THE BALAGHAT TX2 RECOVERY SITE:

Status of Tigers and Conservation Assessment (2014-2017)

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Foreword

The report 'The Balaghat TX2 Recovery Site: Status of Tigers and Conservation Assessment (2014-2017)' has come at the right time, when focus has been on tiger conservation not only in Tiger Reserves but also in forests outside the Protected Areas of Madhya Pradesh.

The conservation of tiger in its natural habitat is of paramount importance to the Madhya Pradesh Forest Department. Forests of Balaghat district is one such sites which exhibit a stellar example of coexistence of large carnivores/other wild animals with humans since time immemorial. Lying between Kanha and Pench tiger reserves, which has a very high density of tiger population, has served as a corridor but a region with a stable resident population of tigers, displaying a perfect example of source-sink dynamics.

The study reveals that the forests of Balaghat Forest Circle has enough potential as a tiger recovery site. The Balaghat TX2 site represents about 20% of the total forest area of Balaghat Circle. The study shows fairly good number of Tigers with density ranging from 0.46 to 0.87 animals per square km. It also provides insight into the presence of other mammalian diversity of this area i.e. the Eurasian Otter, an apex predator of Balaghat's riverine ecosystems, and the tiger, the flagship species of conservation.

The focus on human-wildlife interaction is a vital addition to this study. It provides an overview of the situation in the region for human injury or death by a wild animal, livestock depredation, as well as the temporal overlaps of activity patterns of humans and wildlife. These are essential for any conservation management or action.

Aspects of forest fire control, natural resource extraction with a focus on Non Timber Forest Produce (NTFP), status of wildlife crime, and linear infrastructure and mining provide an important take on the wildlife management outside the Protected Areas, particularly in the wildlife corridors. This comprehensive study should provide a way-forward to future assessments of tiger habitats outside the Protected Areas.

The Madhya Pradesh Forest Department's commitment to conservation of tiger as an umbrella species is complemented by WWF-India.
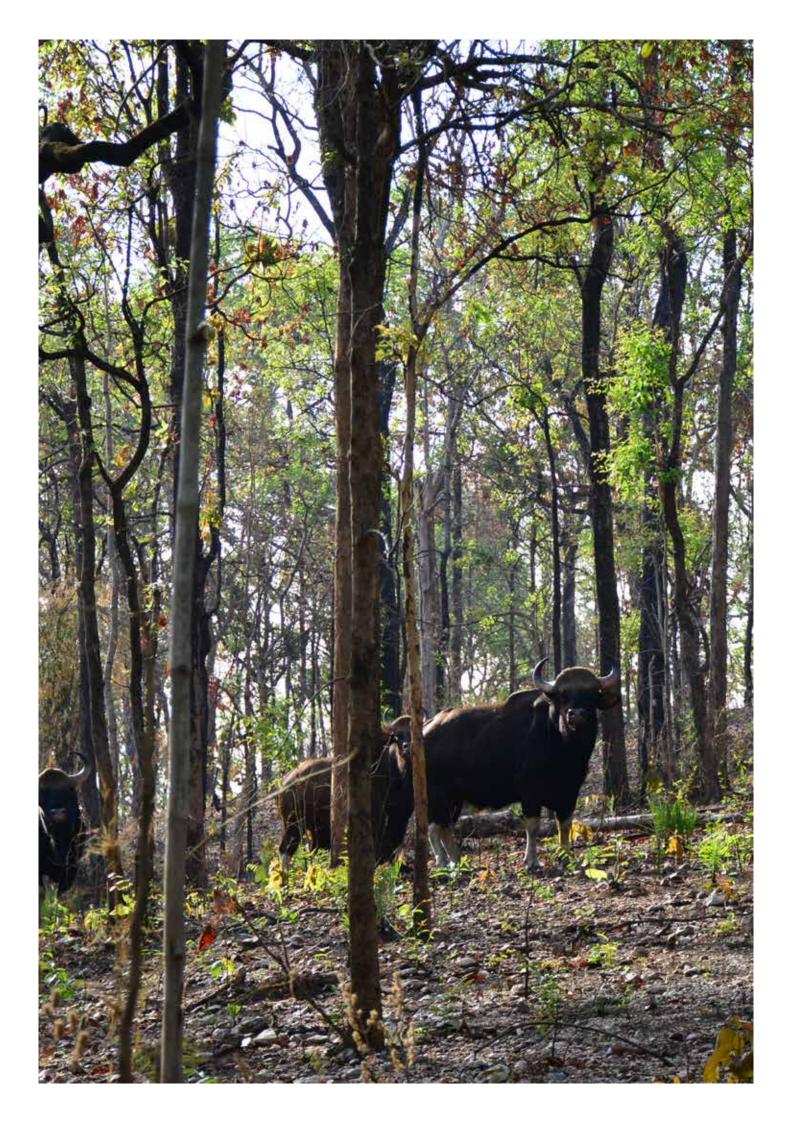
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FOREWORD

Based on a global tiger recovery plan emanating from the St Petersburg Declaration of 2010, WWF selected 18 globally recognised sites with the potential to recover tiger populations. Of these, eight are in India and two in central India, namely Balaghat in Madhya Pradesh and Achanakmar Tiger Reserve in Chhattisgarh. The Balaghat tiger recovery site covers 963 sq. km. It is strategically located in a region connecting four tiger reserves of central India, namely Kanha and Pench Tiger Reserves in Madhya Pradesh, Achanakmar Tiger Reserve in Chhattisgarh, and Navegaon-Nagzira Tiger Reserve in Maharashtra. Owing to its geographic location connecting two healthy source populations of Kanha and Pench tiger reserves, Balaghat has significant potential for the recovery of tigers.

The report titled 'Balaghat TX2 Recovery Site: Status of tigers and conservation assessment (2014-17)' provides an overview of the tiger monitoring studies undertaken in the TX2 site using camera traps and the resultant tiger population estimates. The study highlights critical issues, threats, and opportunities for the recovery of tiger populations. Over the years, several breeding tigers have been recorded within the Balaghat recovery site, attesting to the potential to support a resident population, potentially at higher densities. Besides tigers, the study also highlights the presence of 14 species of carnivores, including the Dhole, Hyena, and Eurasian Otter, and 12 species of non-carnivores, including seven species of wild ungulates.

The rediscovery of a population of Eurasian Otters in the Balaghat TX2 site in 2016 is an indicator of a rich habitat for wildlife. This is a unique record of the Eurasian Otter outside of a Protected Area in Madhya Pradesh, highlighting the need for additional conservation initiatives and protection measures.

I extend my appreciation to the Central India Landscape team of WWF India and Madhya Pradesh Forest Department for highlighting the importance of this non-protected area through this report. I would like to offer my sincere thanks to the Madhya Pradesh Forest Department officials and staff for their support and commitment to the conservation of tigers and wildlife.

- Mr. Ravi Singh, SG & CEO, WWF India

ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

The Balaghat tiger recovery site is situated in the biodiverse Maikal hills of Balaghat district in Madhya Pradesh, comprising 963 km² of forests. It is strategically located in the corridor regions connecting several source population sites, including Kanha and Pench Tiger Reserves in Madhya Pradesh with protected areas of low tiger densities such as Achanakmar Tiger Reserve in Chhattisgarh and Navegaon-Nagzira Tiger Reserve in Maharashtra. Characterized by hills, plateaus, and valleys carved by the Wainganga river and its tributaries, it has significant potential to support a sizable tiger population.

This report has three primary objectives. The first is to collate relevant information on key issues, threats, and opportunities for the recovery of large mammal populations in Balaghat. The second is to analyse camera trap data collected between 2014 and 2017 to provide information on the status of tigers and leopards in this Reserve Forest and analyse the activity patterns of large carnivores and their ungulate prey with respect to human and livestock activities. The third is to advance our understanding of the factors that may limit the distribution, density, and long-term survival of tigers in the Balaghat tiger recovery site and to use this information to plan future conservation interventions.

Between 2014 and 2017, surveys conducted by WWF-India within the tiger recovery sites yielded estimates of 4–9 tigers with associated densities ranging from 0.46 to 0.87 individuals/100 km². These densities are likely influenced by various factors, including prey density, water availability, and human presence and inadequate infrastructure for wildlife protection relative to Protected Areas. Over the years, several breeding tigers have been recorded within the Balaghat recovery site, attesting to the potential to support a local resident population, potentially at higher densities. From the data collected in 2017, 36 individual leopards were photo-captured, of which 10 were males and 24 females.

This study focuses on the tiger densities and abundance of the Balaghat tiger recovery site, a contiguous forest that is 20% of the total area under the Balaghat Forest Circle. We also discuss forest fires' intensity, human-wildlife interactions with respect to personal injury or loss of life, livestock depredation, and wildlife crime rate by identifying critical areas requiring interventions in the TX2 site.

As the next steps, we propose to address the gaps by examining tiger survival, recruitment, and tiger dispersal in determining and realizing the potential of the Balaghat TX2 site. Studies on threats that may hamper revitalizing wild ungulate prey base and recovery for wild tigers have been conducted.

1. BACKGROUND

Balaghat translates to 'a place above the ghats,' signifying the mountainous terrain of the Maikal ranges. Balaghat is one of the oldest districts of Madhya Pradesh, created in 1867-1873 with the amalgamation of parts of two districts of the former Central Provinces, Bhandara and Seoni. The hills of Maikal ranges cover most of the eastern and central portions of the district, while the south-eastern half comprises fertile lowlands extending further south towards the Gondia district in Maharashtra. One of the earliest descriptions of the district is "a forest upland country of romantic scenery and cool and pleasant climate" (Low, 1907). The Maikal Hills are an eastern offshoot of the Satpuda ranges, and running north to south, they form the eastern boundary of the district. The undulating lowlands are drained by two major rivers, Wainganga and Bagh. Wainganga River traverses north to south along the western side of the district, whereas Bagh flows west to east, forming the southern boundary with Gondia and Nagpur districts in Maharashtra. Owing to variation in its elevation, the highlands are generally cooler than the lowlands of the district. The average maximum and minimum temperatures are 40°C and are 25°C respectively. The average rainfall is between 1000-1400 mm, which is about the highest in the state of Madhya Pradesh (Ministry of Earth Sciences, 2014; Farmer Welfare and Agriculture Development Department, Madhya Pradesh, 2015).

The district of Balaghat is flanked by Seoni and Mandla districts to the west and north, respectively, in Madhya Pradesh, Rajnandgaon district to the east in Chhattisgarh, and Gondia and Nagpur districts to the south in Maharashtra. It covers an area of 9,229 sq.km, and comprises the largest forest cover among the districts of Madhya Pradesh at 53.44% (4,932 sq. km) of the geographic area, with the highest forest cover classified as "very dense" and "moderate dense" spread over an area of 1,409 km² and 2,638 sq.km, respectively (Forest Survey of India, 2019).

Demographically, the district is among the least populated in the state, with a total population of 1,701,698 and a density of 184 persons/km² – less than half of the average density of the country (464 persons/km²); Directorate of Census Operations Madhya Pradesh, 2015). A majority of people live in rural areas (85%) relative to Madhya Pradesh state as a whole (72%) and national (69%) average. The tribal communities comprise 22.5% of the total population of Balaghat district and have the highest literacy rate (66.7%) among tribal communities in Madhya Pradesh. Major tribal communities of Balaghat are the Gond and Baiga – the latter considered to be the earliest settlers of the district. The Baiga were primarily semi-nomadic hunter-gatherers who practiced slash-and-burn technique of cultivation locally called bewar, while the Gond were agrarian communities settled in river plains and lowlands. Historically, the district has seen the earliest records of civilizations dating to 7th century AD (Low, 1907). The earliest dynasties were the Kalchuri and the Haihaya, followed by rules under the Gond, Mughal, Maratha, and British colonization until independence.

The forests of Balaghat are both extensive and diverse. The vegetation is classified into five types based on Champion and Seth (1968); Southern Dry Mixed Deciduous Forest 5A/C3, Slightly Moist Teak Forest 3B/CIC, Northern Tropical Moist Deciduous Sal Forest 3C/C2e(ii), Southern Tropical Dry Deciduous Teak Forest 5A/C1b, and Southern Tropical Dry Mixed Deciduous Forest 5A/C3. Key tree species include sal *Shorea robusta*, teak *Tectona grandis*, mahua *Madhuca indica*, saja *Terminalia elliptica*, harra *T. chebula*, behera *T. bellirica*, arjun *T. arjuna*, tendu *Diospyros melanoxylon*, palash *Butea monosperma*, lendia *Lagerstroemia parviflora*, dhaora *Anogeissus latifolia*, bargad *Ficus benghalensis*, tinsa *Desmodium oojeinense*, aonla *Phyllanthus emblica*, kosum *Schleichera oleosa*, moyan *Lannea*

coromandelica, and jamun *Syzygium cumini*. The understorey is characterised by *Pogostemon benghalensis, Colebrookea oppositifolia, Crotalaria spectabilis, Phoenix acaulis,* and grasses such as *Aristida setacea, Heteropogon contortus, Thysanolaena latifolia, Saccharum spontaneum*, with vast expanses of bamboo groves of *Dendrocalamus strictus* and *Bambusa bambos*. Invasive species such as *Lantana camara, Parthenium hysterophorus,* and *Eupatorium perfoliatum* are common in highly degraded forest areas.

In the late 1800s, the natural stands of sal were extensively harvested to be used as railway sleepers for the South-East Central Railway connecting the railway tracks between Nagpur and Bilaspur, Bhusawal, and Jabalpur, and from Jabalpur to Prayagraj. These railway lines formed corridors for transportation of goods as well as coal. The hunting blocks and reserved forests (under the Indian Forest Act, 1927) of Banjar and Halon, along with the Balaghat and Mandla districts, in addition to forest blocks of Seoni, were areas of major timber extraction operations. Post-independence, Kanha National Park was carved out of the contiguous forests of Mandla and Balaghat districts in 1955, and Pench National Park in the neighboring Seoni district in 1983. Kanha and Pench were declared Tiger Reserves in 1973 and 1992, respectively, under the Government of India's flagship Project Tiger.

Presently Balaghat district has forest cover under three management types. The Territorial forests of the Balaghat circle span an area of 4775.54 km², with 3798.55 km² under Reserved Forest, 976.99 km² under Protected Forest (a part of Kanha Tiger Reserve), and the remaining under the Madhya Pradesh Forest Development Corporation for forestry operations. Balaghat circle is further divided into North Balaghat and South Balaghat Forest Divisions. The circle is primarily managed for selective logging, extraction of bamboo (*Dendrocalamus strictus* and *Bambosa bambos*), and collection of Non-Timber Forest Produce (NTFP). Balaghat has the largest forest area under bamboo cover in Madhya Pradesh, at about 2383.34 km², followed by the neighbouring district of Seoni (355.69 km²) (MP State Bamboo Mission, n.d.).

The primary occupation of local communities is rain-fed single-crop cultivation. Non-monsoonal farming is practiced in areas close to rivers and reservoirs. Animal husbandry, especially rearing of cattle, goats, and poultry, are practiced for sustenance. Almost all communities depend on the forests for resources, with a higher degree among tribal communities in the region. NTFP collection is a traditional livelihood activity during non-agricultural season, with many forest produce including fruits, flowers, seeds, leaves, tree resin, and wild mushrooms being extracted for direct use or income generation. Major NTFPs include mahua flower and fruit, tendu leaf, char fruit (*Buchanania lanzan*), bhilwa fruit (*Semecarpus anacardium*), aonla fruit, mahul leaf (*Bauhinia vahlii*), harra, bahera as well as herbs such as safed musli (*Chlorophytum borivilianum*) and shatavari (*Asparagus racemosus*). Harvest of these major NTFPs has been streamlined and standardized by the state government, providing seasonal employment in the case of tendu leaf collection. In 2016, a minimum support price (Ministry of Tribal Affairs, 2018) was proposed for minor forest produce by the Government of India, ensuring a stable income generation option from NTFP for forest-dependent communities. Communities also have the right to collect dry, fallen wood for household use as fuelwood.

The major exports from Balaghat include wood, bamboo, rice, manganese, and copper (Ministry of MSME, 2016) – the former two are extracted mainly from natural stock and plantation sites (especially for teak and bamboo). In contrast, manganese is extracted through a major dolomite mine in Bharveli and Ukwa, and copper from Malanjkhand. All three sites are very close to Kanha Tiger Reserve and the corridor area between Kanha and Pench Tiger Reserves. Madhya Pradesh accounts for 14% of India's manganese ore – a majority of which comes from Balaghat alone. Bharveli is the largest underground operational mine in the subcontinent. Malanjkhand is India's largest open cast copper mine, accounting for 41.39% of India's

copper ore reserve (ENVIS Centre of Madhya Pradesh's State of Environment, 2018). Balaghat is also identified as an important mineral site for bauxite (Aluminium). These mineral deposits make Balaghat an important region of interest for natural resource extraction. Although the district lacks major roadways (such as National Highways), the Gondia-Balaghat-Nainpur narrow-gauge railway was recently upgraded to the broad-gauge railway line (Fig 2).

In the early 1900s, the district supported a notable population of tigers. The Balaghat Gazetteer (Low, 1907) mentions tigers to be "found in all parts of the District, more especially to the north and west where the jungles match with those of Mandla and Seoni" – indicating a historic contiguous tiger population the landscape once supported. While there are no historical estimates of tiger density in the region, the gazetteer mentions that a large number of tigers were shot annually to prevent livestock depredation, indicating human-carnivore conflict.
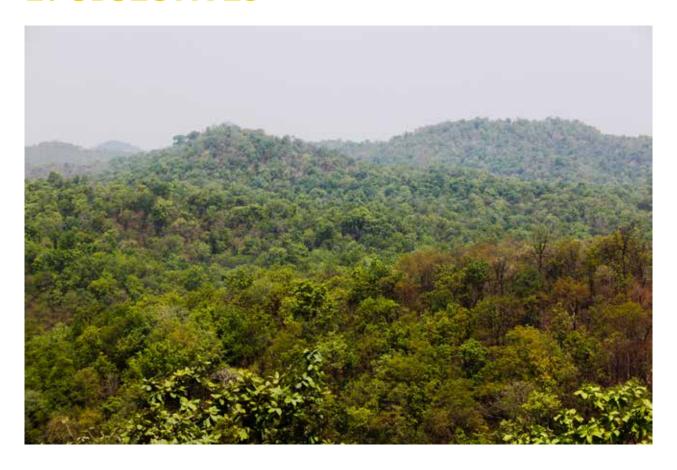
Wild animals as Asiatic wild buffalo (*Bubalus arnee*) and Asiatic elephants (*Elephas maximus*) were extirpated from Balaghat in the early 1900s. In contrast, the hard-ground barasingha (*Rucervus duvaucelii branderi*) population was on the brink of extinction in the 1970s until stringent conservation measures in Kanha National Park successfully recovered the last remaining population. The Eurasian otter (*Lutra lutra = L. vulgaris*), once found in all parts of rivers of the district (Low, 1907), was rediscovered in 2016 during WWF-India's tiger monitoring exercise (Jena et al., 2016). Other notable species of mammals of the region include the Indian leopard (*Panthera pardus fusca*), sloth bear (*Melursus ursinus*), dhole (*Cuon alpinus*), jungle cat (*Felis chaus*), chital (*Axis axis*), sambar (*Cervus unicolor*), gaur (*Bos gaurus*), northern plains langur (*Semnopithecus entellus*), wild pig (*Sus scrofa*), and chousingha (*Tetracerus quadricornis*).

The forest cover of Balaghat increased between 2005 (52.63%) and 2009 (54.13%) by 1.5% but has seen a 0.7% decline between 2011 (54.14%) and 2019 (53.44%) (Forest Survey of India, 2019), although the dense forest cover has increased by about 1% in the same period. The human population density has increased from 162 to 184 persons/km2 between 2001 and 2011, with a 1.5% increase in urban population, whereas the rural population has decreased by the same rate. The average decadal population growth rate of Balaghat is 13.6% (14.4% in rural areas and 11.4% in urban areas). The forests are now restricted to contiguous and fragmented patches in a matrix of human settlements, agricultural fields, open-cast mines, and bisected by linear infrastructures such as roads (including more than 370 km of state highways), canals, and overhead transmission lines. Also, recurrent forest fires have resulted in degradation of the forests, with as much as 8 – 25 km² of forest burnt between 2016 and 2018 (Garg, 2019). Balaghat district ranked first in terms of forest fires in the state of Madhya Pradesh. Balaghat has been earmarked as a priority tiger recovery site within India because it is an area with high potential to support breeding resident tiger population, potentially at densities that are manifold higher than at present. This is an important goal since the identified recovery site is embedded in a larger forest patch spanning about 4,000 km² of the forest. If the tiger population in Balaghat is recovered and protected, in time, it may enable the growth of tiger populations in surrounding Forest Divisions in Madhya Pradesh, Chhattisgarh, and Maharashtra. Conversely, for tiger recovery in Balagaht to occur expediently and be sustained, these conditions that support recovery also need to be created and maintained in these surrounding divisions (WWF, 2014). The process of tiger recovery is slow, dependent on achieving efficacy and convergence of multiple management and planning goals. For tiger recovery to occur, plans with a holistic look at protection, land use planning, stakeholder involvement, financial and political support and influencing development planning to minimise the impacts of infrastructure and resource extraction on wildlife populations will be required.

This report is a detailed study into the tiger densities and indicative leopard numbers in the TX2 site, the intensity of forest fires, human-wildlife interactions with respect to human injury or loss of life, livestock depredation, and wildlife crime rate by identifying critical areas requiring interventions in the TX2 site. The area sampled during the early years of the survey was small compared to more comprehensive studies in 2017. Although no comprehensive estimates of prey densities exist at the moment, encounter rates suggest that chital, wild pigs, and sambar occur at densities lower than the neighbouring Protected Areas such as Kanha and Pench Tiger Reserves. This report is to advance our understanding of dimensions of the conservation issues in Balaghat and to help prioritize future management.

2. OBJECTIVES

1

Estimate tiger and leopard population sizes and densities in the Balaghat TX2 site over three years and investigate the activity of large carnivores and their prey relative to human activity.

2

Understand the social dimensions of the Balaghat TX2 site with special reference to human-wildlife interactions and forest dependence.

3

Identify pressures impacting tiger population recovery and key potential interventions.

3. PROFILE OF BALAGHAT TX2 SITE

Tigers merely occupy roughly 5% of their historical range (Harihar et al., 2018). In 2010, the 13 tiger range countries committed to a 12-year goal of doubling the numbers of wild tigers by 2022 at the St. Petersburg Declaration on Tiger Conservation. The declaration adopted National Tiger Recovery Priorities (NTRPs) and the Global Tiger Recovery Program (GTRP) outlining action plans to strengthen national policies, build institutional frameworks, and secure financial commitments (Global Tiger Initiative Secretariat, 2011; Harihar et al., 2018). With the support from GTRP, the Hua Hin Declaration on Tiger Conservation at the First Asia Ministerial Conference on Tiger Conservation established the goal to reverse the rapid decline of wild tigers and to strive to double the number of wild tigers across their range by 2022, called TX2 (Global Tiger Initiative Secretariat, 2011). Of the 18 globally recognized TX2 sites, 8 are in India and two in central India – Balaghat and Achanakmar Tiger Reserve (Harihar et al., 2018).

3.1 Geographic profile

The Balaghat circle is connected with several protected areas in the Satpuda Maikal Landscape (SML), now also referred to as the Central Indian Landscape (Fig 1). Its northern-most areas form a portion of the corridor between the Kanha Tiger Reserve to the east with forests of Seoni circle and the Pench Tiger Reserve in the south-west, an area referred to as the Kanha-Pench Corridor. Borah et al. (2015) observed 84% tiger occupancy in the Kanha-Pench corridor and suggested that large blocks of forests may support a small population of tigers.
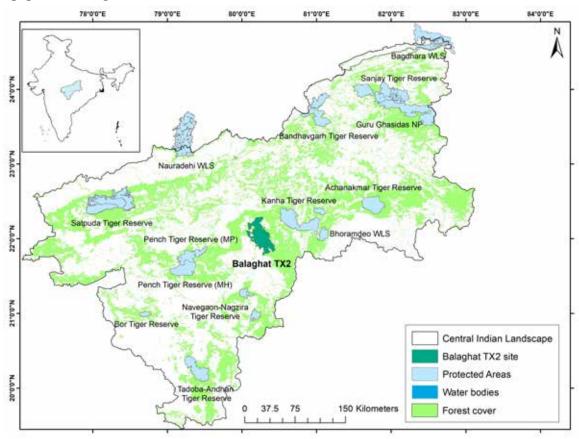
Fig 1. Map of Central Indian Landscape showing location of the Balaghat TX2 site and the Protected Areas.

Balaghat circle also provides connectivity between the Kanha Tiger Reserve and the Navegaon Nagzira Tiger Reserve, a reserve established in 2013 in the state of Maharashtra. The forests of Balaghat adjoining the state of Chhattisgarh provide connectivity with the Achanakmar Tiger Reserve via Bhoramdeo Wildlife Sanctuary, also in the Maikal hill range. Recent studies have documented gene flow between tiger sub-populations in this region, suggesting that the forest linkages between these Protected Areas remain functional (Joshi et al., 2013; Sharma et al., 2013).
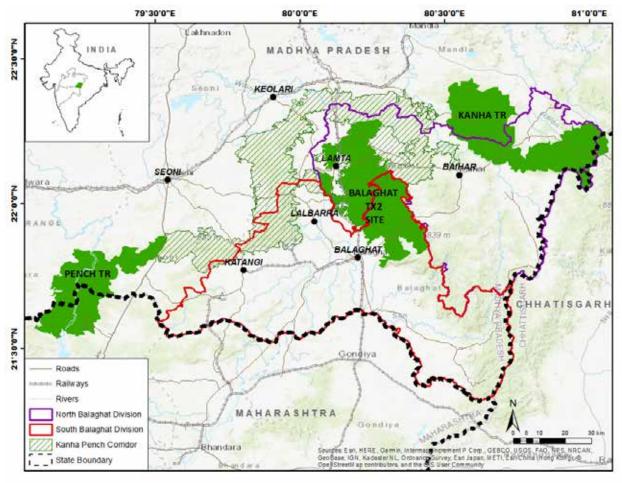
Fig 2. Map showing location of Balaghat TX2 site with respect to the corridor between Kanha and Pench tiger reserves, and the nearby cities.

A forest area (963 km^2) comprising three ranges (North and South Lamta) of North Balaghat Forest Division and two (Loughur and Balaghat) of South Balaghat Forest Division have been designated as a tiger recovery (TX2) site by WWF-India (Fig 3). The site is a contiguous forest area with low human densities (13.4 persons/km), and currently harbours tigers at a low density but has significant potential for recovery because it is connected with Kanha and Pench Tiger Reserves, which have a high tiger density of over 5 tigers/100 km^2. The area is characterized by hills, tablelands, and plains and serves as the catchment of the Wainganga river, which flows to the west of the TX2 site. In addition to several perennial streams, Uskal River, a major tributary of the Wainganga flows through the TX2 site. Two reservoirs, one built on the Wainganga river in Dhuti, and another in Gangulpara, supply water for small-scale non-monsoonal farming around the TX2 site.

3.2 Socioeconomic profile

There are 35 villages within the TX2 site (Fig 3) with a cumulative population of 12,894 (Office of the Registrar General & Census Commissioner, 2015) and a density of 13.4 persons/km². Nine of these villages are small and have 100 or fewer people, and another seven villages have between 100 and 300 persons. Dhansuwa in Balaghat block is the largest village in the TX2 site, with a total population of 1,530 individuals (Census, 2011). Most of the villages were settled as forest villages for timer extraction purposes in the 1800s. The tribal communities comprise 55% of the total population of the TX2 site, compared to 22.5% for the district of Balaghat. The literacy rate of the TX2 site is 57.45% compared to 77% of the district (see Appendix 2).

The TX2 site is surrounded by more than 50 villages with a population of 38,669 persons within 5 km. A majority of these villages (n = 15) have a population of more than 900 persons. The nearest town is Lamta having the largest population of 3,464, followed by Samnapur (population 2,721) and Changotola (population 2,103) (Directorate of Census Operations Madhya Pradesh, 2015). The settlements are higher in density to the west and east of the TX2 site, interspersed with forest pockets, which form one of the pathways of the Kanha-Pench corridor (Jena et al., 2011; Rathore et al., 2012).

The northern and southern parts of the TX2 form a contiguous forest patch with West Mandla forest division to the north, and an extension of the South Balaghat forest division to the south. The State Highway (SH) 26 passes through the southern portion of the TX2 site, and SH 11 passes along the western edge, both these roads are two-lane highways with moderate traffic, whereas the Nainpur-Balaghat railway line currently under construction for broad-gauge trains passes through the TX2 site along its western flank (Fig 3).

A socio-economic study by WWF-India (2014, unpublished) in 16 villages (11 within and five on the periphery of the TX2 site; 573 households) revealed all households depended on forests for at least a part of livelihood, including livestock grazing, and NTFP and fuelwood collection.

Since this is a territorial (non-protected) forest area primarily managed for timber extraction
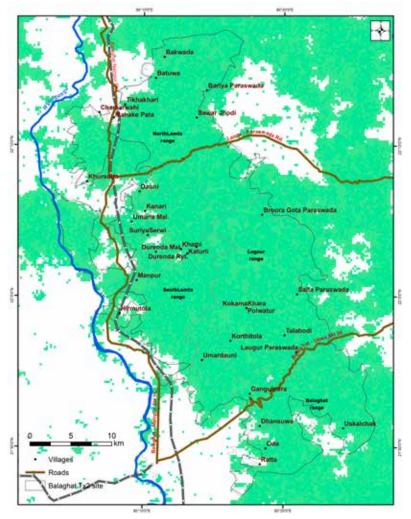
Fig 3. Map showing location of villages within the TX2 site, major roads, and the fragmented forest surrounding the TX2 site.

Mahua flowers are an important NTFP for the local communities in the Balaghat TX2 site, and forms a major part of the income during summer months.

and forestry operations, livestock grazing is permitted in areas where active forestry management is not being undertaken, and collection of dry wood as fuel and NTFP is permitted. The study revealed that the consumption of fuelwood in these villages averaged 9 kg in summer, 13 kg in monsoon, and 19 kg in winters per household per day. NTFP collection was observed in over 80% of the households surveyed, with major income from mahua flower collection at Rs 2,500 per season per household. The collection of tendu leaves provided an income of approximately Rs 1,700 per season per household. The respondents have reported a marked decrease in the amount of tendu leaves collection, requiring them to venture farther inside forests to harvest. The calendar of forest-dependent activities by the local communities in the TX2 site is provided in Table 1.

The primary schools are at an average distance of 3 km by forest roads and secondary school at least 17 km away (3–30 km) from the surveyed villages. Drinking water is accessed mainly through groundwater. During the non-agricultural season, labour work under government schemes such as the National Rural Employment Guarantee Act (NREGA) provides a vital source of income. The National Rural Employment Guarantee Act (NREGA) employed less than half of the population. The forest of Balaghat is actively managed for forestry operation including timber and bamboo extraction. Local populations are employed as labourers in this forestry operation and also to dig trenches, assist with fire management, and support other management activities.

Table 1. Calendar of forest-based resource extraction by local communities in the Balaghat TX2 site

SL	Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Fuelwood	▓	▓	▓	▓	▓	▓				▓	▓	▓
2	Small timber/pole					▓							
3	Thatch grass					▓							
4	Bamboo	▓	▓	▓									
5	Mahua			▓	▓								
6	Tendu leaf					▓							
7	Mahul leaf											▓	▓
8	Wild mushroom								▓				
9	Harra										▓	▓	
10	Bahera	▓	▓								▓	▓	
11	Char				▓								
12	Aonla	▓											▓
13	Livestock grazing	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓

3.3 Human-wildlife interaction

A majority of the residents in 16 villages within the tiger recovery site (WWF, 2014) have received individual forest rights under the Forest Rights Act, 2006, with the land being used for farming. Crop damage by wildlife such as wild pig and northern plains langur a significant concern for rain-fed agriculture. The study revealed that people abandoned millet farming due to the high frequency of damage caused by wild animals. Currently, the most effective mitigation for crop-raiding is camping in farmlands during nights.

SH 26 passes through the Balaghat TX2 site, connecting Balaghat with Baihar and Malanjkhand, a copper mining site. Wild animals regularly cross this highway.

The Madhya Pradesh Forest Department provides monetary compensation for human injury or death, and livestock death, resulting from an encounter with a wild animal. Within the TX2 site, between 2001 and 2015, 663 incidences of human-wildlife conflict have been registered with the forest department, 18 of which resulted in the death of the victims (Madhya Pradesh Forest Department, n. d.). A majority of incidences were caused by wild pig (n = 309), sloth bear (n = 230) and jackal (n = 73). With respect to livestock depredation events, the TX2 site has documented over 1,174 cases between 2010 and 2018 – 99% of the attacks involved tigers (37%) and leopards (62%). These numbers indicate incidences documented by the forest department and provides an overview of the human-wildlife interaction in the TX2 site.

4. METHODS

Three camera trap surveys were carried out between 2014 and 2017, and between 44 and 100 grids were surveyed (Table 2). The survey period varied between 55 and 84 days among different survey sessions. Due to logistical constraints, the TX2 site could not be surveyed in its entirety in the yearly monitoring exercise. Camera traps were deployed with the assistance of the forest department staff at locations having a high probability of encountering tigers, including forest roads, paths leading to a source of water, animal trails, etc. Individual tigers were identified based on stripe patterns. Tigers approximately two years of age and older (post-dispersal) were identified based on their distinct stripe patterns. Data were collated in a data matrix with capture records for individual tigers in rows (entered as 1 or 0), based on whether or not an individual was 'captured' at a location on any given occasion.

Table 2. Sampling effort for camera trap survey in Balaghat TX2 recovery site.

Session	No. of grids surveyed	Camera trapping period	No. of trap nights	Mean inter-trap spacing (km)	Trapping Extent (sq. km)
2014-15	44	22 Nov 2014 - 13 Feb 2015	3696	1.54	138.97
2015-16	67	11 Dec 2015 - 4 Feb 2016	3505	1.42	282.04
2017	100	17 Jan 2017 - 26 Feb 2017	4100	1.64	532.27

Tiger density and abundance were estimated using spatially explicit capture-recapture models (implemented in package secr, version 3.1, Efford et al., 2018) in R version 3.5.1 (R core team, 2018). Capture information for adult individuals was collated and referenced by sampling occasion and capture location. We consistently used a 35 km buffer around the area surveyed with camera traps over which home range centres of animals in the sampled area could be distributed, excluding non-habitat areas. The buffer area also helped capture the movements of tigers whose territories only partially overlapped with the camera trap grids.

We used parsimonious formulation $g_o(.)\sigma(.)$ to model the detection parameters g_o (baseline encounter probability) and σ (parameter describing the movement of tigers around their activity centres). We assumed animal movement around home range centres to be adequately described by a half normal function. The estimated abundance of tigers within the TX2 site (963 sq. km) was calculated following Efford and Fewster (2013).

Given that the area surveyed within the TX2 site varied across years based on camera trap availability, we have standardized density estimation for tigers by defining a common state space area adopted for the analysis for all four years of data. Yet, the demographic estimates across years may not be comparable because of varying survey effort across years.

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Dr Dhirendra Bhargava (IFS), the then CCF, Balaghat circle, on a visit to inspect camera trapping work in the Balaghat TX2 site.

We plotted the daily activity pattern of each species and then measured the overlap between carnivores, humans, and livestock following Ridout & Linkie (2009). A non-parametric circular kernel-density function was employed to assess daily activity patterns. A coefficient of overlapping (D) was used to measure the extent of overlap between two kernel-density estimates, taking the minimum of the density functions from two sets of samples being compared at each point in time. Overlap was assumed as the area lying under both of the density curves. The coefficient of overlapping ranged from 0 (no overlap) to 1 (complete overlap) (Ridout & Linkie, 2009; Linkie & Ridout, 2011, Azevedo, et al. 2018). We used estimator Δhat as we had a large sample size (sample size of >75 camera records), as suggested by Meredith & Ridout (2016). Analyses were performed in the R environment v.2.1 (R Development Core Team 2014) using the 'overlap' R-package (v3.2) (Meredith & Ridout, 2016).

We obtained fire incidence points for the year 2017 from FIRMS (2019) primarily to understand the areas where fire was recurrent for the survey year of 2017. We created an optimized hot spot map that creates a map of statistically significant hot and cold spots using the Getis-Ord Gi* statistic. We identified beats with a high frequency of fire incidences using the significant z-scores.

We obtained data on livestock depredation events, injury to humans or death resulting from an encounter with a wild animal, and wildlife crime cases, from the Madhya Pradesh Forest Department online portal (mpforest.gov.in) primarily to identify beat-wise areas with prevelant human-wildlife interactions.

5. RESULTS

WWF-India has been monitoring tiger populations in the TX2 site since 2014 (Fig 4). Camera trapping effort for the year 2014-15 amounted to a total of 3,696 trap nights, yielding 78 photographs of tigers at 44 trap stations covering an area of 139 km². In 2015-16, survey effort was 3,505 trap nights, yielding 108 photos of tigers at 67 trap stations covering an area of 282 sq km. For the year 2017, the trapping effort of 4,100 trap nights produced 101 photographs of tigers at 100 trap stations covering 532 km². Tiger capture events between 2014 and 2017 are summarized in Table 3.

Table 3. Summary of individual tiger capture events for Balaghat TX2 site.

Session	Total	Male	Female	Unclassified
2014-15	7	2	2	3
2015-16	4	1	2	-
2017	9	4	5	-

Here, we present results of the tiger densities and abundances, leopard captures, incidences of forest fires, human-wildlife interactions, and wildlife crime in the TX2 site, and propose for the examination of habitat quality for wild ungulates, threats that may hamper revitalizing wild ungulate prey base, and recovery of wild tigers as next crucial steps in determining and realizing the potential of this site.
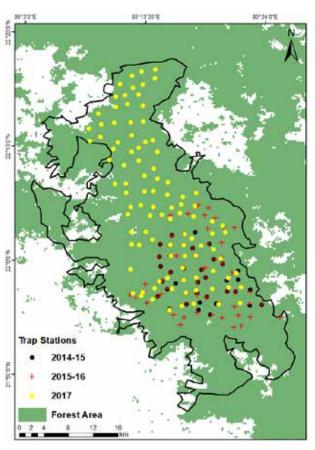
Fig 4. Camera trap locations for each survey period: 2014-15, 2015-16, and 2017 in Balaghat TX2 site.

5.1 Estimates of tiger density and abundance

The maximum likelihood estimates of tiger density were calculated from spatial capture-recapture models. The estimates for g_0 was 0.006 (±0.001), and σ was 5.60 (±0.76) km (Table 4).

Table 4. Maximum likelihood estimates of tiger density (tigers/100 km²) from spatial capture- recapture analysis. Model selected was $g_0(.)σ(.)$.

Sessions	M (t+1)	Density (SE)	95% CI	g_0 (SE)	95% CI	σ (km)	95% CI
2014-15	7	0.87 (0.37)	0.39-1.94				
2015-16	4	0.46 (0.25)	0.16-1.26	0.006 (0.001)	0.004-0.009	5.60 (0.76)	4.30-7.30
2017	9	0.76 (0.28)	0.38-1.52				

The most parsimonious model selected was the null model due to the smaller sample size. We estimated tiger abundance from the ML-secr models – within the boundary of the TX2 site. The abundance of tigers (from a spatially explicit model) in the TX2 site during the study period ranged between 5.53 and 10.11 (Fig 5). However, the extent of habitat surveyed with camera traps varied across the three years hence are not comparable.
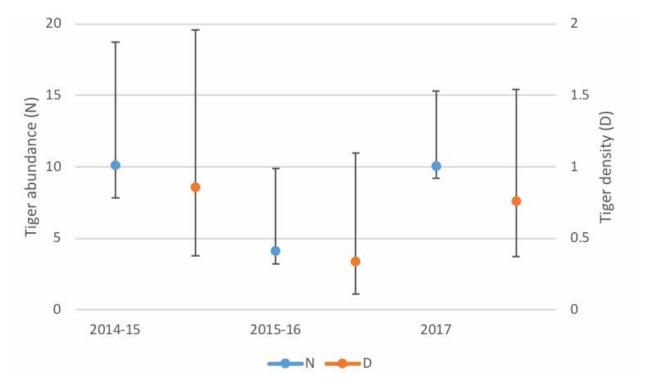
Fig 5*. Estimates of tiger abundance and density (tigers per 100 km²) along with 95% confidence intervals for the Balaghat TX2 site.
*Sampling effort varied across the three years so the estimates are not strictly comparable.

An estimated 4 to 9 tigers reside in portions of the TX2 site surveyed. It is difficult to speculate whether tigers occur in similar densities elsewhere in the region , given that the TX2 site covers 20% of the total area of the Forest Circle. The 963 km² TX2 area earmarked by WWF-India for tiger recovery presently supports lower densities of tigers – between 0.46 and 0.87 per 100 km²– than the adjacent PAs with which it is connected; Kanha (6.1 ±0.71 tigers/100 km²) and Pench (5.67 ±0.81 tigers/100 km²) tiger reserves (Jhala et al., 2015).

5.2 Distribution of tigers

We generated pixel density maps from the spatial capture-recapture models (Fig 6). The tiger density map for the year 2017 (Fig 6a) identified three ranges and 29 beats of 92 surveyed showing comparatively higher densities of tigers than the rest of the region. Tigers occurred at higher densities in the northern part of the TX2 site in the North Lamta range and the southern part, in Balaghat and Loughur ranges (see Appendix 1).

The northern (North Lamta range) part of the TX2 site connects with East and West Baihar ranges. Along with the eastern (Lal Barra range) parts of the TX2 site, it forms a part of the Kanha-Pench corridor, with the southern region (Balaghat and Loughur ranges) extending southwards towards the non-protected areas of the South Balaghat Forest Division. These areas form an important support region of the TX2 site.

During the monitoring period, two females captured in 2014-15 were also captured in 2017. In 2015-16, a female with a cub was captured in the Loughur range, suggesting that a few females are resident in the TX2 site. One individual male captured in 2017 was poached in 2018, while the rest were captured only during one monitoring period. The TX2 site has seen high fluctuations of the male-female ratio over the monitoring periods.

Fig 6 a

Fig 6 b

Fig 6 c
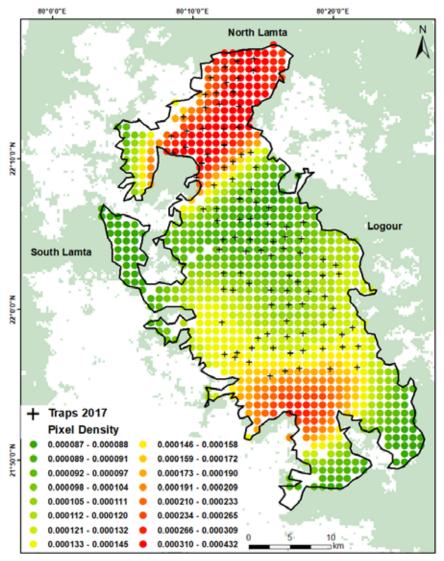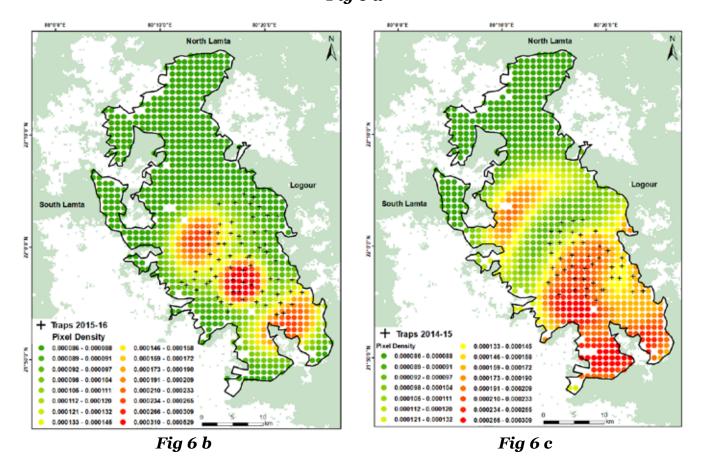
Fig 6. Density maps based on pixel density values (tigers/km²) for: (6a) 2017, (6b) 2015-16, (6c) 2014-15.

5.3 Leopard population

Based on the 2017 sampling efforts, leopards were photo-captured in 54 of the 100 camera trap stations. A total of 36 individuals were identified, of which 10 were males, 24 females, and two unidentified individuals. The sex ratio in the TX2 site was 1:2.4 (0.42), which was at par with the sex ratio of Kanha Tiger Reserve at 0.50 ±0.02 (Kumar et al., 2019). Of the total captures, 19 individuals were re-captured 4.3 (±0.67) times and 17 individuals were captured only once.

Owing to the high number of single-occasion captures, we refrained from using spatial capture-recapture analysis and provide indicative details on leopard presence in the Balaghat TX2 site. The maximum convex polygon (MCP) was 24.42 km² for a male re-captured on ten occasions, and 5.60 km² for a female re-captured on three occasions. Leopards were photo-captured in 32 of the 92 beats of the TX2 site (Appendix 1).

5.4 Mammalian diversity

Camera traps allow for monitoring species diversity, abundance, and changes in abundance and distribution over time. In Balaghat, 26 species of mammals were recorded of the 67 terrestrial mammalian species recorded from the state of Madhya Pradesh (39% of terrestrial mammalian diversity and 27% of total mammalian diversity of the state) (Harshey & Chandra, 2001).

The highest frequency of photographic captures was of humans and human-related activities (75%), including vehicles, livestock, and free-ranging dogs. Wild animals were captured 25% of the time, of which the majority of the captures were of wild ungulates (9%), primates (8%), and wild carnivores (3%). Species could not be determined in 1% of the photographs.

Camera trapping effort captured 14 species of carnivores and 12 species of non-carnivores, including seven species of ungulates (see Appendix 2). Elusive species such as the rusty-spotted cat *(Prionailurus rubiginosus)*, striped hyena *(Hyaena hyaena)*, and ratel *(Mellivora capensis)* were captured only at one to three locations. Photographic captures of Eurasian otter at one location and of a Dhole at three locations were important indicators of these species' existence outside of Protected Area network.

A mother bear carrying two cubs and a pair of leopards passing in front of a camera trap in the in the Balaghat TX2 site.

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5.5 Activity patterns

Information on the coexistence of wildlife with humans, especially in non-Protected Areas, are lacking. In areas with user rights for extraction of NTFP, fuelwood, or using forests as a passage for humans, such information is vital from a managerial perspective to mitigate human-wildlife conflict. We present activity patterns to understand temporal overlaps in movement between wild animals (tiger, leopard, sloth bear, and wild ungulates) and humans, and between wild and domestic animals, in the TX2 site (Fig. 8–10).
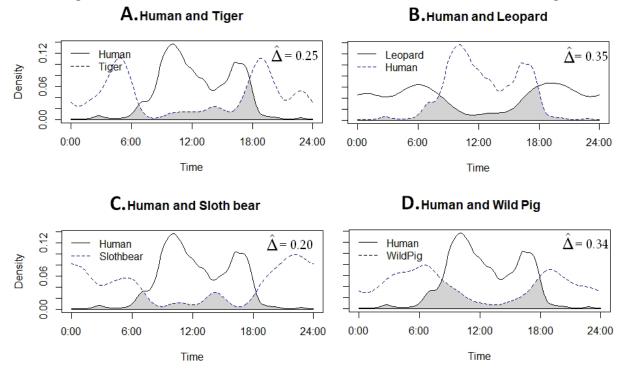
Fig 8. Activity patterns showing area of activity overlap (Δhat). As Δhat approaches 1, there is complete overlap in activities of the two subjects. A = Human and tiger, B = Human and leopard, C = Human and sloth bear, D = Human and wild pig.

Activity patterns between humans and three wild carnivores, the tiger, leopard, and sloth bear, ranged between 0.2 and 0.35, and between humans and wild pig at 0.34. The peak overlap between humans and tigers was in the evening (between 1700 and 1800 hrs), whereas that for leopards showed two peak activity overlaps at 0800-0900 hrs and 1700-1800 hrs. Similarly, the peak activity overlap between humans and wild pig was at 0700-0800 hrs and 1800-1900 hrs. Activity overlap for humans and sloth bears was lowest (Δhat = 0.20), with three peaks at 0600-0800 hrs, 1400-1500 hrs, and 1800-1900.

A. Cattle and Tiger

B. Cattle and Leopard

C. Dog and Large Ungulates

D. Dog and Small Ungulates
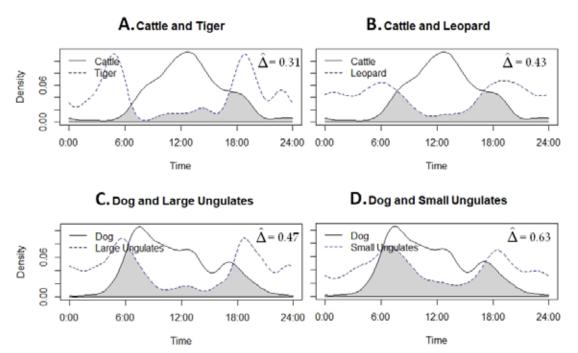
Fig 9. Activity patterns showing area of activity overlap (Δhat). As Δhat approaches 1, there is complete overlap in activities of the two subjects. A = Cattle and tiger, B = Cattle and leopard, C = Dog and large ungulates, D = dog and small ungulates.

We noted higher activity overlap between cattle venturing into forests for grazing and leopard (Δhat = 0.43) than between cattle and tiger (Δhat = 0.31), both carnivores showed peak overlap between 1700 and 1900 hrs. We compared interaction between free-ranging dogs and ungulates to understand interactions because dogs are known to hunt wild ungulates. The activity overlap between free-ranging dogs and large ungulates (including gaur, sambar, and nilgai) was lower (Δhat = 0.47), than that with small ungulates (including chital, barking deer and antelopes, Δhat = 0.63).

Tiger and Leopard
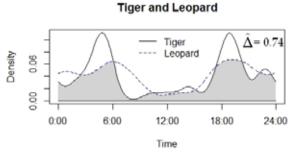
Fig 10. Activity pattern between tiger and leopard showing activity overlap (Δhat).

The activity pattern between the tiger and leopard was compared to understand the habitat and resource sharing vis-à-vis temporal activity between the two sympatric carnivores. We found the activity overlap (Δhat = 0.74) to be higher than expected. Our findings are similar to that of activity patterns between the tiger and leopard outside the PA (Δhat = 0.72) than within the PA (Δhat = 0.58) as documented by Carter et al. (2015) in Chitwan National Park, Nepal.

5.6 Anthropogenic factors

The TX2 site has three clusters of 35 villages; the northern portion has a low density of seven villages with a population of 3,147. The central region has a cluster of ten villages with a population of 3,390 persons, and the southern portion has nine villages with a population of 792 persons (Fig 3; Appendix 3). Since

this is a non-Protected Area, human activities are permitted for livestock grazing, fuelwood collection, and NTFP harvest to a certain extent. It is essential to understand the land-use by humans to understand and devise strategies to manage human-wildlife interactions.

Forest dependence

A socio-economic study of 16 villages showed that all households depended on forests for at least a part of their livelihood. Agriculture is mainly rain-fed, with rice being the major crop, followed by maize, kodo and kutki (millets), mustard, gram, and wheat, which are primarily cultivated for self-sustenance where irrigation facilities are available (WWF-India, 2014). Livestock rearing is practiced in all villages, mainly for agricultural work, manure, and milk. Dominant domestic animals include cows and bulls, buffalo, goat, and poultry. Income from animal husbandry is minimal, with only nine households engaged in selling milk at local markets. Animals are mostly led into forests for open grazing, which travel up to 3–6 km inside forests.

WWF-India staff engaging with Self Help Group (SHG) members to discuss the objectives for formation of SHGs and the 13 sutra of SHGs, including a discussion on environment conservation.

The site is also utilized by over 50 peripheral villages, especially for fuelwood collection and livestock grazing. The effects on the forests are reflected mainly as competition for fodder and space between domestic and wild ungulates, habitat degradation promoting the growth of non-palatable and invasive species such as charota *Cassia tora*, chhind *Phoenix acaulis*, and *Lantana camara*. In addition to the impacts of forest fires on natural regeneration, these issues will be considered in a future study to assess factors influencing wild ungulate and tiger densities.

Forest fires

Balaghat circle ranks first in terms of forest fire incidences in Madhya Pradesh. In 2017, 1,607 incidences of fire were recorded by the Madhya Pradesh Forest Department (872 in South Balaghat and 735 in North Balaghat forest divisions), followed by Dindori (n = 1,067). Between 2016 and 2018, 8–22.5 km²of the forest was burnt in the Balaghat circle (Garg, 2019).
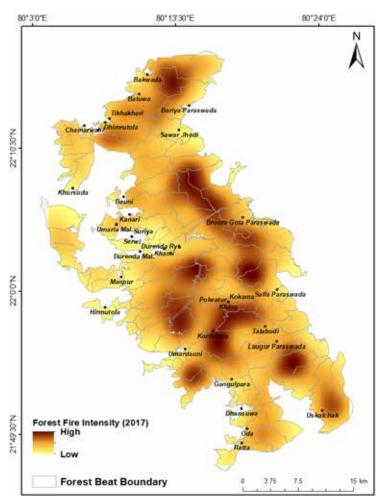
Fig 11. Hot spot map of forest fire incidences for the year 2017 in Balaghat TX2 site. Fire incidences obtained from NRT VIIRS 375 m Active Fire product VNP14IMGT. Available on-line [https://earthdata.nasa.gov/firms]. doi:10.5067/FIRMS/VIIRS/VNP14IMGT.NRT.001.

Patterns of forest fire coincide with the collection of NTFP, such as mahua flower and tendu leaf. Forest fire incidences between 2017 showed an abrupt increase in frequency between February (n = 11) and March (n = 397), which is the peak mahua flower collection season, and further increased in April (n = 758) when forest areas are burnt to promote tendu leaf sprouting which are then collected in May when the fire frequency reduced (n = 34) (FIRMS, 2019). Being mostly mixed and moist-deciduous, chances of natural outbreaks of a forest fire, such as crown fires, are minuscule, hence controlled burning used to prune understorey or promote leaf growth, in addition to the accidental spread of fires from agricultural fields, are major causes of forest fires. Fire control regime for the prevention of the fire is inadequate, as the scale of the problem is too large and extreme to be effectively managed by "fire watchers" hired during the dry season to control the spread.

Based on the Getis-Ord GI* statistic, a hot spot map of fire incidences for 2017 identified seven beats with a significant z-score (p = 0.00059–0.03), and a total of 23 beats with very high to medium frequency of fire incidences (Fig 11, see Appendix 4). The highest frequencies of forest fires were in forested areas farther away from villages of high population density. The impact of forest fires on forest regeneration and distribution of wild ungulates, especially important prey species such as chital, sambar, and wild pig and the distribution, abundance, and recruitment of tigers requires further investigation.

5.7 Human-wildlife interaction

Negative interactions between humans and wild animals, resulting in injury, loss of life and damage to property are often termed as human-wildlife conflict (HWC). HWC is a result of shared resources, including space, food, and water, and also chance encounters. HWC is exacerbated by factors including reliance on forest resources for livelihood, loss of forest cover, and a sustained or a growing wildlife population and ineffective mitigation measures to prevent or reduce the interactions. It is either direct – leading to injury or death of a person, or indirect – damaging crop or depredation of livestock, leading to economic loss. In Balaghat, farmlands close to forested areas are often damaged by wild herbivores, including wild pig, chital, and sambar in varying degrees. Poultry is depredated by canids such as jackal, wolf, and hyena, and small felids, including jungle cat. Livestock such as cattle are depredated by tiger and leopard, and seldom by wolf and hyena. In this section, we discuss interactions between people and wildlife and livestock depredation by wildlife.

A sounder of wild pigs along the edge of the forest. Wild pigs are among the most widespread species responsible for crop damage. In the Balaghat TX2 site, they cause maximum damage to paddy, especially a month before harvest when the crop is ripe.

Conflict resulting in human injury or loss of life

In Balaghat, most incidences of injury or loss of life resulting from direct encounters with wild animals occur in forest areas and farmlands close to forests – a majority are attributed to wild pig (47%) and sloth bear (35%), followed by jackal (11%) (data from 2001 to 2015; Madhya Pradesh Forest Department, n.d.). Sloth bear and wild pig have resulted in the most number of human deaths. The activity pattern of humans and wild pig (Δhat = 0.34; Fig 7) peaks between at 0800 hrs when human activity along forests, forest edges, and farmlands is increasing, and wild pigs are retreating deeper in forests, and around 1800 hrs

when human activity is decreasing and wild pigs are becoming active. Anecdotal references suggest that wild pig and human encounters are mostly along farmlands along forest edges. The activity patterns of humans and sloth bears were lowest (Δhat = 0.20) among large carnivores, although the encounter rate is high. Studies in the Kanha-Pench corridor have shown encounters occurring between 0600 hrs and 1200 hrs, with most attacks recorded between 0800-0900 hrs (Dhamorikar et al., 2017). This difference can be attributed to the fact that most encounters in the forests (81% of all incidences) were chance encounters when people ventured to harvest NTFP (42%), collect fuelwood (15%), and during livestock grazing in forests (13%). Encounters were higher in number in summer (40%) since people ventured into forests in large numbers to harvest mahua flowers and tendu leaf, increasing the chances of sudden encounters.

In comparison to the neighbouring protected area Kanha Tiger Reserve (Fig 12), Balaghat has seen higher incidences of sloth bear encounters, but negligible interactions with tigers (one incident, compared to 13% in Kanha). In addition, cases of leopard attacks on people were higher in Kanha (7%) compared to Balaghat (3%). In the case of jackals, it was found that victims usually approach the Forest Department for compensation after a bite. Since there is no provision to distinguish the bite by free-ranging dog and jackal and the fact that no ex-gratia is given for injuries caused by free-ranging dog bites, it is likely that the compensation sought for bites is attributed to jackals than dogs in Balaghat (11%) compared to Kanha (2%).
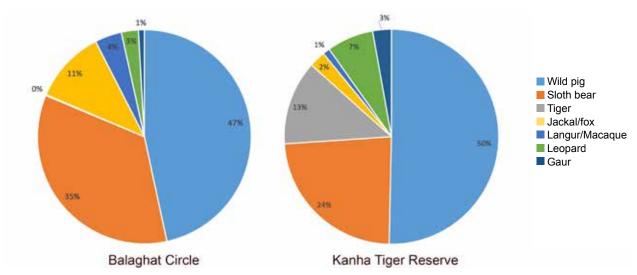
Fig 12. Percent composition of wildlife encounter cases leading to injury or casualty as recorded by Madhya Pradesh Forest Department in Balaghat Circle and Kanha Tiger Reserve (2001-2015).

In the TX2 site, on an average, about 12 incidents per year are registered with the Forest Department. Most injuries resulted from interactions with langur (33%), followed by sloth bear (29%) and wild pig (28%). Between 2001 and 2015, four persons succumbed to injuries from sloth bear and wild pig, both in Balaghat and Loughur ranges in the TX2 site. No recent interactions between people and large mammals, especially tigers, are reported from the TX2 site.

We did not see a temporal pattern in the incidences. However, time, season, and forest-based activities have been observed to play a key role in increased human-wildlife interactions in the region. In the Kanha-Pench corridor area, most encounters with sloth bears took place in summer (40%) during the collection of NTFP such as tendu and mahua, followed by monsoon (35%) during wild mushroom harvest, livestock grazing, and agricultural work along forest edges, and winter (25%) during livestock grazing and fuelwood collection (Dhamorikar et al., 2017). The Forest Department effectively implements an ex gratia

programme for injury or casualty under the Madhya Pradesh Public Service Guarantee Act, 2010, where ex-gratia payment is provided within three days to the family of the deceased due to wild animal attack, seven days in case of an injury caused by a wild animal and 30 days in case of livestock depredation by a wild animal as well as in case of crop damage.

Livestock depredation

Livestock graze in forest areas throughout the year, often traveling several kilometres deeper to access new feeding sites. Waterholes in forests become the only source of water during the dry season for domestic and wild animals, in addition to sharing the same space. These factors expose livestock to wild carnivores. While small livestock such as poultry and goats seldom venture into forests, opportunistic wild carnivores such as jackal, jungle cat, wolf, and hyena, as well as leopards, often lift these animals from village backyards or areas close to human settlements.

According to the records maintained by the Madhya Pradesh Forest Department (2010-2018), Balaghat circle ranks third after Kanha and Bandhavgarh (approx. 500 cases per year) in terms of livestock depredation cases, with approximately 290 cases registered every year. In the TX2 site, an average of 130 depredation cases per year is registered by the Forest Department. If the livestock carcass is found, the owner approaches the department for compensation. A site inspection by the Forest Department field staff for signs of a wild carnivore on the carcass and in the nearby area determines the identity of the carnivore. Based on availability, camera traps are also placed to identify the species. The process of ex-gratia payment to the livestock owner has been streamlined through the Madhya Pradesh Public Service Guarantee Act, 2010.

While species determination is prone to human error, livestock depredation events may be used as a proxy for the presence or absence of a wild carnivore. Interactions with the Forest Department staff, and WWF-India's long-term association in the ex-gratia programme in the Kanha-Pench corridor, have shown less degree of erroneous identification, especially with respect to large carnivores such as tigers and leopards.

In the TX2 site, leopards accounted for most depredation events (62%), followed by tigers (37%) and a small portion by jackals, wolves, and hyena. Between 2010 and 2018, most of the cases were registered in North Lamta (37%) and South Lamta ranges (31%), and between 14–18% in Loughur and Balaghat ranges. In terms of wild carnivore species, tigers accounted for the most number of cases in North Lamta and Loughur (37%), and leopards in North Lamta (37%) and South Lamta (41%) ranges.

Between 2010 and 2018, we observed a marked increase in total and average depredation cases in monsoon (between the months of August and October, n = 470, $\bar{x}$ = 118), compared to summer (n = 330, $\bar{x}$ = 83) and winter (n = 373, $\bar{x}$ = 93) (Fig 13).
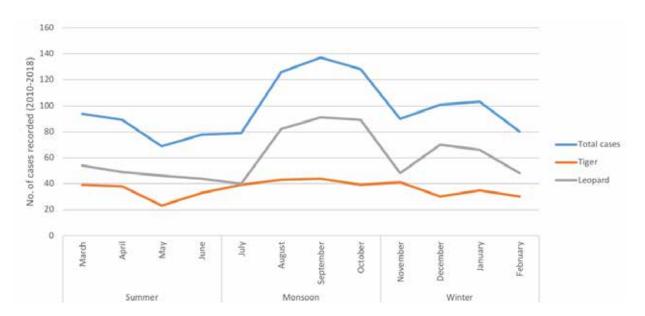
Fig 13. Monthly and seasonal trend of livestock depredation cases registered between 2010 and 2018 in Balaghat TX2 site.
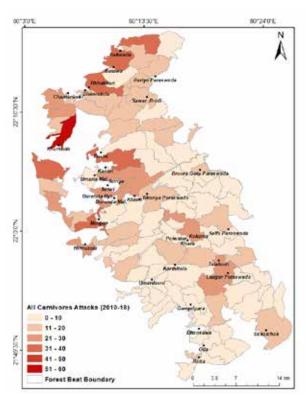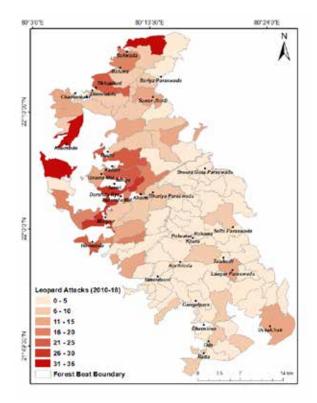
Fig 14a. Map of Balaghat TX2 site showing beats with high frequency of livestock depredation cases for all carnivores.

While livestock depredation cases attributed to tigers ranged between 23 and 44 ($\bar{x}$ = 36) per annum, those for leopards ranged between 44 and 91 ($\bar{x}$ = 60). The peak towards the latter half of monsoon is largely contributed by leopards. With respect to the prey type (buffalo, bull, cow, and goat), there is a marked increase in cows (including calves) preyed upon by leopards in monsoon (n = 160, $\bar{x}$ = 40) compared to summer (n = 112, $\bar{x}$ = 29) and winter (n = 123, $\bar{x}$ = 31) (Madhya Pradesh Forest Department, n.d.). Our hypothesis is that cows are preyed upon more frequently owing to the higher proportion of cows among the cattle population. In addition, the increase in depredation events coincides with cropping season, when cattle owners forbid cattle grazing close to farms from the fear of crop damage and are instead led into forests for grazing or along forest fringes.

We aggregated depredation cases with forest beats (administrative units) within the TX2 site to identify beats with high frequency of depredation events for all carnivores (Fig 14a), tigers (Fig 14b), and leopards (Fig 14c).

Depredation events over the last 8 years show distinct spatial patterns. In case of tigers (Fig 14b), the beats in North Lamta and Loughur show a higher number of events, whereas for leopards, the beats in North Lamta and South Lamta show a higher number of events (also see Appendix 5 for more details).
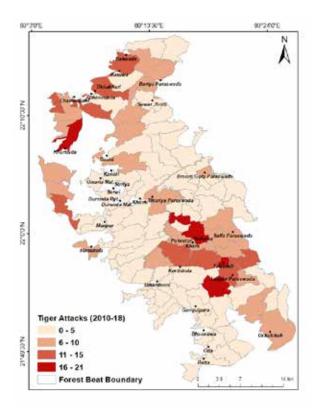
Fig 14c. Map of Balaghat TX2 site showing beats with high frequency of livestock depredation cases (2010-2018) attributed to leopards.

Fig 14b. Map of Balaghat TX2 site showing beats with high frequency of livestock depredation cases (2010-2018) attributed to tigers.

In 2012, WWF-India camera trapped a tiger in the Waraseoni range of South Balaghat (in the Kanha-Pench corridor area). The same individual was photo-captured in the Lamta range of North Balaghat (in the TX2 site) in 2014. Both observations were made through opportunistic camera trapping on cattle carcass. This tiger was identified as a dispersing tiger from Navegaon Nagzira Tiger Reserve in Maharashtra.

We suggest further investigation using a combination of spatiotemporal, ecological, and social parameters to understand the wild-domestic animal interaction in a shared habitat.

5.8 Wildlife crime

In Madhya Pradesh, South Balaghat has reported the second-highest number of wildlife crime cases after the Katni forest division, and North Balaghat ranks fourth after Morena forest division (Madhya Pradesh Forest Department, n.d.). Majority of the offenses reported in Balaghat circle are for wild meat by hunting of species such as wild pig, chital, sambar, porcupine, followed by the hide of species such as tiger, leopard, monitor lizard, bones of species such as sloth bear, monitor lizard, and sambar, and other parts such as teeth, claw, antlers, and hair largely for superstitious beliefs.

In the Balaghat circle, a most of the cases between 2010 and 2018 were reported after the crime occurred. Hence, such reports fall in the "other" or "unknown" category of the method used to commit the crime. In summary, most of the hunting was linked with the use of locally fabricated weapons (spear, axe, knife, arrow, etc.) (18%), followed by livewire trap (16%) and wire trap (snare) (14%) (Madhya Pradesh Forest Department, n.d.). Similarly, in the Balaghat TX2 site, a majority of the cases reported unknown reasons

(55%). The most commonly reported methods of hunting were local weapons (15%), followed by wire traps (13%) and livewire traps (7%) (Fig 15) (Madhya Pradesh Forest Department, n.d.).

Fig 15. Percent composition of methods used in wildlife crime cases recorded by the Madhya Pradesh Forest Department in Balaghat Circle and in Balaghat TX2 site (2010-2018).

Of the five tiger poaching incidents reported from the Balaghat circle between 2010 and 2018, three were killed using a livewire trap, and no cause was determined for two cases. Similarly, of the 14 cases of leopard poaching, five were killed using a livewire trap, followed by poisoning, wire trap/snare, and using local weapons. A majority of sloth bear cases (three out of six) were also killed using a livewire trap. Poaching is, therefore, of grave concern, and recovery will only be possible if enforcement is significantly upgraded, with increased support from local communities in conservation.

5.9 Linear infrastructure and mining

While there are no major linear infrastructures such as national highways within the TX2 site, the NH7 that bisects through the Kanha-Pench corridor along the Pench Tiger Reserve lies about 70 km west of the TX2 site. This highway was recently expanded to four-lane with flyovers and underpasses allow the movement of wildlife. In the TX2 site, all villages are connected via roads; however, only three contain major bulk of the traffic, i.e., SH 26, that connects Balaghat with Baihar, SH 11, connecting Balaghat with Nainpur via Lamta, and the Lamta-Baihar road (see Fig. 3). The southern-most boundary of the TX2 site extends beyond SH-26, which connects Ukwa – a major mining town, with the district headquarters of Balaghat. Although these roads have moderate traffic volumes, it is often impassable for wildlife because of parapets across the length of the way. Since it does not connect any major inter-state roads, it has a comparatively low flow of heavy-duty trucks, except SH 26, which observes a steady flow of trucks from the mining sites. SH 26 has recorded frequent usage by wildlife. In 2014, a tiger cub became a victim of road accident on the SH 26 in Loughur range in the TX2 site. This has resulted in the installation of warning signage by the Forest Department along the major roads. Between 2010 and 2018, there were 193 events of wild animals dying of accident in Balaghat circle, 25% (n = 48) of which took place in the TX2 site (see Table 6). In the TX2 site, a majority of animals including chital, sambar, jackal, and wild pig died because of free-ranging dogs (67%, n = 32) followed by road accidents (23%, n = 11), which included one tiger cub (Naveen, 2014).

Table 6. Wildlife death due to anthropogenic reasons documented by Madhya Pradesh Forest Department (2010-2018).

Reason of death	Balaghat Circle	TX2 site
Electric shock	20	1
Road accident	24	11
Train accident	2	1
Feral dog attack	100	32
Open dug well	12	3
Other	28	0
Unknown	7	0
Total	193	48

A civet road kill along a major road in the Balaghat TX2 site

Only one railway line passes along the western edge of the TX2 site, connecting Balaghat with the town of Nainpur, which further connects with Jabalpur. This narrow-gauge line is currently being upgraded for a broad-gauge railway line connecting Gondia in Maharashtra with Jabalpur. No major wildlife accidents have been reported from this railway route, although the impact of the conversion from narrow to broad-gauge is unknown, and not all fatalities may be detected and reported.

Two canals emerge from the Dhuti dam lying on the western boundary of the TX2 site, one leading along the south-western edge of the TX2 site and the other leading further west into Waraseoni block of Balaghat district. Both these canals provide water for irrigation and do not seem to act as barriers for animal movement to and from the TX2 site.

Mining is a major industry in Balaghat. In 2016-17, Balaghat had 31 operational manganese ore mines, producing 5,08,020 tonnes of Manganese ore valued at Rs. 435 crores (Ministry of Mines, 2017a). In the same year, Balaghat produced 68,187 tonnes of copper concentrates valued at Rs. 302 crores – largest for India (Ministry of Mines, 2017b). Ukwa and Bharveli, both manganese ore sites, lie close to the TX2 site, both situated about 2–10 km from the boundary. There are several minor mines of stone, clay, and sand located around the TX2 site. Considering that Balaghat consists of some of the largest deposits of ores of manganese and copper, it is likely that the mining extent will increase in the near future. Although the copper mine operations will reportedly be underground, the associated activities, such as wastewater and sediments, as well as an increase in transport traffic, may contribute to forest degradation and disturbance in wildlife habitats in the near future. This will also increase pressure on the roads connecting the mines with the inter-state National Highways, increasing the likelihood that the state highways and arterial roads may get widened in the future, creating demand for forest land.

5.10 Challenges to conducting regular conservation work

Insurgency

Balaghat district falls under the red corridor area identified by the Government of India as a Left Wing Extremism (LWE)-affected region (Ministry of Home Affairs, 2019). It is considered a marginally-affected district, connecting the eastern corridor of Chhattisgarh with Maharashtra's hinterland districts, such as Gondia, Chandrapur, and Gadchiroli. While no major untoward incidents have been reported from Balaghat in the recent past, regular patrolling by the forest department has been impeded to an extent. This is one of the major reasons limiting the prevention of wildlife crime and illegal wildlife trade, although the forest department has seen success in inter-state joint operations to bust poaching incidents.

Forest fragmentation in adjacent areas

Balaghat TX2 site has a highly fragmented forest area surrounding it (Fig 1, 2). Given that it is a non-protected forest, it is likely to face a more significant threat from direct or indirect barriers for the movement of animals – such as the expansion of roads, railway, mining sites, as well as human settlements. Currently, although the district has shown very little change in forest cover over the last five years, developmental plans, especially in terms of road broadening and construction of new roads, is an ongoing process. Expansion of highways and railways, and developmental pressures such as tourist resorts blocking the corridor towards Kanha Tiger Reserve, are identified as threats to the movement of tigers (Borah et al., 2015). It is crucial to model future land-use and land-cover changes, which may threaten the population of tigers of the TX2 site. Spatially explicit data on prey density, habitat characteristics (including vegetation types, land use, and invasive species), and socio-ecological parameters of communities living in and around the TX2 area also need to be integrated into future planning.

Security and management

Given that it is a territorial forest, the Forest Department personnel are primarily focussed on forestry/ silviculture operations. Patrolling is an integral part of work, and the Forest Department has been playing an active role in wildlife monitoring. WWF-India has engaged with the Balaghat circle on training at the Balaghat Rangers School. In recent years, the management of the Balaghat circle has taken several steps to understand wildlife density and movement in this non-protected forest. For the 2018 All India Tiger Estimation, a thorough camera trapping exercise was conducted jointly by the staff of Balaghat circle, WWF-India, and the Wildlife Institute of India (WII). In case of livestock depredation events, the Forest Department staff deploy cameras to monitor and identify carnivores – it is also said to deter miscreants from poisoning the carcass, which is left for the carnivore to consume. The department has also taken proactive steps to assist tendu leaf collectors in case of an accident. The ex-gratia amount provided in the event of injury or loss of human life or livestock by a wild animal is also proactively pursued.

6. DISCUSSION

Strategic thinking is the foundation of TX2 (WWF, 2016). This leads to effective planning and ensures investment in areas where one gets the most impact. Doubling tiger numbers depends on a variety of factors, including political support, partnerships with government and non-government agencies, and an integrated landscape conservation approach to ensure that the TX2 site is well connected with source sites for tigers by securing connectivity, reduction of wildlife crime, effective management of human-wildlife negative interactions, and regulating land-use changes that would otherwise degrade or destroy tiger habitat.

The government of Madhya Pradesh is supportive of tiger conservation, and although Balaghat is a non-Protected Area, under the Centrally Sponsored Scheme of Project Tiger (CSS-PT), Balaghat circle, in addition to Dindori and Mandla, receives support from NTCA through the Kanha Tiger Reserve for protection, habitat management, and purchase of monitoring equipment such as camera traps. As stated above, the outlook of the Forest Department in this territorial circle towards wildlife conservation has changed over the last ten years, and this could be attributed to WWF-India's continuous engagement with the Forest Department at various levels. Balaghat has also been included in the Tiger Conservation Plan of Kanha Tiger Reserve and is a part of the Kanha-Pench Corridor Management Plan (2013-14 to 2022-23). The present staff strength of the Balaghat circle has a gap of 22% positions. Balaghat being a TX2 site, a Conservation Assured|Tiger Standards (CA|TS) assessment for North and South Balaghat Forest Divisions have been conducted, and a summary of results shows that tiger conservation has been prioritised in the Working Plans for these divisions. An assessment of the budget requirement for implementing tiger conservation initiatives over the next five years needs to be undertaken. This would form the basis of seeking support from the state budget and CSS funds, as well as support from NGOs. A Security Audit on the lines of assessments done in Tiger Reserves following the protocol agreed by the National Tiger Conservation Authority (NTCA) could be undertaken soon to identify gaps in protection measures, such as capacity building of the staff.

WWF-India studies have found that the density of tigers in the Balaght TX2 site is between 0.46 and 0.87 animals/100 km². It must be noted that the Balaghat TX2 site comprises 20% of the total area of the Balaghat Circle. Therefore, the tiger population is a representation of a small area of the total expanse of the forests of Balaghat. This report does not consider tiger survival, recruitment, and tiger dispersal due to the lack of information on temporal trends of tiger population, but makes an effort to emphasise the importance of studying these aspects of tiger recovery. The tiger density of the Balaghat TX2 site is much lower than the connected source sites, Kanha (6.1 ±0.71 tigers/100 km2) and Pench (5.67 ±0.81 tigers/100 km2) Tiger Reserves, which makes it important to maintain the connectivity. One of the primary attributes for the recovery of tiger populations is adequate prey-base. It would be good to assess prey-base in the TX2 site, compare it with nearby source sites, and prepare a plan for augmenting prey-base. During CA|TS assessment by a joint team of Global Tiger Forum and WWF India, it was found that the genetic profiles of the Balaghat circle match those from Kanha, Pench, and Navegaon-Nagzira Tiger Reserves. This strengthens the argument of conserving the Balaghat circle as an important part of functional connectivity in the Central India Landscape. Balaghat being part of the Kanha-Pench corridor, it is also important to strengthen the management of the Balaghat circle and the forest divisions therein, with conservation actions that would support the recovery of tigers, as stated above. Allocation of additional funds for strengthening protection and management of human-wildlife interactions would be crucial under the

envisaged recovery site. Management of human-wildlife interactions at a site that is not a Protected Area, and where wildlife conservation funds are meagre, is always a challenge. Co-management of this issue, together with the district administration and other line agencies of the state government, would help reach out to the broader constituency of stakeholders. Action plans could be prepared to prevent conflict and reduce economic losses and injuries/ death to humans and livestock.

Maintaining the functionality of this critical connectivity would also require careful planning for land-use change. The development of linear and other infrastructure in this district would depend on demand for mining expansion and the use of forest-based resources. Coordination with relevant stakeholders is required to ensure that the land-use change doesn't hamper the tenuous connectivity.

6.1 WWF-India's initiatives in the Balaghat TX2 site

WWF-India engages with communities in five of the 35 villages (Polbatur, Kurthitola, Khara, Kokma, and Louhgur) of the TX2 site to create space for communities to engage more effectively in conservation action while at the same time generating options for income generation through sustainable livelihood actions. WWF-India recently collaborated with National Rural Livelihood Mission (NRLM) in Balaghat to strengthen community institutions as per the NRLM guidelines in the form of Self Help Groups (SHGs) to work towards a range of diverse goals including rural self-organization, financial empowerment, income generation, biodiversity, and environment conservation, and natural resource management.

To assist in safe forest fire control, WWF-India provided 175 firefighting uniforms to the North Balaghat forest division. Better fire regimes to prevent fires, including the creation of fire lines and implement cool-season controlled burning, need to be adopted to avoid recurring forest fires in the TX2 site.

Livestock depredation is considered a significant driver of retaliation against wild carnivores. Under WWF-India's Interim Relief Scheme (IRS), a monetary sum is immediately provided to livestock owners following a depredation event to enhance tolerance for large carnivores. Between 2010 and 2019, our team attended over 4,000 cases of kill incidents by wild carnivores in the Kanha-Pench corridor area comprising the buffer zones of Kanha and Pench Tiger Reserves and the corridor areas of Balaghat and Seoni circle. Tigers and leopards accounted for 48% and 50% of depredation events, and the remaining 2% were attributed to wild dogs and hyena.

7. RECOMMENDATIONS TO ENABLE TIGER POPULATION RECOVERY

7.1 Security and protection

1. Presently, the ground staff is either posted at range or circle office, with only a few posted in their respective beats due to lack of facilities. This lowers the frequency of monitoring. Setting up anti-poaching camps in strategic locations based on findings of this study (See Appendix 1 for beats with a high density of tigers and Appendix 4 for beats with a high frequency of fire incidences) and additional patrolling, based on strategic LEM/M-STrIPES inputs will strengthen protection and management.

2. Since Balaghat is highly prone to forest fires and given that the TX2 site is a hilly terrain, watchtowers built at strategic positions will serve as a lookout for fire incidences. The department already employs temporary staff as 'fire watchers' during the dry season. Those staff can be empowered with fire prevention management techniques, which includes management of fire lines, cool-season controlled burning and keeping vigilance on fire hot spot areas.

3. The working plans have a provision for the protection of biodiversity and wildlife, such as the construction of waterholes. However, the department also mentions a need for a specific management plan focusing on wildlife, particularly tigers. Strengthening wildlife management as a component of the working plan, which includes comprehensive water management, grassland development and a prey augmentation plan in the least disturbed areas, and stringent patrolling regime is a recommended step for wildlife management.

4. As a promising site for a 'stepping stone' population of tigers, support to the forest staff in terms of field equipment such as camera traps, binoculars, water filters, firefighting equipment, as well as equipment that can detect metal traps and live wire traps is imperative.

5. Training of forest staff (range officer, deputy range officer, and forest guard) in law enforcement, specifically focusing on evidence-based case formation, a protocol of sample collection and storage, and case due diligence will help solve the cases of wildlife crime.

6. Training of frontline staff in patrolling, including the regular foot patrol to survey the area for signs of illegal activities, identifying and destroying snares and traps, monitoring signs of wildlife, and covert patrols forms the basis for effective management. Although the staff is trained in patrolling, specific modules of training, together with the staff of Kanha and Pench Tiger Reserves, will be important to increase the efficiency of the exercises.

7. Scientific sessions may also be introduced as a part of the regular monitoring exercise. Since the Balaghat circle actively engages in opportunistic camera trapping at livestock depredation site and given that Balaghat also participated in the All India Tiger Estimation exercise in 2018, a yearly monitoring programme (Phase IV) on the lines of NTCA's monitoring protocol for tigers, co-predators, prey, and their habitats (Jhala et al., 2009) can be considered.

7.2 Community and other stakeholder engagement

1. The forest department engages local communities through Joint Forest Management Committees (JFMCs) and Van Samiti. These committees form a link between the local communities and the Forest Department. With individual forest rights provided to the residents under the Forest Rights Act, 2006, it is important to explore the potential to encourage community forest rights and support implementation (such as facilitating exercises) to secure tenure rights and promote community-led conservation.

2. The creation of fodder zones for livestock is being considered by the forest department. A pilot-scale project on the creation of commons on village (revenue) land to reduce dependence on forests for grazing can be explored.

3. Exploring sustainable, additional livelihood options for local communities by leveraging support from line departments and mainstreaming government-sponsored schemes such as National Rural Livelihood Mission (NRLM), National Rural Health Mission (NRHM), Pradhan Mantri Ujjwala Yojana (for LPG gas connection), and Urja Van (plantation sites for fuelwood consumption), are crucial in addressing forest dependency in non-Protected Areas. This would need the creation of a coordination committee for tiger conservation in Balaghat, together with the District Administration, the Forest Department, and other line agencies.

7.3 Managing human-wildlife interaction

1. Crop damage by wildlife is one of the major concerns in the TX2 site. While there is a mechanism for compensation provided either by the forest department or the revenue department, it remains inaccessible to the victim of crop damage. Given that agriculture is a primary occupation in the TX2 site, comprehensive site-specific crop damage compensation, as well as a mitigation plan, need be prepared to reduce the loss as well as enable the victim to obtain satisfactory compensation. In the long run, it would also secure the survival of conflict causing species, primarily the crop-raiding herbivores.

2. While there is an ex-gratia scheme in place for addressing injury or loss of human life and livestock, it is important to adopt an avoidance strategy that discourages encounters from taking place. Studies on human-wildlife conflict in the Kanha-Pench corridor have shown that most incidences take place when people engage in a forest-based activity such as the collection of NTFP. An avoidance strategy map can be developed by empowering communities on how to avoid confrontations with wildlife when engaged in forest-based activities.

7.4 Habitat restoration

1. Habitat management, such as the development of grasslands for prey populations, is not on a priority agenda of territorial forests. Since the landscape shares its floral characteristic with nearby Kanha Tiger Reserve, grassland development plans like that of Kanha may be adopted to create small meadows in the least disturbed areas of the TX2 site.

2. Given that the TX2 site is a non-protected area, it faces tremendous pressure on forest regeneration due to the extraction of fuelwood, forest fires, as well as grazing. Identification of poor quality habitats, areas invaded by weed such as *Lantana camara*, require to be identified, and restoration work be undertaken to maintain the natural rate of forest regeneration.

8. KEY RECOMMENDATIONS FROM THIS STUDY

1. Training the forest staff, particularly on evidence-based case formation for wildlife crime, a protocol of sample collection, and case due diligence.

2. Training of regular foot patrolling with a focus on identification of the site of the crime, identification, and destruction of snares and traps, wildlife signs monitoring, and covert patrols.

3. Scientific monitoring of wildlife should be considered a priority in the TX2 site and undertaken yearly.

4. Establishing patrolling and anti-poaching camps in strategic locations based on tiger-bearing beats.

5. Establishing fire management protocol by empowering forest and the temporary staff effectively prevent fire incidences and in fighting forest fires.

6. Expanding upon the component of wildlife conservation in the working plans.

7. Exploring potential of community forest rights in villages within the TX2 site.

8. Engaging with line departments and mainstreaming government-sponsored schemes in villages within the TX2 site.

9. Exploring site-specific human-wildlife conflict mitigation measures pertaining to crop depredation and injury or loss of human life, as well as addressing livestock depredation by modifying current grazing practices or adopting alternative mechanisms such as livestock insurance.

10. Habitat management such as grassland development and control of invasive species of plants to encourage natural restoration of the degraded forest areas.

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APPENDIX 1

Table A. Areas identified under high pixel density for tigers in Forest Department administrative units of Balaghat TX2 site based on density model for the year 2017.

Sr. No.	Division	Range	Beat
1	North Balaghat	North Lamta	Dongaria
2			Sawarjhodi
3			Mohgaon
4			Kumjhar
5			Khamtola
6			Nagarwara
7			Mahkapatta 2
8			Lotmara
9			Lotmara 2
10			Maldhar
11			Basegaon
12	South Balaghat	Balaghat	Pipartola
13			Kera
14			Gangulpara
15			Sonewani
16			Dhansua
17			Dhapewada
18			Jarera
19			Umardoni
20		Loughur	Loughur 1
21			Loughur 2
22			Tallabodi 1
23			Tallabodi 2
24			Khara
25			Kokma
26			Polbattur
27			Khudsud
28			Rupjhar 1
29			Jaitpuri

Table B. Beats showing photo-captures of leopards for the year 2017.

Sr. No.	Division	Range	Beat
1	North Balaghat	North Lamta	Maldhar
2			Lotmara Part 2
3			Basegaon
4			Kumjhar
5			Mohgaon
6			Nagarwara
7			Sawarjhodi

Sr. No.	Division	Range	Beat
8			Mohkapatta Part 1
9			Dongaria
10			Arandia
11			Bhondawa
12			Badgaon
13			Salhe
14		South Lamta	Kanhati
15			Suriya
16			Tikariya Part 2
17			Khami Part 1
18			Aamgaon
19	South Balaghat	Loughur	Barurgota Part 1
20			Barurgota Part 2
21			Polbattur Part 1
22			Kurwahi Part 1
23			Kurwahi Part 2
24			Jaitpuri Part 1
25			Kokma
26			Khara
27			Tallabodi Part 1
28			Tallabodi Part 2
29			Rupjhar Part 1
30			Rupjhar Part 2
31		Balaghat	Kurthitola
32			Keslai

APPENDIX 2

Species diversity captured on camera trap in Balaghat TX2 site for the year 2017.

Sr. No.	Name	IUCN status
1	Tiger (Panthera tigris)	Endangered
2	Wild Dog/Dhole (Cuon alpinus)	Endangered
3	Rusty Spotted Cat (Prionailurus rubiginosus)	Near Threatened
4	Striped Hyena (Hyaena hyaena)	Near Threatened
5	Eurasian Otter (Lutra lutra)	Near Threatened
6	Leopard (Panthera pardus fusca)	Vulnerable
7	Sloth Bear (Melursus ursinus)	Vulnerable
8	Eurasian otter (Lutra lutra)	Vulnerable
9	Sambar (Rusa unicolor)	Vulnerable
10	Gaur (Bos gaurus)	Vulnerable
11	Four-horned antelope (Tetracerus quadricornis)	Vulnerable
12	Jungle Cat (Felis chaus)	Least Concern
13	Indian Fox (Vulpes bengalensis)	Least Concern
14	Indian Jackal (Canis aureus)	Least Concern
15	Small Indian Civet (Viverricula indica)	Least Concern
16	Common Palm Civet (Paradoxurus hermaphroditus)	Least Concern
17	Ratel (Mellivora capensis)	Least Concern
18	Small Indian Mongoose (Herpestes auropunctatus)	Least Concern
19	Wild Pig (Sus scrofa)	Least Concern
20	Barking Deer (Muntiacus muntjak)	Least Concern
21	Chital (Axis axis)	Least Concern
22	Nilgai (Boselaphus tragocamelus)	Least Concern
23	Northern Plains Langur (Semnopithecus entellus)	Least Concern
24	Rhesus Macaque (Macaca mulatta)	Least Concern
25	Indian Crested Porcupine (Hystrix indica)	Least Concern
26	Striped Palm Squirrel (Funambulus palmarum)	Least Concern
27	Indian Hare (Lepus nigricollis)	Least Concern

APPENDIX 3

Profile of villages in Balaghat TX2 site.

Table A. Summary of villages inside and on the edge of the TX2 site.

Details (2011 census)	Inside	Outside (<5km)	Total/%
Villages	35	51	86
Population	12894	38669	51563
Men	6308	18989	25297
Women	6586	19680	26266
ST population	7096	15000	22096
%ST population	55.03%	38.8%	42.85%
SC population	428	2161	2589
Literates population	7408	25242	32650
%Literates	57.45%	65.3%	63.32%
Illiterates population	5486	13427	18913
%Illiterates	42.55%	34.72%	36.7%
Households	3197	8979	12176
Villages in Balaghat block	28	25	53
Villages in Paraswada block	7	26	33

Table B. Population range of villages within and outside the TX2 site.

Population range	Inside	Outside	Total
1 to 100	9	6	15
101 to 200	4	2	6
201 to 300	7	7	14
301 to 400	4	4	8
401 to 500	1	5	6
501 to 600	3	4	7
601 to 700	0	1	1
701 to 800	2	3	5
801 to 900	4	4	8
>900	1	15	16
Total	35	51	86

APPENDIX 4

Areas identified with high incidences of forest fires (in decreasing order of z-score). Higher the z-score, more fire points clustered together indicating high frequency of forest fires. Data used for the year 2017 (FIRMS, 2019).

Sr. No.	Division	Range	Beat	z-score	p-value
1	North Balaghat	North Lamta	Badgaon II	4.331	0.00059
2	South Balaghat	Balaghat	Kurthitola	3.76	0.009
3	North Balaghat	South Lamta	Tikaria I	3.73	0.003
4	South Balaghat	Loughur	Kurwahi I	3.594	0.006
5	South Balaghat	Loughur	Khara	3.49	0.008
6	South Balaghat	Loughur	Tallabodi II	3.45	0.032
7	North Balaghat	North Lamta	Lotmara II	3.163	0.06
8	South Balaghat	Loughur	Kokma	2.906	0.04
9	South Balaghat	Loughur	Tallabodi I	2.668	0.112
10	North Balaghat	South Lamta	Samnapur	2.611	0.073
11	South Balaghat	Loughur	Polwatur I	2.42	0.099
12	North Balaghat	South Lamta	Salhe	2.32	0.171
13	South Balaghat	Loughur	Kurwahi II	2.146	0.125
14	South Balaghat	Loughur	Barurgota II	2.068	0.136
15	South Balaghat	Balaghat	Kanhatola	2.058	0.136
16	North Balaghat	North Lamta	Maldhar	2.029	0.169
17	South Balaghat	Loughur	Jaitpuri I	1.874	0.179
18	South Balaghat	Balaghat	Manjhara	1.776	0.166
19	South Balaghat	Loughur	Katejhiria	1.635	0.306
20	South Balaghat	Balaghat	Palagondi	1.094	0.319
21	North Balaghat	North Lamta	Badgaon I	1.026	0.1
22	North Balaghat	North Lamta	Kumangaon	0.608	0.257
23	South Balaghat	Balaghat	Jarera	-0.08	0.16

APPENDIX 5

Range and beat-wise incidences of livestock depredation for tigers and leopards in Balaghat TX2 site based on Madhya Pradesh Forest Department D4 data for 2010-2018.

Forest Division	Range	Beat	Tiger	Leopard	All cases
North Balaghat	North Lamta	Lamta	21	32	53
North Balaghat	North Lamta	Basegaon	15	20	35
North Balaghat	North Lamta	Mahkapatta-II	12	7	20
North Balaghat	North Lamta	Ghunadi	11	14	24
North Balaghat	North Lamta	Khamtola	11	24	35
North Balaghat	North Lamta	Dongaria	10	8	18
North Balaghat	North Lamta	Lotmara	10	4	14
North Balaghat	North Lamta	Mahkapatha	10	11	21
North Balaghat	North Lamta	Lotmara Part-II	8	8	16
North Balaghat	North Lamta	Mohgaon	7	10	17
North Balaghat	North Lamta	Bhondawa	6	12	18
North Balaghat	North Lamta	Budhiyagaon	6	10	18
North Balaghat	North Lamta	Arandia	5	4	9
North Balaghat	North Lamta	Salhe	5	1	6
North Balaghat	North Lamta	Badgaon Part-I	4	12	15
North Balaghat	North Lamta	Janamkhar	4	6	9
North Balaghat	North Lamta	Kumangaon	4	10	15
North Balaghat	North Lamta	Sawarjhodi	4	13	18
North Balaghat	North Lamta	Badgaon Part-II	3	6	9
North Balaghat	North Lamta	Nagarwara	3	10	13
North Balaghat	North Lamta	Kumjhar	1	7	8
North Balaghat	North Lamta	Maldhar	0	36	36
North Balaghat	South Lamta	Chacheri	13	16	29
North Balaghat	South Lamta	Dhhuti	9	31	40
North Balaghat	South Lamta	Tikaria Part-II	8	7	15
North Balaghat	South Lamta	Magardarra	7	22	30
North Balaghat	South Lamta	Chicoli	6	5	11
North Balaghat	South Lamta	Kanhari	6	25	31
North Balaghat	South Lamta	Titwa	5	29	34
North Balaghat	South Lamta	Suriya	4	24	28
North Balaghat	South Lamta	Khami Part-II	3	19	22
North Balaghat	South Lamta	Chacheri Part-II	2	16	18
North Balaghat	South Lamta	Kategaon	2	13	15
North Balaghat	South Lamta	Charegaon	1	26	27
North Balaghat	South Lamta	Dongarwodi North	1	19	20
North Balaghat	South Lamta	Aamgaon	0	12	12
North Balaghat	South Lamta	Dongarwodi South	0	1	1
North Balaghat	South Lamta	Khami Part-I	0	9	9

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Forest Division	Range	Beat	Tiger	Leopard	All cases
North Balaghat	South Lamta	Manpur	0	6	6
North Balaghat	South Lamta	Mohgaon	0	15	10
North Balaghat	South Lamta	Panchera	0	1	1
North Balaghat	South Lamta	Salhe	0	1	1
North Balaghat	South Lamta	Samnapur	0	1	1
North Balaghat	South Lamta	Tikaria Part-I	0	3	3
South Balaghat	Loughur	Lougur II	19	2	21
South Balaghat	Loughur	Polbattur I	17	5	22
South Balaghat	Loughur	Lougur I	15	12	27
South Balaghat	Loughur	Tallabodi II	14	6	20
South Balaghat	Loughur	Rupjhar II	13	3	16
South Balaghat	Loughur	Khara	12	1	13
South Balaghat	Loughur	Jairpuri I	10	7	17
South Balaghat	Loughur	Katejhiria	10	0	10
South Balaghat	Loughur	Kokma	9	1	10
South Balaghat	Loughur	Rupjhar I	9	1	10
South Balaghat	Loughur	Varudgota I	9	3	12
South Balaghat	Loughur	Khudsud	6	3	9
South Balaghat	Loughur	Keslai	5	4	9
South Balaghat	Loughur	Varudgota II	3	0	3
South Balaghat	Loughur	Tallabodi I	3	0	3
South Balaghat	Loughur	Gohndi	1	1	2
South Balaghat	Loughur	Jairpuri II	1	0	1
South Balaghat	Loughur	Kurwahi I	0	0	0
South Balaghat	Balaghat	Pallagondi	9	11	20
South Balaghat	Balaghat	Kanhatola	7	1	8
South Balaghat	Balaghat	Kurthitola	6	2	8
South Balaghat	Balaghat	Uskal	6	2	8
South Balaghat	Balaghat	Jarera	5	4	9
South Balaghat	Balaghat	Katangi	4	1	5
South Balaghat	Balaghat	Sonewani	3	8	11
South Balaghat	Balaghat	Payeli	2	6	8
South Balaghat	Balaghat	Sarra	2	6	8
South Balaghat	Balaghat	Umardoni	2	3	5
South Balaghat	Balaghat	Dhansua	1	2	4
South Balaghat	Balaghat	Mate I	1	1	2
South Balaghat	Balaghat	Gangulpara	1	0	1
South Balaghat	Balaghat	Bandarkoh	0	4	4
South Balaghat	Balaghat	Bori	0	6	6
South Balaghat	Balaghat	Dhapewada	0	0	0
South Balaghat	Balaghat	Kaveli	0	2	2
South Balaghat	Balaghat	Kera	0	5	5
South Balaghat	Balaghat	Khairi	0	0	0

Forest Division	Range	Beat	Tiger	Leopard	All cases
South Balaghat	Balaghat	Manjhara	0	4	4
South Balaghat	Balaghat	Mate II	0	0	0
South Balaghat	Balaghat	Oda I	0	8	14
South Balaghat	Balaghat	Ratta	0	7	7

APPENDIX 6 A

Profile of tigers captured in Balaghat TX2 site in 2014-15

TF 1

TF 2

TM 1

TM 2

TU1

TU2

TU3

APPENDIX 6 B

Profile of tigers captured in Balaghat TX2 site in 2015-16

TF 1

TF 2

T3

T4

APPENDIX 6 C

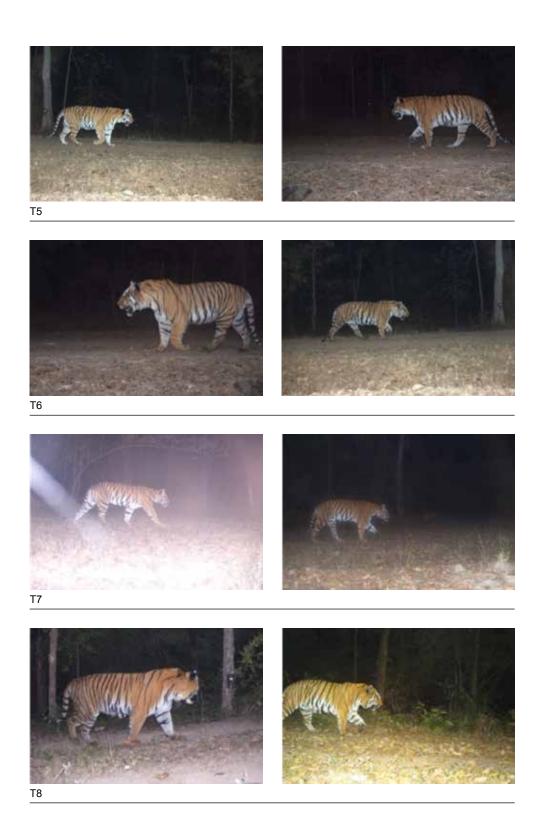Profile of tigers captured in Balaghat TX2 site in 2017

TF 1

TF 2

T3

T4

T5

T6

T7

T8

T9

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