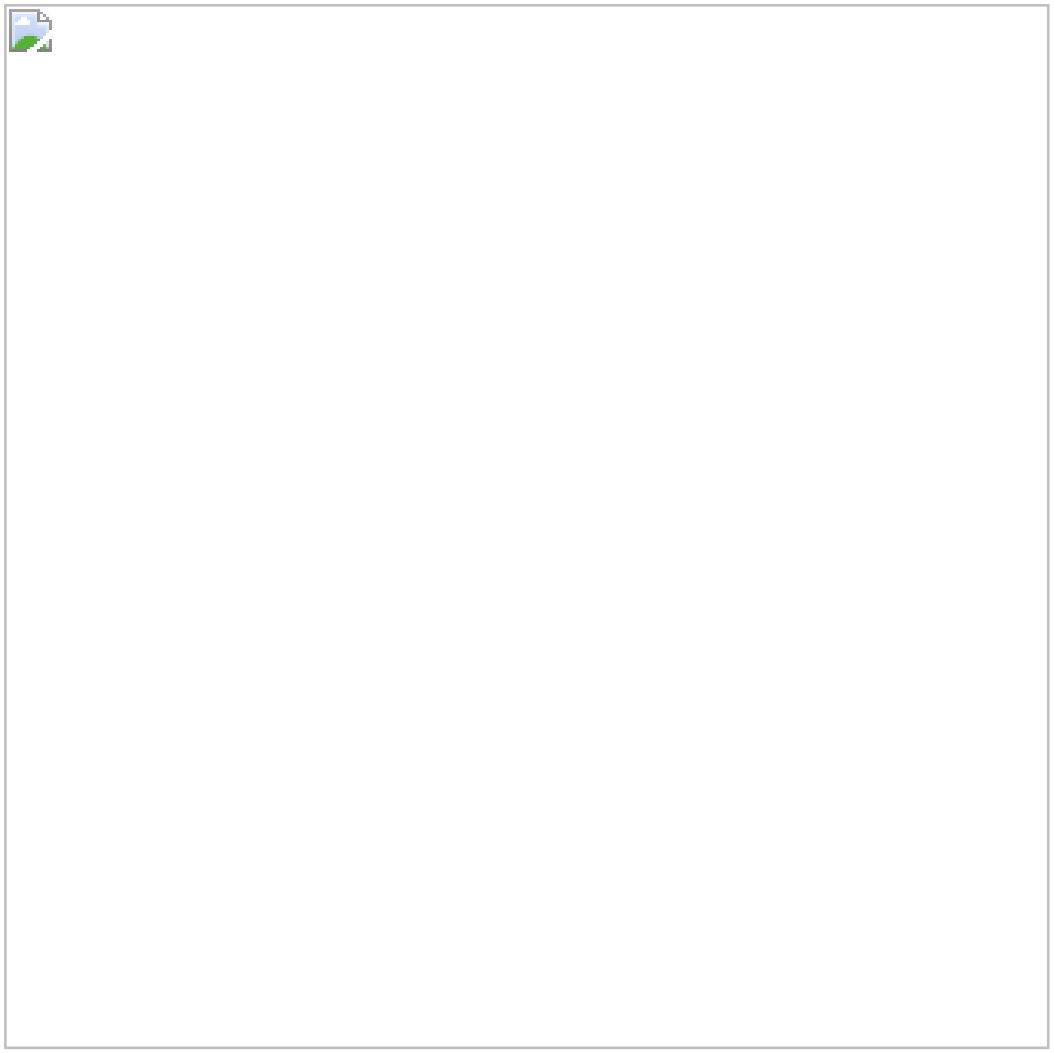

Movement and activity pattern of a collared tigress in a human-dominated landscape in central India

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Research Article

Movement and activity pattern of a collared tigress in a human-dominated landscape in central India

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Abstract

Tigers (*Panthera tigris*) are wide-ranging species, and a permeable landscape matrix outside Protected Areas (PAs) is extremely important for their dispersal. A tigress which had fallen in a water duct in the Nagpur district was rescued by the Forest Department on 12th October, 2011 and released on 27th November, 2011 in a forest adjacent to the site of capture. A GPS-GSM collar that we fitted on her indicated that she remained in the same forest area until 25th December, 2011, and then moved eastwards into a human-dominated landscape where she was present until 25th March, 2012, after which the GPS battery ceased to function. She moved a minimum distance of 454.65 km from the time of her release up to 25th March, 2012, using a total area of 726 km^2 (95% MCP), but between 30th December, 2011 and 25th March, 2012, after moving into the human-dominated forest-agricultural landscape her home range was 431 km^2 (95% MCP). Her home range also encompassed villages, roads and croplands. Her activity was largely nocturnal and she rested in dense foliage inside forest patches during the day. About half of all the prey items that we identified during this period (n = 12) were wild pigs (*Sus scrofa*). Although, she was present very close to areas where humans were active in the day, no untoward incident occurred. She was photographed in April 2013, a year after the collar stopped functioning, in the same region about 40 km from the release site, indicating that she is still present in the human-dominated area. Very little is known about tiger ecology, and their temporal and spatial patterns of movement, outside PAs. These areas will be crucial in terms of dispersal between PAs as well as sensitive in terms of conflict.

Keywords: Panthera tigris, collaring, human-use landscape, home range, movement patterns

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Introduction

Over the last century the tiger's (*Panthera tigris)* landscape has changed dramatically, with a range collapse of 93% due to habitat loss, prey depletion and direct hunting [1,2]. The potential for conflict between humans and wildlife is increasing with the expansion of human populations, farming frontiers, and housing [3-6] into wildlife habitats. An expanding human population has put increased pressure on the tiger's habitat and its prey [7]. Most wild tigers today survive on the Indian subcontinent, and the species is classified as Endangered by the IUCN [added new citation 8 = IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. <www.iucnredlist.org>, downloaded on 30 August 2013]. It is known to inhabit various forest types such as dry deciduous, moist deciduous, semi-evergreen, wet evergreen, riverine, swamp and mangrove [7]. Most ecological studies on tigers have been within PAs [9-12], and there is little information about how tigers behave in human-dominated landscapes. This knowledge is scarce but increasingly important, given that most source sites are embedded in larger human-dominated landscapes [13].

There are historical records of tigers from the Chandrapur district in eastern Maharashtra, where Tadoba-Andhari is a prominent tiger reserve. Even today, Chandrapur and its adjoining districts contain large patches of forests interspersed with agricultural areas that potentially form important corridors for large-bodied wildlife moving between PAs in the region [14]. The presence of tigers, leopards (*Panthera pardus),* and sloth bears (*Melursus ursinus*) in these human-dominated areas results in increased interaction between large carnivores and humans. The state Forest Department often reports large carnivore attacks on livestock and humans [15], as well as instances when wild carnivores have to be rescued from man-made structures such as wells and canals. In this paper, we present the results from monitoring a tigress after she was rescued from an irrigation canal and then released nearby in a forest patch in Central India. She was fitted with a GPS-GSM collar to monitor her habitat use, activity budget, and movement pattern in a human-dominated landscape.

Methods

Study area

The site where the tigress was released was a forested patch of *c.* 100 km^2 in Nagpur district which is categorized as reserve forest and protected forest (Fig. 2). This patch of forest has recently been declared as the Umred-Karhandla wildlife sanctuary. Human density in the district is nearly 409 people/km^2 [16], while village density is 1 village per 5.3 km^2 [16]. Other nearby PAs with known tiger populations are: Tadoba-Andhari tiger reserve to the south (*c.* 45 km straight line distance), Navegaon national park and Nagzira wildlife sanctuary to the east (*c.* 70km), and Pench tiger reserve (*c.* 75km) to the north. The region where the tigress was present lies between the above PAs and the Tadoba-Andhari tiger reserve in the south.

After December 2011, the tigress moved and used the northern parts of Chandrapur district (Fig. 2), in the Nagbhid and North Brahmapuri sub-districts that are administered by the Brahmapuri Forest Division (BFD). These are human-dominated areas, and the human density of the Chandrapur district is reported at 193/km^2 (Census of India data, 2001). Agriculture in the district is dominated by cultivation of oilseeds, cereals, cotton and pulses.

The Chandrapur district occupies an area of 11,443 km^2, which is 3.72 percent of the total area of the state of Maharashtra. The dominant vegetation in the region can be characterized as Tropical Dry Deciduous Forest [17] with some of the important species being *Terminalia tomentosa, Pterocarpus marsupium, Diospyros melanoxylon, Anageissus latifolia and Madhuca*

latifolia. The dense forests occur in the plains, and the slopes of the hills usually support poor and low density vegetation.

Fig. 1. The tigress was rescued from a water canal duct, maintained in captivity for 45 days and then released near the site of capture in the Nagpur district, Maharashtra.

Habitat-use, home range and activity pattern

On 12th October 2011, the tigress had fallen in a duct of an irrigation canal near a forest patch near Tass village in Nagpur district (Figure 1). She was tranquilized and captured on 13th October 2011, and was kept in captivity for nearly 45 days to treat her injuries. Her enclosure was located in the Forest Department complex in Nagpur and covered on all sides by greenhouse material to minimize human contact. On 27th November 2011, the tigress was fitted with a GPS-GSM collar (Plus I, Vectronic Aerospace, Germany), microchipped (000-6CC-2E56), and released in the Bhiwapur range of Nagpur Forest Division, *c.* 6 km (straight line distance) from her site of capture (Figure 2).

GPS location data collected by the collar were sent directly via a GSM mobile telephone network. The locations were downloaded and viewed in Google Earth (Google Inc. 2011). The collar also had a VHF transmitter which was used when the GPS battery was drained. Initially, after her release, the collar was set to obtain GPS locations once every hour; in January it was changed to once every two hours in order to extend battery life. The GPS locations were uploaded to a hand held GPS.

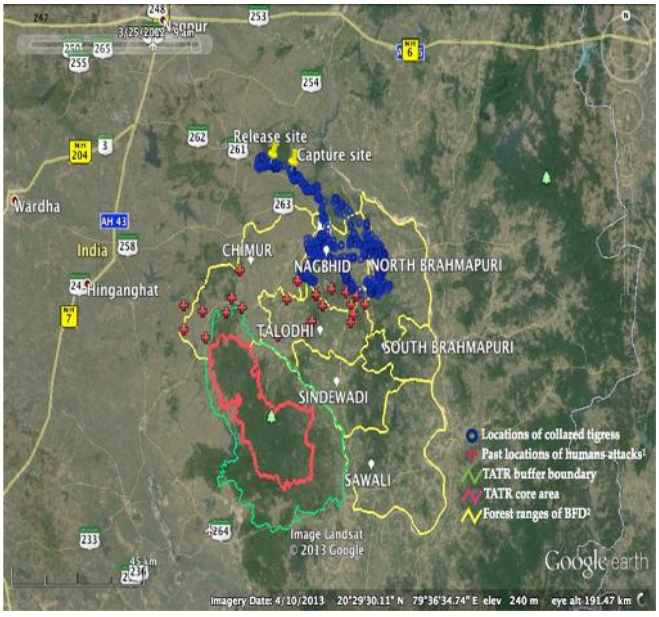


Fig. 2. Map of Brahapuri Forest Division (Chandrapur district), showing the movement of the collared tigress as blue dots. The nearest tiger reserve of Tadoba Andhari is outlined in red and its buffer area in green. The different ranges of BFD, a human-dominated landscape, are outlined in yellow.

We searched for the tigress's signs such as tracks, hairs, scrapes, scats or kills using multiple locations (> 8) in one place or close to each other (henceforth referred to as clusters), and care was taken to check both the day and night clusters. We did not venture close to the tigress, in order to minimize disturbance and avoid making her presence obvious to the people in the human-dominated landscape. Therefore, the locations were checked for her signs only after the tigress had moved out of the cluster location.

The habitat at her resting place, represented by the dominant land use (forest, agricultural field, grassland, fallow land, plantation, reed bed, and stream or river bed), and the percentage of canopy cover were noted. Other features like visibility (high, medium or low) and the substrate of her resting place (hard, soft or grass) were also noted. The proportion of forest and non-forest habitat where she was present was assessed using two-hour intervals and assessing the habitat where she was found on Google Earth. The above was carried out for points between November 30, 2011 and March 25, 2012 in order to omit data for the period immediately after her release.

Visibility was subjectively defined as how visible the tigress would have been to a person from the outside and was assessed only after the tigress moved away from the site. The visibility was categorized as low if the tigress was not visible to a person standing 20-30 m from her; medium if she could be seen from 20-30 m, and high when she was completely visible from 50m away. The visibility data were collected from 7 December 2011.

We looked for remnants of any kills within a radius of 50 m of each cluster and tried to identify the species that were preyed upon. If there were many clusters close to each other, it was likely to indicate a kill, and all the locations were checked till the remnants of the kill were found.

We estimated home range size with 95% minimum convex polygon (MCP) and 95% fixed kernel estimators (Least Squares Cross Validation smoothing factor) using the Animal Movement extension in ArcView 3.3. To analyze the temporal distribution of movements and movement patterns in relation to houses and villages, we used a subset of locations with two-hour intervals. Locations with longer time intervals between them were removed from the data set. Villages were delineated by drawing polygons around clusters of houses that were not separated by agricultural fields or other vegetation. The boundaries of the villages were digitized using Google earth, and further analyses, i.e. estimating movement distances and distances to villages, were conducted using ArcView 3.3 and Quantum GIS. Here, locations between 6 am and 6 pm were defined as daytime positions and the others as nighttime positions. We used locations obtained after her first confirmed kill on the 30th November, 2011, and omitted those immediately after her release in order to avoid biasing the results due to the stress of transport and release. The minimum distance travelled was calculated by summing up all the straight line distances for all the GPS locations.

During the monitoring we also noted the presence of other tigers and large carnivores in the landscape, if we found any, and recorded human and livestock attacks that occurred in the area.

Results

During the monitoring period, the habitat analysis was carried out using a total of 1,358 GPS locations, which indicated that the tigress used both forested and non-forested areas such as agricultural fields, lake-side reed beds outside forest, small patches of grassland in the middle of agricultural fields, and scrub patches around irrigation canals (Figure 3). The tigress traveled a minimum distance of 454.65 km from 27th November, 2011 to 25th March, 2012. The GPS battery of the collar ceased to function after 25th March, 2012.

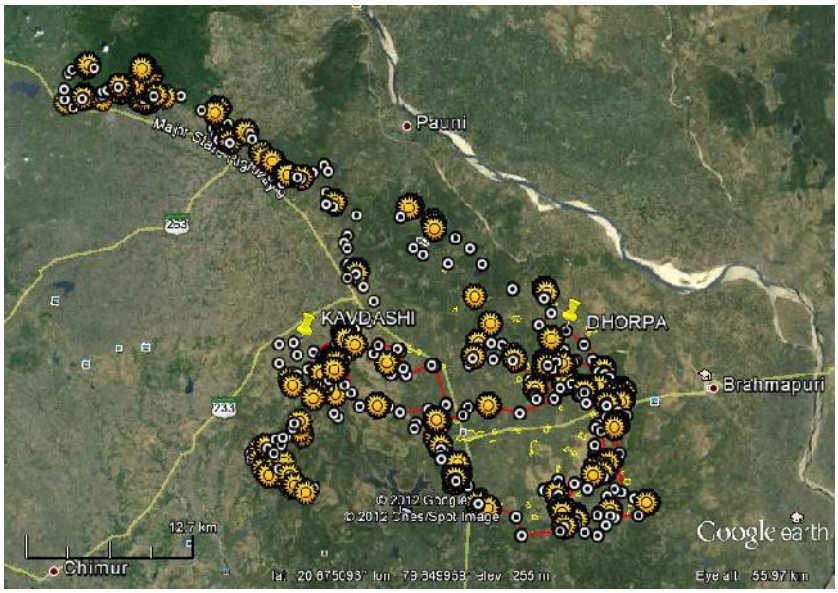
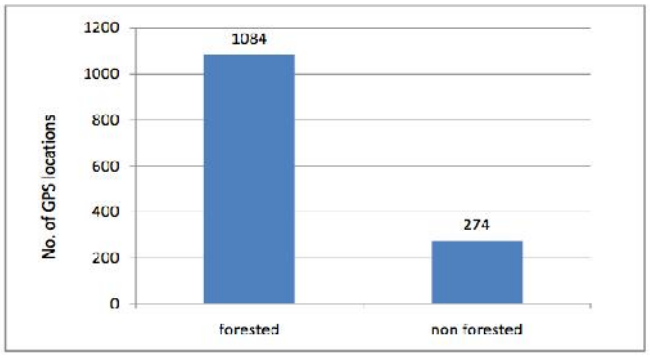
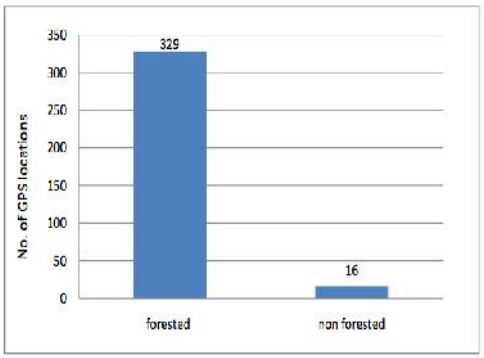


Fig. 3. The GPS locations of the collared tigress in the Brahmapuri Forest Division (Chandrapur district) from the date of release until 25 Mar 2012, when the collar sent its last signal. The yellow icons indicate her day locations and the white circles her night locations. The yellow polygons denote the boundaries of villages as digitized in Google Earth.

For the initial month after her release, the tigress was largely localized in the Umred Karhandla forest, after which she began ranging outside this area. If the location of all the points over the entire four months of monitoring are considered, only one-fifth of the points were outside forests, but this includes the first month after release when she remained largely within the Umred Karhandla forests (See Figure 4(a-c) below).



a)



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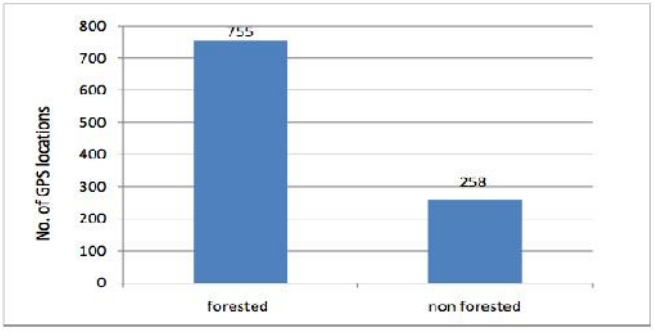

c)

Fig. 4. Proportion of locations of the collared tigress with respect to forest and non-forest (eg. agricultural fields) over the: (a) entire monitoring period between November 30 2011 and March 25 2012. (b) hourly locations for the period immediately after release (November 30 2011 to December 28 2011) in the Umred Kharandla forests (Nagpur district). (c) two-hourly locations for the last three months of monitoring (December 29 2011 to March 25 2012) in the human-dominated landscape in Chandrapur district.

Home-range and habitat-use

Her home range estimates for the whole period of study were 917 km^2 using the kernel estimator and 726 km^2 using the MCP. When only the last three months (January-March 2012) of monitoring were considered, we reached smaller home range estimates of 459 km^2 (kernel) and 431 km^2 (MCP). From the release point to the last point on April 2013, the straight line distance was 40 km. The state forest department (Deputy Conservator of Forests, Brahmapuri, pers. comm.) obtained her photograph in the same region using a camera trap placed at a livestock kill in April, 2013, indicating that she was still in the area. Although the home range of the tigress encompassed numerous villages, she rarely came near any village borders. Only three out of 1,323 locations used in the movement analyses were closer than 100 m (0.2% of locations), and only 3.5% were closer than 250 m from villages.

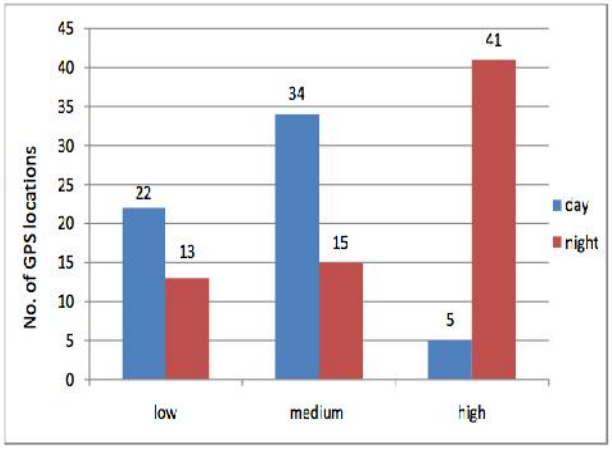

Fig.5. The visibility of the collared tigress at her day and night time locations. The visibility was subjectively categorized as low if the tigress was not visible to a person standing 20-30 m from where the tigress was present; medium, if she could be seen from 20-30 m, and high when she was completely visible from 50m away. The visibility data were collected between December 7, 2011 and March 25, 2012.

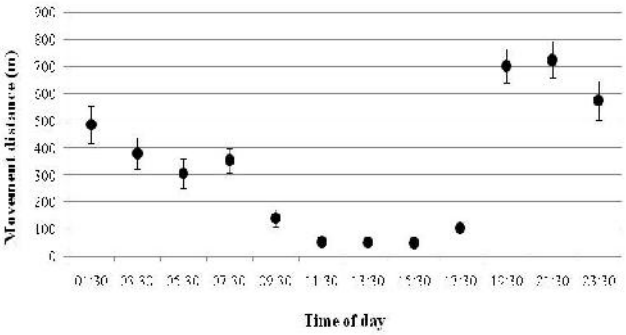

Fig. 6. The collared tigress's average two-hour movement distances throughout the diel cycle (with 95% confidence limits) during the period December 30, 2011- March 25, 2012.

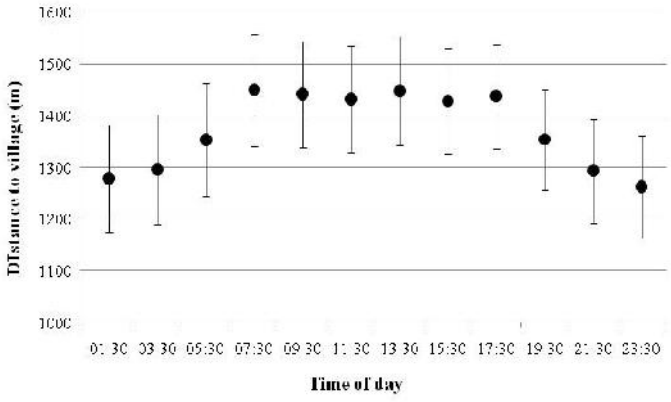

Fig. 7. The collared tigress's average distances to villages throughout the diel cycle (95%CI) during the period December 30, 2011 - March 25, 2012.

A total of 112 day clusters and night time locations were checked from 20th January 2012 to 25th March 2012 to note the visibility at her locations. She rested in dense vegetation and thickets during the daytime and moved in open fields at night where visibility was high (Fig. 5).

Temporal usage

We obtained a total of 1,761 GPS locations (hourly locations in the initial month and subsequent two hourly locations) from the collar, out of which 838 were daytime locations and 923 were night-time locations. Her temporal movement patterns revealed a pronounced nocturnal behavior, as the distances between re-locations (2-hr time lag) averaged 527 ± 27 (SE) m during the night and only 126 ± 12 (SE) m during the day (Figure 6), indicating that she moved much less in the day. This difference was statistically significant (One-Way ANOVA, $F = 21.5$, $DF = 1$, $P < 0.001$). As illustrated in Figure 7 and 8, she was closer to the villages during the night (1308 ± 43 m) than during the day (1446 ± 44 m). This difference was also statistically significant ($F = 4.8$, $P < 0.001$).

Table 1. Details of kills made by the collared tigress in the Nagpur and Chandrapur districts, Maharashtra.

	Date	Species killed	Location
1	30/11/2011	Goat	Forest
2	16/12/2011	Goat	Forest
3	20/12/2011	Wild Pig	Agricultural field
4	18/01/2012	Wild pig	Forest
5	01/02/2012	Langur	Forest
6	05/02/2012	Yet to identify	Agricultural field
7	08/02/2012	Wild pig	Forest
8	11/02/2012	Wild pig	Lake reed bed
9	24-2-2-12	Wild pig	Agricultural field
10	02/03/2012	Wild pig	Agricultural field
11	10/03/2012	Cow (scavenged)[1]	Forest
12	22/03/2012	Goat (scavenged)[2]	Agricultural field
13	22/03/2012	Goat (scavenged)[2]	Agricultural field
14	23/03/2012	Yet to identify	Forest

[1] Cow (scavenged) - when we inquired in the village next to the forest patch where the carcass was found, no loss was reported, even to the Forest department.

[2] Goat (scavenged) - only bones and skull of goat were found, these were her night points, assuming there would not be any goat at night and she would not have come to agricultural field during the day and has spent less time there.

The presence of other tigers and conflict in the landscape

We obtained photo evidence of two other adults, a male and a female in the locality, during the first month of monitoring. On 28th November, 2011, one day after the tigress was released, at 16:30, a woman was killed by a tiger while she was collecting firewood 16 km away from the release site. The GPS-collar confirmed that the tigress was not the animal responsible because her GPS location for 16:30, when the attack occurred, was 16 km away from the location of the attack. The Chandrapur Forest division has reports of human deaths due to tiger attacks and the collared tigress's movements were in areas where in the recent past tigers had killed people. Between 2005 and 2011, 103 people were attacked by tigers and 29 by leopards [15]. In the five years from 2007 to 2011, 1,607 livestock were reportedly killed by tigers and leopards in the Brahmapuri forest division (records of the BFD; [15]). The BFD reports a minimum of 15 individual tigers in the landscape since these are regularly photographed using camera traps deployed by the forest officials (Deputy Conservator of Forests, Brahmapuri pers. comm.).

Discussion

The collared tigress's ranging was extensive, and in the last three months of intensive monitoring she used c. 400 km^2 of human-dominated areas which encompassed forest, villages and agricultural fields with human densities close to 200/km^2. She rarely moved in the day and was active mainly at night. The data showed that she was rarely close to villages, although she would cross agricultural fields in the night and crossed railway tracks and highways as well. A study of tiger activity patterns [18] found lowered activity in the daytime, which was related to the activity of the prey. In a human-use landscape, human activity patterns would be higher while wild prey would be less active in the day. Even though she used the human-dominated landscape, and on a few occasions there were humans within 100 m of her location, she rested in dense shrubbery in the day that made sighting her difficult. Wild pigs seem to have been an important part of her diet, although the sample size is too small to make a definitive conclusion. Although other tigers in the region have killed large livestock such as cows and bullocks (BFD records), the tigress primarily preyed on wild pigs, only occasionally preying on mid-sized livestock and scavenging one cow during time the collar was transmitting locations.

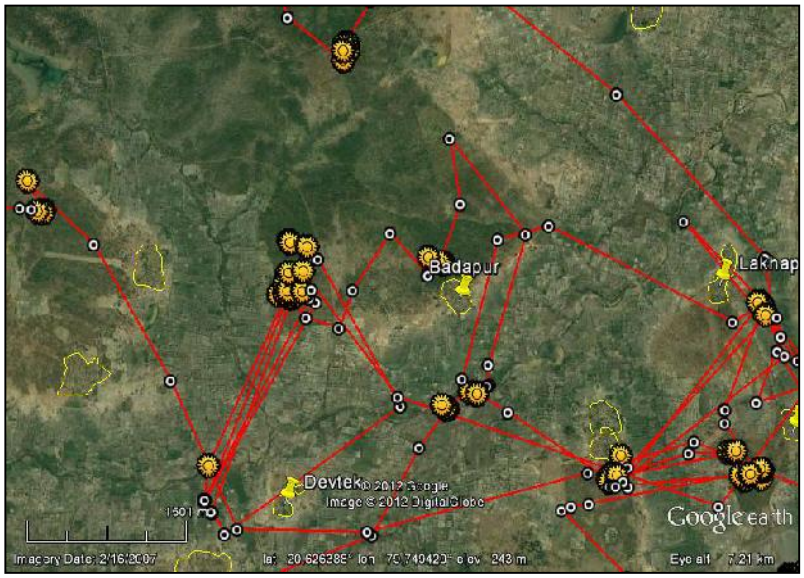

Fig. 8. A sample of the collared tigress's day and night time locations; most daytime points (yellow circles) are clustered and located in the forest patches. The night time points (white circles) are scattered and occur even in agricultural landscape. The yellow polygons are villages in the area.

It is unclear why she had such a large range compared to those known from tigers collared in PAs [18-20], but home range sizes are known to be strongly related to the prey biomass [20]. It was thought that she may have been a transient, but latest camera trap images (BFD records) of her at a livestock kill with another tiger taken in April 2013 show that she was still present one and a half years later in the same region, indicating that she is likely a resident.

The collar data, although from a single tigress, underscore our lack of information on large felid ecology and behaviour outside PAs in India. This is particularly relevant in issues of conflict as well as dispersal between PAs. Wild felids are known to disperse long distances [22-24]. In India there are reports of tigers having travelled more than 200 km [25], making it inevitable that they will use human dominated areas to move between PAs. Research on the genetic structure of tigers shows a high degree of connectivity among Indian tiger populations [26] although the genetic diversity has declined since historical times [27]. The importance of areas outside PAs to allow dispersal and maintain the genetic diversity of large-bodied, wide-ranging animals can only be re-emphasized.

Roads are known to adversely affect tiger numbers due to various related factors such as increased poaching, vehicle accidents to prey and tigers, and habitat fragmentation [28]. GIS analysis of potential corridors for tigers rate agricultural landscapes, roads, and degraded landscapes [29,30] as having a very low suitability compared to forested landscapes. However, to move between PAs in a densely populated country such as India, wild animals will have to use human-dominated landscapes. The tigress we collared demonstrated an ability to cross agricultural landscapes and roads. In order to retain or increase the permeability of the landscape for the movement of large bodied wildlife, there is a need for measures to aid their natural dispersal and movement. Considering the rapid pace of development in India, this need is urgent.

The presence of large felids outside PAs implies that conflict is imminent, and the Chandrapur district does report attacks on humans by tigers [15]. Although traditionally an area with rich forests and tiger populations, fragmentation due to mining, canals, and deforestation could increase conflict. However, the actual reasons for high conflict are unknown, and recent studies indicate that the presence of a large felid in a human use area does not necessarily imply high conflict [31].

In conclusion, the focus of tiger research until now has largely been inside PAs where human presence is usually low. We recommend that studies of ecology and interactions between large felids and humans, along with the impact of large scale fragmentation of habitats outside PAs, be carried out to better understand large felid use of human-dominated landscapes and minimize large felid conflict with humans.

Implications for conservation

Research on tigers in India is extensive but largely conducted within PAs that are considered as source populations. Large felids within PAs are much easier to manage, but when they use human-use landscapes, especially to disperse between tiger reserves, the welfare of both tigers and humans has to be addressed. Large felids require an ecologically and socially permeable landscape to effectively disperse, and their presence in human-dominated landscapes would imply losses to people, of life and livestock. These issues have to be effectively addressed for the successful long-term conservation of this species. It is hoped that this paper leads to increased research and management focus on the presence of large felids outside PAs, and the use of data from collared animals to assess the continuity between PAs.

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