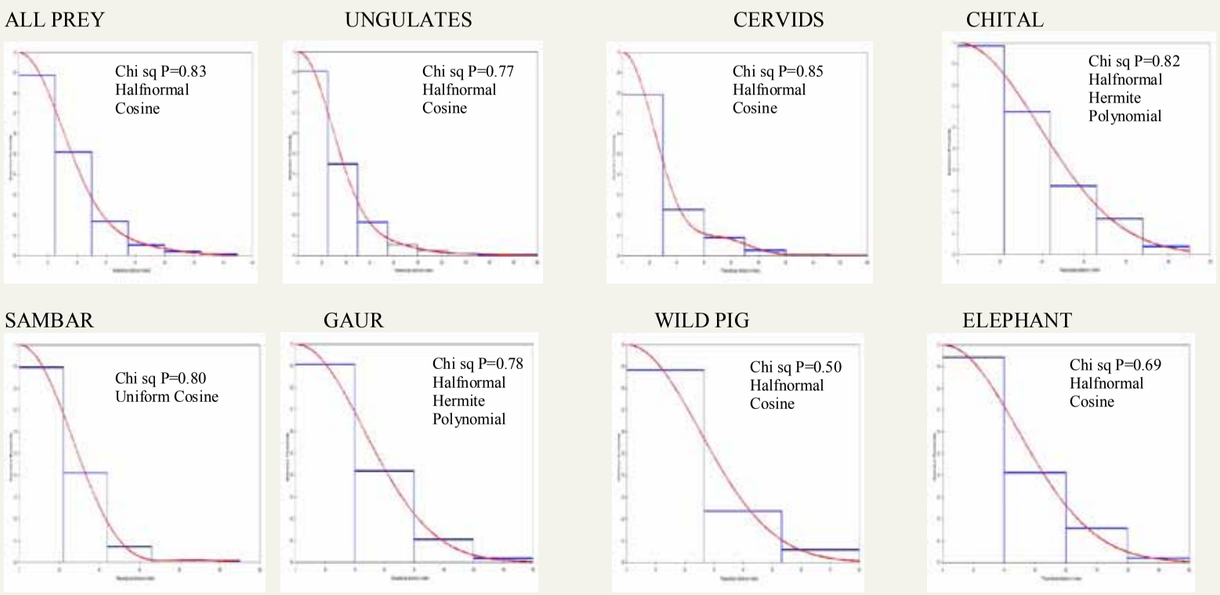


Table 6.5h . Density per km^2, effective strip width in meters (ESW), group density, and detection probability (p) estimates for the Evergreen forests of the Western Ghats landscape sampled in Kalakkad-Mundanthurai, Parambikulam and Mudumalai sites with 19 spatial replicates and 189 km effort.

Species/ category	ER	seER	Den	seDen	ESW	ESW SE	Grp Den	seGrp Den	p
All Prey	0.33	0.09	15.84	5.15	32.43	3.15	5.07	1.46	0.32
Ungulates	0.30	0.08	14.17	4.55	35.42	3.84	4.26	1.17	0.44
Cervids	0.16	0.05	9.66	4.46	30.72	4.49	2.59	0.96	0.38
Chital	0.10	0.06	8.02	6.89	35.21	8.18	0.83	0.51	0.35
Sambar	0.10	0.04	2.12	1.08	27.12	5.98	1.17	0.53	0.34
Gaur	0.12	0.03	5.57	2.00	45.29	5.54	1.29	0.34	0.60

Fig. 6.5h.

Results of models fitted in DISTANCE to estimate detection probability and effective strip width for Evergreen forests of Western Ghats landscape from Kalakkad-Mundanthurai, Parambikulam and Mudumalai sites.

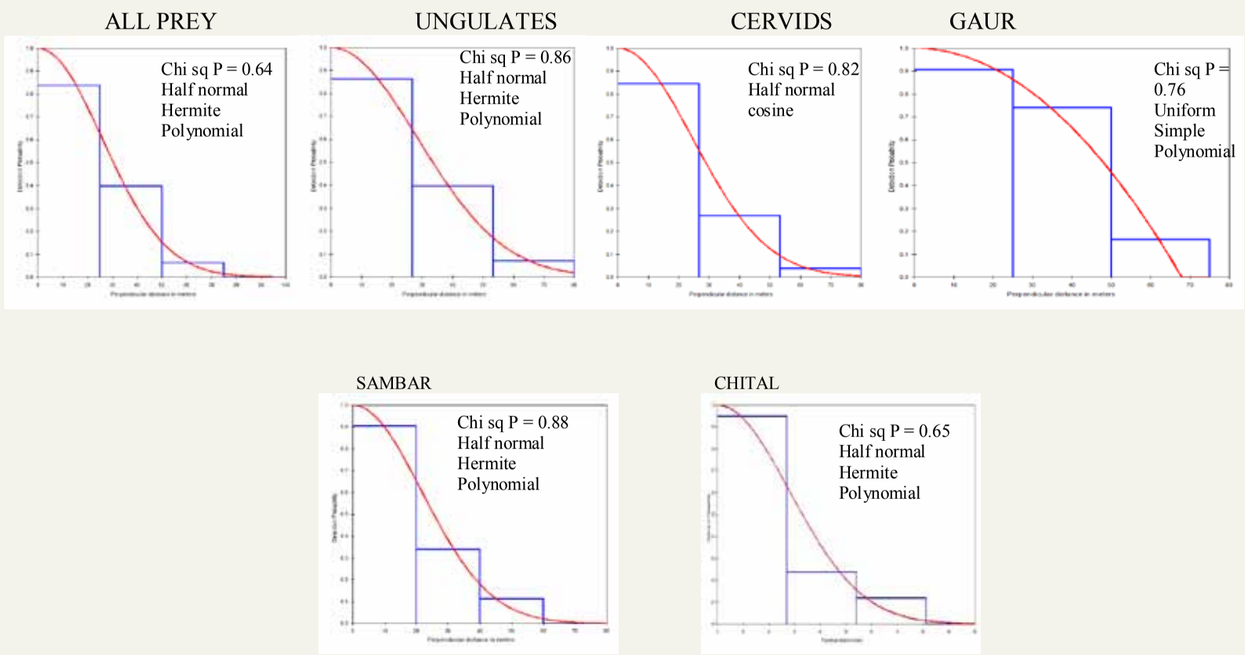
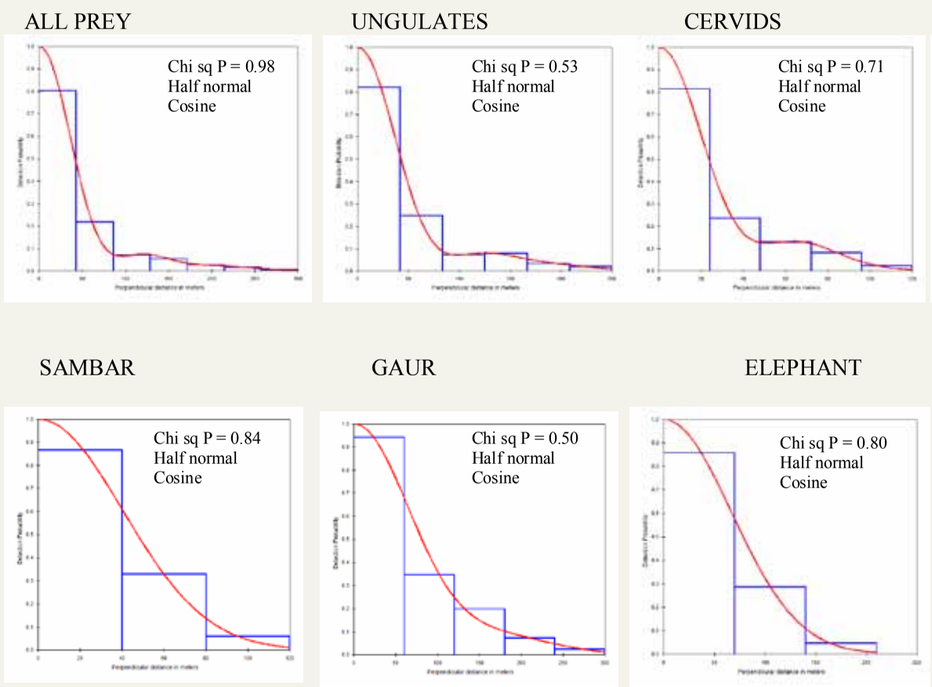


Table 6.5.i. Density per km^2, effective strip width in meters (ESW), group density, and detection probability (p) estimates for the Scrub forests of the Western Ghats landscape sampled in Mudumalai, Moyar-Sigur, Kalakkad-Mundanthurai and Sathyamangalam sites with 35 spatial replicates and 191 km effort.

Species/ category	ER	seER	Den	seDen	ESW	ESW SE	Grp Den	seGrp Den	p
All Prey	1.15	0.19	54.72	10.82	51.14	3.44	11.23	1.99	0.17
Ungulates	1.00	0.18	45.99	10.33	53.21	4.03	9.37	1.88	0.21
Cervids	0.57	0.10	45.85	11.69	30.87	3.11	9.22	1.90	0.26
Chital	0.29	0.09	37.07	14.91	27.98	2.83	5.23	1.66	0.28
Sambar	0.22	0.05	4.06	1.11	50.21	6.27	2.18	0.56	0.42
Gaur	0.33	0.10	8.23	2.89	95.19	11.47	1.76	0.56	0.32
Elephant	0.13	0.05	3.14	1.49	83.36	13.39	0.78	0.33	0.40

Fig. 6.5.i.

Results of models fitted in DISTANCE to estimate detection probability and effective strip width for Scrub forests of Western Ghats landscape from Mudumalai, Moyar-Sigur, Kalakkad-Mundanthurai and Sathyamangalam sites.



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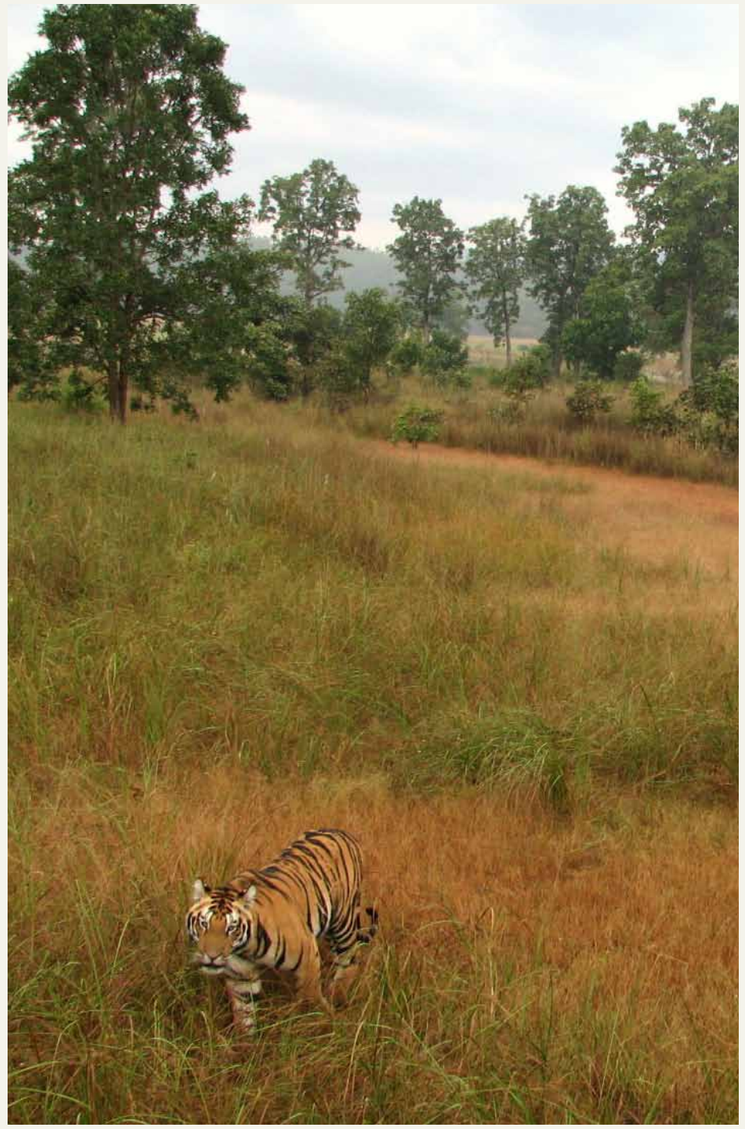


APPENDIX -1 Training and Research Team

Faculty Members involved in Phase-I Training:

I. Shivalik Hills and Gangetic Plains Landscape
Dr. V.P. Uniyal Sh. S. Sen Dr. B.S. Adhikari
Dr. Parag Nigam Dr. K. Ramesh Dr. Y.V.Jhala

II. Central Indian Landscape and Eastern Ghats
Dr. S. Choudhury Dr. S.P. Goyal Dr. K.Vasudevan Ms. Bitapi Sinha
Dr. K. Sivakumar Sh. G.S. Bhardwaj Sh. S. Sen Dr. Bilal Habib
Dr. Gautam Talukdar Sh. Qamar Qureshi

III. Western Ghats Complex
Dr. K. Sankar Dr. V.K. Malkani Dr. A.K. Bhardwaj Dr. K. Vasudevan
Sh. Qamar Qureshi

IV. North Eastern Hills and Brahmaputra Flood Plains
Dr. S.A. Hussain Sh. G.S. Bhardwaj Dr. Gopi G.V. Dr. P. Pal
Sh. Qamar Qureshi

V. Sundarbans
Dr. V.Y. Jhala Sh. Qamar Qureshi

Wildlife Institute of India Research Team:
Senior Biologist: Ms. Priya Singh
Biologists:

Abinash Parida	Debmalya R. Chowdhury	Malemleima Nuigombi	Raju Lal Gurjar
Amol Sahadeo Kumbhar	Dipankar Lahkar	Manas P. Manjrekar	Richa Kesharwani
Anant Pande	Farhat Masood	Megha Aggarwal	Rubi Kumari Sharma
Anil Kumar Dashahre	Francis, P.	Monideepa Mitra	Sanskruti Marathe
Anirudhkumar G. Vasava	Gaurang C. Patwardhan	Monika Kumari	Sawant Dipak Sadashiv
Anup Kumar Pradhan	Geoby George	N. Sridharan	Srinivas Yellapu
Arka Pratap Ghosh	Gitanjali Kanwar	N.Gokulakkannan	Subhasis Mahato
Ashish Prasad Tribhuwan	Gitanjali Katlam	Navneethan B.	Sudip Banerjee
Ashok Kumar K.	K. Narasimmarajan	Neha Awasthi	Sunit Kumar Das
Avanish Kumar Rai	Khrietetouzo Kesiezie	Nilanjan Kundu	Tamma Ajay Kumar
Bidyut Bikash Barman	Lalthanpuia	Partha Sarathi Mishra	Yogesh J.
Charles Leo Prabhu	M. Bubesh Guptha	Pradeep Kumar Sahoo	Zaara Kidwai
Chitaranjan Dave	M. Kamalakannan	Preeti Shirish Virkar	
Daya Ajit Thakur	M. Naveen	Pushkal Baghchie	
Devlin Leishangthem	Madhura Prakash Davate	Rahul Rana	

Junior Research Fellow:
Ujjwal Kumar, Shikha Bisht, Manjari Roy, Deepanjan Naha

Volunteers:
Pranita Sambhus, Ninad Mungi, Sagar Sonone, Wasi Azmi
Priyanka Runwal

WWF Research Team:
Joseph Vattakaven , Jimmy Borah , Meraj Anwar, Chakravarthi P.P. Harish Guleria , K.D. Kandpal, Dabir Hussein, Jyotirmay Jena, Sanjay Thakur, Sunny Shah, Ishtayaque Patel, Shivaji Chauhan Mohanraj, Vijayakumar K., Ravikumar K., Krishnakumar N. , Desai A., Tridip Sharma, Pranjit Sharma, Sanjay Gogoi ,Pranab J. Bora,Amit Sharma, Anupam Sarma, Ms. Priya Ranaut

WTI Research Team:
Dr. Anil Kr. Singh , Milind Pariwakam, Rahul Ashem Singh, Shashank Kasare Nikhil Simon, Khursheed Alam, Sanjay Babu, Ramendra Kumar Alkesh Thakare, Devna Arora, Dr. Samir Kumar Sinha, K. Karthik Dr. Prabal Sarkar, Mahi Puri, Dr. Rajendra P. Mishra , Debobroto Sircar Moizuddin Ahmad, Krishnendu Basak, Dibyendu Mondal, S. Rathnakumar

Aaranyak Research Team:
M. Firoz Ahmed, Kamal Azad, Ajit Basumatary, Arif Hussain, Bedobrata Singha, Pranab Bori, Pranjit Sarma, B K Talukdar, Bipul Das, Bibhuti P Lahkar, Anil Das , Jillol Haque.

ATREE Research Team:
Niraj Kakati , Dhirthiman Das, Nilmani Rabh

Project Assistants:
Ms. Babita Sharma and Mr. Vinay Sharma

SCIENCE (GIS Firm):
Ms. Swati Saini (Senior GIS Executive), Mr. Prabir De (Consultant)

APPENDIX -2 Details of spatial and attribute data used for assessing patterns of tiger distribution

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

	Dataset	Sensors	Spatial Resolution	Radiometric Resolution
1	Forest Cover Forest Survey of India (2003 & 2009)	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)	30 m	2 bands
4	Night-time visible lights	US Air Force Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS)	560 m	2 bands (NIR & IR)

Night Light Data
Night light data was obtained form NOAA/NGDC. Data was collected by 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. 1997). 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 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) (Townshend 1994).
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).

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.

Forest Cover Map
Forest Cover map was obtained from Forest Survey of India (FSI 2003, 2009). 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.

DEM (Digital Elevation Model)
The Shuttle Radar Topography Mission produced the most complete, highest resolution digital elevation model of the Earth (Rodriguez et al 2005). The project was a joint endeavor of NASA, the National Geospatial-Intelligence Agency, and the German and Italian Space Agencies, and flew in February 2000. It used dual radar antennas to acquire interferometric radar data, processed to digital topographic data at 1 arc-sec resolution (approximately 30 x 30 m). The data has linear vertical absolute height error of less than 16 m (Rodriguez et al 2005).

Appendix 3

Camera Trap Pictures of 635 Tigers

SHIVALIK HILLS AND THE GANGETIC PLAIN LANDSCAPE

CORBETT TIGER RESERVE (101 TIGERS)


T1 RIGHT


T1 LEFT


T2 RIGHT


T2 LEFT


T3 RIGHT


T3 LEFT


T4 RIGHT


T4 LEFT


T5 RIGHT


T5 LEFT


T6 RIGHT


T6 LEFT


T7 RIGHT


T7 LEFT


T8 RIGHT


T8 LEFT


T9 RIGHT


T9 LEFT


T10 RIGHT


T10 LEFT


T11 RIGHT


T11 LEFT


T12 RIGHT


T12 LEFT


T13 RIGHT


T13 LEFT


T14 RIGHT


T14 LEFT


T15 RIGHT


T15 LEFT


T16 RIGHT


T16 LEFT


T17 RIGHT


T17 LEFT


T18 RIGHT


T18 LEFT


T19 RIGHT


T19 LEFT


T20 RIGHT


T20 LEFT

T21 RIGHT

T21 LEFT

T22 RIGHT

T22 LEFT

T23 RIGHT

T23 LEFT

T24 RIGHT

T24 LEFT

T25 RIGHT

T25 LEFT

T26 RIGHT

T26 LEFT

T27 RIGHT

T27 LEFT

T28 RIGHT

T28 LEFT

T29 RIGHT

T29 LEFT

T30 RIGHT

T30 LEFT

T31 RIGHT

T31 LEFT

T32 RIGHT

T33RIGHT

T34 RIGHT

T35 RIGHT

T36 RIGHT

T37 RIGHT

T38 RIGHT

T39 RIGHT

T40 RIGHT

T41RIGHT

T42 RIGHT

T43 RIGHT

T44 RIGHT

T RIGHT 45

T46 RIGHT

T47 RIGHT

T48 RIGHT

T49RIGHT

T50 RIGHT

T51RIGHT

T52 RIGHT

CORBETT TIGER RESERVE (DEC-JAN 2010-2011)

T1 RIGHT | T1 LEFT | T2 RIGHT | T2 LEFT | T3 RIGHT | T3 LEFT | T4 RIGHT | T4 LEFT

T5 RIGHT | T5 LEFT | T6 RIGHT | T6 LEFT | T7 RIGHT | T7 LEFT | T8 RIGHT | T8 LEFT

T9 RIGHT | T9 LEFT | T10 RIGHT | T10 LEFT | T11 RIGHT | T11 LEFT | T12 RIGHT | T12 LEFT

T13 RIGHT | T13 LEFT | T14 RIGHT | T14 LEFT | T15 RIGHT | T15 LEFT | T16 RIGHT | T16 LEFT

T17 RIGHT | T17 LEFT | T18 RIGHT | T18 LEFT | T19 RIGHT | T19 LEFT | T20 RIGHT | T20 LEFT

T21 RIGHT | T22 RIGHT | T22 LEFT | T 23 RIGHT | T 23 LEFT | T24 RIGHT | T24 LEFT | T25 RIGHT

T25LEFT | T26 RIGHT | T26 LEFT | T27 RIGHT | T27 LEFT | T28 RIGHT | T28 LEFT | T29 RIGHT

T29 LEFT | T30 RIGHT | T30 LEFT | T31 RIGHT | T31 LEFT | T32 LEFT | T33 RIGHT | T33 LEFT

T34 LEFT | T35 LEFT | T36 LEFT | T37 LEFT | T38 LEFT | T39 LEFT | T40 LEFT | T41 RIGHT

T41 LEFT | T42 LEFT | T43 LEFT | T44 LEFT | T45 LEFT | T46 LEFT | T47LEFT | T48LEFT

T49 LEFT | T50 RIGHT | T50 LEFT | T51 LEFT | T52 LEFT

RAMNAGAR (26 TIGERS)

T1-Right | T1-Left | T2-Right | T-2Left | T3-Right | T3-Left | T4-Right | T4-Left

T5-Right | T5-Left | T6-Right | T-6Left | T7-Right | T8-Right | T8-Left

T9-Right | T9-Left | T10-Right | T-10Left | T11-Right | T11-Left | T12-Right | T12-Left

T13-Right | T3-Left | T14-Right | T-14Left | T15-Right | T15-Left | T16-Right | T16-Left

T17-Right | T7-Left | T18-Right | T-18Left | T19-Right | T19-Left | T20-Right | T20-Left

T21-Right | T21-Left | T22-Right | T-22Left | T23-Right | T23-Left | T24-Right | T24-Left

T25-Right | T25-Left | T26-Right

RAJAJI-CHILLA (6 TIGERS)

T1-Right | T1-Left | T2-Right | T-2Left | T3-Right | T3-Left | T4-Right | T4-Left

T5-Right | T5-Left | T6-Right

DUDHWA (15 TIGERS)

T1-RIGHT T1-LEFT T2-RIGHT T-2LEFT T3-RIGHT T3-LEFT T4-RIGHT T4-LEFT

T5-RIGHT T-5LEFT T6-RIGHT T6-LEFT T7-RIGHT T7-LEFT T8-RIGHT T-8LEFT

T9-RIGHT T9-LEFT T10-RIGHT T10-LEFT T11-RIGHT T-11LEFT T12-RIGHT T12-LEFT

T13-LEFT T14-LEFT T15-LEFT

PILIBHIT (11 TIGERS)

T1-RIGHT T-1LEFT T2-RIGHT T2-LEFT

T3-RIGHT T3-LEFT T4-RIGHT T4-LEFT T5-RIGHT T-5LEFT T6-RIGHT T6-LEFT

T7-RIGHT T7-LEFT T8-RIGHT T-8LEFT T9-RIGHT T9-LEFT T10-RIGHT T10-LEFT

T11-RIGHT T11-LEFT

KISHANPUR (19 TIGERS)

KT1-RIGHT KT1-LEFT KT2-RIGHT KT2-LEFT KT3-RIGHT KT3-LEFT KT4-RIGHT KT4-LEFT

KT5-RIGHT KT5-LEFT KT6-RIGHT KT6-LEFT KT7-RIGHT KT7-LEFT KT8-RIGHT KT8-LEFT

KT9-RIGHT KT9-LEFT KT10-RIGHT KT10-LEFT KT11-RIGHT KT11-LEFT KT12-RIGHT KT13-RIGHT

KT13-LEFT KT14-RIGHT KT15-RIGHT KT15-LEFT KT16-RIGHT KT16-LEFT KT17-RIGHT KT17-LEFT

KT18-RIGHT KT18-LEFT KT19-RIGHT KT19-LEFT

KATARNIAGHAT TIGER RESERVE (17 TIGERS)

KG1-RIGHT | KG1-LEFT | KG2-RIGHT | KG2-LEFT | KG3-RIGHT | KG3-LEFT | KG4-RIGHT | KG4-LEFT

KG5-RIGHT | KG5-LEFT | KG6-RIGHT | KG6-LEFT | KG7-RIGHT | KG7-LEFT | KG8-RIGHT | KG8-LEFT

KG9-RIGHT | KG9-LEFT | KG10-RIGHT | KG10-LEFT | KG11-RIGHT | KG11-LEFT | KG12-RIGHT | KG12-LEFT

KG13-RIGHT | KG13-LEFT | KG14-RIGHT | KG14-LEFT | KG15-RIGHT | KG15-LEFT | KG16-RIGHT | KG16-LEFT

KG17-LEFT

VALMIKI (6 TIGERS)

T1-RIGHT | T1-LEFT | T2-RIGHT | T-2LEFT | T3-RIGHT | T3-LEFT

T4-RIGHT | T4-LEFT | T5-RIGHT | T5-LEFT | T6-RIGHT | T-6LEFT

CENTRAL INDIAN AND EASTERN GHATS LANDSCAPE

RANTHAMBORE TIGER RESERVE (23 TIGERS)

T3 RIGHT | T3 LEFT | T5 RIGHT | T5 LEFT | T6 RIGHT | T6 LEFT | T8 RIGHT | T8 LEFT

T9 RIGHT | T9 LEFT | T11 RIGHT | T11 LEFT | T13 RIGHT | T13 LEFT | T16 RIGHT | T16 LEFT

T17 RIGHT | T17 LEFT | T19 RIGHT | T19 LEFT | T20 RIGHT | T20 LEFT | T22 RIGHT | T22 LEFT

T23 RIGHT | T23LEFT | T24 RIGHT | T24 LEFT | T25 RIGHT | T25 LEFT | T26 RIGHT | T26 LEFT

T28 RIGHT | T28 LEFT | T29 RIGHT | T29 LEFT | T30 RIGHT | T30 LEFT | T31 RIGHT | T31 LEFT

T33 RIGHT | T33 LEFT | T39 RIGHT | T39 LEFT | T41 RIGHT | T41 LEFT

KANHA TIGER RESERVE (27 TIGERS)

T1 Right | T1 Left | T2 Right | T2 Left | T3 Right | T3 Left | T4 Right | T4 Left

T5 Right | T5 Left | T6 Right | T7 Right | T7 Left | T8 Right | T8 Left | T13 Right

T9 Right | T9 Left | T10 Right | T10 Left | T11 Right | T11 Left | T12 Right | T12 Left

T15 Right | T15 Left | T16 Right | T16 Left | T17 Right | T17 Left | T18 Right | T18 Left

T19 Right | T19 Left | T20 Right | T20 Left | T14 Left | T21 Right | T22 Right | T23 Left

T24 Right | T24 Left | T25 Right | T25 Left | T26 Right | T27 Right | T27 Left

BANDHAVGARH TIGER RESERVE (34 TIGERS)

T1 Right | T1 Left | T2 Right | T2 Left | T3 Right | T3 Left | T4 Right | T4 Left

T5 Right | T5 Left | T6 Right | T6 Left | T7 Right | T7 Left | T8 Right | T8 Left

T9 Right | T9 Left | T10 Right | T10 Left | T11 Right | T11 Left | T12 Right | T12 Left

T13 Right | T13 Left | T14 Right | T14 Left | T16 Right | T16 Left | T21 Right | T21 Left

T22 Right | T22 Left | T29 Right | T29 Left | T30 Right | T30 Left | T31 Right | T31 Left

T15 Right


T17 Right


T18 Right


T19 Right


T20 Right

T23 Right


T24 Right


T25 Right


T26 Right


T27 Right


T28 Right


T32 Right


T34 Right


T35 Right

SATPURA TIGER RESERVE (11 TIGERS)


T1 RIGHT


T1 LEFT


T2 RIGHT


T2 LEFT


T3 RIGHT


T3 LEFT


T4 RIGHT


T4 LEFT


T5 RIGHT


T5 LEFT


T6 RIGHT


T6 LEFT


T7 RIGHT


T7 LEFT


T8 LEFT


T9 LEFT


T10 RIGHT


T10 LEFT


T11 RIGHT


T11 LEFT

PANNA (3TIGERS)


T1 RIGHT


T2 LEFT


T3 RIGHT

PENCH TIGER RESERVE (23 TIGERS)


T1 RIGHT


T1 LEFT


T2 RIGHT

T2 LEFT

T3 RIGHT

T3 LEFT

T4 RIGHT

T4 LEFT

T5 RIGHT

T6 RIGHT

T6 LEFT

T7 RIGHT

T8 RIGHT

T9 RIGHT

T9 LEFT

T10 RIGHT

T11 RIGHT

T12 RIGHT

T13 RIGHT

T13 LEFT

T14 LEFT

T15 RIGHT

T15 LEFT

T16 RIGHT

T17 RIGHT

T17 LEFT

T18 RIGHT

T19 RIGHT

T19 LEFT

T20 RIGHT

T21 RIGHT

T22 RIGHT

T23 RIGHT

SUPKHAR (10 TIGERS)

T1 RIGHT

T1 LEFT

T2 RIGHT

T2 LEFT

T3 RIGHT

T3 LEFT

T4 RIGHT

T4 LEFT

T5 RIGHT

T5 LEFT

T6 RIGHT

T6 LEFT

T7 RIGHT

T7 LEFT

T8 RIGHT T8 LEFT T9 RIGHT T9 LEFT T10 RIGHT T10 LEFT

ACHANAKMAR (1 TIGER)

T1-R IGHT T1-LEFT

MELGHAT TIGER RESERVE (12 TIGERS)

T1-RIGHT T1-LEFT T2-RIGHT T2-LEFT T3-RIGHT T3-LEFT T4-RIGHT T4-LEFT

T5-RIGHT T5-LEFT T6-RIGHT T6-LEFT T7-RIGHT T7-LEFT T8-RIGHT T8-LEFT

T9-RIGHT T9-LEFT T10-RIGHT T10-LEFT T11-RIGHT T12-LEFT

TADOBA TIGER RESERVE (18 TIGERS)

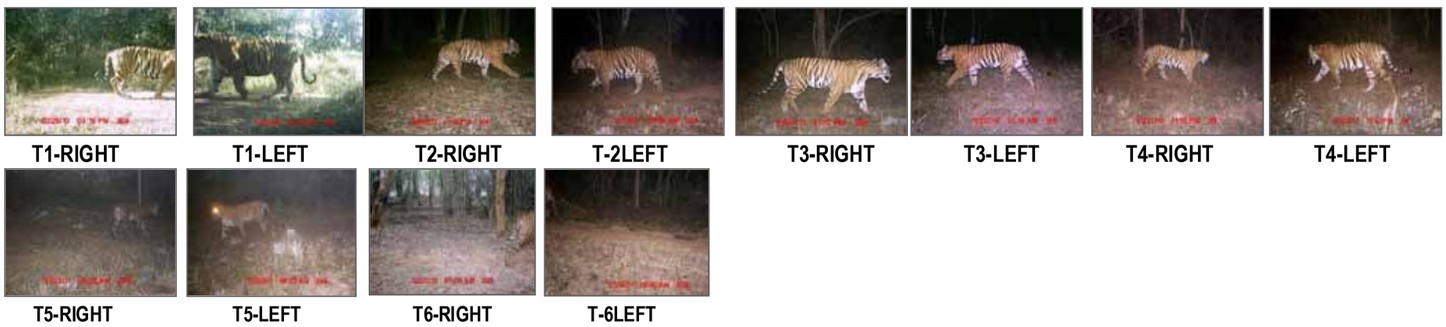
T1-RIGHT T1-LEFT T2-RIGHT T2-LEFT T3-RIGHT T3-LEFT T4-RIGHT T4-LEFT

T5-RIGHT T5-LEFT T6-RIGHT T6-LEFT T7-RIGHT T7-LEFT T8-RIGHT T8-LEFT

T9-RIGHT T9-LEFT T10-RIGHT T10-LEFT T11-RIGHT T11-LEFT T12-RIGHT T12-LEFT

T13-RIGHT T14-LEFT T15-RIGHT T16-LEFT T17-RIGHT T18-LEFT

NAGARJUNASAGAR SRISAILAM TIGER RESEARVE (NSTR) (6 TIGERS)



T1-RIGHT T1-LEFT T2-RIGHT T-2LEFT T3-RIGHT T3-LEFT T4-RIGHT T4-LEFT

T5-RIGHT T5-LEFT T6-RIGHT T-6LEFT

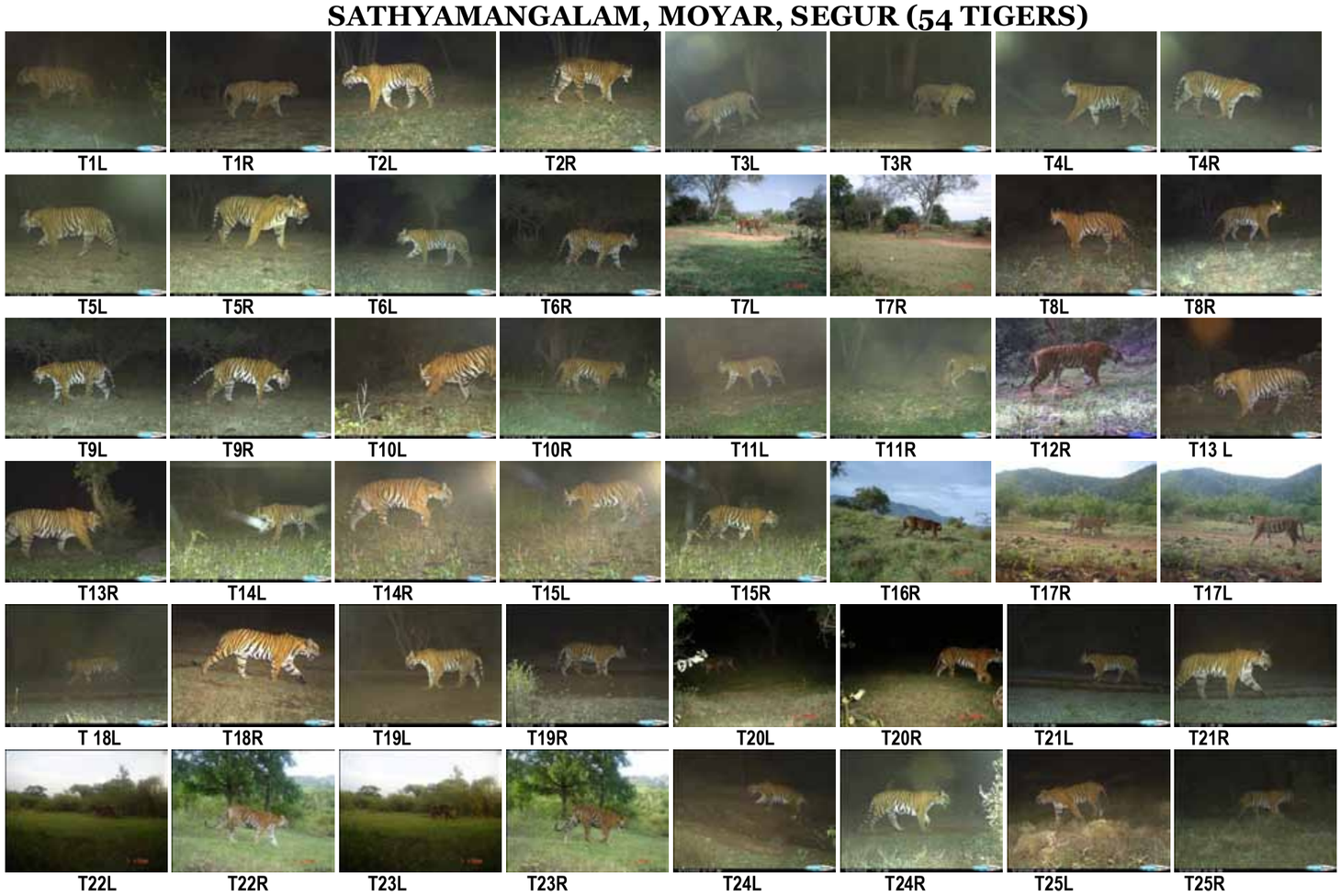
WESTERN GHATS LANDSCAPE COMPLEX

BANDIPUR TIGER RESERVE (33 TIGERS)

KALAKKAD MUNDANTHURAI (4 TIGERS)

MUDUMALAI TIGER RESERVE (32 TIGERS)

SATHYAMANGALAM, MOYAR, SEGUR (54 TIGERS)



ERAVIKULAM NATIONAL PARK (3 TIGERS)

PERIYAR TIGER RESERVE (11 TIGERS)

PARAMBIKULAM TIGER RESERVE (15 TIGERS)

PK1L PK1R PK2L PK2R PK3L PK3R PK4L PK4R

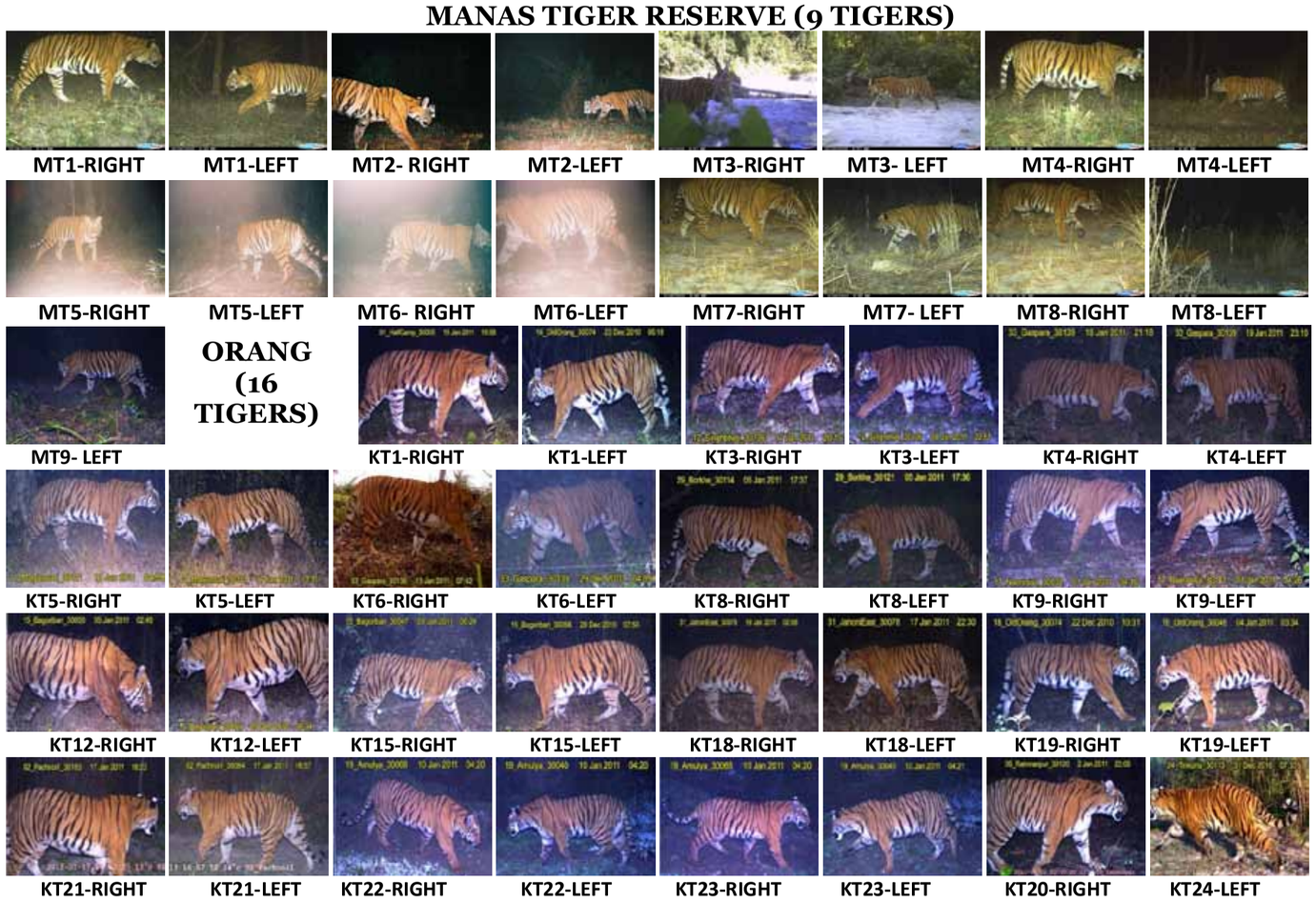
PK5L PK5R PK6L PK6R PK7L PK7R PK8L PK8R

PK9L PK9R PK10L PK10R PK11L PK11R PK12R PK13R

PK14L PK14R PK15L PK15R

NORTH-EASTERN HILLS AND BRAHMAPUTRA FLOOD PLAINS

MANAS TIGER RESERVE (9 TIGERS)



MT1-RIGHT MT1-LEFT MT2- RIGHT MT2-LEFT MT3-RIGHT MT3- LEFT MT4-RIGHT MT4-LEFT

MT5-RIGHT MT5-LEFT MT6- RIGHT MT6-LEFT MT7-RIGHT MT7- LEFT MT8-RIGHT MT8-LEFT

MT9- LEFT

ORANG (16 TIGERS)

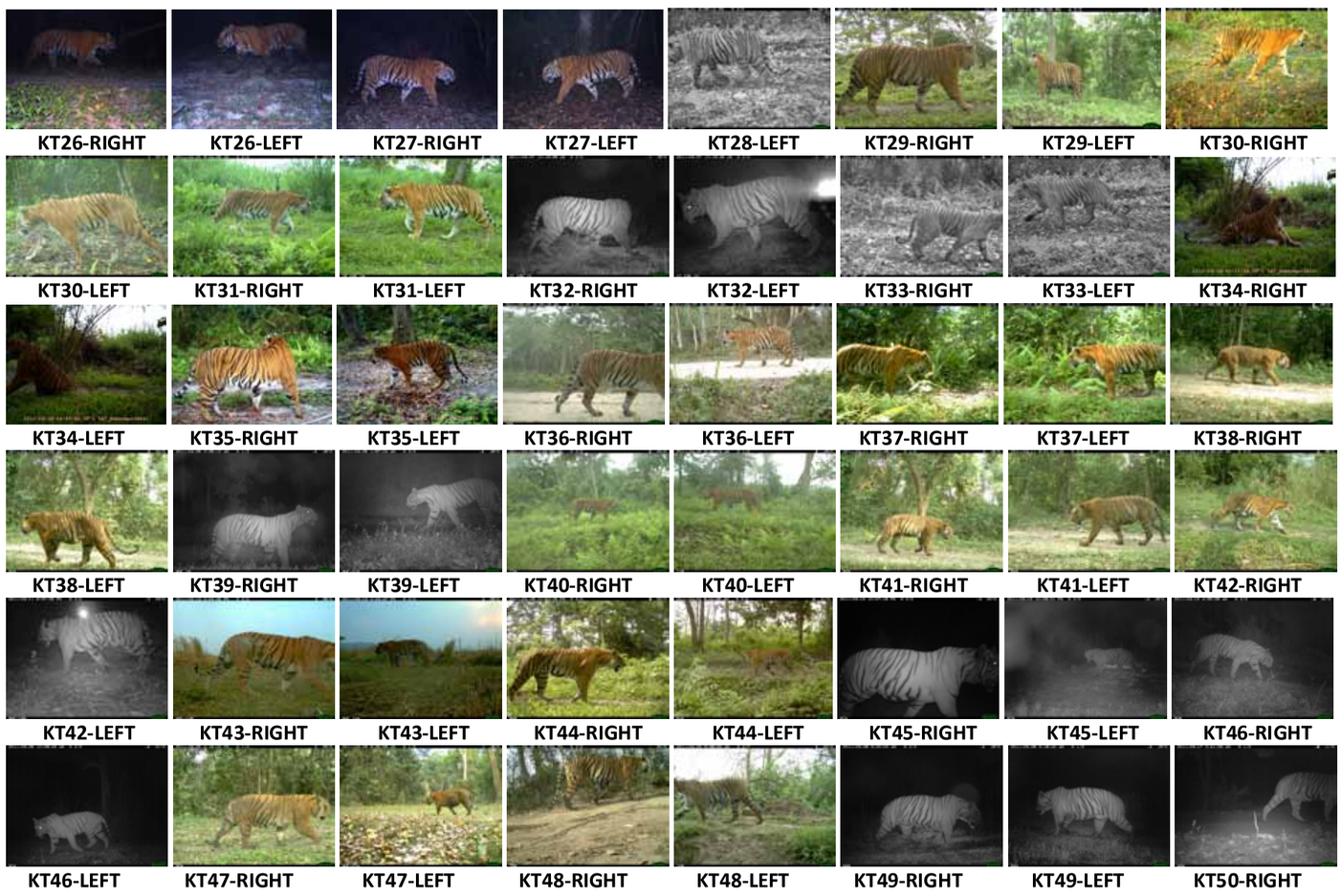
KT1-RIGHT KT1-LEFT KT3-RIGHT KT3-LEFT KT4-RIGHT KT4-LEFT

KT5-RIGHT KT5-LEFT KT6-RIGHT KT6-LEFT KT8-RIGHT KT8-LEFT KT9-RIGHT KT9-LEFT

KT12-RIGHT KT12-LEFT KT15-RIGHT KT15-LEFT KT18-RIGHT KT18-LEFT KT19-RIGHT KT19-LEFT

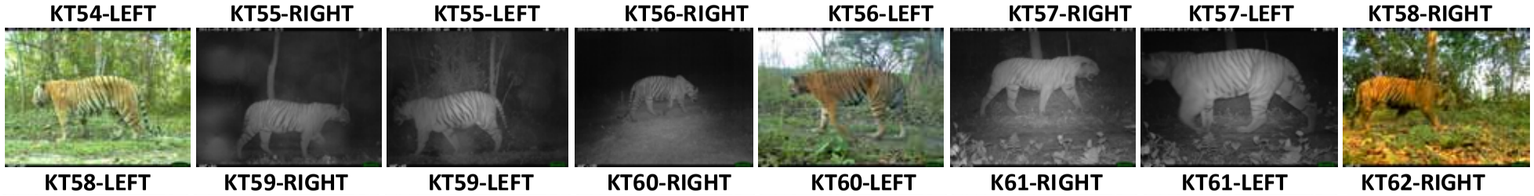
KT21-RIGHT KT21-LEFT KT22-RIGHT KT22-LEFT KT23-RIGHT KT23-LEFT KT20-RIGHT KT24-LEFT

KAZIRANGA NATIONAL PARK (69 TIGERS)



KT50-LEFT KT51-RIGHT KT51-LEFT KT52-RIGHT KT52-LEFT KT53-RIGHT KT53-LEFT KT54-RIGHT

KT54-LEFT KT55-RIGHT KT55-LEFT KT56-RIGHT KT56-LEFT KT57-RIGHT KT57-LEFT KT58-RIGHT



KT58-LEFT KT59-RIGHT KT59-LEFT KT60-RIGHT KT60-LEFT K61-RIGHT KT61-LEFT KT62-RIGHT

KT62-RIGHT KT63-LEFT KT63-RIGHT KT64-RIGHT KT64-LEFT KT65-RIGHT KT65-LEFT KT66-RIGHT

KT66-LEFT KT67-RIGHT KT67-LEFT KT68-RIGHT KT68-LEFT K69-RIGHT KT69-LEFT

PAKKE-NAMERI TIGER RESERVE (10TIGERS)

PTR 1 RIGHT PTR 2 RIGHT PTR 2 LEFT PTR 3 RIGHT PTR 3 LEFT PTR 4 LEFT PTR 5 RIGHT PTR 6 LEFT

PTR 7 LEFT PTR 8 LEFT PTR 8 RIGHT PTR 9 RIGHT PTR 10 RIGHT

SUNDARBANS TIGER RESERVE (10 TIGERS)

T1 RIGHT T1 LEFT T2 RIGHT T2 LEFT T4 RIGHT T4 LEFT T5 RIGHT T5 LEFT

T6 RIGHT T6 LEFT T7 RIGHT T7 LEFT T8 RIGHT T8 LEFT T9 RIGHT T9 LEFT

T10 RIGHT T10 LEFT T3 RIGHT

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Y.V. Jhala & Qamar Qureshi

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