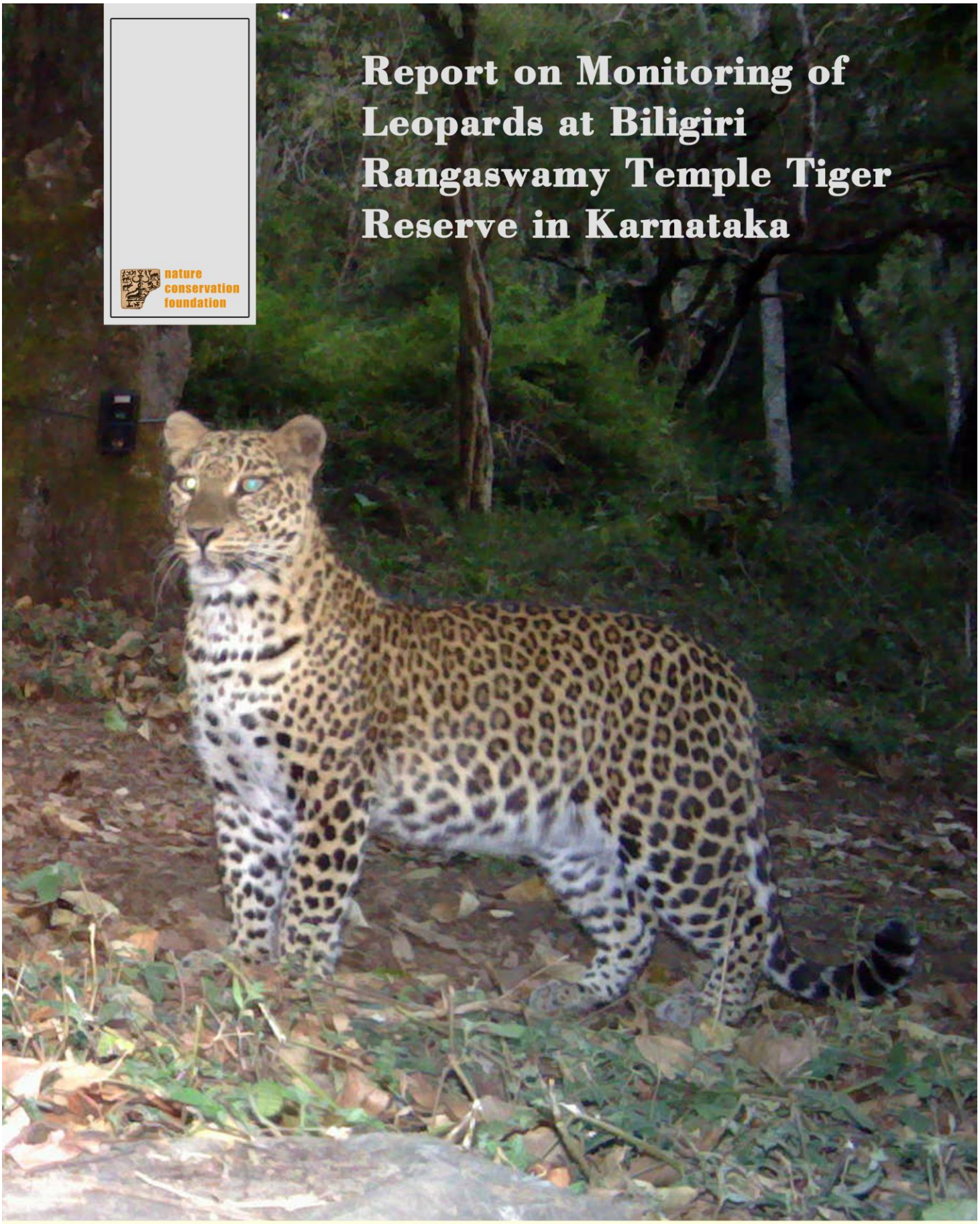
Report on Monitoring of Leopards at Biligiri Rangaswamy Temple Tiger Reserve in Karnataka



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Introduction

The leopard (*Panthera pardus*) is an elusive, solitary species that is found over a broad geographic range and has also adapted to human-dominated landscapes. They inhabit a variety of habitats and their diet constitutes a wide range of prey species. They are also one of the most conflict-prone species due to these reasons. The main threats that are contributing to their declining population include habitat loss and fragmentation, retaliatory killing, vehicular collisions, poaching, depletion of prey and others (Jacobson *et al.* 2016; Gubbi *et al.* 2017).

Currently, the leopard has been listed as Vulnerable under the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Stein *et al.* 2016). In India, under the Wildlife Protection Act 1972, they are listed as a Schedule 1 species which provides them with the highest level of protection. There is a need for reliable and systematic collection of data to estimate the abundance and density of these cats, and establish a population trend in order to implement necessary management measures. This needs to be done across protected areas, and other leopard habitats outside protected areas.

In Karnataka, studies have previously documented the occurrences of leopards in protected areas and human-dominated habitats (Gubbi *et al.* 2017). In 2017, Gubbi *et al.* (2017) estimated a mean abundance of ~ 300 (SD ± 15.2) leopards in a ~3,170 km^2 area comprising of protected areas and multiple use forests in Karnataka. In continuation of the previous study, this report provides the first estimates of abundance and density of leopards in BRT.

Study Area

BRT is situated in Chamrajanagara District in southeastern Karnataka and lies at the confluence of the Western and Eastern Ghats. Declared as a wildlife sanctuary in 1974 and a tiger reserve in 2011, currently BRT covers an area of 574.8 km^2 and is part of a 9,561 km^2 protected area network which includes Satyamangalam Tiger Reserve, Malai Mahadeshwara Wildlife Sanctuary, Cauvery Wildlife Sanctuary, other protected and reserved forest areas (Lingaraja *et al.* 2015; Gubbi *et al.* 2017). BRT is connected by stretches of forest corridor to Malai Mahadeshwara Wildlife Sanctuary in the east, and to Satyamangalam Tiger Reserve in the south.

The altitude of the tiger reserve ranges between 620 to 1950 m above mean sea level. Annually, BRT receives an average of 650 mm (range 600 – 3000 mm) of rainfall in low-lying plateaus and 1990 mm in the higher altitudes. The temperature within the reserve varies over a range of 18 to 38°C (Lingaraja *et al.* 2017).

Location co-ordinates

Latitude: 11° 43' 11.3772" N to 12° 8' 46.3272" N

Longitude: 77° 0' 32.6808" E to 77° 15' 44.4852" E

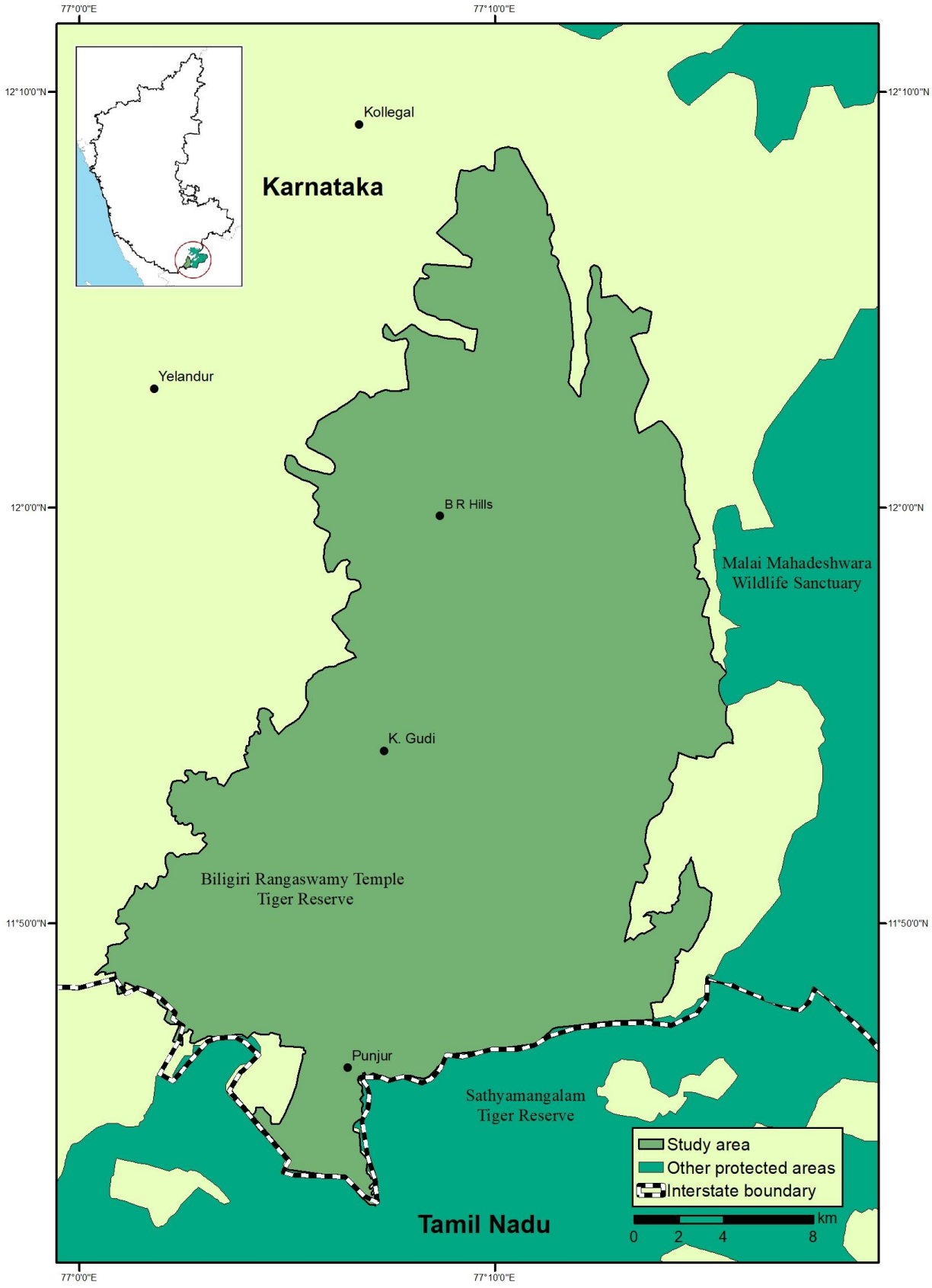

Figure 1: Bilgiri Rangaswamy Temple Tiger Reserve with adjoining protected areas

Flora

BRT is characterized by a variety of habitats due to the high altitudinal variations (Kumara and Rathnakumar, 2010). The forest types found in BRT include dry open scrub forests at lower elevations, deciduous forests in the hills between 500-1000 metres, riparian and moist deciduous at mid-elevation, and sholas and evergreen forests at higher elevations (Kumara *et al.* 2014). Plantations of eucalyptus (*Eucalyptus spp.*), silver oak (*Grevillea robusta*) and teak (*Tectona grandis*) are predominant in some areas of the reserve (Lingaraja *et al.* 2015). Some of the important floral species in BRT include *Elaeocarpus tuberculatus, Salix tetrasperma, Syzygium malabaricum, Cocculus laurifolius, Viburnum punctatum, Pterocarpus marsupium, Terminalia alata, Terminalia paniculata, Canthium dicoccum, Catunaregam torulosa, Meyna laxiflora, Dimocarpus longan, Boswellia serrata, Chloroxylon swietenia* and *Commiphora caudate* (Lingaraja *et al.* 2015).

Fauna

BRT is an important habitat for large carnivores such as tigers (*Panthera tigris*), leopards (*Panthera pardus*) and dholes (*Cuon alpinus*). Prey species such gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*), wild pig (*Sus scrofa*), barking deer (*Muntiacus vaginalis*), four-horned antelope (*Tetracerus quadricornis*), Indian Chevrotain (*Moschiola indica*), tufted gray langur (*Semnopithecus priam*), black-naped hare (*Lepus nigricollis*) and bonnet macaque (*Macaca radiata*) are found in the tiger reserve and are important for the sustenance of large carnivore populations (Lingaraja *et al.* 2017).

Other carnivores that the tiger reserve harbours includes sloth bear (*Melursus ursinus*), golden jackal (*Canis aureus*), Indian fox (*Vulpes bengalensis*), jungle cat (*Felis chaus*), rusty spotted cat (*Prionailurus rubiginosus*), leopard cat (*Prionailurus bengalensis*), small Indian civet (*Viverricula indica*), common palm civet (*Paradoxurus hermaphrodites*), common mongoose (*Herpestes edwardsii*), ruddy mongoose (*Herpestes smithii*), stripe-necked mongoose (*Herpestes vitticollis*), Indian smooth-coated otter (*Lutrogale perspicillata*) and others (Kumara *et al.* 2012a; Lingaraja *et al.* 2015). Brown mongoose (*Herpestes fuscus*) was first documented in BRT during this study. A healthy population of Asian elephants (*Elephas maximus*) has been recorded in the tiger reserve as well (Kumara *et al.* 2012b).

Methodology

Camera trapping

The study area was divided into three blocks covering an area of 574.82 km^2. Camera traps were deployed at 209 locations between 30th January and 26th March 2018 for 16 days in each block resulting in 16 unique sampling occasions. The assumption that the population of leopards is closed within the study site was met due to the short camera trapping period. The camera trap locations were identified prior to the deployment of the cameras based on evidence of the presence of the study species i.e. leopard, in order to ensure higher capture probability. Locations where signs of leopard movement including scats, pugmarks, scrape marks were found were prioritized as camera trap locations. Panthera V4 and V6 cameras with passive infrared motion detection were secured using python cables to an appropriate support at a height of ~ 40 cm from the ground. This is the optimal height to ensure capturing both flanks of an animal. In order to capture both flanks that help in identifying individual animals, camera traps were placed on either side of a trail/forest road. The camera traps operated throughout the day and were checked once in 2-3 days to download photographs, replace batteries if required, and ensure their proper functioning.

The downloaded images were then sorted and tagged with the name of the mammal species captured using the software Digikam (Version 5.8.0; Gilles *et al.* 2018). The unique combination of the camera trap location and camera ID provided the date, time and location coordinates for each captured image. Once the images were sorted, leopard individuals were matched based on the rosette patterns on their respective flanks using WildID. Blurred images were not used during this process. The flanks with maximum number of unique individuals were used for analysis.

Statistical Analysis

The statistical analysis was carried out in R using SECR package which is based on Spatially Explicit Capture-Recapture methodology. The input files, i.e. detector layout, capture history matrix and mask layer, were prepared according to the SECR operational manuals. The detector layout file accounted for the functioning or non-functioning of camera traps on different sampling occasions. The mask layer represented the spatial information about suitable habitat for a 2 km buffer area connecting the outermost camera trap locations (Efford 2018). The capture history matrix had one row each for individually identified leopards at a particular location and sampling occasion. The program then utilised this spatial information to estimate capture probabilities and fitted models by maximising the likelihood (Borchers and Efford 2008). In order to select the model with the best estimates of density and abundance, the Akaike's Information Criterion for likelihood-based models was considered. A finite mixture model was selected which used hazard rate as detection function and accounted for the heterogeneity in detection probabilities among individuals.

Results

Camera traps were placed at 209 locations for a period of 16 days amounting to a trapping effort of 3,342 days.

Abundance and density estimates for leopards

The camera traps captured 288 leopard images and a total of 44 adult individual leopards were identified which was further used for analysis. Of the identified individuals, 14 were male and 20 were female. The sex of ten individuals could not be identified. A total of five sub-adults and one cub were also identified but were not used for analysis. The SECR analysis provided an abundance estimate of approximately 58 leopards and a density estimate of 6.97 leopards per 100 km^2. The results are given in Table 1. Accounting for individual heterogeneity, individuals were segregated into two groups with different detection probabilities. The first group considered 98% of the individuals with a detection probability of 0.06 ± SE 0.03 and second group included the remaining 2% with a detection probability of 0.99 ± SE 1.32 e^{-07}.

Table 1: Results of the SECR analysis for leopards for habitat mask area of 2 km in Bilgiri Rangaswamy Temple Tiger Reserve

	Estimate	**SE estimate**	**lcl**	**ucl**
Abundance	57.77	5.12	50.80	71.87
D	6.97	1.11	5.12	9.50
σ	508.70	216.16	228.90	1130.48
z	1.80	0.16	1.51	2.15

D – Leopard density/100 km^2, σ – Spatial scale of detection function (in meters), z – the shape parameter used for hazard rate detection function

Other fauna

A total of 27 wild mammalian species were captured in camera traps at BRT during the study period. The results of the Relative Abundance Index (RAI) of leopards' natural and domestic prey are given in Table 2. Cow and buffalo were categorized as large livestock while sheep and goat were grouped as small livestock. All other mammal species are listed in Table 3.

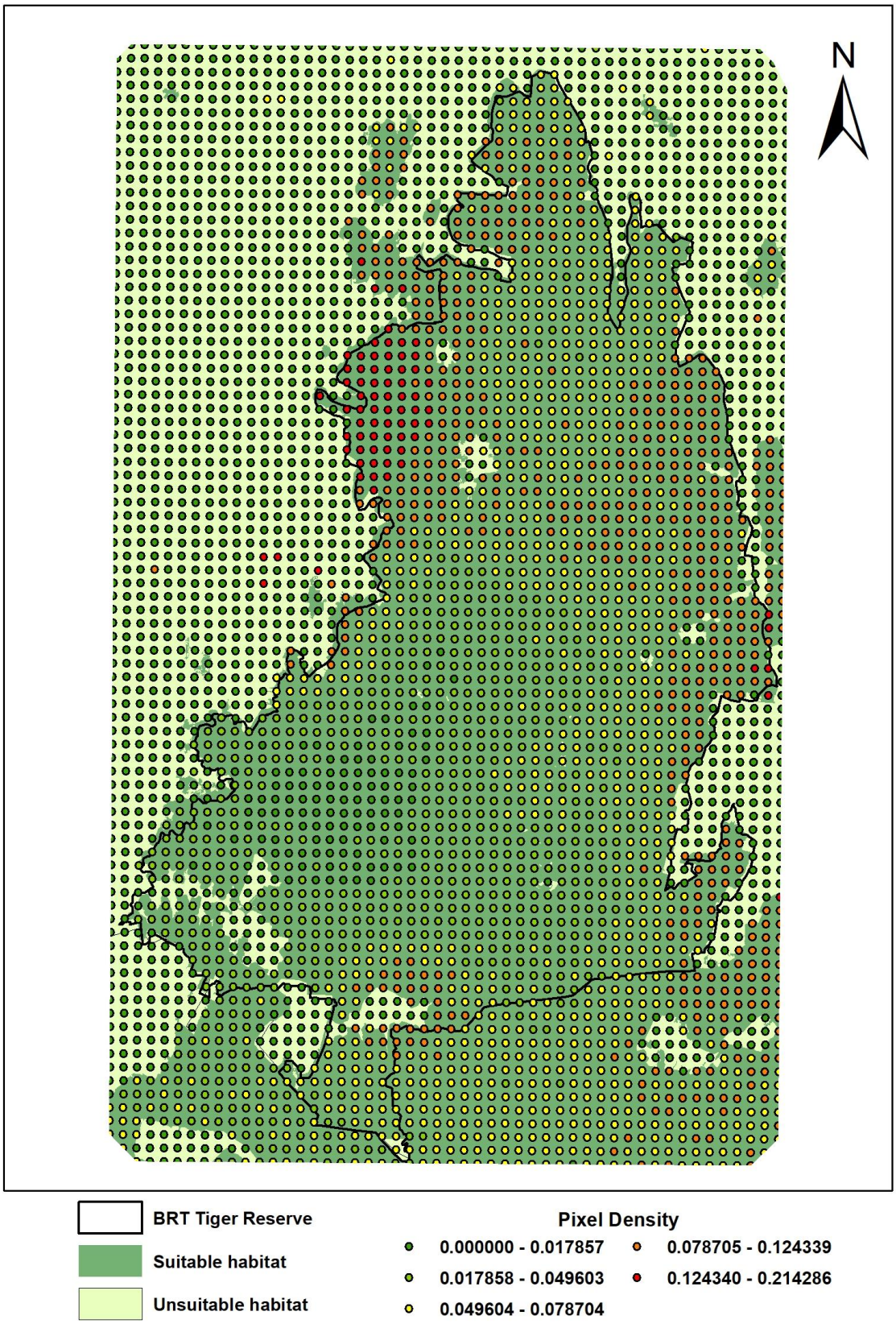

Figure 2. Pixel density map showing the fine scale variation in leopard numbers per km^2 in Bilgiri Rangaswamy Temple Tiger Reserve

Table 2: Results of the Relative Abundance Index (RAI) calculated for leopards' natural and domestic prey in Bilgiri Rangaswamy Temple Tiger Reserve

Species	Schedule status under the Wildlife Protection Act 1972	Global status under the IUCN Red List	RAI/100 trap days (SE)
Wild prey			
Barking deer (*Muntiacus vaginalis*)	III	Least Concern	9.19 (0.004)
Chital (*Axis axis*)	III	Least Concern	31.09 (0.021)
Indian Chevrotain (*Moschiola indica*)	I	Least Concern	4.49 (0.003)
Sambar (*Rusa unicolor*)	III	Vulnerable	53.68 (0.020)
Four-horned antelope (*Tetracerus quadricornis*)	I	Vulnerable	1.32 (0.001)
Gaur (*Bos gaurus*)	I	Vulnerable	7.72 (0.004)
Wild pig (*Sus scrofa*)	III	Least Concern	11.82 (0.006)
Black-naped hare (*Lepus nigricollis*)	IV	Least Concern	64.66 (0.026)
Porcupine (*Hystrix indica*)	IV	Least Concern	28.49 (0.010)
Bonnet macaque (*Macaca radiata*)	II	Least Concern	2.51 (0.002)
Hanuman langur (*Semnopithecus sp.*)	II		10.86 (0.008)
Domestic prey			
Large livestock	NA	NA	6.73 (0.010)
Small livestock	NA	NA	7.75 (0.008)
Domestic dog	NA	NA	9.96 (0.008)

Table 3: Other mammal species photo-captured in camera traps in Bilgiri Rangaswamy Temple Tiger Reserve

Species	Schedule status under the Wildlife Protection Act 1972	Global status under the IUCN Red List
Tiger (*Panthera tigris*)	I	Endangered
Dhole (*Cuon alpinus*)	II	Endangered
Jungle cat (*Felis chaus*)	II	Least Concern
Leopard cat (*Prionailurus bengalensis*)	I	Least Concern
Rusty spotted cat (*Prionailurus rubiginosus*)	I	Near Threatened
Sloth bear (*Melursus ursinus*)	I	Vulnerable
Elephant (*Elephas maximus*)	I	Endangered
Malabar giant squirrel (*Ratufa indica*)	II	Least Concern
Brown mongoose (*Herpestes fuscus*)	II	Least Concern
Grey mongoose (*Herpestes edwardsii*)	II	Least Concern
Ruddy mongoose (*Herpestes smithii*)	II	Least Concern
Stripe-necked mongoose (*Herpestes vitticollis*)	II	Least Concern
Brown palm civet (*Paradoxurus jerdoni*)	II	Least Concern
Common palm civet (*Paradoxurus hermaphroditus*)	II	Least Concern
Small Indian civet (*Viverricula indica*)	II	Least Concern

Discussion

The result of this study establishes a baseline estimate of abundance and density for leopards in BRT. The abundance estimate was found to be lower than in the adjoining protected areas namely Malai Mahadeshwara (65.78, SD ± 5.47) and Cauvery Wildlife Sanctuary (88.61, SD ± 9.88) (Gubbi *et al.* 2017). Since both the latter protected areas are larger in area, our results are in corroboration with the finding that the abundance estimate for leopards perhaps increases with patch size (Gubbi *et al.* 2017). The abundance estimates could also be attributed to other factors such as habitat characteristics.

More importantly, BRT has been identified as an important habitat for tigers and, considering that tigers and leopards are sympatric in nature, the higher density of tigers might have resulted in lower density and abundance of leopards. In order to establish this, more variables need to be recorded and correlated with the abundance estimates.

BRT is documented to have an abundance of ~55 (±2.66, 49 - 59) tigers with densities of 6.9 tigers/100 km^2. (±0.33, 6.31 - 7.78) (Lingaraja *et al.* 2017). There has been evidence of niche partitioning in regions where both tigers and leopard co-exist due to their dietary overlap (Harihar *et al.* 2011) but with densities that impact each other. The pixel density map indicates that leopard densities were higher at the edges of the study area possibly due to tigers occupying the interiors of the tiger reserve (Figure 2.).

Results from our ongoing study have recorded a leopard, this year in BRT, which was also captured in Malai Mahadeshwara Wildlife Sanctuary in December 2014. Besides this, another individual was captured in cameras deployed in the corridor connecting BRT with Malai Mahadeshwara Wildlife Sanctuary (Kolekar *et al.* 2018). This evidence of corridor utilization highlights the importance of the Doddasampige-Edyaralli forest connectivity between these protected areas as a functional corridor. This connectivity should be insulated from different threats including the State Highway (SH - 38) that has high traffic density.

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