REPORT

nature conservation foundation

Rosettes in Chikkaballapur: Estimating leopard densities and abundance through camera trapping




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Introduction

Leopards (*Panthera pardus*) are elusive and solitary species that are found over a wide geographic range. Many times they are the top predators in their ecosystems and are well adapted to human-dominated landscapes. The ability to adapt to different habitats and prey on a wide range of species makes leopards also a highly conflict-prone species.

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

There are a few of studies estimating leopard population size in both forested and human-dominated landscapes in India (Harihar *et al.* 2009; Athreya *et al*. 2013; Borah *et al.* 2014; Gubbi *et al.* 2017), however there is a lack of baseline population and distribution data for leopards especially outside the protected areas. Baseline information regarding leopard distribution and population size as well as their interactions with the ecosystem is essential to implement effective management and conservation strategies. Hence more information on the population and abundance estimates would help in evidence-based management of leopards and its habitats.

The occurrences of leopards in some Protected Areas (PAs), reserved forests and other leopard habitats within Karnataka has received recent attention. Gubbi *et al.* (2017) estimated a mean abundance of ~ 300 (SD ± 15.2) leopards in a ~3,170 km^2 area comprising of PAs and reserved forests in Karnataka. The prevailing issues in these landscapes include poaching of prey, vehicular collisions, loss of habitat, human-leopard conflict and other unconventional threats, all of which poses a serious threat to leopard populations (Gubbi *et al.* 2014; Gubbi *et al.* 2017; Gubbi et al. 2019a).

In continuation to the previous studies (Gubbi *et al.* 2017, 2018, 2019b), this report provides the first estimates of abundance and density of leopards for Chikkaballapura Division.

Study Area

Chikkaballapura division has 684.3 km^2 of forested area which covers 16.91% of the geographical area of the district (Devaraj 2014). The study area covers an area of 195.5 km^2 and is characterized by southern tropical dry deciduous vegetation. The study area comprised of three State Forests (SF) namely Nandi SF (11.8 km^2), Narasimhadevarabetta SF (178.5 km^2) and Kallukote SF (5.21 km^2), which will collectively be referred to as Chikkaballapura from here on. Nandi SF and Narasimhadevarabetta SF fall under Chikkaballapura Forest Division. Kallukote SF, which comes under the Bangalore Rural Forest Division, was included as it forms a continuous forest patch with Narasimhadevarabetta SF. The administrative ranges covered during this study include Chikkaballapura, Gudibande and part of Doddaballapura Ranges.

Human population density within the study area is about 15.36/km^2 (GoI 2011). Devanahalli, Gouribidanuru, Chikkaballapur, Gudibande and Bagepalli towns are very close to Narasimhadevarabetta SF.

Nandidurga, at an altitude of 1416 m above sea level, is one of the most accessed hills by the public in Nandi SF while the highest peak, which is 1478.6m above sea level, lies in Narasimhadevarabetta SF. The region witnesses four seasons i.e. dry season (December to February), hot season (March – May), monsoons (June-October) and retreating monsoons (November). The average rainfall of Chikkaballapura is 730.5 mm while at higher elevations it is 1195.8 mm. Overall district temperature ranges between 20.6 - 40°C while at higher elevations such as Nandi hills it ranges between 12.6 - 23.7°C (Devaraj 2014).

Location co-ordinates

Latitude: 13° 20' 55.8276" N to 13° 43' 16.6908" N

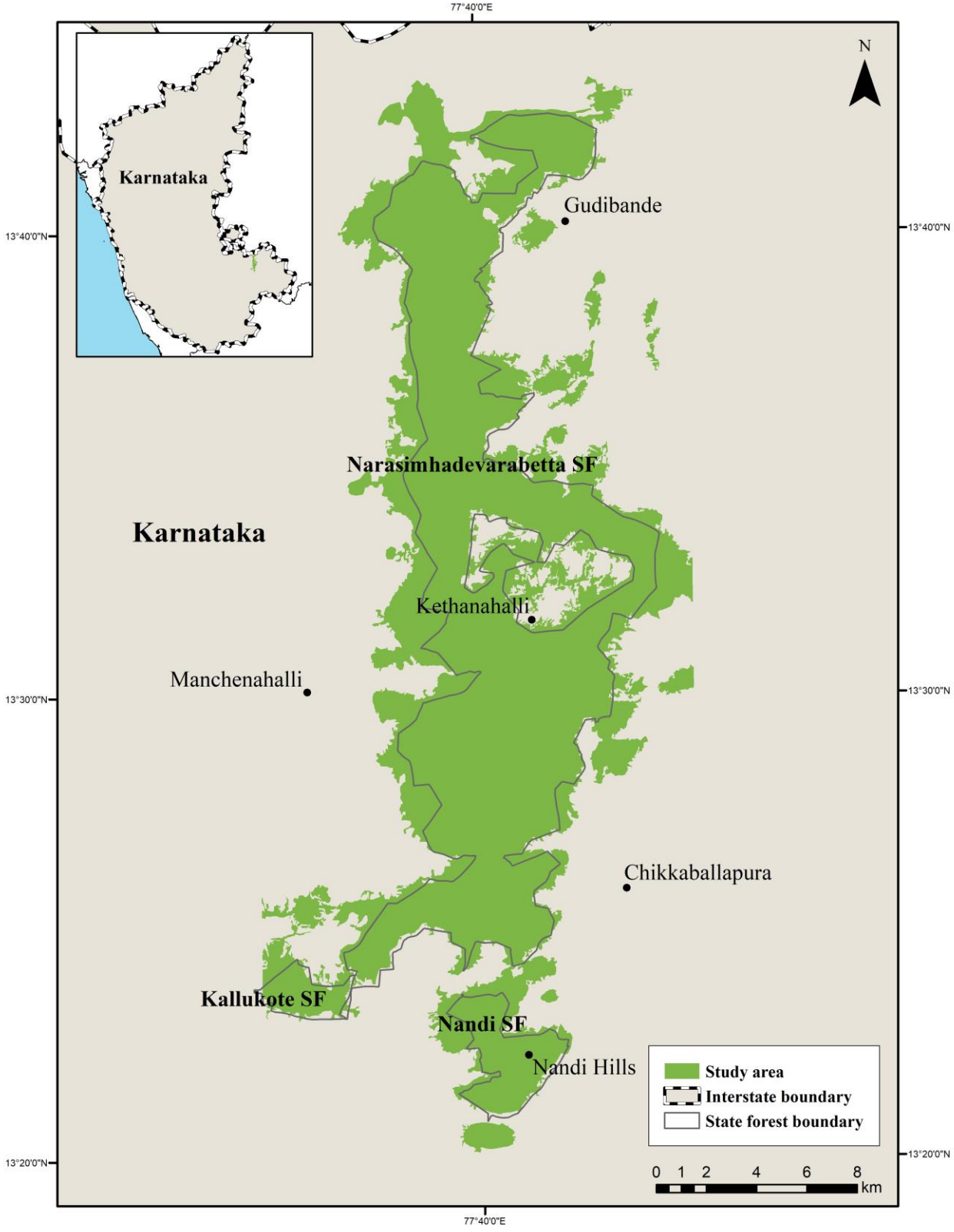
Longitude: 77° 34' 57.756" E to 77° 45' 12.366" E

Flora

Chikkaballapura is characterized by southern tropical dry deciduous forests and has higher tree species diversity than the neighbouring Kolar district. However, the vegetation cover in the study area is sparse, shrubby and thorny with low rocky hills (Praveen 2006).

This area has a mixed vegetation cover that includes plantations, natural forest and mixed agriculture. The varied climate, topography and large area contribute to a large species heterogeneity along the valleys as well as slopes. Some tree species that are commonly found include *Anogeissus latifolia*, *Pongamia pinnata*, *Premna tomentosa*, *Albizia amara*, *Hardwickia binata*, *Acacia catechu*, *Cassia fistula*, *Chloroxylon swietenia*, *Lagerstroemia parviflora*, *Shorea talura*, etc (Ramachandra & Rao 2005; Devaraj 2014; Sarmah 2019). Sandal (*Santalum album*) can also be found sparsely in these forests.

Plantations of Eucalyptus, *Prosopis juliflora*, *Cassia siamea*, *Dalbergia sissoo* and *Casuarina equisetifolia* are present in the landscape (Devaraj 2014). Human dominated parts are mainly cultivated or fallow lands with a few vineyards (Vanak 2005; Devaraj 2014). *Lantana camara*, an invasive species, also poses a problem here as it covers quite a bit of the area under growth in these forests



Map 1. Study area comprising of Narasimhadevarabetta State Forest, Nandi State Forest and Kallukote State Forest in Karnataka, India.

Fauna

A few bird species that can be observed in this area include Nilgiri wood-pigeon (*Columba elphinstonii*), spotted babbler (*Pellorneum ruficepsi*), blueheaded rock-thrush (*Monticola cinclorhynchus*), ashy drongo (*Dicrurus leucophaeus*), Asian paradise-flycatcher (*Terpsiphone paradisi*), Nilgiri blackbird (*Turdus simillimus*) and Tickell's blue-flycatcher (*Cyornis tickelliae*) (Lethaby 2006). Pied thrush (*Geokichla wardii*) and ultramarine flycatcher (*Ficedula superciliaris*) are some of the migratory and wintering species found in this area (Lethaby 2006). The yellow-throated bulbul (*Pycnonotus xantholaemus*), which is endemic to southern peninsular India can also be found here (Subramanya *et al.* 1991). Very few species of mammals have been documented from this area like the small Indian civet (*Viverricula indica*), jungle cat (*Felis chaus*) and slender loris (*Loris lydekkerianus*) (Kumara *et al.* 2006; Kumara & Singh 2007). Besides mammals and birds, Chikkaballapura division shelters many reptiles and insects.

Methodology

Camera trapping

The study area was divided into three blocks covering an area of 195.5 km^2. The camera trap locations were identified in advance, i.e. before deployment, based on signs of leopard movement which included scats, pugmarks and scrape marks. This approach was taken to prioritize high capture probability of leopards.

Panthera V4 and V6 motion detection cameras were secured using python cables to an appropriate support (trees or poles) 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 114 locations between 5th June and 1st August 2019 for 54 days (16 days in each block resulting in 16 unique sampling occasions). The trapping period conferred to the assumption that it was a closed population (no mortality, natality, immigration and emigration during the study period).

The camera traps were operational through the day and night (24 hrs). They were checked once in 2-3 days to download photographs and resolve any technical issues such as battery drainage. An automated classifier built on the Python platform was used to process the downloaded images, which segregated the photos into folders based on species (Rampi *et al.* Unpublished). These folders were then manually 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). Date, time and location coordinates for each photo-captured species was provided by the unique combination of the camera trap location and camera ID.

The leopard images were matched based on the rosette patterns on their respective flanks using Wild-ID (Bolger *et al.* 2011) to identify individuals. Unclear images were discarded

during this process. The flanks with maximum number of unique individuals were used for analysis.

Density and abundance estimation

The statistical analysis was done on R program 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 was tabulated based on occasions and corresponding locations where a camera trap was either functional or non-functional. The mask layer represented the spatial data of the habitat potentially used by leopards i.e. forested areas for a 2 km buffer area from the outermost camera trap locations (Efford 2018). The capture history matrix recorded an individual 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).

The Akaike's Information Criterion (AIC) for likelihood-based models was considered to select the model with the best estimates of density and abundance. 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 large prey species (both wild and domestic) using the photographic capture rate i.e. the number of independent photo captures for a particular species per 100 trap days. This was used as a surrogate for the number of events occurring based on a threshold time interval between photographs. This threshold time interval (or event duration) was predefined for each species based on the time taken by different species (individually or as a group) to cross the camera trap location (Appendix-2). 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 wild and domestic 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 Microsoft Excel (Version 14.4760.1000). This resulted in extraction of individual events for each species. Photos with multiple individuals of the same species were considered as one event. Cow and buffalo were categorized as large livestock while sheep and goat were merged 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.

The number of independent events was then tabulated and 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 146 leopard images and a total of 14 adult individual leopards were identified which was used for analysis. Of the identified individuals, five were male and seven were female. The sex of two individuals could not be identified.

The SECR analysis provided an abundance estimate of approximately 16 leopards (SE ±2.05, 14.42 – 24.45) and a density estimate of 6.02 (SE ±1.69 leopards per 100 km^2) (Table 1).

In the multiple models that were simulated for SECR analysis, the model that gave the best results accounted for individual heterogeneity and considered different detection probabilities by segregating individuals into two groups. The first group considered 22% of the individuals with a detection probability of 0.03 (SE ±0.01) and second group included 78% with a detection probability of 0.006 (SE ±0.002).

Table 1: Results of the SECR analysis for leopards for habitat mask area of 2 km in Chikkaballapura division.

	Estimate	**SE**	**lcl**	**ucl**
Abundance (N)	16.09	2.05	14.42	24.45
Density (D)	6.02	1.69	3.51	10.31
σ	4250.41	455.55	3447.15	5240.84

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 25.37 and domestic prey was 66.02. The results of the Relative Abundance Index (RAI) of leopards' natural and domestic prey are given in Table 2.

Other fauna

A total of 18 wild mammalian species were captured in camera traps at Chikkaballapura Division during the study period. All the 18 mammal species are listed in Table 2 and 3 and photographs are provided in Appendix-1. Of the 18 species camera trapped three species belonged to Schedule I, nine species to Schedule II, four to Schedule III and two to Schedule IV.

Table 2: Results of the Relative Abundance Index (RAI) calculated for leopards' natural and domestic prey in Nandi State Forest, Narasimhadevarabetta State Forest and Kallukote State Forest.

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	0.66 (0.002)
Chital (*Axis axis*)	III	Least Concern	0.33 (0.001)
Blackbuck (*Antilope cervicapra*)	III	Least Concern	0.17 (0.0007)
Four-horned antelope (*Tetracerus quadricornis*)	I	Vulnerable	0.17 (0.0005)
Wild pig (*Sus scrofa*)	III	Least Concern	2.48 (0.001)
Bonnet macaque (*Macaca radiata*)	II	Least Concern	1.77 (0.001)
Tufted gray langur (*Semnopithecus priam*)	II	Near Threatened	0.11 (0.0003)
Porcupine (*Hystrix indica*)	IV	Least Concern	1.32 (0.001)
Black-naped hare (*Lepus nigricollis*)	IV	Least Concern	17.54 (0.016)
Domestic prey			
Large livestock	NA	NA	46.61 (0.033)
Small livestock	NA	NA	33.70 (0.027)
Domestic dog	NA	NA	48.32 (0.027)

Table 3: Mammal species photo-captured in camera traps in Nandi State Forest, Narasimhadevarabetta State Forest and Kallukote State Forest.

Species	**Schedule status under the Wildlife Protection Act 1972**	**Global status under the IUCN Red List**
Leopard (*Panthera pardus fusca*)	I	Vulnerable
Jackal (*Canis aureus*)	II	Least Concern
Indian fox (*Vulpes bengalensis*)	II	Least Concern
Jungle cat (*Felis chaus*)	II	Least Concern
Sloth bear (*Melursus ursinus*)	I	Vulnerable
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

Discussion

The abundance and density estimates from this study provides baseline information for leopards in Chikkaballapura Division. An abundance of ~16 leopards with a density estimate of 6.02 SE ±1.69 per 100 km^2 for an area of 179.73 km^2 is quite high and depicts the adaptation of leopards in smaller habitats. The state forests in Chikkaballapura division considered for the purpose of this study form the largest continuous forest patch in this area.

Studies have shown that leopard population are also higher even outside protected areas (Stein *et al.* 2011; Swanepoel *et al.* 2013) possibly due to absence of conspecific predators like tigers (*Panthera tigris*) and dholes (*Cuon alpinus*) and this seem to be true even for Chikkaballapura division.

In South Africa, Swanepoel *et al.* (2013) found that NDVI, which accounted for abundance of prey, water and vegetation cover, and livestock density, had a high influence on the extent of suitable habitat despite fragmented unprotected lands. The conservation intervention suggested for such fragmented lands was to maintain connectivity of the fragments and more effort must be focused on habitats outside protected areas. Stein *et al.* (2011) suggested that prey availability is key for leopards because population density of leopards in Waterberg Plateau Park in north-central Namibia was lesser within the park (1 leopard /100km^2) as opposed to farmlands nearby (3.6 leopards/ 100km^2).

In our study area the relative abundance index of large livestock (46.61 ± 0.033) and small livestock (33.70 ± 0.027) is considerably higher than that of natural prey species which might be contributing to the high population density of leopards (Table 2). While the RAI of sambar, chital and four-horned antelope are low depicting that the natural large prey availability for leopard was low.

The depletion of natural shrubby, thorny and dry deciduous forests could also affect the native wildlife which in turn changes the dynamics and species composition of the ecosystem. For example, the Indian gray wolf (*Canis lupus pallipes*) has been known to be one of the top predators in Karnataka and inhabit landscapes in Chikkaballapura and Kolar districts. They have been slowly disappearing from southern parts of these districts (Singh & Kumara 2005). Singh & Kumara (2005) suggest a positive correlation between the increased activity of leopards and the disappearance of wolves from these habitats based on archival encounter data from the Forest Department. They attributed it to the intrusion of leopards due to expansion of afforested land with improved vegetation cover and water availability.

Many degraded patches have been afforested with fast growing, non-native varieties of trees such as Eucalyptus. The extension of such afforested areas might be influencing the dispersion of leopards into more human dominated areas. This is a cause of concern as it would increase human-leopard conflict in such localities. Conflict issues involving leopards include livestock and human attacks which will only increase with reducing natural forest cover and animals getting pushed to the forest edges due to lack of prey and cover. There has been increasing evidence of such conflicts in forested areas close to human settlements from

Karnataka (Athreya *et al.* 2016). Appropriate measures must be taken to reduce these conflicts by increasing awareness amongst the local communities and sensitizing them towards wildlife. Besides this, poaching which reduces natural prey availability for leopards might be quite prevalent in this area as documented in this study. During this study, a sloth bear was photo-captured with a snare, possibly set to catch wild prey, attached to its neck. Presence of poachers was also detected by the camera traps hence this issue needs to be addressed from a long-term leopard conservation and reduction of human-leopard conflict perspective.

Overall, leopards are facing different threats which might be area specific but in order to assess how the threat is affecting their population and take mitigation measures, it is important to have baseline data to monitor their population. This study establishes a population density estimate to start monitoring the population. Additionally, we were able to establish presence and relative abundances of other mammals that inhabit this area.

In the background of presence of various species under different schedules of the Wildlife Protection Act 1972 and the high density of leopards, we propose that Narasimhadevarabetta and Kallukote SFs to be notified as a wildlife sanctuary for the long-term conservation of the species found there. Though Nandi SF is contiguous to Narasimhadevarabetta, it may not be feasible to make it as part of the wildlife sanctuary due to very high levels of tourism that's already being carried out there.

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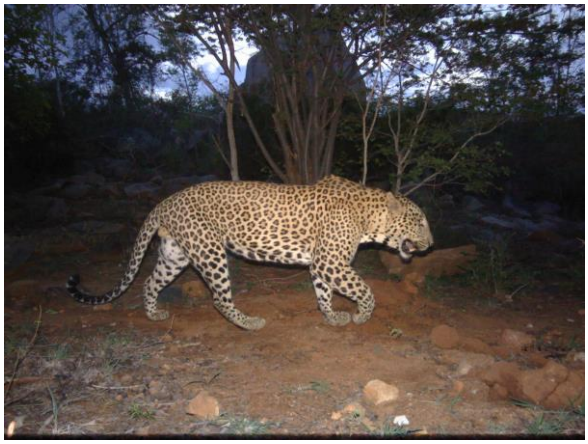
Appendix – 1

Photographs of mammal species captured in Chikkaballapura Division comprising of Narasimhadevarabetta State Forest, Nandi State Forest and Kallukote State Forest during camera trapping session in June-August 2019.



Leopard (*Panthera pardus fusca*)

Jungle cat (*Felis chaus*)

Jackal (*Canis aureus*)

Indian fox (*Vulpes bengalensis*)

Sloth bear (*Melursus ursinus*)

Porcupine (*Hystrix indica*)

Sambar (*Rusa unicolor*)

Chital (*Axis axis*)

Blackbuck (*Antilope cervicapra*)

Four-horned antelope
(*Tetracerus quadricornis*)

Bonnet macaque (*Macaca radiata*)

Tufted gray langur
(*Semnopithecus priam*)

Wild pig (*Sus scrofa*)

Black-naped hare (*Lepus nigricollis*)

Small Indian civet
(*Viverricula indica*)

Common palm civet
(*Paradoxurus hermaphroditus*)

Grey mongoose (*Herpestes edwardsii*)

Ruddy mongoose (*Herpestes smithii*)

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
Blackbuck (*Antilope cervicapra*)	60
Four-horned antelope (*Tetracerus quadricornis*)	60
Wild pig (*Sus scrofa*)	60
Bonnet macaque (*Macaca radiata*)	360
Tufted gray langur (*Semnopithecus priam*)	180
Porcupine (*Hystrix indica*)	60
Black-naped hare (*Lepus nigricollis*)	60
Domestic prey	
Large livestock	300
Small livestock	180
Domestic dog	60

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