Leopards of Bannerghatta National Park: A camera-trapping exercise to estimate abundance and densities of leopards

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Acknowledgements

Introduction

The leopard (*Panthera pardus*) is one of the top predators found over a wide geographic range and also adapted to human-dominated landscapes. They are elusive and solitary species with a diet that constitutes a wide range of prey species. The combination of habitat adaptability and catholic diet also makes it a highly conflict-prone species.

The leopard is listed under the 'Vulnerable' category in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Stein *et al.* 2016). Under the Wildlife Protection Act 1972 in India, they are listed as a Schedule 1 species which provides them with the highest level of protection.

In India, few studies have been carried out over the years to estimate leopard density and abundance in protected areas (PAs) and adjoining habitats that include both forested and human-inhabited areas (Harihar *et al.* 2009; Athreya *et al.* 2013; Borah *et al.* 2014; Gubbi *et al.* 2017). However, there is a serious lack of population information about the species both within PAs and their habitats outside PAs due to the limited number of studies and the leopards' wide geographic distribution.

Leopards are exposed to several threats such as habitat loss and fragmentation, retaliatory killing, vehicular collisions, poaching, depletion of prey and other unconventional threats (Gubbi *et al.* 2014; Jacobson *et al.* 2016; Gubbi *et al.* 2017; Gubbi *et al.* In press). To implement effective management and conservation strategies, it is important to know their distribution, abundance and also interactions with other biotic and abiotic elements in their habitat.

In Karnataka, the occurrences of leopards have been documented in PAs and human-dominated habitats. Gubbi *et al.* (2017) estimated a mean abundance of ~ 300 (SD ± 15.2) leopards in a ~3,170 km2 area comprising of PAs and multiple-use forests in Karnataka. Poaching of prey, vehicular collisions, loss of habitat and human-leopard conflict are the prevailing issues in Karnataka that pose serious threats to leopards (Gubbi *et al.* 2014; Gubbi *et al.* 2017). Several known habitats of leopards are yet to be surveyed and their overall distribution has to be estimated which would help in management and resolution of these consistent threats.

In continuation of the previous study (Gubbi *et al.* 2017), this report provides the first estimates of abundance and density of leopards in Bannerghatta National Park.

Study Area

Bannerghatta National Park (BNP), located in the Eastern Ghats forest ecosystem and adjoining Bengaluru city to its north, covers an area of 260.5 km^2. There are four administrative ranges, which includes Bannerghatta, Harohalli, Kodihalli and Anekal.

It extends linearly and is irregularly shaped. BNP adjoins with Cauvery Wildlife Sanctuary (1,027 km^2) to the south-west and other reserved forests of Tamil Nadu i.e. Bilikal and Tali

reserved forests to the south and south-east respectively; forming a contiguous landscape of tropical scrub forests (See Map 1) (Adhikari *et al.* 2017).

It is characterized by tropical thorn shrub vegetation towards the fringes of the national park and dry deciduous vegetation towards the hilly regions and valleys, the latter being relatively less disturbed due to inaccessibility (Varma *et al.* 2009; Gopalakrishna *et al.* 2015).

The altitude of the BNP ranges between 700 and 1035 m above mean sea level with a mean of 865m. Annually, BNP receives an average of 1065 mm (range 682 – 1607 mm) of rainfall. The temperature within the national park varies over a range of 12 to 38°C (Gopalakrishna *et al.* 2015). Human density is quite high around and within the park with a density of 14.87 individuals per km^2 within the national park. There are six villages within BNP and 117 within a five km radius from the national park (Varma *et al.* 2009; Nagendra *et al.* 2013; Adhikari *et al.* 2017).

The people living in the region belong to Gowda, Reddy and Lingayath communities and Schedule Tribes such as Aadi Karnataka, Hakki-pikki, Iruliga, Lambani, etc. (Singh 2008; Gopalakrishna *et al.* 2010). The southern part seems to be dominated primarily by Schedule Tribes who are dependent on agriculture and cattle rearing while in the northern part local communities have been shifting to more urbanized livelihoods like small businesses (Varma *et al.* 2009). This might be due to the expansion of Bengaluru city which alleviates their accessibility to the city.
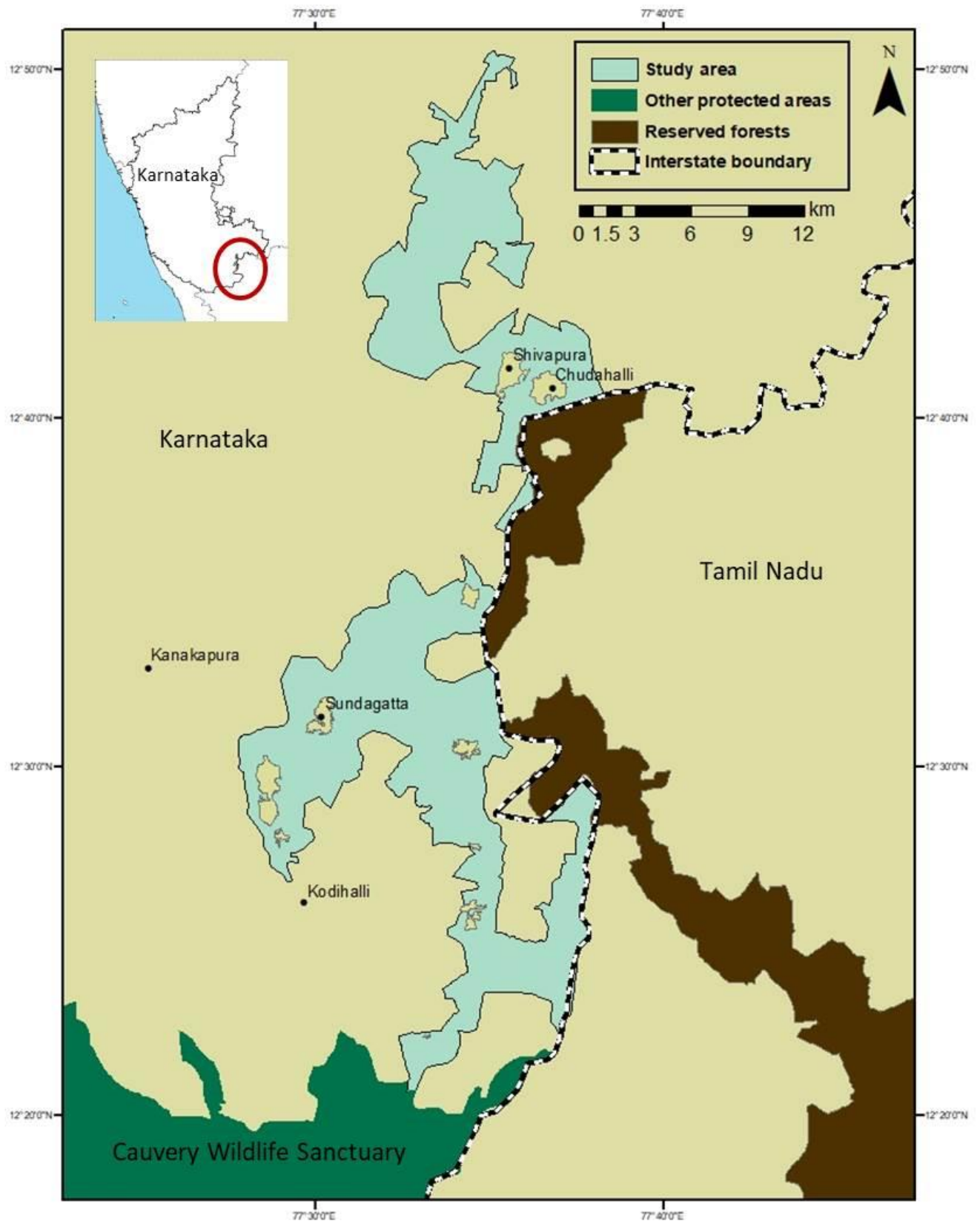
Location co-ordinates

Latitude: 12° 20' 46.6188" N to 12° 50' 37.1112" N

Longitude: 77° 27' 46.3752" E to 77° 38' 19.32" E

Figure 1. Bannerghatta National Park is characterised by dry deciduous and tropical thorn shrub vegetation

Map 1. Bannerghatta National Park, Cauvery Wildlife Sanctuary and adjoining reserved forests in Tamil Nadu.

Flora

The national park is characterized by dry deciduous and tropical thorn shrub vegetation. Gopalakrishna *et al.* (2015) documented 128 tree species from 45 families of which some dominant species included *Anogeissus latifolia*, *Acacia chundra, Cedrela toona, Ixora arborea* and *Gymnosporia montana*. Invasive species such as *Lanatana camara* and *Chromolaena odorata* have been observed to occupy patches throughout the national park possibly altering the ecosystem to a certain extent (Varma *et al.* 2009)

Fauna

BNP provides shelter for several species of mammals, amphibians, reptiles and birds apart from the endangered Asian elephant (*Elephas maximus*). The other mammals seen in the national park include Indian gaur (*Bos gaurus*), sambar deer (*Cervus unicolor*), spotted deer (*Axis axis*), leopard (*Panthera pardus fusca*), wild dog (*Cuon alpinus*), wild pig (*Sus scrofa*), sloth bear (*Melurus ursinus*), grey mongoose (*Herpestes edwardsii*), pangolin (*Manis crassicaudata*), slender loris (*Loris lydekkerianus*), black-naped hare (*Lepus nigricollis*) and others. The national park harbours around 222 species of birds, 53 species of reptiles and 12 species of amphibians (Sharma 1972; Rajeev 2002; Thirumalai *et al.* 2007; Singh 2008).

Methodology
Camera trapping

The study area was divided into three blocks covering an area of 260.5 km^2. The camera trap locations were identified before the initial deployment of the cameras in order to ensure high capture probability. Locations where there were signs of leopard movement including scats, pugmarks, scrape marks were prioritized for placing camera traps. Panthera V4 and V6 motion detection cameras were secured using python cables to an appropriate support at a height of ~ 40 cm from the ground, which is the optimal height to ensure capturing both flanks of a leopard. Camera traps were placed on either side of a trail/forest road to ensure that both flanks were captured.

Camera traps were deployed at 191 locations between 3rd February and 31st March 2019 for 48 days (16 days in each block resulting in 16 unique sampling occasions). The population of leopards was assumed to be closed (no mortality, natality, immigration and emigration) within the study site due to the short camera-trapping period.

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 processed using an automated classifier built on the Python platform which essentially segregated the photos into folders based on species (Rampi *et al.* Unpublished). These folders were then validated and the name of the species captured was written to the image metadata 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 Wild-ID (Bolger *et al.* 2011). Unclear images were not used during this process of identifying individuals. The flanks with maximum number of unique individuals were used for analysis.

Density and abundance estimation

The statistical analysis was carried out with R programming using SECR package which is based on Spatially Explicit Capture-Recapture methodology (Efford 2018). 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 from 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 (AIC) 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.

Relative Abundance Index calculation

Relative Abundance Index (RAI) was calculated for all prey species using the photographic capture rate i.e. the number of independent photo captures for a particular species per 100 trap days. Studies show that the photographic capture rates correlate with density estimates for large terrestrial mammals and thus RAI can be used as a valid index of density for unmarked species (Rovero & Marshall 2009; Palmer *et al.* 2018)

All the different mammal species that were photo captured were segregated into specific folders with species names. Using the timestamp in the metadata of the image, images were matched automatically using a VBA (Visual Basic for Applications) script in excel in order to extract number of individual events for each species separately. A threshold time interval (or event duration) that was considered to categorise photos as an independent event was predefined for each species and based on the amount of time taken by different species (individually or as a group) to cross the camera trap location (Appendix-2). Photos with multiple individuals of the same species were considered as one event.

In the case of livestock, cow and buffalo were categorized as large livestock while sheep and goat were grouped as small livestock. If different livestock species were to be camera trapped at the same location during the same event duration, it was still considered as one event.

After the number of independent events was tabulated, it was divided by the total number of camera trapping days and further multiplied by 100 to give the RAI for each species per 100 trap days.

Results
Abundance and density estimates for leopards

The camera traps captured 589 leopard images and a total of 34 adult individual leopards were identified which was used for analysis. Of the identified individuals, 17 were male and 16 were female. The sex of one individual could not be identified. A total of five sub-adults and one cub were also identified but not used for analysis. The SECR analysis provided an abundance estimate of approximately 40 leopards and a density estimate of 7.96 leopards per 100 km^2 (Table 1).

Accounting for individual heterogeneity, individuals were segregated into two groups with different detection probabilities. The first group considered 73% of the individuals with a detection probability of $0.03 \pm SE\ 0.005$ and second group included the remaining 27% with a detection probability of $0.08 \pm SE\ 0.01$. Map 2 shows the pixel density estimates of leopards within a 2 km buffer around BNP.

Table 1: Results of the SECR analysis for leopards for habitat mask area of 2 km in Bannerghatta National Park

|	**Estimate**	**SE**	**lcl**	**ucl**
Abundance (*N*)	40.31	2.84	36.72	48.62
Density (D)	7.96	1.37	5.68	11.13
σ	2484.84	244.73	2049.57	3012.55

N - Estimate of total number of individuals in the study area, D – No of leopards/100 km^2, σ – Spatial scale of detection function (in meters)

Relative Abundance Index (RAI) of leopard prey

The combined RAI per 100 trap days for wild prey was 116.85 and domestic prey was 21.24. The results of the Relative Abundance Index (RAI) of leopards' natural and domestic prey are given in Table 2.

Table 2: Results of the Relative Abundance Index (RAI) calculated for leopards' natural and domestic prey in Bannerghatta National Park.

Species	**Schedule under the Wildlife Protection Act 1972**	**Global status under the IUCN Red List**	**RAI/100 trap days (SE)**
Wild prey			
Sambar (*Rusa unicolor*)	III	Vulnerable	5.11 (0.005)
Chital (*Axis axis*)	III	Least Concern	5.89 (0.004)
Barking deer (*Muntiacus vaginalis*)	III	Least Concern	0.95 (0.001)
Four-horned antelope (*Tetracerus quadricornis*)	I	Vulnerable	0.68 (0.001)
Gaur (*Bos gaurus*)	I	Vulnerable	3.83 (0.003)
Wild pig (*Sus scrofa*)	III	Least Concern	7.67 (0.004)
Bonnet macaque (*Macaca radiata*)	II	Least Concern	2.98 (0.004)
Porcupine (*Hystrix indica*)	IV	Least Concern	1.21 (0.001)
Black-naped hare (*Lepus nigricollis*)	IV	Least Concern	45.56 (0.019)
Domestic prey			
Large livestock	NA	NA	15.73 (0.017)
Small livestock	NA	NA	7.37 (0.008)
Domestic dog	NA	NA	19.83 (0.025)
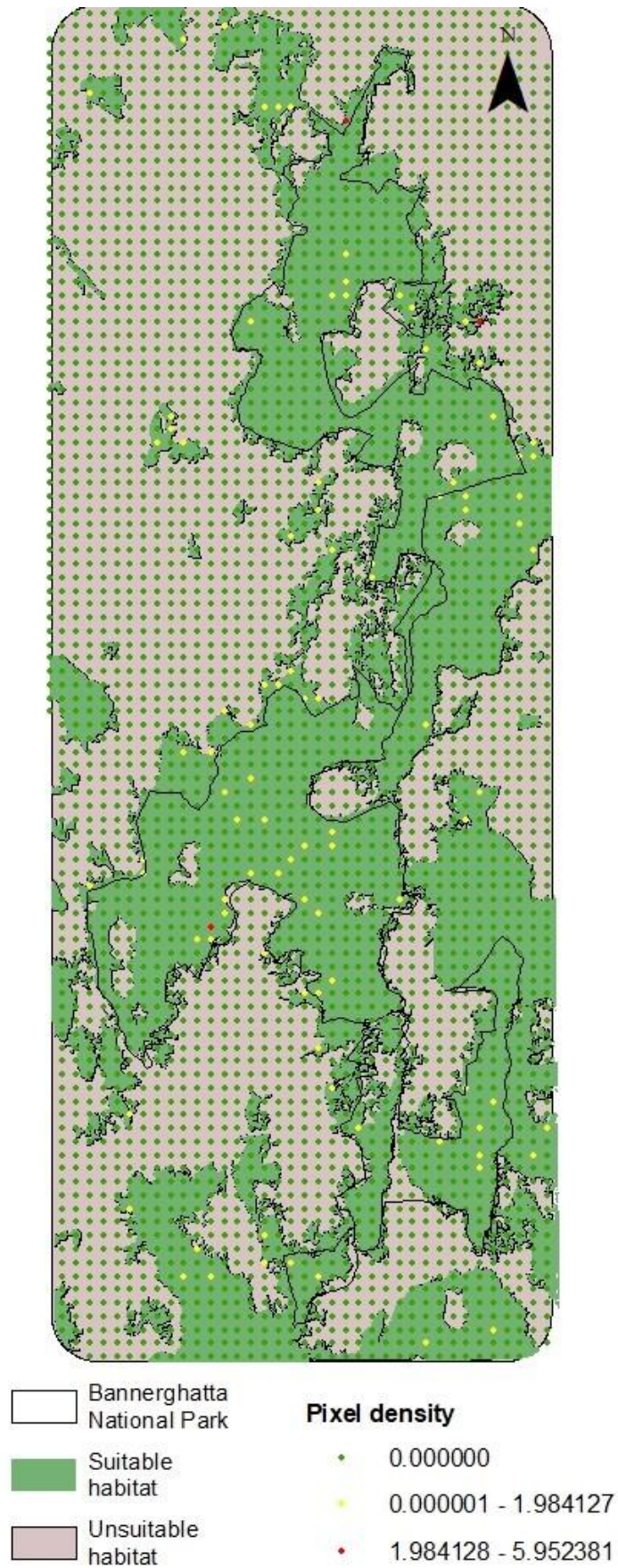
Map 2. Pixel density map showing the fine scale variation in leopard numbers per km^2 in Bannerghatta National Park

Other fauna

A total of 24 wild mammalian species were captured in camera traps at BNP during the study period. All the 24 mammal species are listed in Table 3 and photographs are attached as Appendix-1.

Table 3: Other mammal species photo-captured in camera traps in Bannerghatta National Park

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
Jackal (*Canis aureus*)	II	Least Concern
Indian fox (*Vulpes bengalensis*)	II	Least Concern
Jungle cat (*Felis chaus*)	II	Least Concern
Rusty spotted cat (*Prionailurus rubiginosus*)	I	Near Threatened
Sloth bear (*Melursus ursinus*)	I	Vulnerable
Elephant (*Elephas maximus*)	I	Endangered
Ratel (*Mellivora capensis*)	I	Least Concern
Grey mongoose (*Herpestes edwardsii*)	II	Least Concern
Ruddy mongoose (*Herpestes smithii*)	II	Least Concern
Common palm civet (*Paradoxurus hermaphroditus*)	II	Least Concern
Small Indian civet (*Viverricula indica*)	II	Least Concern
Indian gerbil (*Tatera indica*)	IV	Least Concern

Discussion

The abundance and density estimates from this study provide baseline information for leopards in BNP. An abundance of ~40 seems fairly high for a national park with an area of 260.5 km^2. The density (7.96/km^2 SE ±1.37) in BNP is higher than adjoining PAs such as Cauvery Wildlife Sanctuary (4.91/km^2 SE ±0.58) which has an area more than four times that of BNP (Gubbi *et al.* 2017).

The larger driving factor in the case of BNP could be the availability of wild prey in good abundance. The combined RAI per 100 trap days for all wild prey was 116.85, which is considerably higher as compared to a combined RAI of 47.99 from the adjoining and much larger Cauvery Wildlife Sanctuary (1,027 km^2) (Gubbi *et al.* 2017). In addition to this, domestic prey in surrounding habitats might contribute to a higher abundance of leopards since pastoralism is one of the primary occupations in the area (Varma *et al.* 2009; Athreya *et al.* 2016). Further analysis is required to understand the extent of dependence of leopard abundance on the relative abundance of wild and domestic prey.

The national park is under constant pressure of encroachment and conversion of land due to the close proximity to Bengaluru city, which is ever growing (Nagendra *et al.* 2013). Even

settlements within the park have been observed to be expanding on forestland for their livelihood activities from time to time (Nagendra *et al.* 2013). The leopards often move into human- inhabited areas to prey on domestic animals leading to human-wildlife conflict, which is a major threat that has to be addressed.

There are several major tarred roads such as Bannerghatta-Kaggalipura road, Bannerghatta-Raagihalli-Harohalli road, Jigani-Harohalli Road, Agara-Kodihalli road, Anekal road, all of which cut across the national park. The proposed Satellite Town Ring Road will further fragment the national park. The NICE road falls within deemed forests that are connected to BNP. Developmental projects involving road construction add pressure on the ecosystem causing disturbance and fragmentation of the habitat, thus taking a toll on the local biodiversity. Road kills due to vehicular collision have become a common issue with road networks within forested areas. Gubbi *et al.* (2014) recorded 23 leopards that were killed in vehicular collisions in Karnataka during July 2009-June 2014. Over duration of four years (2011-15), there have been four reports of leopards being killed by vehicular collision near BNP and mostly on highways (Appendix-3). Therefore, appropriate mitigation measures have to be taken in order to incorporate the needs of wildlife in existing road and new roads should be aligned outside the national park.

Metapopulation

Two leopard individuals that were photo-captured in BNP in 2019 were previously captured in Cauvery Wildlife Sanctuary in 2018 (Gubbi *et al.* Unpublished). One of the individuals has moved nearly 16 km (shortest distance between the two farthest camera trapped locations) from Cauvery Wildlife Sanctuary to Bannerghatta National Park within two months (December 2018 to February 2019) (Figure 2). The area surrounding the national park connecting Cauvery Wildlife Sanctuary acts as a corridor for wildlife. But it is mainly degraded native forest, agricultural land and plantations (Rashmi and Lele 2010; Adhikari *et al.* 2014). This leads to habitat fragmentation and such movements of wildlife through human habitation can in turn give rise to conflict or perceived conflict situations. Hence, ensuring that the native forest connectivity is maintained between the two PAs is very crucial both for people and wildlife.

BNP is also contiguous with Gollahalligudda (0.57 km^2), BM Kaval Reserved Forest (4.28 km^2), Roerich Estate (1.29 km^2), UM Kaval Reserved Forest (0.63 km^2) and a large chunk of deemed forests (~12.95 km^2) between Bannerghatta and Roerich Estate (See Map 3). All these areas together form a contiguous forest patch of 21.6 km^2 and acts as an important buffer between BNP and Bengaluru city. Hence we recommend that these areas should be notified as the Roerich Conservation Reserve (in recognition of the famed artist Svetoslav Nikolaevich Roerich who also conserved a large forest patch and lakes in this landscape) for the long-term conservation of wildlife of BNP and also to pro-actively avoid human-wildlife conflict.

Figure 2. A leopard (*Panthera pardus*) catalogued as BG-23 camera-trapped in Bannerghatta National Park in February 2019 (above) and previously in Cauvery Wildlife Sanctuary in December 2018 (below).

Besides leopards, we have 24 other mammal species captured in our camera traps. Our camera trapping efforts have revealed the presence of one individual tiger within the national park (Figure 3). The threats discussed above, apply to all of these mammal species of which many might be affected more severely than others.

Since this study provides a baseline data for many of these mammal species, we should be able to monitor any changes in their relative abundance with systematic monitoring over the coming years.
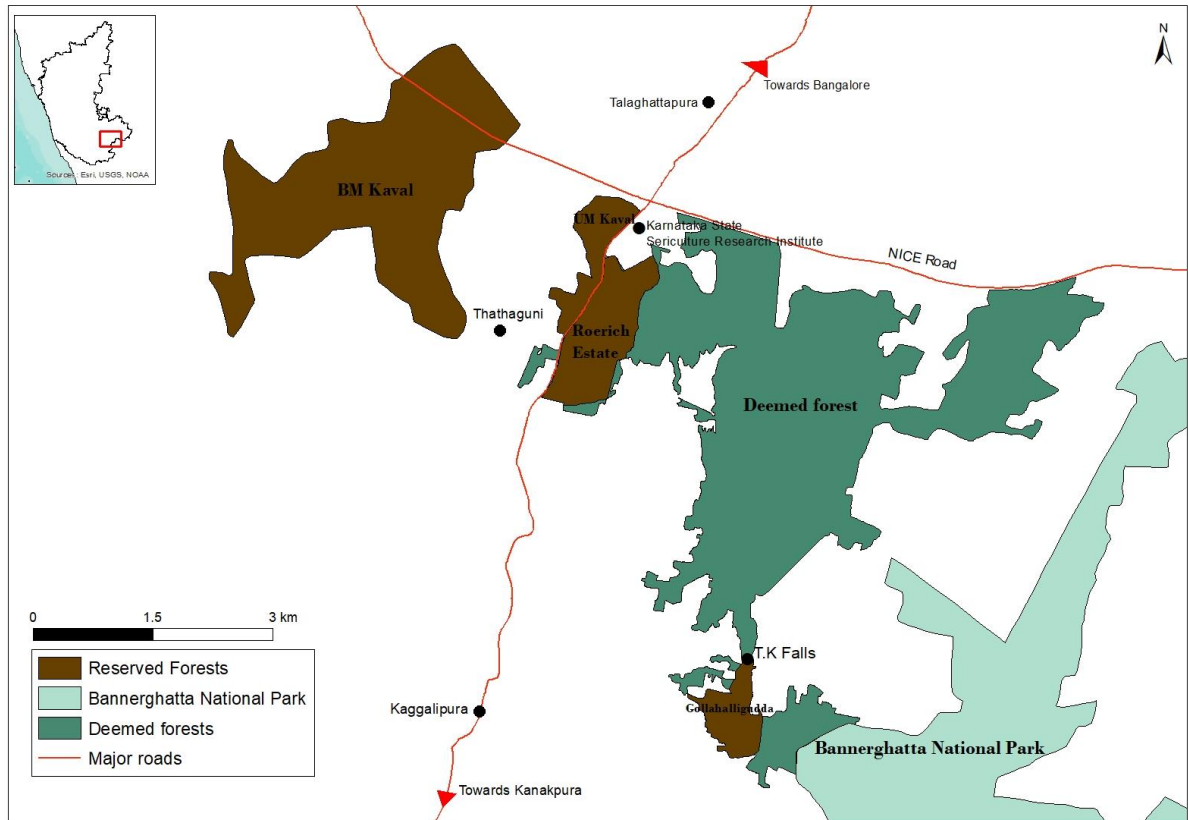
Map 3: Bannerghatta National Park and its adjoining areas that are proposed to be notified as a Conservation Reserve.

Figure 3 . The only tiger (*Panthera tigris*) individual camera trapped in Bannerghatta National Park

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Appendix – 1

Photographs of mammal species captured in Bannerghatta National Park during camera trapping session in February-March 2019.

Leopard (*Panthera pardus fusca*)

Tiger (*Panthera tigris*)

Jungle cat (*Felis chaus*)

Rusty spotted cat (*Prionailurus rubiginosus*)

Jackal (*Canis aureus*)

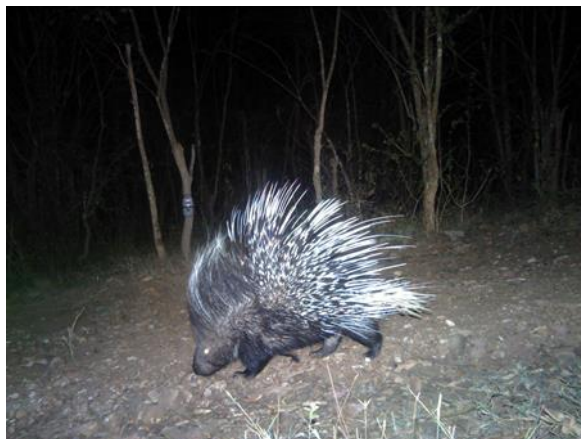Bengal fox (*Vulpes bengalensis*)

Dhole (*Cuon alpinus*)

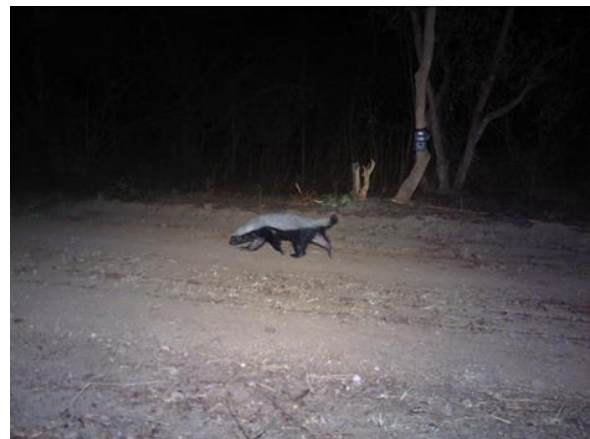Elephant (*Elephas maximus*)

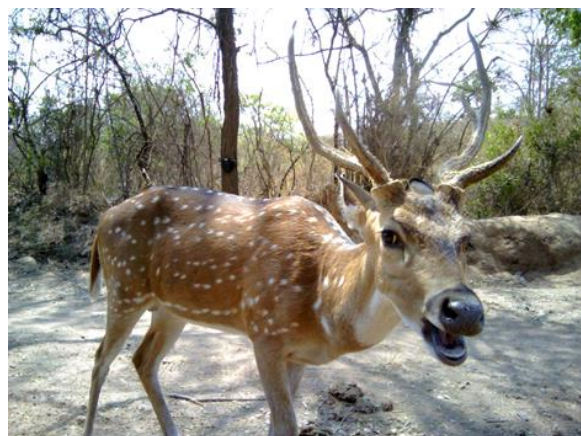Sloth bear (*Melursus ursinus*)

Gaur (*Bos gaurus*)

Porcupine (*Hystrix indica*)

Ratel (*Mellivora capensis*)

Chital (*Axis axis*)

Sambar (*Rusa unicolor*)

Barking deer (*Muntiacus vaginalis*)

Four-horned antelope
(*Tetracerus quadricornis*)
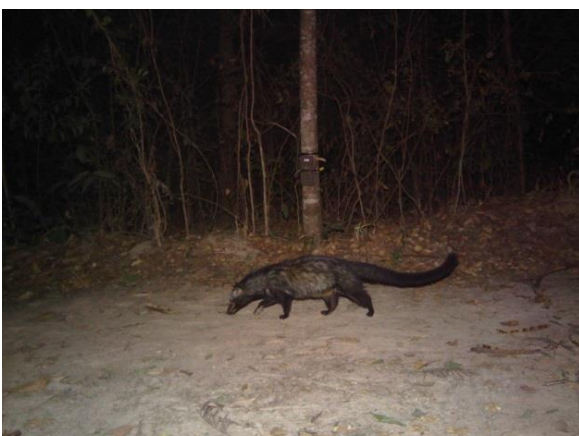

Wild pig (*Sus scrofa*)
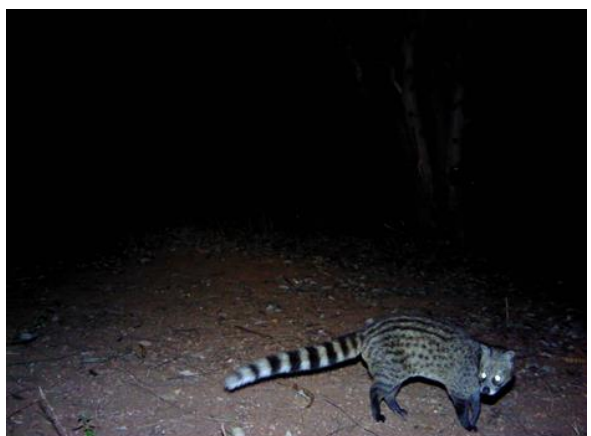

Indian gerbil (*Tatera indica*)

Black-naped hare (*Lepus nigricollis*)

Bonnet macaque (*Macaca radiata*)

Common palm civet
(*Paradoxurus hermaphroditus*)

Small Indian civet
(*Viverricula indica*)

Ruddy mongoose (*Herpestes smithii*)

Grey mongoose (*Herpestes edwardsii*)

Appendix – 2

Event duration used for calculating Relative Abundance Index (RAI) of leopards' natural and domestic prey

Species	Event duration (seconds)
Wild prey	
Sambar (*Rusa unicolor*)	60
Chital (*Axis axis*)	120
Barking deer (*Muntiacus vaginalis*)	60
Four-horned antelope (*Tetracerus quadricornis*)	60
Gaur (*Bos gaurus*)	180
Wild pig (*Sus scrofa*)	60
Bonnet macaque (*Macaca radiata*)	360
Porcupine (*Hystrix indica*)	60
Black-naped hare (*Lepus nigricollis*)	60
Domestic prey	
Large livestock	300
Small livestock	180
Domestic dog	60

Leopards killed in vehicular collisions near Bannerghatta National Park during February 2011 and February 2015

Date	Publication / Source	Incident	Sex	Road Name	District
1-Feb-11	The Hindu	Lorry runs over leopard	Male	NICE road	Bangalore Urban
7-Mar-11	Deccan Herald	Leopard killed in accident	Female	NICE road	Bangalore Urban
13-Oct-14	Deccan Herald	4 year old pregnant female leopard killed by vehicular collision.	Female	Bannerghatta road	Bangalore Urban
16-Feb-15	The Hindu	3 year old leopard male killed by vehicular collision.	Male	NICE road	Bangalore Urban

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