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Between the Sharda and the Mala:

STATUS OF TIGERS IN PILIBHIT FOREST DIVISION

Terai Arc Landscape, Uttar Pradesh, India

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Cover: A male tiger inspects a camera trap in a Eucalyptus plantation in morning light. Mahof Range, Pilibhit Forest Division. Photo: WWF-India

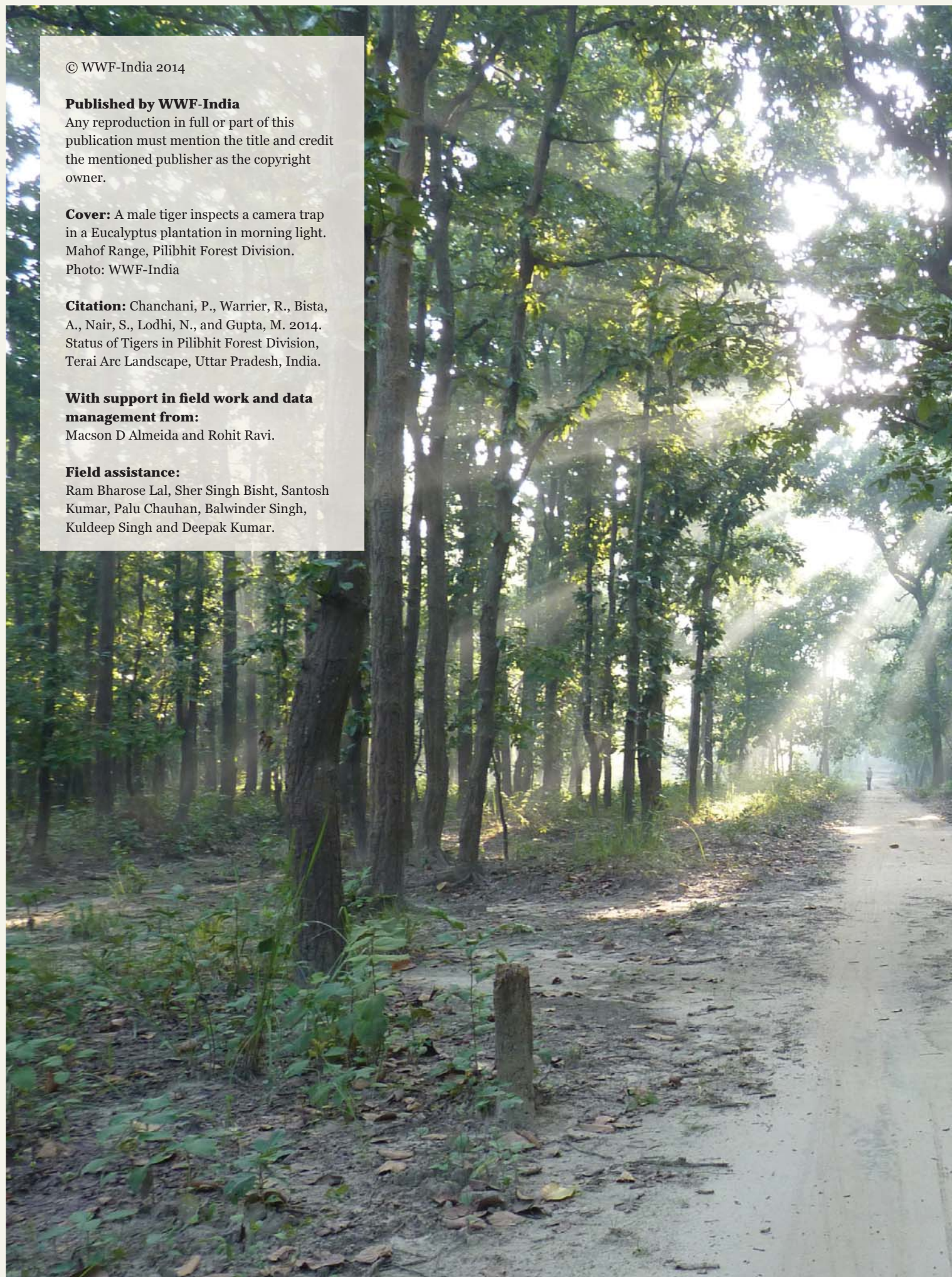
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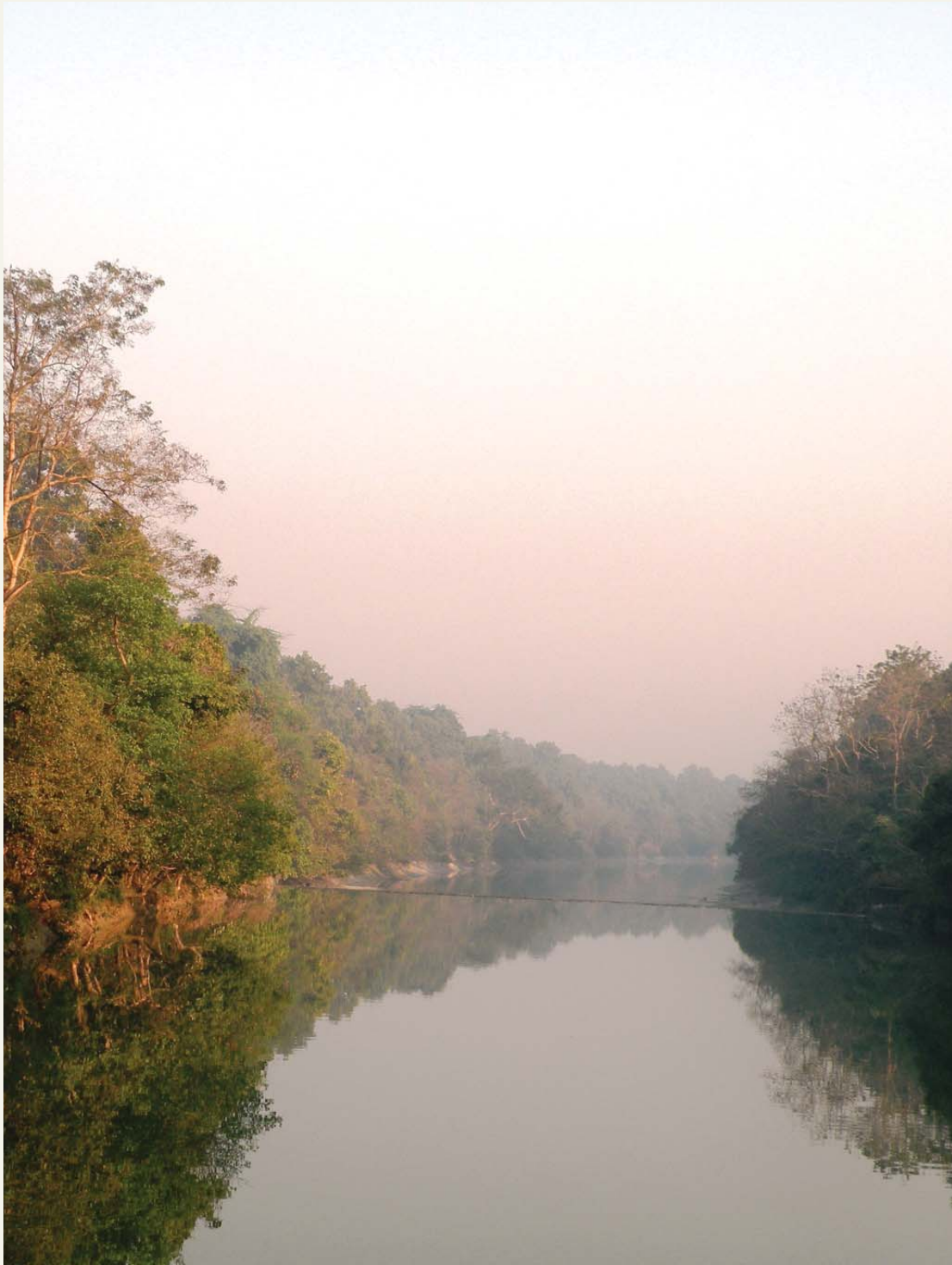
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The Kheri branch of the Sharda Canal originates in Pilibhit Forest Division and passes through nearly 80 kilometers of high quality tiger habitat.

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These surveys were made possible by the involvement, engagement and support of a number of individuals and organizations who contributed to planning, administration and field implementation.

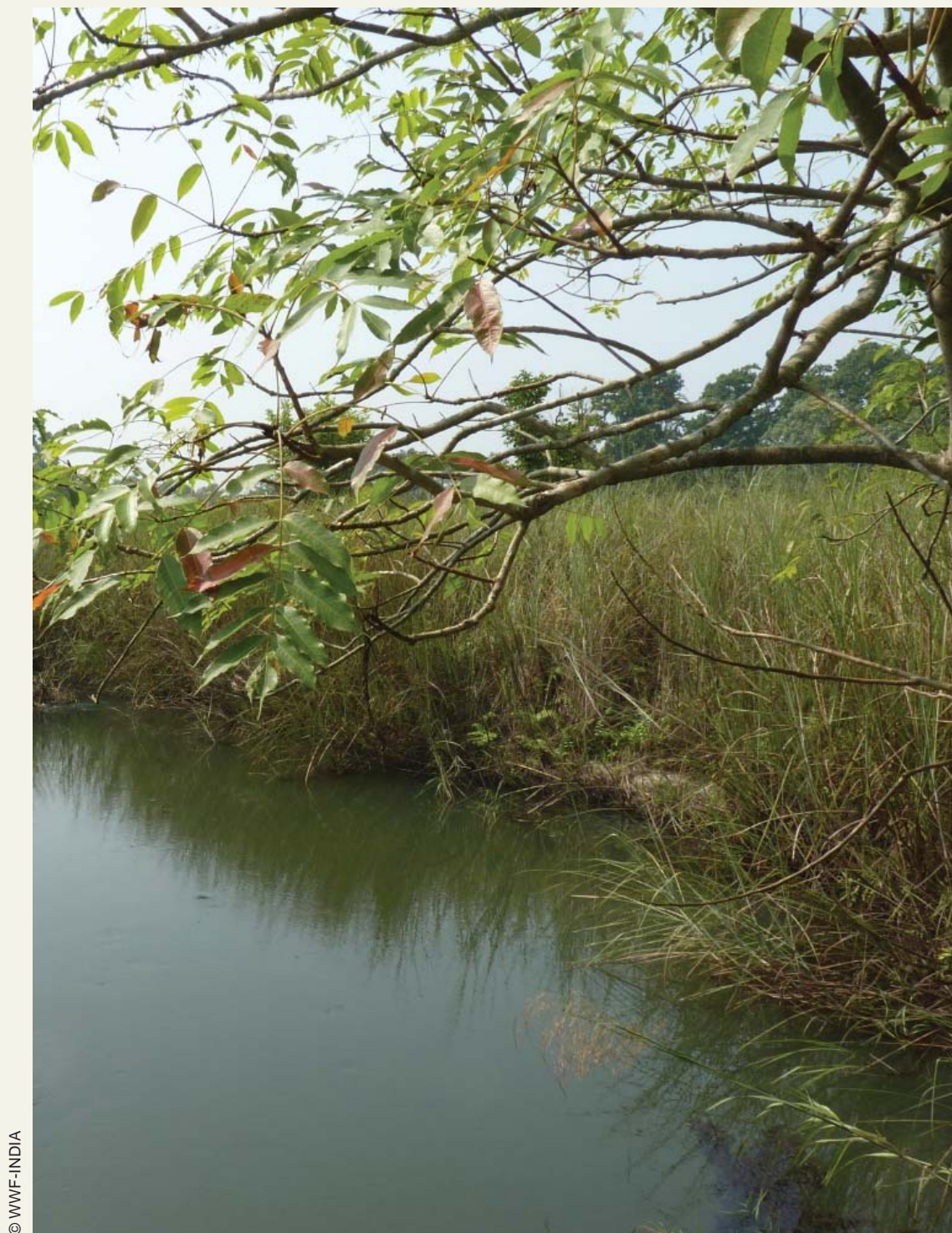
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While surveying Pilibhit Forest Division, we also concurrently sampled some areas of Surai range, Terai East Forest Division, Uttarakhand. DFO Terai East: P.K. Patro, RO Mahof: Anil Shah and RO Surai: U.D. Kandpal readily granted us permissions for these surveys, and we are grateful to them and field staff of Surai range for enthusiastically participating in this exercise. We are grateful to Ruchir Sharma and Yashada Kulkarni for their involvement with fieldwork in 2011, and to our field assistants for their efforts.

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The Mala River and its grassy banks are a lifeline for Pilibhit's tigers and ungulate populations.

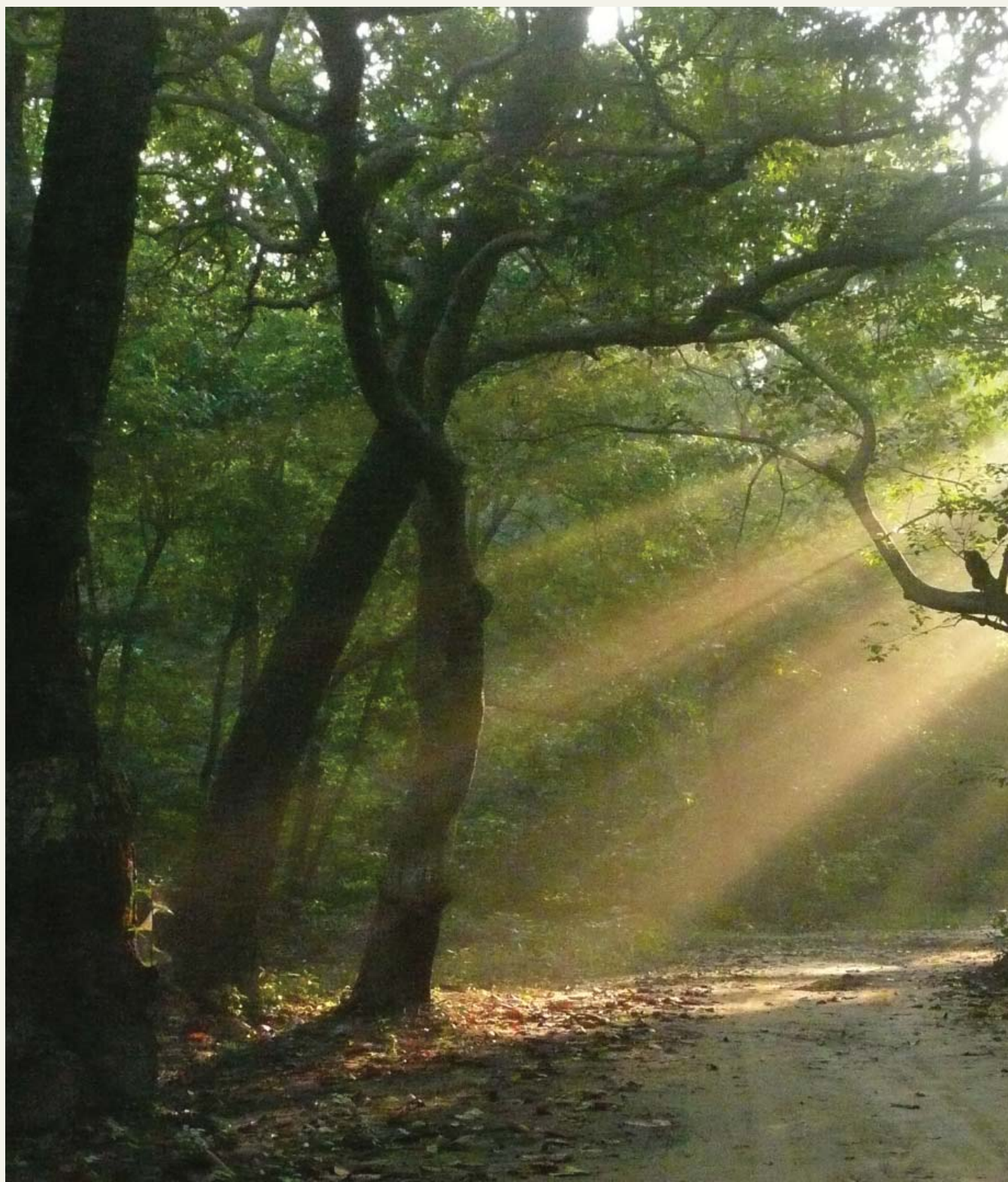
SUMMARY

In order to sustain tiger populations in large landscapes, it is essential to monitor and conserve populations that occur in Reserve Forests and other habitat patches which lie outside of protected areas. Our surveys in Pilibhit Forest Division (PFD) in 2013 were carried out to estimate tiger abundance and density. The present camera-trap surveys were more intensive than previous studies, and included in addition to Pilibhit Forest Division, other tiger habitat areas in its proximity. Within PFD, we sampled 171 locations in the five forest Ranges in a 60 day period. The surveys were designed to maximize spatial coverage, and to sample all habitats and forest areas, including areas that had previously been identified as low density zones for tigers.

Our surveys, spanning the entire forest division, yielded a population estimate of 22 - 26 tigers for Pilibhit Tiger Division, based on closed population mark-recapture analyses. The estimated density and associated posterior intervals from a spatially explicit capture-recapture model were 3.44 (2.32 - 4.54) tigers/ 100 km². Although lower than before, the Bayesian posterior intervals for these estimates overlap with those from previous estimates for PFD. Importantly, they are similar to estimates for various other sites in the Terai Arc Landscape, several of which are protected areas. Survey results also indicated that there was considerable variation in the density of tigers within PFD, with high values associated with riparian zones in Mahof, Mala and Haripur Ranges, and lower values of density in other regions of PFD. We attribute these differences to underlying variation in the distribution and density of prey species, and to associated habitat variables.

Pilibhit Forest Division in the state of Uttar Pradesh is a unique site for tiger conservation because it supports a breeding tiger population even though the forests are narrow and disturbed. We believe that the persistence of tigers in this Reserve Forest has been aided by its proximity to other prominent tiger habitats (most importantly, Kishanpur Wildlife Sanctuary). In addition, several perennial water sources including canals, rivers and a reservoir, and complex grassland-forest mosaics around these have created a complex of habitats that sustain tiger populations and support prey species that are unique to the terai, including hog deer and swamp deer. These habitats have also allowed tigers to persist in spite of high human presence in Pilibhit Forest Division. Human presence in the forest during day-time hours is primarily in the form of on account of timber harvesting (selective felling) and dependence of populous forest-fringe communities for fuel-wood and grass.

We emphasize the need for strategic conservation planning for Pilibhit to continue to serve as a regionally important site for the conservation of tigers and other endangered wildlife of the terai. Tiger conservation in the area will benefit from management strategies that recognize the entire forest complex (PFD, Kishanpur, Surai and South Kheri) as a single conservation block. We advocate that management practices be oriented to maintain heterogeneity in forests and grasslands. Some areas merit greater protection because of the narrowness of the forest and their proximity to an international border. In particular, we emphasize the need for enhanced protection along riparian tracts, forest edges and in areas along the Sharada River, Deoria Range and in the Surai Range of Terai East Forest Division. Finally, we note that the persistence of tigers in this region of the Terai Arc Landscape may be significantly enabled by the restoration of three key corridors, namely Garah-Lalpur-Deoria, Pilibhit-Shuklaphanta and Kilpura-Khatima (Terai East Forest Division), which will make available ~3000 km² of contiguous tiger habitat in India and Nepal.



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Morning light, Pilibhit Forest Division.



INTRODUCTION

Pilibhit Forest Division holds a unique position in the roster of wildlife areas of India. Even though this site is a commercially valued timber-yielding Reserve Forest, it still sustains a notably large population of wild tigers. The findings of recent studies (Chanchani *et al.*, 2011, Bista 2011) suggest that tiger and prey populations in Pilibhit FD may be among the most significant in a large span of the Terai Arc Landscape of India, (the section for forests that lies between Corbett Tiger reserve in the West and Valmiki Tiger Reserve in the East). While prominent tiger reserves such as Corbett, Kanha and Kaziranga are well recognized for being important tiger habitats and serve as prominent conservation sites for large mammals, Reserve Forests such as Pilibhit Forest Division (PFD) receive considerably less conservation attention. Typically, wildlife in such sites is often a secondary concern, relative to forest management for timber production, as is evidenced by departmental working plans and other statutory documents that determine how such areas are administered and managed. Although Pilibhit has long been known to harbour a population of tigers, it has also long served as a valuable forest for sal (*Shorea robusta*) timber (Strahorn, 2009).

Aside from being a Reserve Forest with high wildlife values (Johnsingh *et al.*, 2004), other factors also make Pilibhit unique. Notably, its geographical location and proximity to other forests makes this region crucial for the conservation of tigers and other large mammals in the terai regions of Nepal and Terai. In a sense, Pilibhit is an important 'node' that connects a vast span of tiger habitat in India and Nepal. Pilibhit Forest Division abuts the forests of Surai Range (Terai East Forest Division) to the North. The Surai forests are tenuously connected with the Nandhour forests (Haldwani Forest Division), which comprises a large block of tiger habitat (~1500 km²), or larger if one considers the boundaries shared with Bhramadev and vast areas in the Churia Hills of Nepal that lie across the Sharada River (Fig 1). To the South, PFD shares a boundary with Bhira Range of South Kheri Forest Division (SKFD) and Shahjehanpur Forest Division. These forests share boundaries with Kishanpur Wildlife Sanctuary, which is flanked to the south by Bhira, Mailani, Mohammadi and Gola Ranges of SKFD.



Figure 1: Map of Pilibhit Forest Division showing administrative ranges (red lines), camera trap locations in 2013 (green dots), the extent of the buffer for density estimation (purple polygon with double lines). Non-habitat areas (shaded grey) within the 15 km buffer were ‘masked-out’ for the analysis. Major roads (dark-grey lines), canals (deep blue), and drainages (pale blue) have also been plotted. Inset: location of Pilibhit FD in the terai and India.

In all, the habitat block comprising of PFD, Surai, Kishanpur and SKFD (Tiger Habitat Block IV, sensu Johnsingh *et al.*, 2004) spans an area > 1200 km² making it one of the largest tiger habitat blocks in the TAL in India. A small portion of Pilibhit forest division called Lagga Bagga lies East of the Sharda River and is in-fact a ‘corner’ of Shuklaphanta Wildlife Reserve (Nepal) which is well known for its extensive *phantas* (grasslands) that sustain the world’s largest swamp deer (*Rucervus duvaucelii*) congregations. Descriptions of vegetation and administrative units and history of PFD and proximate forests can be found in Johnsingh *et al.*, (2004); Anwar *et al.*, (2010), Bista (2011) and Strahorn (2009).

Pilibhit has some other unusual features that make it a unique site for tiger conservation. Prominent among these are (i) the presence of the Sharda Sagar reservoir, the swampy Mala River and the extensive network of earthen canals that criss-cross through the forest, (ii) absence of forest-interior villages, (iii) a high dependence of forest-fringe populations on the forests for fuelwood and grass and non-timber forest produce, (iv) the ongoing harvesting of timber by the state Government; and (v) forest-grassland mosaic habitats which are

intensively managed by silvicultural practices and controlled burning. These and other factors of the habitat and social-ecology of the region have resulted in an unusual scenario where a relatively large tiger population has persisted in a forest that is both ‘disturbed’ and intensively managed.

In this report, we provide details of a recently conducted study (April-June 2013) to document the status of tigers in Pilibhit Forest Division. Previous surveys ascertained that Pilibhit had a resident tiger population (Anwar *et al.*, 2010 and Chanchani *et al.*, 2011), that was notably large. Moreover, these studies indicated that tiger densities in PFD were as high as those reported in several prominent PAs in the *terai* and elsewhere in India such as Pench TR and Dudhwa TR (Jhala *et al.*, 2011). The current study is the most detailed camera trap study in PFD and its surrounding forests to-date. Specifically, in this study, we have sampled all tiger habitats with camera traps to (a) estimate the abundance of tigers; (b) estimate the density of tigers in PFD; and (c) monitor the tiger population in Pilibhit, relative to previous surveys. We use these results to draw conclusions about the status of tigers in PFD and provide explanations for observed patterns of tiger distribution and density. While the estimation of population parameters is the chief concern of this report, these survey results have also been used to provide broad guidelines for site-specific conservation actions to promote and sustain tiger populations in this unique region within the Terai Arc Landscape.

FIELD METHODS AND DATA ANALYSIS

Camera trapping in a mark - recapture framework was carried out in PFD for 60 days between April 15, 2013 and June 15, 2013. We placed pairs of camera traps at 171 sites in an area of approximately 650 km² spanning Mahof, Mala, Barahi, Haripur and Deoria ranges. Cameras were placed using a block design, wherein a block comprised of a set of camera sites, which would remain active for a 15-20 day period. This corresponds to survey design type 4 of Nichols & Karanth (2002). An effort was made to maintain a distance <2 km between camera sites, and to minimize 'holes' in the trap array.

Due to logistical difficulties not all cameras in a block were installed on the same day, while some cameras also became dysfunctional for one or more days during a trapping session. However, we tried to ensure that cameras in all sites were active for a minimum of 15 days within each block. During analysis active and inactive days of a trap station were also explicitly incorporated into the estimation models. On completion of a trapping block, cameras were shifted to the adjacent block. We camera trapped in three blocks in all for a total of 2814 trap nights, (see Table 1 for details).

Sites for cameras trapping were selected based on sign surveys along trails and water courses and by consulting with local forest department staff. Camera sites were selected in a manner that allowed us to maximize spatial coverage and increase the probability of photo-capturing tigers. Cameras were spaced 10-20 feet away from trails at a height ~45 cm from the ground (see Figure 1 for distribution of camera trapping stations in PFD).

We identified individual tigers by their stripe patterns. Each photo was assessed by three independent observers to eliminate identification errors, and disputed pictures were not used in the analyses. Following Karanth and Nichols (1998), only adult tigers (greater than 2 years in age which we identified as large animals, independent of their mothers and young siblings) were included, pictures cubs and juveniles were omitted from the analysis (see appendix).

Tiger abundance was estimated using closed capture-recapture models of Otis *et al* (1978) in program MARK ver 7.1 (White & Burnham 1999). Data used for analysis was in the form of a matrix with capture records for individual tigers in rows (entered as 1 or 0). Each column described a sampling occasion, which we defined as a day (24 hour period). Because our sampling was conducted in three 'blocks', we folded the dataset to a single 20 'occasions' period that contained records of all captures over the 60 day sampling period (following Karanth and Nichols 2002). We used the Huggins parameterization of the closed Capture-Recapture models and allowed capture probabilities to vary by time, behavior, individual heterogeneity and some combinations of these (Cooch and White 2010).

We assume population closure (for adults) because the study was carried out in a 60 day period, which is thought to be sufficiently small for the population to not experience demographic changes (Karanth and Nichols 2002).

We estimated tiger densities using spatially explicit capture recapture (SECR) models implemented in a Bayesian analysis framework (Royle *et al.*, 2009). The SECR models are a major improvement on the earlier ‘aspatial’ density estimation methods and are now the recommended method (Borchers and Efford 2008, Gopalaswamy *et al.*, 2012, O’Connell *et al.* 2011, , Royle and Gardner 2011). These methods have been shown to generate estimates that are relatively unbiased when key model assumptions are met, and the definition of an adequately ‘state-space’ ensures geographic closure (Ivan *et al.*, 2013; Gerber *et al.*, 2011). Model assumptions and parameterization have been discussed in detail by Royle *et al.*, (2013).

Analysis was carried in R statistical language & programming environment (R core team 2013), using the program SPACECAP (Gopalaswamy *et al.*, 2012). To estimate tiger density, we created a habitat-mask so as to include only forest and grassland areas (habitat) within a 15 km buffer area around the extent of the camera trap array in Pilibhit Forest Division. A ‘trap-flag’ file was created and included in the model to specify ‘active’ days of a particular camera-trap station. This incorporated the “block” sampling design and explicitly accounted for dysfunctional cameras (on account of theft or malfunction). We used a binomial encounter process and specified a data augmentation value of 300 and ran 50,000 iterations to generate posterior distributions for parameters of interest.

Table 1: Summary of camera trap sampling in Pilibhit Forest Division in 2013.

Site/ Block	Ranges Sampled	Sampling period	Trap nights	Trap stations
Pilibhit I	Haripur	April 15 - May 2	285	15
Pilibhit II	Haripur, Bahari, Mahof	May 5 - May 23	1438	93
Pilibhit III	Mala, Deoria, Surai	May 25 - June 13	1090	64
TOTALS			2814	171



A small population of sambar persists in Pilibhit Forest Division but the species is rarely encountered on surveys.

RESULTS

Estimates of Tiger Abundance and Density

Over the 60 day sampling period in Pilibhit, we photo captured 23 unique tigers in 2013. Seventeen of these individuals were recaptured on two or more occasions. In total, we obtained 97 usable tiger pictures. Captures of six cubs and juvenile tigers (likely to be < 2 years) were not incorporated into the capture-recapture data files, as is common practice for the analysis of mark-recapture data of tiger populations (Karanth and Nichols 2002). Because we did not have left and right flank pictures for all tigers, we only identified unique individuals using all available ‘both-flank’ pictures and “right flank pictures”, while omitting “left-flank-only” pictures. Model summaries from program MARK are presented in Table 2.

The estimated abundance (model-averaged) of tigers in Pilibhit Forest Division in 2013 was 23 (95% CI 22 - 26). The associated per-occasion capture probability p was estimated to be 0.13 (SE 0.33).

Table 2 (Right): Summary of model results from closed-population capture recapture analysis in program MARK.

Model	AICc	Delta AICc	AICc Weights	Model Likelihood	Num. Par	Deviance
{Mo}	402.9314	0	0.64657	1	1	359.9032
{Mb}	404.7864	1.855	0.25575	0.3955	2	359.7407
{Mh}	406.9753	4.0439	0.0856	0.1324	3	359.9032
{Mbh}	410.8923	7.9609	0.01208	0.0187	5	359.7407

Table 3 (Below): Current and previous (posterior) estimates of tiger density (animals/100 km²) for PFD. Following Royle and Gardner, 2011, density is reported as the number of tigers/100km². σ is the parameter describing spatial scale detection process away from the home-range. λ_0 is the baseline encounter intensity, or the capture rate in a trap for an individual having s located precisely on a trap location. ψ is the data augmentation parameter. p_1 and p_2 are the probabilities of capturing a tiger that has not previously been captured, and the probability of capture subsequent to initial capture.

The estimated density of tigers/100 km² for Pilibhit for 2013 from Bayesian spatially explicit capture-recapture analysis is 3.44 (95% posterior intervals 2.33 - 4.54). Previously the density of tigers in PFD was estimated to be 4.22 (2.22 - 6.49) (Chanchani *et al.*, 2011). Maps depicting pixel-wise estimates of tiger density for Pilibhit Forest Division in 2011 and 2013 are provided in Figure 2.

We have photographic evidence for the movement of two tigers out of PFD between 2011 and 2013 surveys. One of these individuals, an adult male, has established a territory near Jhadi Tal in Kishanpur Wildlife Sanctuary (Figure 3). The other, an adult female, had taken up residence in sugarcane plantations near Amariya on the UP-Uttarakhand border. This tigress was raising 3 cubs in the farmlands (documented by a

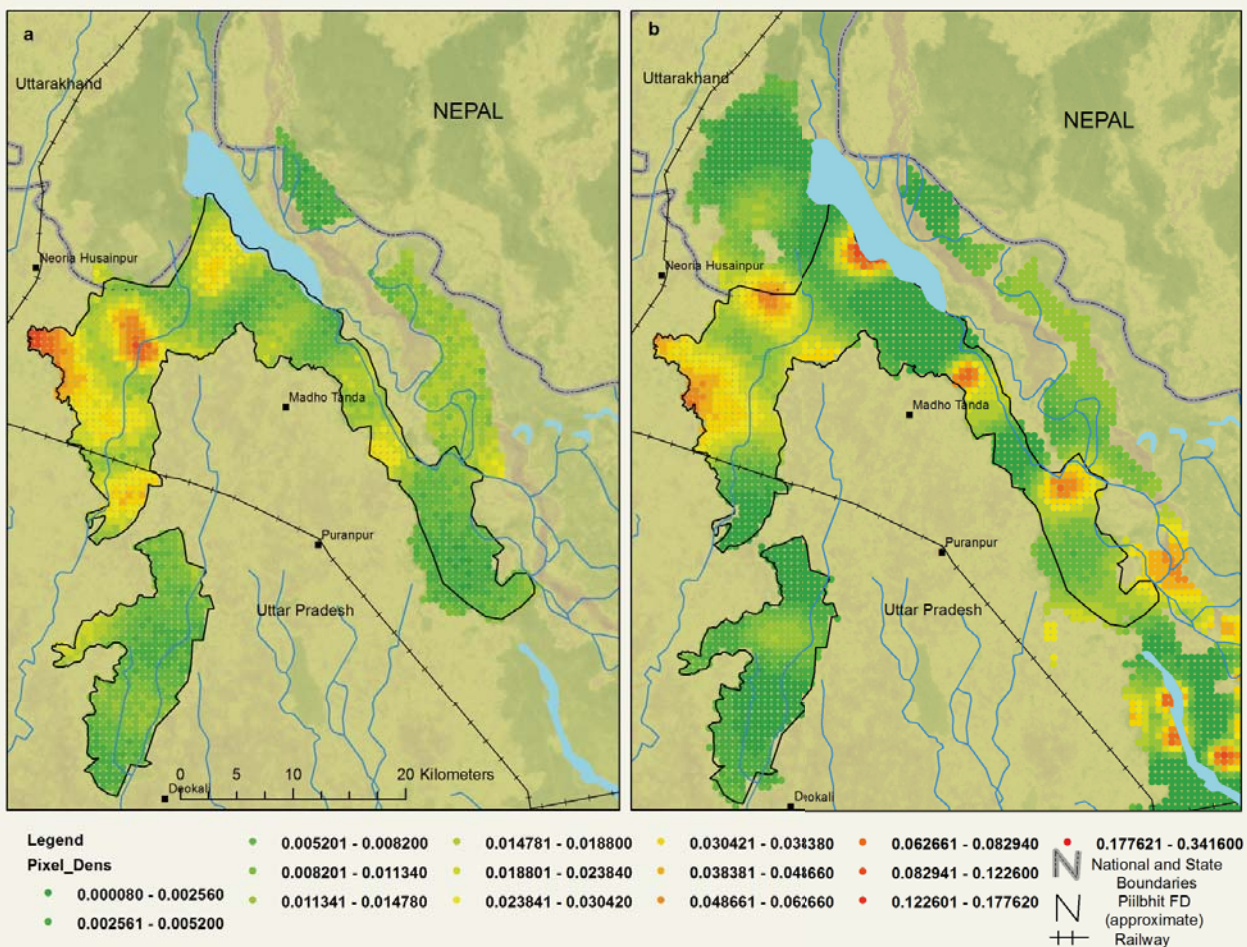
* From Chanchani *et al.*, 2011.

Year	Density (sd)	95% PI	σ (sd)	95% PI	λ_0 (sd)	95% PI	Ψ (sd)	95% PI	p_1 (sd)	95% PI	p_2 (sd)	95% PI
2011*	4.22 (1.17)	2.22 - 6.49	1.46 (0.50)	0.64 - 2.47	0.02 (0.04)	0.01 - 0.02	0.22 (0.07)	0.11 - 0.36	0.01 (0.004)	0.01 - 0.02	0.81 (0.08)	0.66 - 0.92
2013	3.44 (0.58)	2.32 - 4.54	3.65 (0.36)	3.00 - 4.40	0.01 (0.003)	0.0 - 0.02	0.22 (0.04)	0.14 - 0.31	0.01 (0.003)	0.01 - 0.02	0.74 (0.08)	0.57 - 0.87

WWF-India and Uttar Pradesh Forest Department team), and occupied the sugarcane fields from November 2012 to September 2013. There are unconfirmed reports that this tigress and her cubs may subsequently have returned to the Amariya area. Of the three known tiger mortality events between 2012 and 2013 in Pilibhit Forest Division, we were unable to identify carcasses of two adult males (recovered from Haripur Range in May 2012) because the skin had degraded. A third individual (2-3 year old male) whose body was recovered from the Hardoi branch of the Sharada canal near Deoria Range was found to have originated from Kishanpur Wildlife Sanctuary, where he had previously been photographed on a camera trap. We do not have specific evidence for tigers immigrating into Pilibhit or of births, apart from the visual detection of 3 young cubs (3-5 months old) on the border of Barahi and Haripur ranges in January 2013 by members of the research team.

Figure 2: Pixel densities for tigers in Pilibhit Forest Division. (a) Pixel densities for 2010-2011 from Chanchani *et al.*, 2011; (b) pixel densities for data from the current study (April - June 2013). Each pixel on this map represents an area of ~0.34 km².

While camera trap sampling was being undertaken in Pilibhit, we concurrently sampled Maharajnagar Block of South Kheri Forest Division which lies immediately south of PFD, and Surai Range (of Terai East Forest Division, which lies to the North). From 30 camera traps in Surai, we obtained photographs of 4 individual tigers (1 adult male and 2 adult females, one of which was accompanied by a cub), of which three were also recorded in cameras in Mahof Range of PFD. From the six cameras deployed on Maharajnagar block of SKFD, we obtained captures of three adult tigers, two of which were also observed to range in Kishanpur Wildlife Sanctuary.



DISCUSSION

The key findings of this study are listed below and subsequently discussed in further detail.

1. The 2013 surveys indicate that Pilibhit Forest Division supports a resident population of tigers with a density ~4 tigers/ 100 km².
2. The estimated population size for adult tigers is 23-28 individuals.
3. There are considerable local-scale variations in tiger distribution and density with areas of high density in portions of Mahof, Mala and Haripur ranges and lower densities in Barahi and Deoria ranges.
4. The estimated density of tigers in PFD is marginally lower than estimates from 2011 (Anwar *et al.*, 2010, Jhala *et al.* 2011, Chanchani *et al.*, 2011).
5. Studies in forests adjacent to PFD revealed that Surai Range (of Terai East Forest Division) supports a very low tiger density. Of the four tigers recorded in Surai, three were also captured in Pilibhit. The presence of five adult tigers was recorded in Maharajnagar block of Bhira Range (SKFD), of which three were also photo-captured in Kishanpur WLS or in PFD).

Resident Tiger Population

PFD has emerged as a prominent site for tigers in the TAL. It stands out among the few (<6) Reserve Forests in the country that support known populations of breeding tigers. Although Reserve Forests that lie outside of National Parks and Tiger Reserves have been recognized as important for securing tiger populations at landscape scales, they are seldom known to be important population centers by themselves. Typically, such forests are viewed as population sinks or sub-optimal habitats for tigers that emigrate from high-density source populations in nearby protected areas (Wikramanayake *et al.*, 2004; Rajapandian *et al.*, 2011, Walston *et al.*, 2011).

It is likely Pilibhit's tiger population is sustained on account of its proximity to other tiger occupied areas, most notably to Kishanpur wildlife Sanctuary. We have recorded dispersal events of young male tigers to-and-fro between these two sites and believe that such events may be relatively commonplace, given that these tigers are essentially members of the same population (see Figure 2, for an example of inter-site dispersal). Therefore, it might benefit tiger conservation if the entire forest block (THB VI) comprising of PFD, SKFD, Kishanpur WLS and Surai Range could be managed and protected in a manner that allows greater synergy between the constituent management units.

Sensitive Areas for Tiger Conservation

We describe *sensitive areas* for tiger conservation as those that are (i) tiger bearing forest areas with high human and livestock presence/pressure; (ii) forest-edge areas

that are peripheral to high-density tiger sites, and to which tigers may disperse; and, (iii) prey-limited areas within the landscape which may be occupied by tigers.

It is essential to bring such areas under greater wildlife management purview (especially given that territoriality and dispersal are integral aspects of the social behavior of wild tigers). We believe that tiger conservation in PFD will benefit from enhancing protection in the following sensitive regions, (a) Lalpur and Deoria Ranges of Pilibhit Forest Division; (b) Surai Range of Terai East FD; (c) riparian areas and grasslands along the along the Sharda and Chuka rivers; (d) Maharajnagar beat (SKFD) and Shahjehanpur Forest Division. (d) the Mala and Khannot rivers and banks of the Sharada Sagar reservoir (e) forest edges with high crop depredation by wild ungulates.

Table 4: Details of areas recommended for intensified protection.

Sensitive site (Beat, Range, Division)	Reason for selection	Remarks
Lalpur-Mala, Deoria (PFD)	The site of the infamous 2010 man-eater, this isolated forest fragment (~200 km ²) witnesses high levels of disturbance and cattle grazing. Also infiltrated by east-west trails that are heavily used by village traffic. The loss of several cameras in these areas, and reluctance of staff to deploy cameras in several locations highlights the areas sensitivity. Although this area has perennial water and sal-forest - riparian-zone - plantation mosaics, it supports a small fraction of PFD's tiger population (8 - 10%), even though it comprises about 3-% of the total area of PFD.	Need to limit human presence in the forest by demarcating some 'no-go' zones and restricting human movement to a few roads, with strict enforcement, particularly in riparian zones. This area may be earmarked for the targeted recovery of tiger and prey species populations.
Surai Range (Terai East FD)	Surai Range is more 'disturbed' than many areas of PFD because (a) it contains Bagga village with several roads and day-night traffic; (b) it supports a number of Gujjar <i>deras</i> , and buffaloes from these usually graze in the Chaugabe grasslands and along the Mala river in Mahof Range of PFD; and (c) the area's proximity to the Nepal border and to the sensitive Kilpura-Banbasa area may make animals here vulnerable to poaching.	Even though Surai Range does not have extensive grasslands, the presence of several perennial water sources and its location between Nandhour, Pilibhit and Shuklaphanta make it an important conservation site.
Riparian habitats and grasslands along the Sharda and Chuka Rivers in Hariपुर and Barahi Ranges of PFD and in Sampoorana Nagar and Palia Ranges of North Kheri Forest Division, including the Tatarganj forest patch.	These areas merit protection because (a) they are among the most extensive grassland tracts in the region and are high-quality habitat for tigers and prey species (most notably hog deer and swamp deer); (b) they currently experience intensive and largely unregulated grazing by several thousand buffaloes that live in cattle camps along the rivers; (c) the Sharda river and its associated grassland habitats serve as an important corridor between Shuklaphanta in Nepal and Pilibhit-Kishanpur in India; (d) riparian habitats, the lack of formal roads and division of the area between multiple two or more forest divisions with somewhat nebulous boundaries may result in lacunae in protection; (e) some of these areas are associated with the Rai Sikh community, known to be involved in hunting; and (f) cattle grazing pressure (from Navjalua and other Bengali settlements across the Sharada river) and cattle camps in and around the Lagga Bagga forests are exceedingly high; and (g) Lagga Bagga has occasional tiger, rhino and elephant movement and swamp deer are commonly observed here. Some of these sites are also associated with the endangered Bengal florican (<i>Houbaropsis bengalensis</i>).	The death of two male tigers in this area in 2012 (purportedly by poisoning) highlights its importance for tigers, and their vulnerability. A rhino (that is likely to have moved into the area from Shuklaphanta, Nepal) was caught on our camera traps in Hariपुर Range in May 2013 indicating that the corridor may be used by large mammals (also see Kanagaraj <i>et al.</i> , 2013).
Maharajnagar Beat, Bhira Range (South Kheri Forest Division), and areas of Shahjehanpur Forest Division proximate to Hariपुर range.	Maharajnagar beat of SKFD lies along the Sharada river and comprises of complex riparian and woodland habitats. The forest here is narrow, and has several large villages within it and numerous unpaved roads leading to these. This small area witnesses 'disproportionately' high tiger use because of its proximity to the Sharda river and corridor, Pilibhit and Kishanpur. There is a great need for heightened protection.	A lactating tigress accompanied by 1-2 cubs in sugarcane field and scrub forests of Paraspur (Palia Range, NKFD) during December 2012- March 2013 is likely to have originated from Maharajnagar. Forests along the Sharada comprise high-quality tiger habitat.

The Mala River in Mahof and Mala Range, banks of the Sharda Sagar Reservoir in Mahof and Surai Ranges and Khannot River.	Riparian habitats and their associated grassland tracts appear to be highly correlated with high tiger densities (Figure 4). There is a need for intensive foot patrolling in these areas, including river islands. The Khatima (Jhankiya) to Puranpur road passes through optimal tiger habitats in Surai and Mahof Ranges and there is a need to regulate and monitor day and night-time traffic on this road and on the Pilibhit-Mathna-Puranpur road. It is also important to reduce or regulate cattle and buffalo grazing along the Kheri Canal and in the Chaugabe areas of Mahof Range. we have located breeding tigresses with cubs in these areas in 2011 and 2013, and have also observed congregations of swamp deer and other wild ungulates. The banks of the Sharda Sagar Reservoir are densely forested, insular, and there is relatively little forest department presence apart from the Chuka reservoir rest house complex..	These rivers and their associated riparian habitats are likely to be the 'lifelines' for Pilibhit's tigers. Public roads in prime tiger habitats may have a number of negative impacts on wildlife.
Forest edges	A large number of ungulates including chital, wild pigs, nilgai and hog deer venture out of the forests into adjoining farmlands, particularly at night. In informal interviews, village residents in several areas indicated that ungulates are prone to being poached, particularly when feeding in farmlands.	Mechanisms need to be evolved to reduce poaching risks for crop-raiding animals or to reduce the entry of wild ungulates into farmlands.

A number of these sites, with the exception of the Mala river and Maharajnagar block, are areas important for tiger conservation even though they currently have relatively low tiger densities. Camera trap data indicates that sites that witness low-current use are often associated with young, dispersing tigers, and areas along water courses also witness use by females and cubs. Dispersing tigers (typically young males that often come to occupy these areas) often make perilous journeys in search of new territories, and in the process they risk conflict with territorial tigers, or become embroiled in conflict with humans on account of attacks on livestock, and more occasionally on humans (Smith 1993, Horev *et al.*, 2012). The tragic consequences of such events are loss of life or impacts on human livelihoods, and often the death of erring tigers. Such events also polarize human communities against conservation programs and wildlife management that aspires to increase or sustain tiger populations.

Restoring Corridors and Connectivity

Landscape connectivity is a key requirement for the conservation of several large carnivores (Crooks and Sanjayan 2006) and maintaining and restoring patch connectivity is an important tiger conservation objective for the Terai Arc Landscape (Wikramanayake *et al.*, 2004). Three 'corridor' areas are of particular relevance for Pilibhit Forest Division (Figure 4). These are the Garah-Lalpur corridor, the Surai-Khatima-Kilpura corridor and the Pilibhit-Tatarganj-Shuklaphanta corridor (and associated Lagga-Baggga corridor). The restoration of these forest corridors will make available >3000 km² of contiguous forest habitat.

The **Pilibhit-Tatarganj-Shuklaphanta** corridor comprises of extensive tracts of *Saccharum spontaneum* dominated grasslands, and patches of *Dalbergia sissoo*, *Acacia catechu* and *Bombax ceiba* forests along the flood plain of the Sharada River. These areas are prone to severe monsoon season flooding, but otherwise provide rich habitats for hog deer, swamp deer and tigers. However the presence of several dozen cattle camps along the Sharada river and human pressure on forest resources from Tatarganj and other settlements make this a hazardous place for tigers. The death of two tigers in

this corridor (purportedly as a result of feeding on a poisoned buffalo carcass) in 2012 highlights these dangers. There is a break in forest connectivity beyond Tatarjanj, in Nepal. To reach Shuklaphanta Wildlife Sanctuary (from the Tatarjanj forests), a tiger would either have to traverse through sparsely-populated farmlands for 2-4 kilometers, or follow the Sharada River upstream for about 6 kilometers and gain entry into the Lagga Bagga patch. Several small forest islands between Lagga-Bagga and others forests of Barahi Range may also serve as a corridor, with 'stepping stones'. A restoration of this corridor over-land may require active reforestation/ resettlement in India and Nepal, and sustained trans-boundary monitoring and engagement.

The **Garah-Lalpur Deoria corridor** comprises of farmland (dominated by sugarcane, wheat fields and the farm-houses of relatively prosperous agriculturalists). This patch of farmland, measuring 1.5 km at its shortest, lies between the forests of Garah (Mala Range) and Lalpur-Deoria (Mala and Deoria Ranges). The Lalpur-Deoria forests (~200 km²) have been inhabited by 2-4 tigers in recent years (2010 - 2013). We believe that the tiger population sizes in the Lalpur-Deoria patch have been suppressed, at least in part, by the absence of forest connectivity. Interviews with local residents suggest that tigers occasionally move between these forest patches. Animal movement through the agricultural zone between the forests is likely to be hindered by (i) NH 26 with a high volume of day and night time traffic, (ii) a large wood-depot near Garah Forest Rest House, (iii) large homes in the farmlands, some of which have generators and dogs, and (iv) an earthen canal. The Deoria-Lalpur patch has considerably large tracts of riparian habitat (particularly along the Khannot river), and its linkage through the restoration of a corridor to the rest of PFD via a forest corridor is likely to be beneficial for the tiger population.

The **Surai-Khatima-Kilpura corridor** lies in Uttarakhand, and connects Surai Range of Pilibhit Forest Division with the Nandhour Wildlife Sanctuary and Haldwani Forest Division (THB IV, approximately 1200 km²). Forests in this corridor have been fragmented by the main Sharada canal (~ 100m wide) which bisects the narrow corridor area in two places, and by a highway. The canal likely limits the movement of wild elephants and deters them from entering the Surai and Pilibhit forests from Haldwani Forest Division. Parts of these forests are also heavily disturbed by constant human pressure and encroachment of forest land stemming in part from the residents of the town of Khatmia and its neighborhoods. The Nandhour forests are reported to support a small tiger population (Mann *et al.*, 2012), but may have the potential to harbor many more tigers if appropriate conservation actions are implemented (Johnsingh *et al.*, 2010; Mann *et al.*, 2012). Boom Range of Haldwani Forest Division is separated from the Bhramadev forests of Nepal by the Sharada river. To the west, the Gola river separates Haldwani Forest Division from the Terai West and Ramnagar Forest divisions. Increased urbanization and industrial development in the lower reaches of the Gola are thought to have severely impacted connectivity between these patches.

Prey Density and Tiger-Prey Relationships

Bista (2011) estimated the density of ungulate prey species in Pilibhit Forest Division to be 40.5/km² (CV 10.6). There are considerable differences in the distribution of ungulate prey within PFD. There is a higher concentration of Chital (*Axis axis*) and hog deer (*Axis porcinus*) in Mahof, Mala and portions of Barahi ranges and a relatively lower densities of these species in the sal-dominated forests of Haripur Range (Bista 2011). Sign encounter surveys in Deoria suggest that Chital and hog deer occur at lower densities in this forest range than they do in Mala and Mahof, but wild pig (*Sus scrofa*)

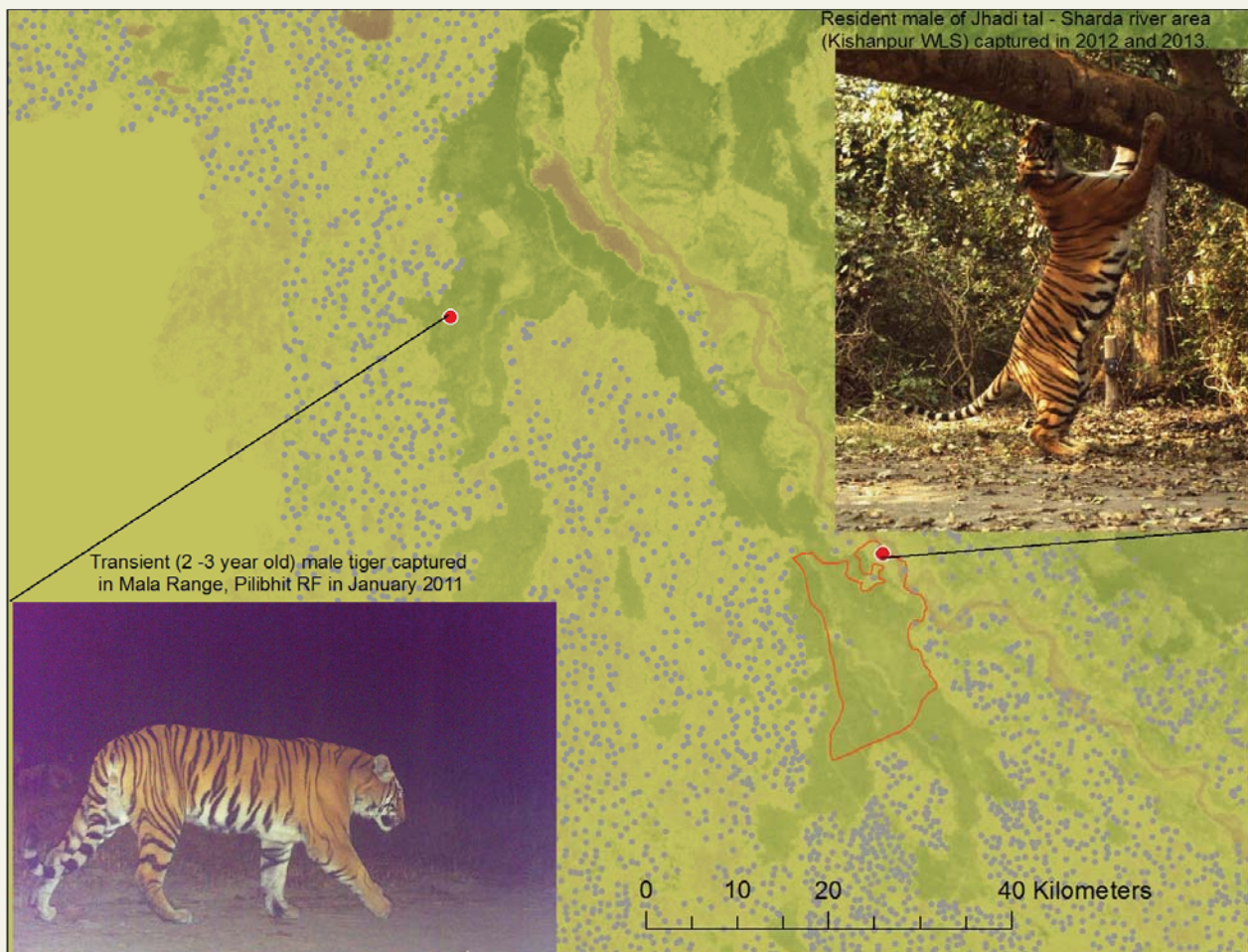


Figure 3: Dispersal of a male tiger from Mala range (Mathna beat) of Pilibhit to Sharda beat of Kishanpur Wildlife Sanctuary. The animal is likely to have dispersed in 2011. Dispersal events such as these are likely to be frequent, given the territorial behavior of tigers. Grey dots indicate locations of villages in the landscape.

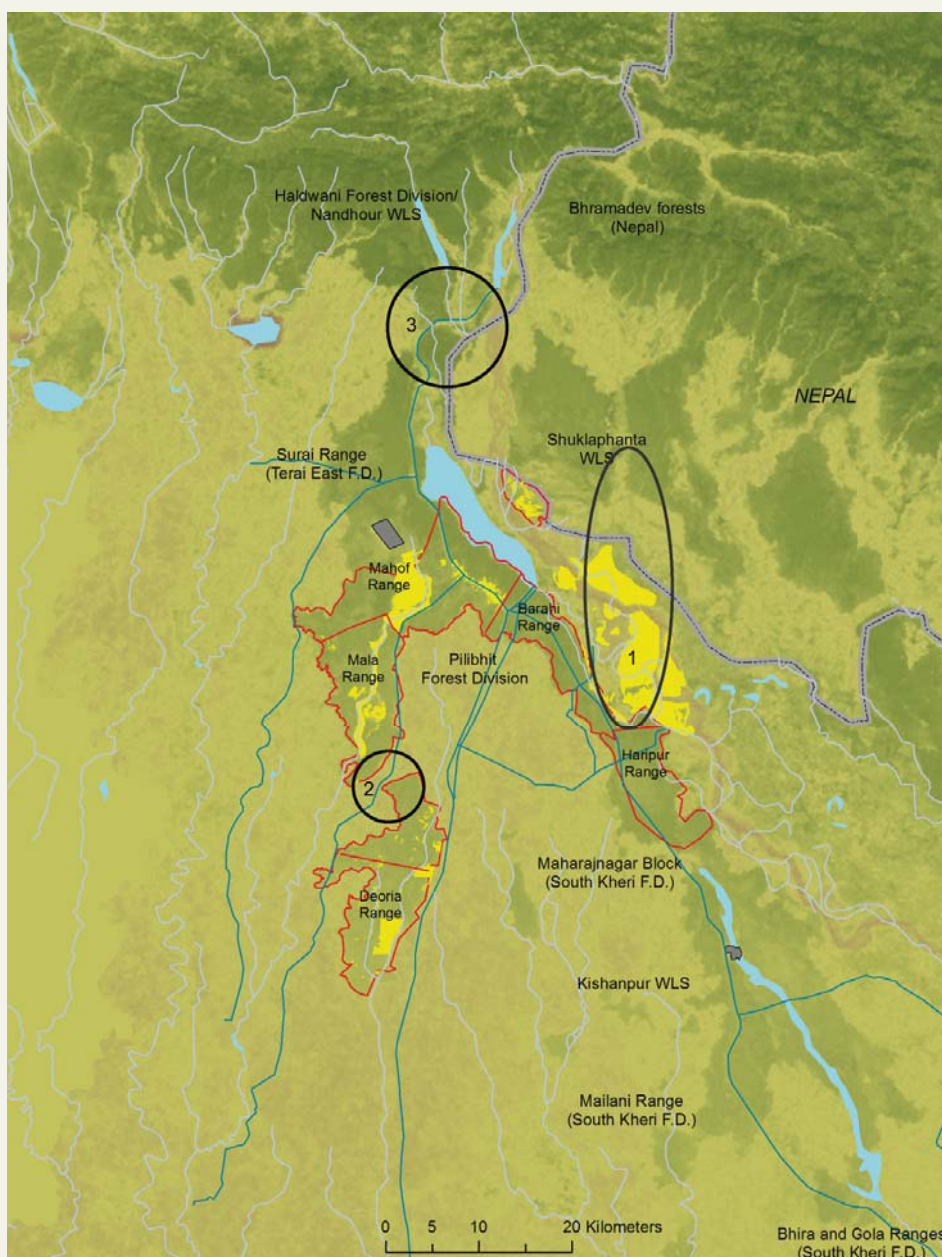
and nilgai (*Boselaphus tragocamelus*) were commonly encountered. Understorey species composition and structure are likely to be primary determinants on the distribution and abundance of wild ungulate prey. Grassland-forest mosaics and canopy openings (natural or those created by logging) may provide suitable habitat for chital in particular.

The observed prey densities in Pilibhit are considerably high. Karanth *et al.*, (2004) reported that several other sites with similar prey densities support > 8 tigers/ 100 km². On this count, it appears that Pilibhit may have enough tiger prey to sustain higher tiger density than the currently observed 3-4 tigers /100 km². However, it is important to mention here that realized tiger densities in PFD are likely to be determined not only by prey abundance, but also their distribution. Some ranges (associated with more diverse habitats and grasslands, eg. Mala and Mahof) have contributed disproportionately to the prey density estimates of Bista (2011), whereas other areas of the forest (notably sal-dominated stretches in Haripur range) are associated with low densities of chital and other species. The occurrence and abundance of tigers is therefore likely to be influenced by the interactive effects of habitat-prey density and distribution and by human-disturbance.

Tiger-Habitat Relationships

Prey abundance, though a key determinant of tiger abundance, is not likely to be the only constraining factor on tiger densities. The habitat may also directly influence the distribution and abundance of tigers, both because habitat structure and composition influence tiger behaviour and space-use and because habitat (arrangement and composition of vegetation, water) strongly influence the occurrence and abundance of key prey species of tigers.

Figure 4: Map of Pilibhit Forest Division and adjacent forested areas. Areas in yellow are prominent grasslands and riparian habitats which support various wild ungulates and provide habitat for tigers. The areas encircled in black are important corridors that need restoration efforts (1) Lagga-Bagga Tatarganj-Shuklaphanta corridor; (2) Garah-Lalpur-Deoria corridor and (3) Surai-Kilpura corridor (Uttarakhand). If tigers are able to disperse effectively between patches using these corridors, a large contiguous habitat block of >3000 km² (depicted in this map) in India and Nepal will be created for tiger conservation.



A large portion of the forest of PFD is strung along two narrow limbs that extend southwards from the forests of Surai and Chuka. The western limb comprises predominantly of Mala range, and it tapers off near where a major highway passes through the forest. About 1.5 kilometers to the south (with the intervening space composed of agricultural fields, a highway, several small settlements and a canal), lies the patch of Lalpur–Deoria. Because of this peculiar elongated shape, the forest has a high perimeter-area ratio. As a consequence, it is difficult to mark-out a core-area in large parts of Pilibhit. This narrow forest is further bisected by multiple roads and several large canals.

With regard to the vegetation component of the habitat, we identify *Saccharum* dominated *grassland* patches and patches of *riparian forest and grasslands along rivers* as being key to the persistence of tigers in PFD. Notable among these are the large grasslands in the Bheemtal–Chaugabe and Mainakot areas of Mahof range, and smaller grasslands scattered across the northern areas of Mala range. Tall grasslands along the banks of the Mala river (Mahof and Mala range), the Khannot River (Deoria Range) and the Chuka River (Barahi and Haripur Ranges) are also significant. These grasslands are important tiger habitats because (a) they are attractive areas for a number of important prey species like hog deer (Wegge *et al.*, 2007) and are likely to play a crucial role in maintaining the prey-base that supports this tiger population and, (b) these grassland patches possibly serve as day-time refuges for Pilibhit's tigers, given the high levels of human disturbance (from roads, forestry and logging operations and fuel wood collection by locals). This point is important because large areas of the sal forests of Pilibhit are subjected to management practices (such as understorey clearing and late-winter fires). It is therefore important to judiciously employ prescribed cutting and burning to maintain both tall and short grass patches that provide forage and cover for grazing ungulates and other species.

Finally, a feature of the physical habitat that is likely to have significant influence on populations of tigers and other large mammals in Pilibhit is the distribution and year-round availability of water. Apart from seasonal water holes and ponds that are rain-fed, wildlife in Pilibhit benefits hugely from three perennial rivers namely the Sharada (which flows along the eastern boundary of Bahari and Haripur Ranges), the Mala (which flows through Mahof and Mala ranges) and the Khannot in Deoria Range. In addition, the presence of canals in all five Ranges ensures ample water availability. While these rivers and canals may impose some limitations in the distribution of wild mammals, particularly ungulate prey, the edges of canals and rivers are associated with complex vegetation formations (comprising of dense grasslands, swamps or riparian woodlands) providing habitats that are frequently used by tigers.

Human Presence in Forests

For a number of reasons, Pilibhit's forests are occupied by humans all year round, particularly in the day-time hours. A major form of human presence and activity in the forests is due to annually conducted forestry operations (which commence soon after the monsoon until the following summer). Forestry operations bring in large crews of labor and contractors on tractors, motor cycles and bicycles. These teams selectively fell marked trees in designated 'lots', load the wood into tractors and transport it to depots. Apart from the noise and physical alteration of many forest patches by these operations, logging results forming a network of roads (with varying degrees of use and disuse) because the flat terrain permits the creation of roads to the exact site of felling. We believe that these forestry operations certainly affect ungulates and carnivores, and

expect that animals temporarily migrate out of areas with the onset of intensive logging operations. However, this is not a sustained form of disturbance, rather a constantly shifting one, and crews cover several sites over the course of a few weeks.

A second (less intrusive but more pervasive) form of anthropogenic activity in forests is local dependence on forests for biomass (predominantly fuel wood and grass resources). Forest edges in the proximity of villages are used most intensively and villagers on foot or bicycles collecting wood for fuel (mostly dry tree-limbs from the forest floor) are a common sight all year round. We also frequently encountered local people harvesting grass (both by head loads, and with tractors), as well as collecting fish and other non-timber forest produce. In late summer, around the onset of the monsoons, many people (probably several thousand) comb the forest floor for *katurba*, a truffle-like fungus that is a much sought after delicacy in local markets, and at other times of the year local residents of the area harvest the fruits of *Zizyphus*, *Grewia* and *Syzigium*.

Vehicular traffic on most forest roads is strictly regulated and restricted primarily to forest department vehicles. However in Barahi and Haripur Ranges, a number of minor unpaved roads bisect the forest, cross over the Kheri canal and link villages to the North and south of the Forest. There is an incessant day-time flow of traffic that includes cars, tractors and motorcycles, and many ferry agricultural commodities and milk from the villages along the Sharda to Purnapur and other towns that lie to the south. Traffic on these roads is likely to be a source of disturbance for wildlife in the narrow Barahi forest. The railway line which bisects Mala range is an additional source of disturbance, and can be a threat to some mammals because trains often speed through the forest at speeds >60 km/ per hour. Similarly, the highway in Mala Range (NH 26) witnesses heavy day and night time traffic use.

Increased tourist interest in PFD in recent years has led to a rise in visitor numbers to this Reserve Forest and in the development of lodging and other infrastructure, particularly in Chuka (Mahof Range), one of the few areas of this forest that can be considered to be a 'core-zone'. Our subjective assessment is that Lalpur and Banjanganj Beats of Mala Range and Deoria Range experience greater day-time and night time disturbance, by way of human presence in forests, than most other areas of PFD. The presence of two ashrams with growing infrastructure, along perennial streams in the interior of Deoria Range are other sources of disturbance.

However, what is significant to tiger conservation in Pilibhit is that all the aforementioned sources of disturbances are restricted to daytime hours (with the exception of a few roads, and areas like Lagga Bagga, where buffaloes graze both during the day and at night). Further, there are no sizable human settlements or villages within the forest interior in Pilibhit Forest Division, and we believe that tigers and their prey species may be more resilient to day-time disturbance than they are to human and cattle populations that permanently reside in forests and sometimes compete with wildlife or restrict their access to resources. In this respect, human presence and disturbance in PFD is of a different nature than it is in other areas e.g. in Rajaji National Park, where the buffalo-herding Gujjar community lives in *deras* or hamlets within the forest. The continuous presence of people and livestock in the forests is thought to have depressed densities of tigers and key prey species in Rajaji NP (Harihar *et al.*, 2009, 2011). We see some evidence of similar effects in Surai Range (a few kilometers north from Mahof Range), where the forest is considerably more disturbed on account of presence of a large village (Bagga gaon) and numerous Gujjar *deras*.

We speculate that high human presence in PFD (particularly Forest Department personnel or logging crews on foot or bicycle) may actually aid enforcement. This is because there are ‘many more eyes’ in the forest, and thereby greater vigilance in remote regions of the forest interior for many months of the year. This situation is in contrast to other sites in the terai, where relatively large sections of the forest interior (particularly away from forest roads) may go unvisited by Forest Department personnel for relatively long durations for various reasons.

We recognize also that the presence of large numbers people in forests may, in some situations, exacerbate the potential for human-wildlife conflict (Gurung *et al.*, 2008), and may in other ways adversely influence occupancy or abundance of mammals or undermine protection efforts (Karanth *et al.*, 2011). We do not advocate that forests be ‘opened’ to the unregulated entry of a large number of people. However, we believe that there is room for carefully designed studies to understand human-tiger co-occurrence in sites like PFD, and for thoughtful discussion on conservation and management strategies for such sites which are associated both with high tiger use and significant human presence in the forests (Harihar *et al.*, 2012).

Forest-Management Burning and Assisted Natural Regeneration

Each year, in the fire season (February–May), large portions of PFD are subjected to burning by the Forest Department. Burning by the department is primarily to rid the forest of dead and dry biomass (particularly Sal leaves on the forest floor and tall grass) which would otherwise accumulate and increase the risk of catastrophic forest fires during the summer. Burning is sometimes carried out repeatedly within a season, and forest officials try and ensure that their fires cover their respective beats and sections, almost in entirety.

While we acknowledge that the risks associated with large summer forest fires are high, we propose that burning be managed differently such that refugial habitat patches, particularly grasslands are burnt selectively or with rotation, and by sparing some proportion of grasslands from fire. These practices will ensure that cover essential for tigers, and their prey which give birth in the spring is not entirely decimated by fires. Such practices are also likely to benefit a host of other species including birds in the nesting season, reptiles, amphibians and arachnids (Hore and Uniyal 2008). A planned and well informed combination of grass-cutting and burning can help create habitat patches that are beneficial to some grazing ungulates (Kumar *et al.*, 2002).

Assisted Natural Regeneration (ANR) involves clearing the forest undergrowth in designated areas by clearing shrubs and saplings that are of less value for forestry. Many years of this practice in Pilibhit, has resulted in large tracts of uniform homogenous Sal forests, with a relatively simple understorey. The impacts of burning and other removal of snags, deadwood and grass by humans on forest ungulates, and other faunal groups in the terai have received some attention in the studies of Hore and Uniyal 2008, Peet *et al.*, 1999 and Wegge *et al.*, 2004, and Kumar *et al.*, 2002. These studies concur in their recommendations that (a) well-managed burning of cutting and burning grasslands in the late winter (January) can make grasslands more productive for grazing animals until the summer months and (b) ‘rotational’ burning of patches once in two years may be adequate to maintain grassland composition while providing cover for wildlife and habitat for grassland obligate species.

Engaging with Local Communities

Given the high dependence of forest-fringe human communities on forest resources including fuel-wood, timber and NTFP, we believe that there are several opportunities to involve key communities in the region to reduce human pressure on forests, to engage with communities afflicted by human-wildlife conflict and to develop approaches to sustainable use of forest resources.

While we do not discuss specific measures in length here, we believe that some or all of the following merit the urgent attention of the government and conservation groups: (i) Zonation of the forest and working with communities to maintain some 'inviolate' spaces in the forest, particularly in areas with known presence of breeding tigresses. It is important to work on a priority basis with communities whose dwellings are within forests, namely residents of Bagga *gaon* and various Gujar families in Surai Range and some villages in the Chandi-Hazara region of Haripur Range. We believe that there is a pressing need to document the use of grasslands along the Sharada river by domestic buffaloes (in the thousands), and to work towards socially equitable solutions to 'secure' tigers in these areas (ii) Identifying areas of high conflict in the landscape, where human communities are most afflicted by conflict with wildlife, including crop depredation. Specific measures like electric fences can be installed with community participation, where needed. (iii) Strengthening local level institutions like eco-development committees and working with Panchayati Raj institutions within the larger objective of participatory conservation and forest management. (iv) Creating appropriate and sustainable livelihood opportunities that can provide an incentive for supporting conservation and reducing dependence on forest resources.

CONCLUSION AND RECOMMENDATIONS

The growth and persistence of tiger populations is fostered by protecting these endangered animals from poachers, and by effectively managing human-carnivore conflict. It is also well established that tiger populations thrive where preferred prey (large bodied wild ungulates) exist at high densities. Protection therefore need to be extended not only to the population of tigers, but also to their prey, and by extension to the forest and grassland habitats these species occupy. We emphasize the need for systematic and organized patrolling and intelligence gathering in PFD to effectively protect species that are very vulnerable to hunting. We have noted that several forest Ranges within and around PFD merit greater protection. In recent years, the Forest Department, with support from NGO partners, has taken several steps to enhance and revitalize patrolling efforts with the goal of conserving wildlife.

We believe that managers can also sustain tiger population in PFD by managing habitats in order to maintain grasslands and primary successional riparian forests, and by maintaining forest heterogeneity. Dinnerstein 1980 emphasizes the importance of these vegetation communities for having major influences on the diversity, distribution and density of ungulate prey species in the terai. In PFD, forest and grassland habitats are typically managed by 'controlled' burning, and clearing of the understorey in some areas. It is important for managers to peruse the work of Kumar *et al.*, 2002 and use the findings of these and other studies to prescribe appropriate treatment and management regimes. *Prima facie*, we do not have specific evidence from our studies that suggest that timber operations in PFD may have a negative impact on wild ungulate or tiger populations. We do not - at this point - advocate that revised management regimes preclude such activities from PFD. We do however call for the recognition of some areas (riparian grasslands in particular) as key tiger habitats and recommend that human intrusion and livestock grazing in such areas be regulated to provide 'in-violate' spaces for tigers.

Finally, we reiterate that the persistence of tigers in PFD to this date has been enabled to a large degree, by its proximity to other tiger-occupied sites, most notably Kishanpur Wildlife Sanctuary. The restoration the three key corridors (previously described) will make it possible for tigers to disperse through forested habitats that link three important tiger population centers/ recovery sites (namely Pilibhit-Kishanpur-South Kheri, Shuklaphanta, and Nandhour-Bhramadev).

We list a set of broad management recommendations here and note that these will be followed up by more specific recommendations from ongoing studies being carried out by WWF in association with the state forest department.

Based on encounters of tiger signs, camera trap data, and interviews, we believe that tiger conservation in PFD will benefit from the inclusion of the following into conservation and management plans and programs.



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A tiger in one the canals passing through the Pilibhit Forest Division

- 1 Active day and night-time patrolling along forest edges, and along reservoirs, canals, rivers and stream courses.
- 2 Increased management focus / protection in sensitive areas particularly along the Sharada River, in Lalpur, Banganj and Ghunchai blocks (Mala Range) and in Deoria and in Surai ranges.
- 3 Streamlining management to create synergy in administration and management practices in the entire Pilibhit forest Complex for tiger conservation.
- 4 Enhanced trans-boundary monitoring, with a particular focus on the Sharda River forests and Lagga Bagga.
- 5 Restoring key corridors by
 - (a) reducing human pressure and cattle grazing in corridor zones;
 - (b) restoring forest-cover;
 - (c) engagement with agriculturalists to provide safe passage for animals while ensuring human safety
 - (d) engineering wildlife underpasses/ bridges/ flyovers for some highways and canals.
- 6 Reducing or regulating traffic on forest roads with heavy public use. Engaging with the railways to regulate the speed of trains.
- 7 Maintaining vegetation heterogeneity, through forest and active grassland management in some sites.
- 8 Maintaining cover and 'disturbance free' areas, particularly along stream and river courses.
- 9 Minimizing anthropogenic disturbance in the forest interior and in areas where the forests are narrow.
- 8 Reducing day time disturbance by discouraging 'fanning-out' of large numbers of people simultaneously in the forest interior.
- 8 Regulating burning and understory manipulation in assisted natural regeneration related procedures to retain cover and vegetation heterogeneity for wildlife.
- 9 Working with forest fringe villages to ameliorate the impacts of crop depredation, reduce forest dependency and hunting and mitigate human-wildlife conflict.
- 10 Creating livelihood opportunities for forest dependent groups.



Post-monsoon harvest of grass, Mahof range, Pilibhit Forest Division

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A machan erected by the forest department serves as a vantage point for summer-fires and camp for forest watchers

ANNEXURES

Appendix 1

A) Tiger individuals used for analysis



B



J



C



L



D



O



F



U



H



W (Deceased)





ZA



ZB



ZD



ZH



Pili 3



Pili 7



Pili 8



Pili 10



Pili 12



K 14



Pili 8



E



New 3

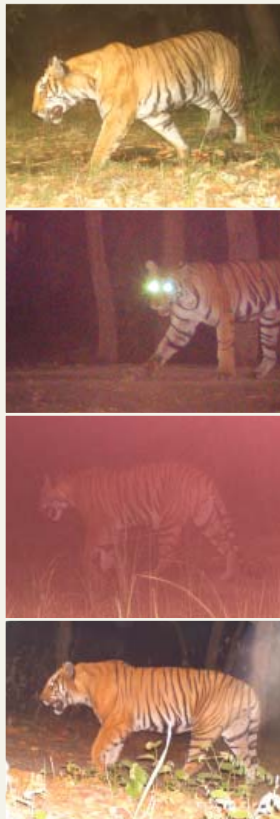
B) Tiger individuals excluded from analysis



Amarya tigress - previously photo-captured in Mahof range in 2010-11. Monitored by WWF team in farmlands near Amarya, Pilibhit district between November 2012-September 2013. Accompanied by three cubs.



Individuals likely to be less than two years of age, excluded from analysis



Individuals with left flank captures only omitted from analysis

Appendix 2

Note on Tiger monitoring in Surai range (Terai East Forest Division) 2013

WWF India, Terai Arc Landscape Program

Surai range of Terai-east forest division was sampled using camera traps to estimate tiger population size in the Surai-Pilibhit-Kishanpur complex. Sampling in Surai commenced following the completion of camera trapping in Mahof, Barahi and Haripur ranges of Pilibhit forest Division. Surai range was intensively sampled using a trapping web of 30 camera locations placed at an approximate distance of 2 kilometers from each other. The trap sites were selected following an initial reconnaissance survey conducted with beat forest guards. Camera Traps (Cuddeback Attack) were active in Surai between 30th May and 15th June 2013 and traps were also simultaneously active in Mala and Deoria ranges of Pilibhit Forest Division.

Four tiger individuals were captured during the camera trap sampling. The three individuals include 2 females (one accompanied by a ~1year old cub) and a male. Two of these individuals (a male and a female) were previously captured in Mahof range of Pilibhit forest division.

Along with the camera trapping exercise, transect sampling was also carried out to enumerate prey species abundance. Seven randomly placed transect lines were sampled on three occasions to estimate densities of principal ungulate prey species. Each transect was 2 kms long and, the total sampling effort for Surai was 42 kms. Animal encounters were rare. The sampling effort yielded only 6 detections of Chital, and one each of Nilgai and wild boar. Encounter rates for these ungulate species are presented in the table below.

Species	Encounter rate/km
Chital	0.81
Nilgai	0.048
Wild boar	0.02

Profiles of Tigers Camera Trapped in Surai Range



INDIVIDUAL ID- Surai female
CAPTURED AT- Compartment 53 and Bagga1

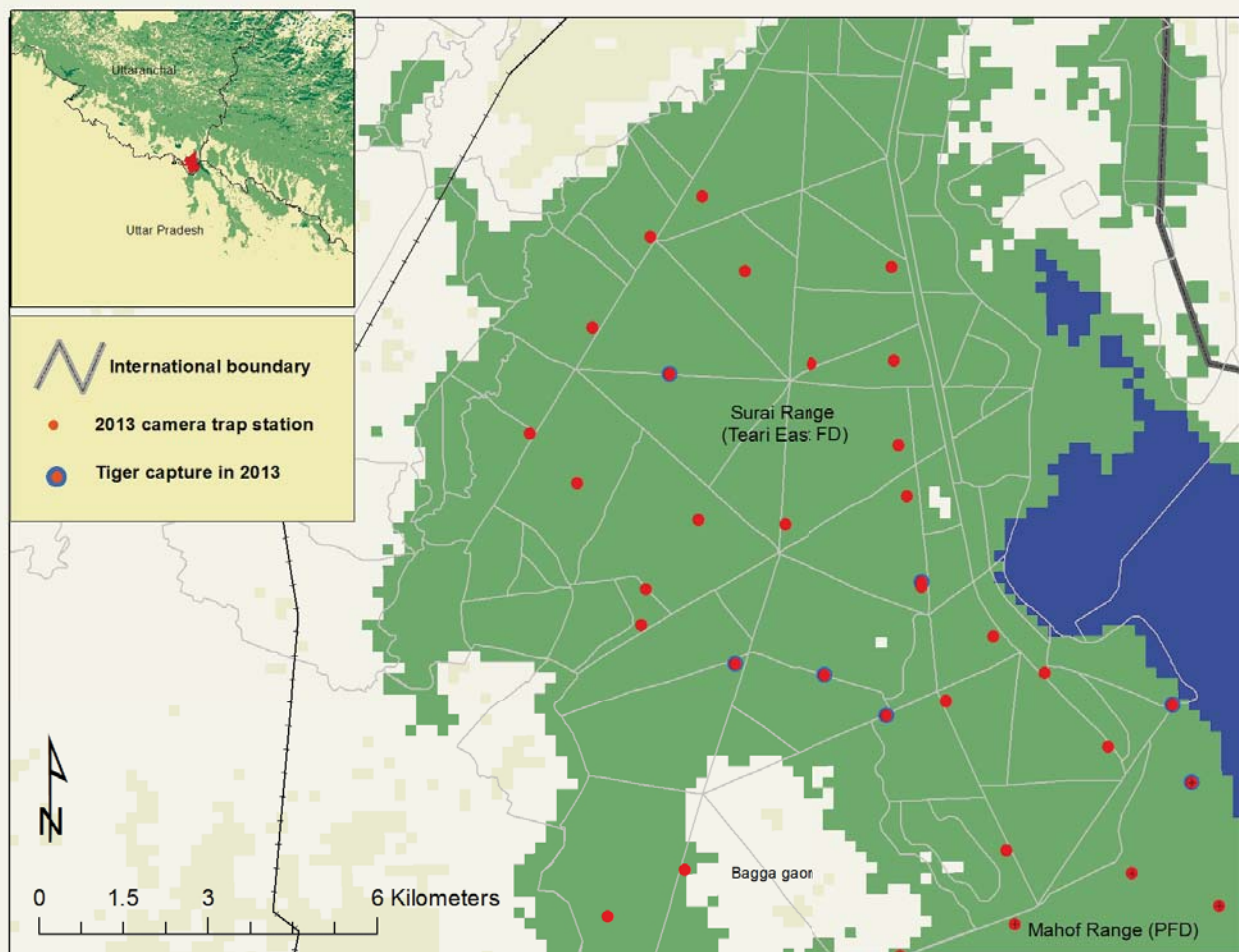


INDIVIDUAL ID- Chuka female with cub
CAPTURED AT- Compartment 46,47, 46b of Surai range and Mahof range of Pilibhit Forest Division



INDIVIDUAL ID- Mahof Male
CAPTURED AT- Lukat and Mahof range of Pilibhit Forest Division





Locations of Camera Traps in Surai Range (May - June 2013).

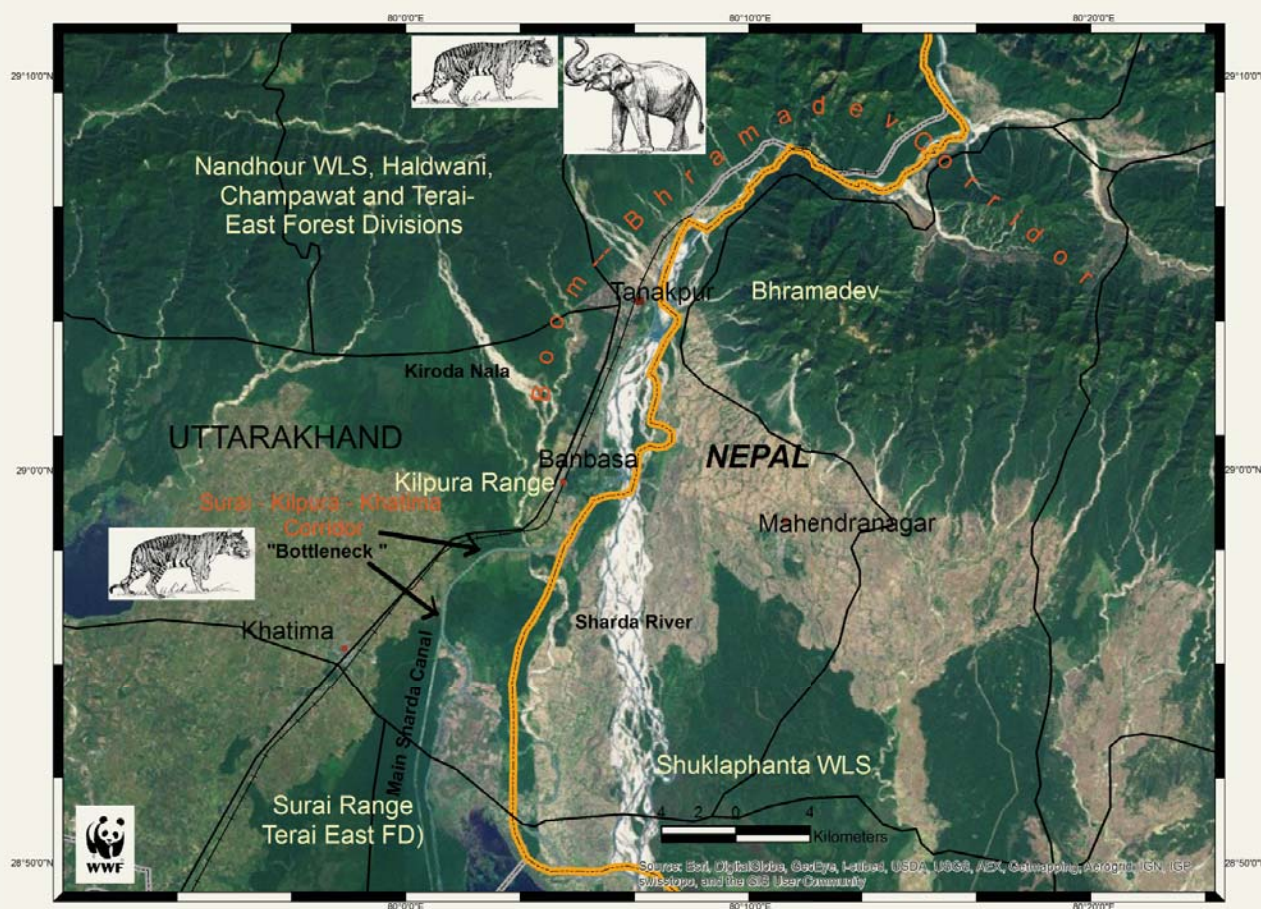
Appendix 3



The Haripur-Tatarganj-Lagga Bagga-Shuklaphanta Corridor. Areas that most merit conservation and management attention are (a) the riparian grasslands in Pilibhit Forest Division and North Kheri Forest Division along the Sharda River. This area faces high anthropogenic use, primarily by way of grazing buffaloes. There are several dozen cattle camps scarred along the banks of the Sharda in the non-monsoon months. The buffaloes graze in *Saccharum spontaneum* grasslands, and their milk is sold in towns like Madho Tanda and Puranpur. (b) Tatarganj in Sampoonnagar Range of North Kheri Forest Division. This patch represents high quality habitat for tigers and a number of ungulates in the form of grasslands and successional riparian forests. However, there is enormous human pressure on this relatively small forest patch by way of buffalo grazing, high human use for fuel-wood and grass, and hunting by local communities (Johnsingh *et al.*, 2004). (c) The patch of farmland between Tatarganj and Shuklaphanta/ Lagga Bagga. This represents the only 'non-habitat' area on this corridor between Kishanpur-Pilibhit and Shuklaphanta. Although development is currently small-scale, we believe that there is an urgent need to develop a forest corridor along the Sharda river, or in its vicinity.



The Garah-Lalpur-Deoria corridor. This ‘corridor’ exists as agricultural land (usually under sugarcane and wheat cultivation) between the Pilibhit-Surai-Kishanpur-South Kheri Forest complex (~1000 km²) and the Lalpur-Deoria forest patch (~200 km²). The occurrence of tigers in the Lalpur-Deoria patch, turnover of individuals present and accounts of tiger movement reported by local residents indicates that tigers use the area that is represented by the shortest distance between these forests to disperse between the patches (area between the dotted-red lines on the map). This has been confirmed by a recent connectivity model using circuit theory (Bista *et al.*, 2013 -unpublished report, WWF-India). The presence of a number of large and growing farm-houses in this area, and the appearance of Dhabas (roadside restaurants) may deter tigers from using this corridor. Suggested mitigation efforts include (i) Regulating development in the key corridor area shown here, and in proximate areas by declaring a ‘green-zone’; (b) reforestation of area between dotted lines; (iii) engagement with local agricultural community to avoid putting up fences and walls in this corridor area, and to provide a safe passage for wildlife, (iv) building of an flyover or re-alignment of a section of SH-26 to reduce road impacts on the corridor and wildlife; (v) overpass for wildlife over Malasi canal in corridor.



The Surai-Khatima-Kilpura Corridor: This corridor lies in Terai East Forest Division, Uttarakhand. Although forest cover exists along the corridor, its effectiveness to serve as a conduit for the movement of large mammals between Pilibhit and Nandhour WLS and Bhramadev- Shuklaphanta (Nepal) has probably been severely impacted by (i) The presence of a highway (Khatima to Tanakpur); (ii) a railway line (Pilibhit - Tanakpur), (iii) The wide canal Sharda, often with a large volume of water that bisects the corridor in two places, and (iv) growing settlements and reported encroachments in the areas marked bottleneck' on the map. Recommended restoration efforts for this corridor include engineering solutions to mitigate canal and road impacts on tiger and other wild-animal movement, and removal of encroachments in the corridor. The Boom Bhramadev Corridor lies North of Tanakpur town and connects the Nandhour forests to Bhramadev in Nepal. This corridor is known to have been used by wild elephants, but it has been eroded by the growth of Tanakpur town.





An old British Era bridge over a Canal in Pilibhit



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