Status of Leopards, Co-predators and Megaherbivores in India 2018

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CHAPTER 1:
INTRODUCTION

Global biodiversity is under severe threat due to human impacts on the planet, large carnivores are one of the worst affected taxa in the Anthropocene (Ripple et al. 2014). Often conservation efforts directed for the apex predator in an ecosystem are believed to play an umbrella role for the conservation of entire biodiversity (Caro 2003). Indeed, this has been the driving concept of Project Tiger, a flagship conservation initiative by the Government of India since 1973. In recent years, India is one country where the tiger is on its way to recovery (Jhala et al. 2021). However, to assess the impact of tiger conservation investments on other sympatric species requires their targeted estimation and monitoring. Herein, we evaluate the status of leopards *(Panthera pardus)*, sloth bear *(Melursus ursinus)*, smaller felids, wild canids, megaherbivores, and a few mustelids in tiger *(Panthera tigris)* habitats of 20 Indian states.

After tigers and lions *(Panthera leo)*, leopards occupy the next level in the trophic pyramid along with dhole *(Cuon alpinus)*. Unlike tigers that colonized India from the East (Malayan realm), but like lions, leopards originated in the Ethiopian realm and entered into India from the Western corridor much earlier than lions and tigers (Mani 1974).

Leopard's historic range spanned across nearly 35,000,000 km² covering all of the sub Saharan North, Central and South Africa, the Middle East, Asia Minor, South and Southeast Asia, and extends into the Amur Valley in the Russian Far East. Island ranges included Sri Lanka, Java, Zanzibar and Kangean (Seidensticker and Lumpkin 1991, Uphykrina et al. 2001, Jacobson et al. 2016). Leopards are extremely versatile and occur in almost every kind of habitat, from the rainforests of the tropics to deserts and temperate regions (Kitchener 1991). The Indian subspecies, *Panthera pardus fusca*, is found in all habitats of India, absent only in the arid Thar desert and Sundarban mangroves (Prater 1980, Daniel 1996). In the Himalayas they are sometimes sympatric with snow leopards *(Panthera uncia)* and have been recorded as high as 5,200 m (Uphyrkina et al. 2001). They serve as major predators in most of the forested landscapes in India and are sympatric with tigers, lions and dhole. In comparison to other large carnivores, leopards are quite adaptable with respect to their habitat needs and food requirements, being found in agro-pastoral landscapes, plantations, and near human habitation (both rural and urban; Nowell and Jackson 1996). They are prolific breeders with faster life history traits compared to tigers (Chapron et al. 2008). Kumar et al. (2019) recorded an annual growth rate of 15% from parts of Kanha Tiger Reserve in Central India from a six-year study. The leopard being one of the most widely distributed felid (Sunquist and Sunquist 2002), due to its diet flexibility (Hayward et al. 2006) and ability to persist in a variety of environments including human dominated landscapes (Athreya et al. 2013, Gubbi et al. 2020a), often conflicts with humans and can become a conservation challenge in parts of its range (Rahalkar 2008,

Athreya et al. 2011, Navya et al. 2014, Sidhu et al. 2017, Naha et al. 2018).

Current distribution and number of leopards have significantly decreased across their global range due to habitat loss, prey depletion, conflict with human interests and poaching over the last century. Recent meta-analyses of leopard status and distribution suggest 48–67% range loss for the species in Africa and 83–87% in Asia (Jacobson et al. 2016). This is in consonance with a recent genetic study in India which suggests that leopards have experienced 75-90% human induced population decline within the last ~120-200 years (Bhatt et al. 2020). These threats have resulted in IUCN changing the species status from 'Near Threatened' to 'Vulnerable' (Stein et al. 2016). Often parts and products of leopards are illegally traded as tiger parts and the impact of poaching on leopards is significant (Raza et al. 2012). Therefore, the leopard is also listed in Appendix I of the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES) and in Schedule I of the Wildlife (Protection) Act 1972 in India providing it with the highest level of protection. Despite historical persecution, among all the subspecies, Indian leopard retains the largest population size and range outside of Africa (Jacobson et al. 2016). In the Indian subcontinent poaching, habitat loss, depletion of natural prey and conflict are major threats to leopard populations (Athreya et al. 2011, Raza et al. 2012). In areas devoid of other charismatic large carnivores, leopards can act as an umbrella species for biodiversity conservation.

Despite Hamilton's (1976) acknowledgment that leopards have had the reputation of being one of the least studied large felid, studies in the last two decades have barely addressed this void. Most studies on leopard ecology and behaviour have been done in Africa (Hamilton 1976, Bertram 1982, Bailey 1993, Jenny 1996). Much of our knowledge on leopard status in the Indian subcontinent comes from site specific studies which highlight their ecology (Edgaonkar 2008, Mondal 2011), co-occurrence with other apex predators (Schaller 1967, Chellam 1993, Harihar et al. 2011, Kumar et al 2020, Chaudhary et al. 2020), abundance estimation (Chauhan et al. 2005, Harihar et al. 2009, Wang and Macdonald 2009, Kalle et al. 2011, Borah et al. 2014, Thapa et al. 2014, Pawar et al. 2019, Kumar et al. 2019), demography (Mondal et al. 2012, Dutta et al. 2012, Dutta et al. 2013, Kumar et al. 2019), diet and predation (Karanth and Sunquist 2000, Ramesh et al. 2009, Mondal et al. 2011, Kshettry et al. 2018) and conflict (Athreya 2012, Sondhi et al. 2016, Gubbi et al. 2020a, Krishnakumar et al. 2020).

The National Tiger Conservation Authority (NTCA) in collaboration with the State Forest Departments, Conservation NGO's and coordinated by the Wildlife Institute of India (WII), conducts a National level assessment of "Tigers, Co-predators, Prey and their Habitat" every four years since 2006. For species besides tigers and leopards, the past assessments were mostly limited to occupancy. Leopard density and abundance was reported for the first time in the 2014 cycle across tiger occupied states of India which estimated the leopard population at 7,910 (SE 6,566-9,181) leopards (Jhala et al. 2015) within tiger habitats.

This report assesses the status of leopards from camera trap data and occupancy surveys conducted in 2018-19 across 20 States of India where tigers occur, using spatially explicit capture recapture framework. Since the 2018-19 survey sampled a substantial part of the forested landscape in these 20 States with camera traps, we also use photo-capture data to reliably estimate occupancy, relative abundance and understand the eco-geographical correlates of species occurrences for all felids, wild canids, megaherbivores, sloth bear and a few mustelids. Earlier assessments of some of these taxa relied primarily on detection of their sign to infer occupancy. Though this works well for many species, some smaller cats, canids, and mustelids cannot be identified to species very reliably from their signs. Camera trap images are unambiguous in identifying species and do away with human errors that can occur from sign-based species identification and are therefore more reliable. We use occurrence and photo-capture intensity to model species distribution and relative abundance using meaningful ecoclimatic variables in a Maximum Entropy model framework (Phillips et al. 2004). This report will provide a first large scale baseline for many taxa and species against which future trends in their population can be monitored and specific conservation actions initiated in a timely manner. We hope that this information will be useful to wildlife biologists in furthering scientific research, wildlife managers and policy makers in assisting to better conserve our natural heritage through a more holistic scientific understanding of ground realities.

CHAPTER 2: **METHODS**

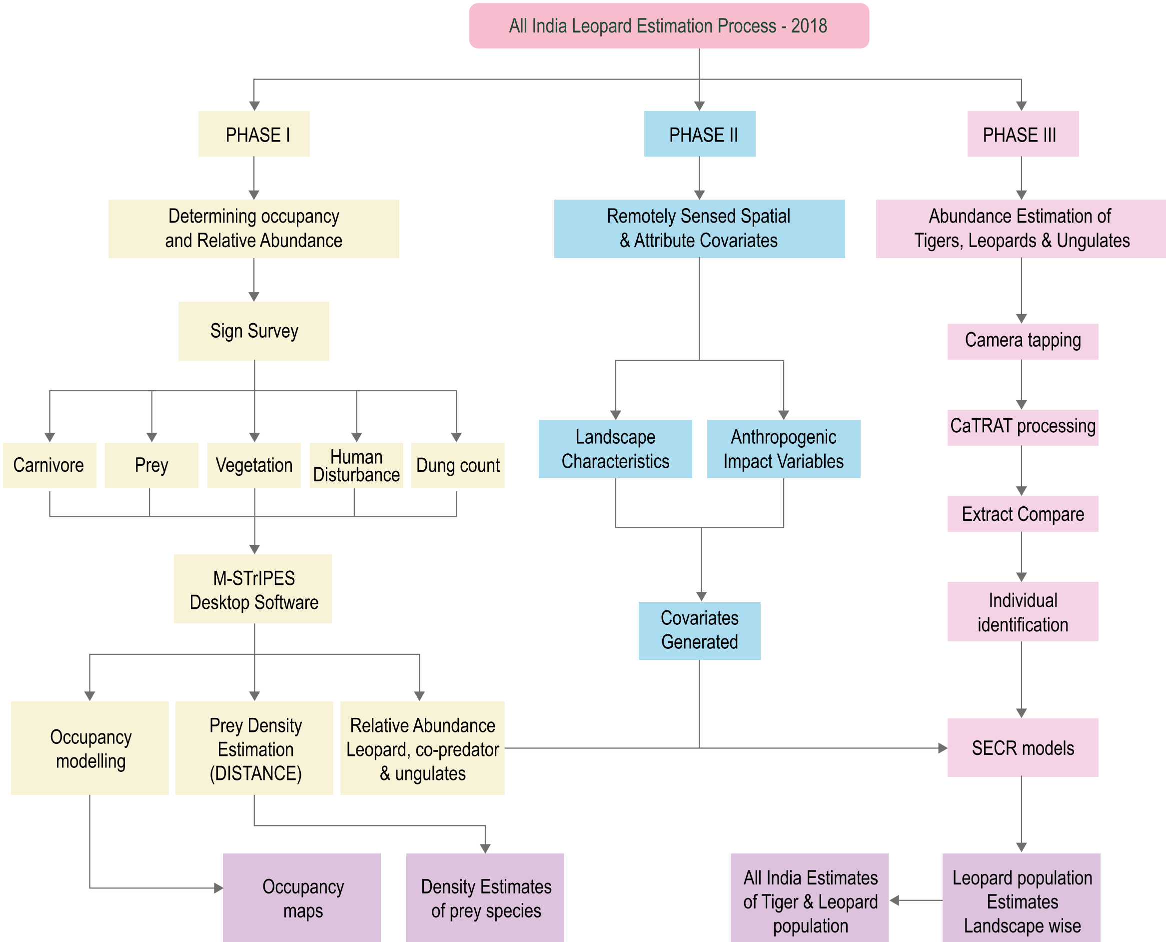
During the National tiger estimation exercise of 2018, leopard population was also estimated within the forested habitats of tiger occupied states. Other leopard occupied areas where leopards were known to occur, such as coffee and tea plantations in the Western Ghats and north Bengal, higher elevations in the Himalayas, much of the semi-arid landscapes of the western India, and majority of the North Eastern hill landscapes were not sampled. Non-tiger states like Gujarat, Himachal, Jammu and Kashmir, and parts of Rajasthan (outside the range of the tiger) were not assessed. Therefore, the population estimation should be considered as minimum number of leopards in each of the landscapes.

Leopard abundance was estimated at the scale of four major tiger conservation landscapes 1) Shivalik hills and Gangetic plains, 2) Central India and Eastern Ghats, 3) Western Ghats and, 4) North Eastern hills and Brahmaputra flood plains (for details please see Jhala et al. 2020). Spatial data on individual leopard photo-captures was used in combination with spatial data on prey, habitat, and anthropogenic factors as covariates in a likelihood based spatially explicit capture mark-recapture (SECR) framework (Efford 2015) to arrive at leopard population estimates for each tiger landscape. This method entails recording of covariate information at a fine spatial resolution of a forest beat (~15 km^2, Phase I and II) on leopard occupancy and sign intensity, ungulate abundances, human impact indices, and habitat characteristics across all potential tiger habitats in India (Jhala et al. 2011). Subsequently replicate areas within each landscape were sampled using camera traps at a high spatial density of one double camera per location in a 2 km^2 grid (Phase III). The concept is similar to that of double sampling wherein indices or raw counts of abundance obtained from the entire sample space are calibrated against absolute density obtained from limited samples (Figure 2.1). The difference between double sampling and SECR approach is that double sampling uses ratio or regression to calibrate indices while leopard population estimation uses spatial information on capture-mark-recapture (that accounts for detection correction) in a likelihood framework with spatial covariates of leopard sign intensity, prey abundance, human disturbance and habitat characteristics. This approach estimates leopards directly within camera trapped areas, calibrates it with covariates, and extrapolates density based on covariate relationships to forested areas where leopards were present but the area was not camera trapped.

Phase I – Determining occupancy and relative abundance:

The forest administration system across most of India is based on division of States into Forest Divisions, Divisions into Ranges and Ranges into Beats in a spatially hierarchical manner. The boundaries of Beats are based on natural features that are easily identifiable in the field. Besides, each forest beat is usually allocated to a beat guard who has intimate knowledge of his beat. The average size of a forest beat in India is about 15-16 km^2. We used this spatial administrative system to systematically distribute sampling units at a very fine spatial scale across all forested areas within each landscape.

Figure 2.1. Outline of the sampling framework for landscape level leopard estimation



Frontline staff of State Forest Departments of 18 tiger bearing states, Nagaland and Goa were trained by NTCA-WII Tiger Cell to collect the Phase I data **(Appendix I).** A field guide in nine regional languages was published (Jhala et al. 2017) and provided to each beat guard. Sampling was done in all current and potential tiger habitats (in Tiger Reserves, Protected Areas, Reserve Forests, Protected Forests, Revenue Forests in all Wildlife and Territorial divisions) with each beat as a sampling unit (Figure 2.2). Data were either recorded manually on forms or digitally using M-STrIPES (Monitoring System for Tigers: Intensive Protection and Ecological Status) ecological android mobile application. The protocol for Phase I (Jhala et al. 2017) consisted of five forms with simple procedures for:

a) Carnivore sign encounters (Form 1: Occupancy surveys with replicates in a beat)
b) Ungulates abundance (Form 2: Distance sampling on line transect(s) in a beat)
c) Vegetation (Form 3A and 3C: Canopy cover, tree (15m), shrub, and weed infestation (5m), and herb composition (1m radius) on plots on transect(s) in a beat)
d) Human disturbance (Form 3B: Plots of 15m radius on line transect(s) in a beat) and
e) Dung counts (Form 4: count of all dung identified to species in 40m² [20mX2m] plots on transects)

With two persons (a forest guard and his assistant) sampling a beat, the entire exercise of laying transects and data collection for the above mentioned five aspects (Phase I data) were collected within a period of eight to ten days.

Phase I Data Processing and Analysis:

Shape files of all administrative boundaries of Divisions, Ranges and Beats were customized for major part of the country so that the data could be collected using M-STrIPES mobile android app and could directly be imported and analysed in M-STrIPES desktop software. Phase I data was received from 491 Forest Divisions of India and these were processed using M-STrIPES desktop software. Data for each spatial and temporal replicate recorded at the beat scale (occupancy surveys, line transects, and plots) were transferred to the standard 100 km² grids for analysis and subsequent inference. Tiger and leopard sign encounter rates, ungulate encounter (direct sighting) rates, ungulate dung density, human disturbance indices (signs of livestock, human trails, wood cutting, lopping, grass removal) were computed as average encounter rates for 25 km² (5 km X 5 km) grids based on effort (km of survey) invested in each grid.

Phase II- Remotely sensed spatial and attribute covariates:

Distribution and abundance of leopards (wildlife) are likely to be determined by habitat characteristics and anthropogenic impacts. These covariates were obtained from remotely sensed data and used to model leopard occupancy and abundance. Habitat characteristics were surrogated by forest area, vegetation cover [Normalized Difference Vegetation Index, (NDVI)], forest patch size, forest core areas, elevation, distance from protected areas and drainage density. Human impacts were surrogated by human pressure, distance to night lights, night light intensity, distance to roads and density of road network (see Appendix 2 for details). All these information were extracted at a resolution of 1 km².

Phase III: Camera trap based Capture-Mark-Recapture:

With availability and affordability of digital camera traps, these have become a mainstream tool for monitoring elusive wildlife (Sunarto et al. 2013). Tigers and leopards with their unique individualistic stripes and rosettes permit individual identification and subsequent estimation of their abundance using capture-mark-recapture framework. Spatially explicit capture-recapture models (SECR) consider the spatial context of capture and recapture of individuals alongside their capture history to estimate density. SECR ties the detection process to the actual space usage of an animal allowing robust parameter estimates (Borchers and Efford 2008).

Camera traps were placed at 26,838 locations spread across 141 sites for mark recapture analysis (Figure 2.3). Camera traps were systematically distributed within the sampling area by superimposing 2 km² grid and deploying at least one pair of cameras within each grid. Cameras were placed at the best possible location to maximize photo-captures of tigers and leopards, identified through extensive search during sign surveys. Each grid was uniquely coded and was set within the 100 km² country wide grid that has been fixed since first cycle of National Tiger Status Estimation in 2006 so that subsequent inferences can be compared at the same spatial scale and extent. Sampling was carried out simultaneously in a minimum block of 200 km². If more number of camera traps were available, then sampling was done in larger size blocks. Minimum camera trap location spacing was maintained at around 1 km. Cameras were usually operated between 25 to 35 days at each site, with an average effort of over 1,200 trap-nights per ~100 km².

Figure 2.2. Spatial coverage of sampled forests for carnivore signs, ungulate abundance, habitat characteristics and anthropogenic impacts. Sites where leopard evidence was recorded is shown in orange and provides a range map of leopard distribution within sampled forests in India for 2018-19

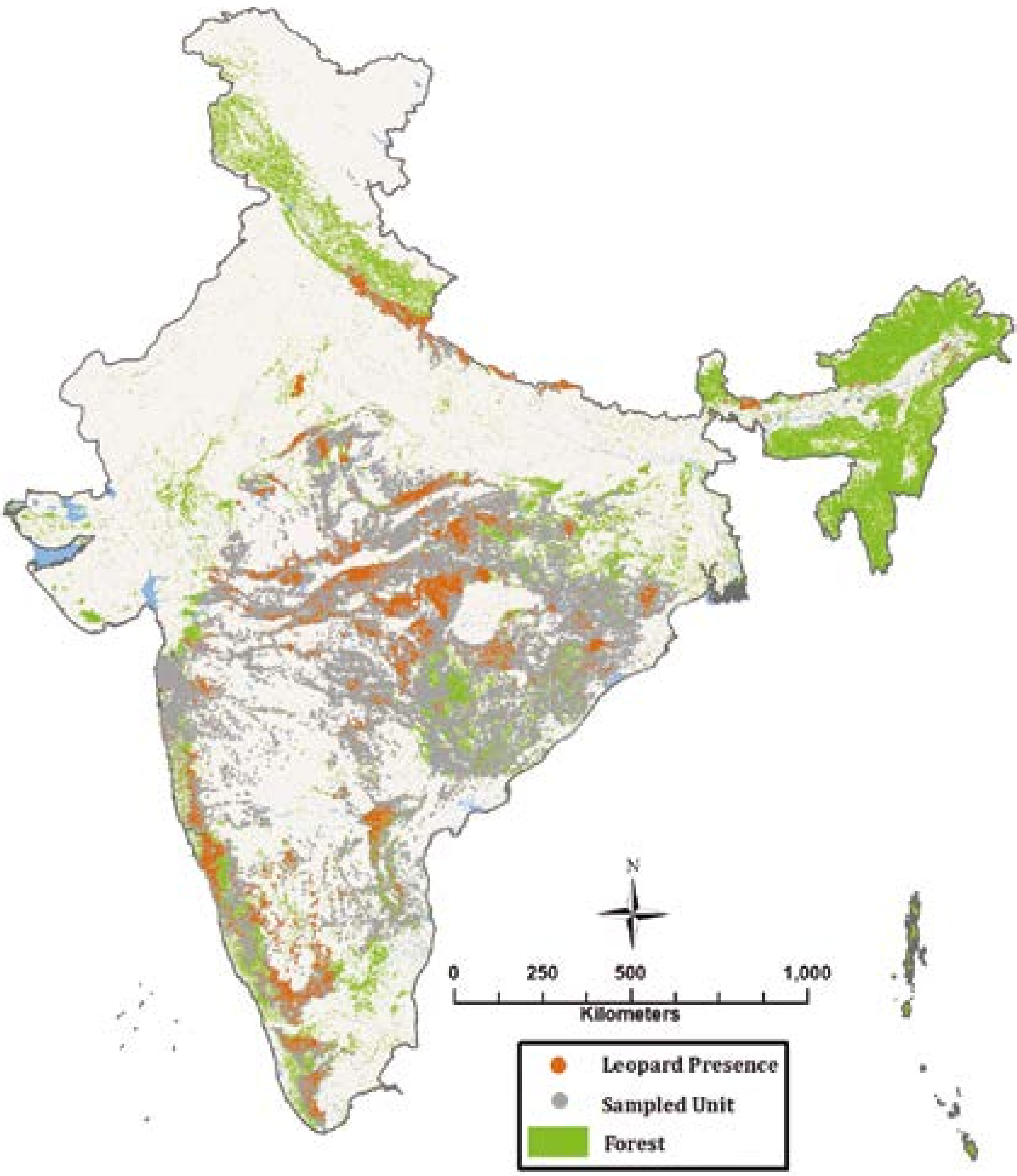
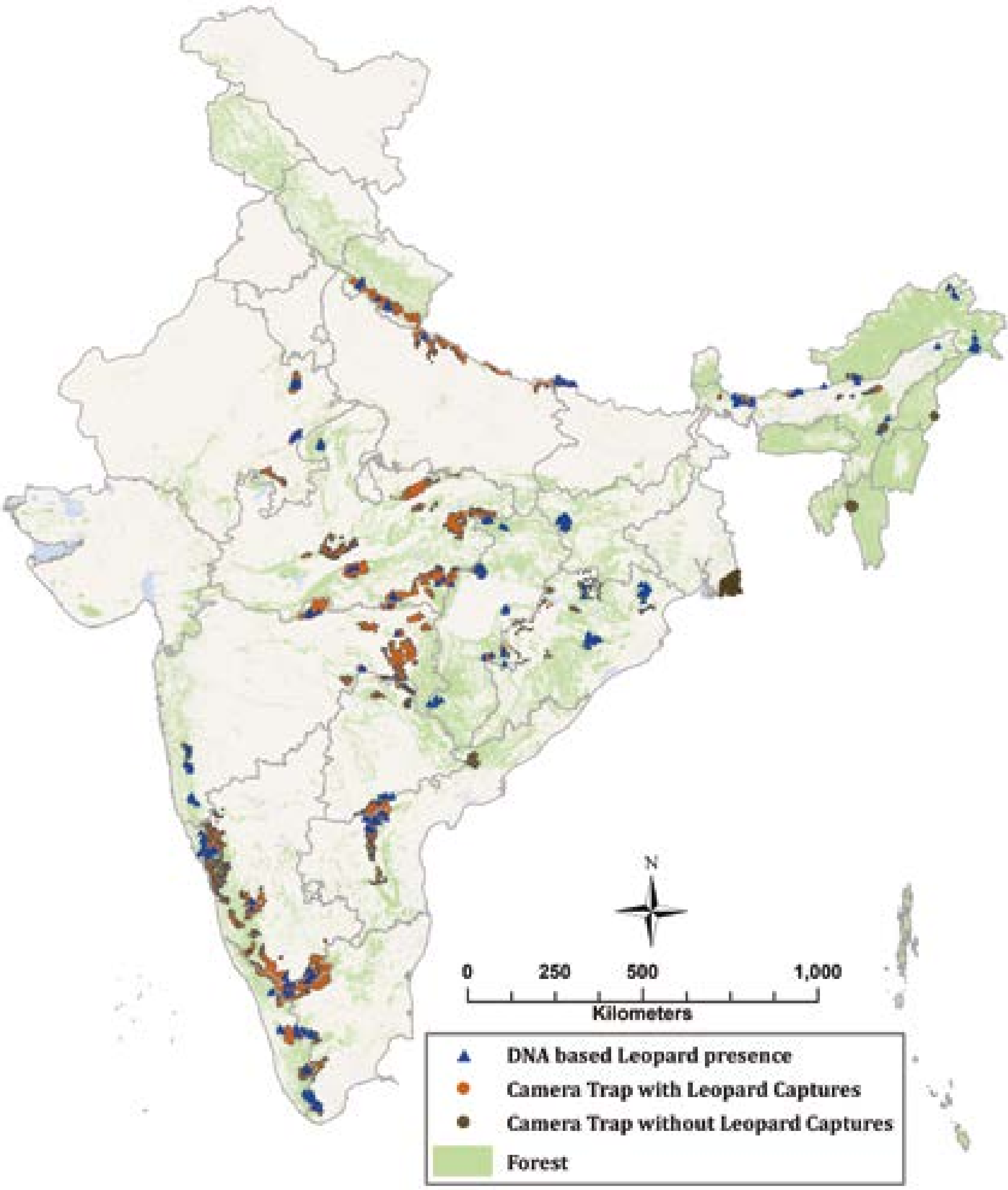


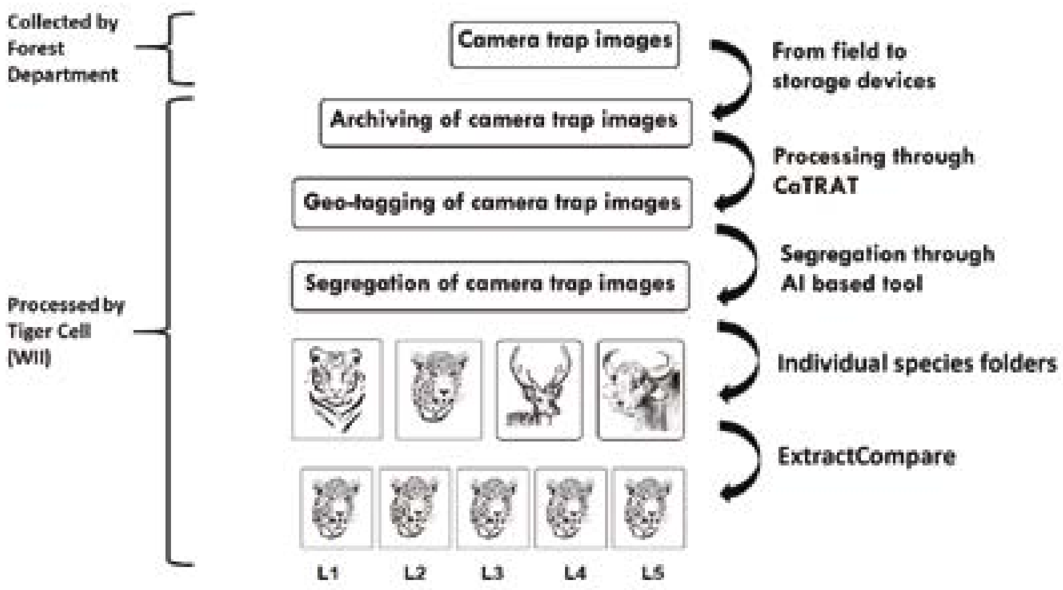
Figure 2.3. Camera trap locations, cameras with leopard captures and leopard positive scat locations across tiger bearing forests of India in 2018-19



Processing of Phase III data:

An artificial intelligence (AI) based image processing software CaTRAT (Camera Trap Data Repository and Analysis Tool) (Cheema et al. 2018) was used for geotagging, coding and segregating the images to individual species folders (Figure 2.4). The geo-tagged images were manually scrutinized for potential software misclassification. Segregated photos of tigers and leopards were further processed for identification of individual tigers and leopards.

Figure 2.4. Workflow of species identification from camera trap images using artificial intelligence based tool, CaTRAT

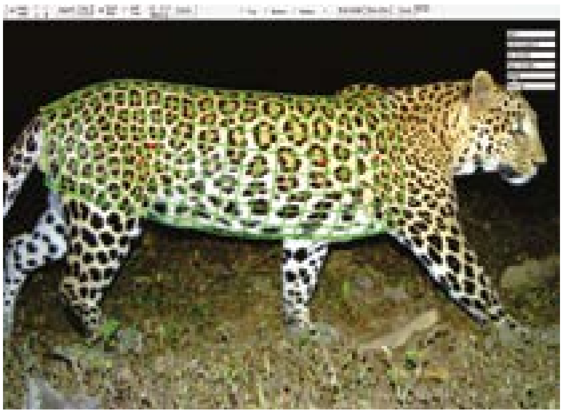


Individual identification of leopards:

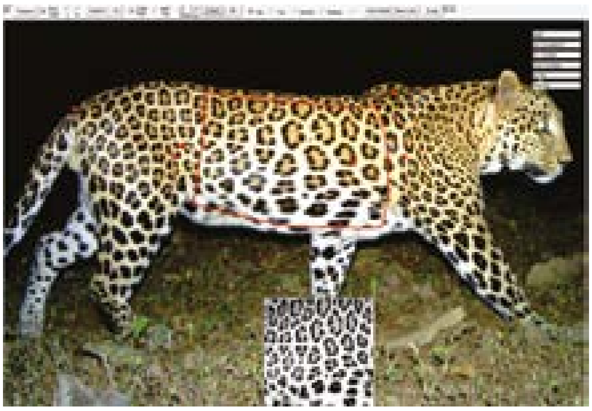
We first grouped leopard images into those potentially belonging to the same individual using Hotspotter (Crall et al. 2013) at a camera trap site scale and subsequently used ExtractCompare (Hiby et al. 2009) for final identification of individual leopards at the landscape scale. A total of 51,337 leopard photographs were obtained from camera traps. In ExtractCompare, a three-dimensional surface model of a leopard is superimposed on leopard photographs to account for pitch and roll related to body posture before extracting the spot patterns (Figure 2.5). Using an automated process, pattern recognition software searches through the database of images, to calculate similarity scores between digitized leopard coat patterns to recognize common and unique individuals. Leopard(s) photo-captured at each camera trap site were first identified to unique individuals. Subsequently, leopard photographs of adjoining sites and within each landscape were compared using the National database, so as to merge duplicate leopards, if any, and understand leopard dispersal events. Once individual leopards were identified, a matrix of spatial capture history for each leopard was developed for each site with camera trap IDs, their coordinates, deployment and operation history of each camera.

Figure 2.5. Process of individual identification of leopards using Program ExtractCompare

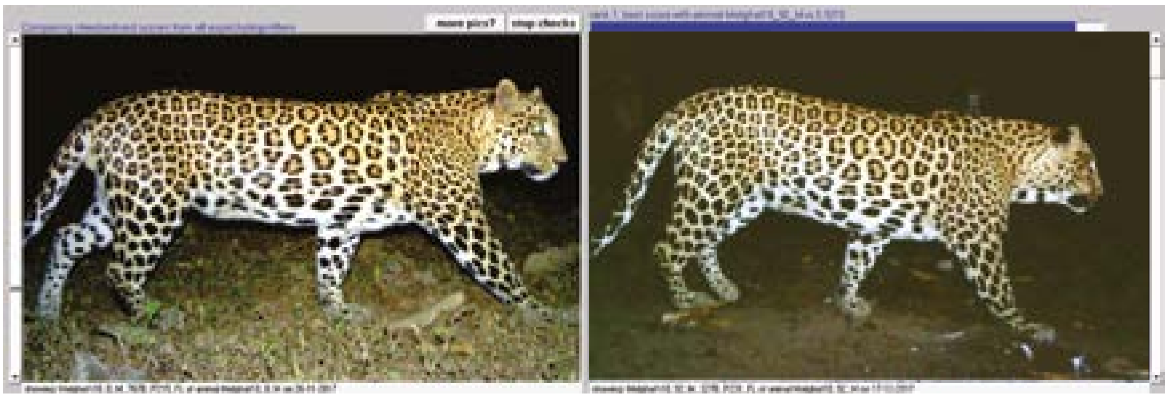
a) Placing seeds on prominent body parts (mid shoulder, tail, hip)



b) 3-D model fitting which takes into account the angle at which the photo is taken



c) Pattern extracted



d) Visual compare to match leopard images after the computer program has provided a few options from several thousand images

Abundance estimation through Spatially Explicit:

Capture Recapture (SECR): We used likelihood based SECR (Borchers et al. 2008, Efford 2011) to estimate leopard abundance from camera trap data. The two basic detection parameters in SECR are detection probability (g_0) at the home range centre of the animal and a parameter for spatial movement (σ). We provided a habitat mask with a sufficient buffer around the camera trap array that excluded non-habitat. In our analysis, density was modelled as a function of covariates. Leopard sign encounter rates, prey encounter or dung densities and human footprint variables obtained from ground surveys and remotely sensed data were used within SECR as covariates to model leopard density through package secr (Efford 2015) in program R (R Development Core Team 2010). Covariate based abundance models were developed for each landscape to estimate leopard abundance within sampled forests. The best covariate model was then selected on the basis of Akaike Criteria Information (Akaike 2011) for that landscape. In areas where leopards were detected but the area was not camera trapped, their numbers were then estimated by extrapolating leopard density from covariates (prey, habitat and human disturbances) using the best model or model averaged parameters.

Genetic sampling:

To understand the genetic structure of leopards across tiger habitats in the country, putative carnivore scats were collected during the monitoring exercise across the country. DNA from these scats was extracted and assigned to species based on molecular identification through species specific primer amplification (Maroju et al. 2016). Leopard positive samples from the aforementioned step were then identified to individuals based on a panel of eleven microsatellites, as described in Kolipakam et al. (2019).

Occupancy and distribution of carnivores and megaherbivores:

Since the 2018-19 monitoring exercise had an extensive camera trap coverage, we used species photo-captures to model the distribution of all felids, canids, sloth bear, and megaherbivores using Maximum Entropy Species Distribution Modelling in MaxEnt (Version 3.4.1) (Phillips and Dudík 2008, Elith et al. 2011, Phillips et al. 2017). The software MaxEnt uses machine learning so as to develop relationships from known occurrence locations and background data with environmental covariates. The program then predicts potential distribution of species from these covariate relationships across modelled space (Phillips and Dudik 2008).

The habitat covariates **(Appendix 2)** were exported to the Export to Circuitscape (Shah and McRae 2008) plugin in ArcMap to obtain uniform resolution and concordance with a grid size of 1 km². A correlation matrix for all environmental layers was computed in ArcMap for each species. The correlation threshold was set at $r>\pm0.60$ to check for redundancy in information. No two correlated variables were used together in a single model.

Since some species locations (events) used for training our models were from a restricted part of the modelled space; therefore, a bias correction file was created using inverse distance weight (IDW) interpolation method in ArcMap (10.5.1) to guide MaxEnt to pick background locations from space containing occurrence locations (Phillips et al. 2009, Elith et al. 2011). Such an approach would increase model accuracy by limiting the predictive relationships to be developed from the extent of presence vs background from the same area. Of the total events captured for each species 70% of

event locations of each species were used to train MaxEnt models and the remaining 30% were used to test models. Linear, Threshold, Hinge and Quadratic functions were used as required in MaxEnt to model relationships between covariates and species abundance. Regularization Multiplier was set at 1 for all species. One hundred bootstrap simulations were run for the best model for each species. The mean prediction of 100 bootstraps is reported as occurrence probability spatial maps for each species.

Variable and model selection was based on a) environmental variables that were most likely to influence species ecology, b) Receiver Operation Characteristic (ROC) curve (Jiménez-Valverde 2012), c) contribution of covariates to explain the variability of the training and test data sets, and, d) omission/commission analysis of test dataset. Species response curves to each covariate were examined and ecologically interpreted.

Determining activity patterns for carnivores and megaherbivores:

Camera trap based frequency of photo-capture events at various times of the day by individual species were used for measuring activity level. Activity level of a population is defined here as the proportion of time animals are active in a day. Activity level was estimated by fitting circular kernel probability density function (PDF) on the time of detection data, In order to obtain the underlying activity pattern and then calculate overall proportion of time active from the distribution (Rowcliffe et al. 2014) R package activity (Rowcliffe 2019) was used. Standard error and 95% confidence interval were estimated by bootstrapping the data with 10,000 iterations.

CHAPTER 3:
STATUS OF LEOPARDS AT A GLANCE

Camera traps deployed at 26,838 locations across India resulted in 34,858,623 photographs of wildlife of which 51,777 were of leopards. A total of 5,240 adult leopards were photo-captured. The overall leopard population in tiger range landscape of India was estimated at 12,852 (SE range 12,172 - 13,535) (Table 3.2). Out of a total 10,602 surveyed grids (100 km²) in India, leopard presence was recorded for 3,475 grids having 186,698 km² of forest. Major population block in India having 5,906 (SE range 5,599 – 6,213) leopards occurs in 91,427 km² forested landscape of Central India comprising of several Tiger Reserves and Protected Areas (Figure 3.1). Second major population block supporting about 2,924 (SE range 2,812 – 3,036) leopards occur in the Western Ghats.

Leopard sign index was the major covariate for leopard population estimates through spatially explicit capture-recapture model (Table 3.1).

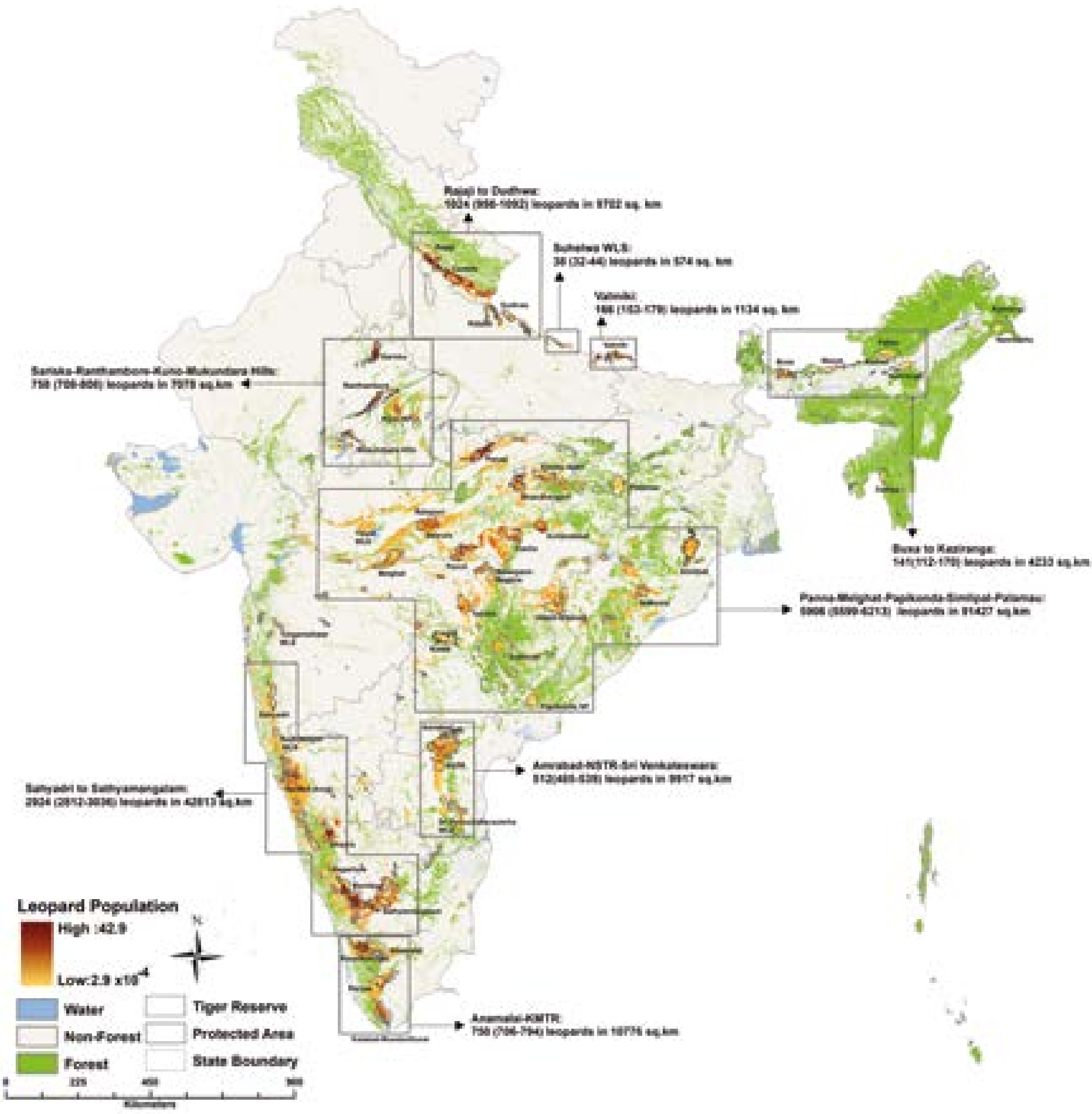
Table 3.1 : β coefficients of the covariates from the best selected model of SECR based population estimates

Landscape	Covariates (Relative indices)	β coefficients (SE = standard error)
Shivalik Hills and Gangetic Plains Landscape	Leopard sign	0.26 (SE 0.03)
Central Indian Landscape and Eastern Ghats	Leopard sign	0.19 (SE 0.02)
Western Ghats Landscape	Leopard sign	0.15 (SE 0.02)
	Prey	0.21 (SE 0.03)

Table 3.2. Leopard population estimates in the forested areas of tiger states, 2018

State	2018 population estimates with SE limits
Shivalik Hills & Gangetic Plains	
Bihar	98 (90-106)
Uttarakhand	839 (791-887)
Uttar Pradesh	316 (277-355)
Shivalik-Gangetic	**1,253 (1,158-1,348)**
Central India & Eastern Ghats	
Andhra Pradesh	492 (461-523)
Telangana	334 (318-350)
Chhattisgarh	852 (813-891)
Jharkhand	46 (36-56)
Madhya Pradesh	3,421 (3,271-3,571)
Maharashtra	1,690 (1,591-1,789)
Odisha	760 (727-793)
Rajasthan	476 (437-515)
Central India & Eastern Ghats	**8,071 (7,654-8,488)**
Western Ghats	
Goa	86 (83-89)
Karnataka	1,783 (1,712-1,854)
Kerala	650 (622-678)
Tamil Nadu	868 (828-908)
Western Ghats	**3,387 (3,245-3,529)**
North East Hills, and Brahmaputra Flood Plains*	
Arunachal Pradesh	11 (8-14)
Assam	47 (38-56)
West Bengal	83 (66-100)
North East Hills, and Brahmaputra Flood Plains	**141 (115-170)**
TOTAL	**12,852 (12,172-13,535)**

Figure 3.1: Leopard distribution, population blocks and density (individuals/ 100 km²) depicted on a 25 km² grid in India 2018-19.



Since leopard abundance was estimated in a spatially explicit framework, it was possible to provide abundance estimates for individual tiger reserves along with the number of leopards using each tiger reserve (Table 3.3). There is always an issue of defining a number within an area that has contiguous habitat which can potentially be used by leopards outside of tiger reserves (Tiger Reserves not having hard boundaries but embedded within larger forested and multiple use areas). In such cases leopards that were photo-captured within a reserve could potentially have their activity centers way beyond the boundaries of a tiger reserve, but visit and use the tiger reserve and thus get photo-captured. In such cases, often when extensive and intensive camera trapping is done, the number of leopards photo-captured can exceed the population estimate from within the administrative boundaries of a tiger reserve. To avoid this confusion, we report estimates of leopards that have their activity centers located within and in very close proximity of the tiger reserve administrative boundary (leopard population within the Tiger Reserve). We also report the estimated leopard population that could potentially utilize the tiger reserve and be exposed to the camera traps (as leopards using the Tiger Reserve). It is the latter number that is to be used for annual Phase IV monitoring as well as for non-spatial capture-mark-recapture based abundance estimation.

Table 3.3: Population estimates of leopards in tiger reserves for the year 2018.

State		Leopards Using the Tiger Reserve		Leopards within the Tiger Reserve	
	Tiger Reserves	Leopard Number	SE	Leopard Number	SE
Shivalik Hills and Gangetic Plains					
Bihar	Valmiki	156	8	113	1.1
Uttar Pradesh	Dudhwa	157	43	93	7.8
Uttar Pradesh	Pilibhit	44	2.89	39	1.69
Uttarakhand	Corbett	179	9.81	137	4.66
Uttarakhand	Rajaji	221	11.56	145	2.55
Central India and Eastern Ghats					
Andhra Pradesh	Nagarjunasagar Srisailam	224	10.59	159	2.69
Chhattisgarh	Achankamar	124	8.4	87	2.76
Chhattisgarh	Indravati*	NA	NA	58	2
Chhattisgarh	Udanti Sitanadi*	NA	NA	95	9
Jharkhand	Palamau	36	9	26	5.67
Madhya Pradesh	Bandhavgarh	183	8.17	139	2.04
Madhya Pradesh	Kanha	207	10.93	142	3.16
Madhya Pradesh	Panna	350	12.2	273	5.24
Madhya Pradesh	Pench	199	10.92	138	3.64

Madhya Pradesh	Satpura**	212	3.12	NA	NA
Madhya Pradesh	Sanjay Dubri	91	8.4	60	2.69
Maharashtra	Bor	41	3.6	33	1.11
Maharashtra	Melghat	168	4.73	150	0.88
Maharashtra	Navegaon Nagzira	102	6.42	76	1.41
Maharashtra	Pench	106	8.09	67	0.54
Maharashtra	Sahyadri*	NA	NA	40	7
Maharashtra	Tadoba Andhari	120	6.6	91	1.53
Odisha	Satkosia*	NA	NA	47	5
Odisha	Similipal*	NA	NA	125	7
Rajasthan	Mukundara Hills	83	9.39	51	2.89
Rajasthan	Ranthambhore	105	7.7	89	5.2
Rajasthan	Sariska	273	9.67	231	5.23
Telangana	Amrabad	160	12.68	94	3.04
Telangana	Kawal*	NA	NA	42	3
Western Ghats					
Karnataka	Anshi Dandeli (Kali)	221	17.5	114	3.08
Karnataka	Bandipur	200	8.28	152	1.36
Karnataka	Bhadra	129	9.91	86	3.12
Karnataka	Biligiri Rangaswamy Temple (BRT Hills)	71	10.79	41	3.94
Karnataka	Nagarhole	136	7.3	102	2.02
Kerala	Parambikulam	180	12.28	126	5.28
Kerala	Periyar	96	15.38	53	6.0
Tamil Nadu	Anamalai	115	12.10	70	4.17
Tamil Nadu	Kalakad Mundanthurai	156	14.32	111	6.85
Tamil Nadu	Mudumalai	209	13.78	138	4.91
Tamil Nadu	Sathyamangalam	172	10.15	132	5.22
NE Hills and Brahmaputra Plains					
Arunachal Pradesh	Pakke	15	2	13	0.33
Assam	Manas	35	2.7	32	1.6
Assam	Nameri	11	1.2	10	0.1
West Bengal	Buxa	38	2.9	33	0.98

**estimates from landscape covariate model; **non-spatial mark recapture estimates; NA = estimates not available*

In some tiger reserves that abut each other (Bandipur, Mudumalai, and Sathyamangalam, BRT Hills; Pench – Madhya Pradesh and Pench- Maharashtra, Pakke and Nameri) individual leopards could be double counted. These double counts are accounted for while estimating the leopard population at the landscape and state scale. However, in Table 3.3 they are reported in each Tiger Reserve.

Panna Tiger Reserve in Madhya Pradesh had the largest leopard population at about 273 leopards followed by Sariska (at about 231 leopards). Both these Tiger Reserves lost their tigers in between 2004 and 2009 and in absence of tigers (or with low density of tigers after reintroductions), leopards occupied the major forested habitats within the Tiger Reserve. Some of the low to medium tiger density tiger reserves (such as Nagarjunasagar Srisailam, Amrabad, Melghat, Satpura, Anshi Dandeli, Anamalai, Parambikulam, Kalakad Mundanthurai, Similipal) support over hundred leopards within their administrative boundaries. Tiger Reserves such as Bandhavgarh, Bandipur, Nagarhole, Mudumalai which support over hundred tigers (Jhala et al. 2020), also harbor populations of more than hundred leopards. Buxa and Palamau which recorded no presence of tigers during 2018 estimation, had sizeable populations of leopards.

CHAPTER 4:

SHIVALIK HILLS AND GANGETIC PLAINS

Background

The Shivalik Hills and Gangetic Plains landscape in India spans across the states of Himachal Pradesh, Uttarakhand, Uttar Pradesh, Bihar, West Bengal and Assam and is comprised of three parallel geological zones, *viz.* the Shivaliks, the Bhabar tract and the Terai plains. For convenience of assessment, herein, this landscape is limited to the eastern extent of Bihar. The lower altitude hills of West Bengal and Assam are included in the Brahmaputra plains and North-eastern hills (for details refer Jhala et al. 2020). We assessed leopard population only in the potential areas where tigers could occur in this landscape. Leopards are distributed in the Shivalik Forest Division adjoining Rajaji tiger Reserve, towards Himachal Pradesh, and in the higher hilly regions of the state of Uttarakhand. But these areas were outside the purview of the current project's study area and hence, we provide a minimum number and estimate of leopard populations from only the potential tiger bearing forests (upto an altitude of 2400m).

Leopards are distributed across the Shivaliks and Gangetic plains landscape and are reported to use non-forested areas that include vicinity of human habitations, plantations and agricultural fields. Major wild prey for leopard in the landscape were chital, sambar, hog deer, barking deer and wild pig. A study in Chilla range of the Rajaji Tiger Reserve reports fluctuations of leopard density ranging from 2.07 to 9.76 per 100 km² over the years negatively correlated with the increase in tiger density in the park (Harihar et al. 2011). A WWF-India study in 2013 reported 9.57 leopards per 100 km² from the newly established Nandhour Wildlife Sanctuary. Landscape level surveys (Johnsingh et al. (2004) and India (2014) have reported high encounter rate of leopard sign in areas that are devoid of tigers, such as the Suhelwa Wildlife Sanctuary in Uttar Pradesh. Apart from this most of the studies in this landscape have focussed on the leopard-human conflict and not on leopard population estimation. High levels of leopard-human conflict is reported from across the hills of Uttarakhand (Chauhan and Goyal 2001) suggestive of a wide range in leopard distribution with good density across Uttarakhand. A study on pattern of livestock depredation by tigers and leopards in and around Corbett Tiger Reserve shows that areas near the hills of Almora Forest Division had more leopard depredation than its southern boundary (Bargali and Ahmed 2018). The study also identified major leopard-human conflict hotspots in areas of Ramnagar and Terai West Forest Division. Public awareness and strategies of living with leopards need to be promoted in such areas so as to minimize conflicts.

Leopard occupancy, population extent and abundance

Phase I data collected by the forest department shows leopard sign to be distributed across the forested areas of Uttarakhand, Uttar Pradesh and parts of Bihar. The population in much of Uttar Pradesh is contiguous with habitats in Nepal. Leopards were also reported from the higher reaches of Himalayas (Nainital and Champawat Forest Divisions) wherever the habitat was sampled.

Leopard density was computed from 19 camera trapped sites within this landscape. A total of 5,298 leopard photo-captures were obtained from which 825 adult individuals and 19 cubs were identified. Leopard sign encounter rate, prey density and human disturbance were used as covariates to model leopard density in a likelihood SECR framework. Model with leopard sign encounter best explained leopard density across the landscape.

Of the 295 grids (100 km²) that were sampled, 262 grids were occupied by leopards in the landscape. Total population of leopard within the sampled forested landscape of Shivalik-Gangetic plains was estimated at 1,253 (SE range 1,158- 1,348) as compared to 929 (SE range 855-1,004) in 2014.

Kishenpur, parts of Katarniaghat and Sohagibarwa Wildlife Sanctuary in Uttar Pradesh have shown increase in leopard occupied areas in 2018 as compared to 2014 (Figure 4.1). Leopard occupied areas in the landscape have remained consistent over the two monitoring cycles and only few areas in Mussoorie and some parts of Lansdowne in Uttarakhand show loss in leopard occupancy in 2018 (Figure 4.1). Medium to high leopard density was observed in Rajaji Tiger Reserve, Corbett Tiger Reserve, Ramnagar Forest Division, Nandhour Wildlife Sanctuary of Uttarakhand and Bijnore Forest Division and Sohagibarwa Wildlife Sanctuary of Uttar Pradesh (Figure 4.2).

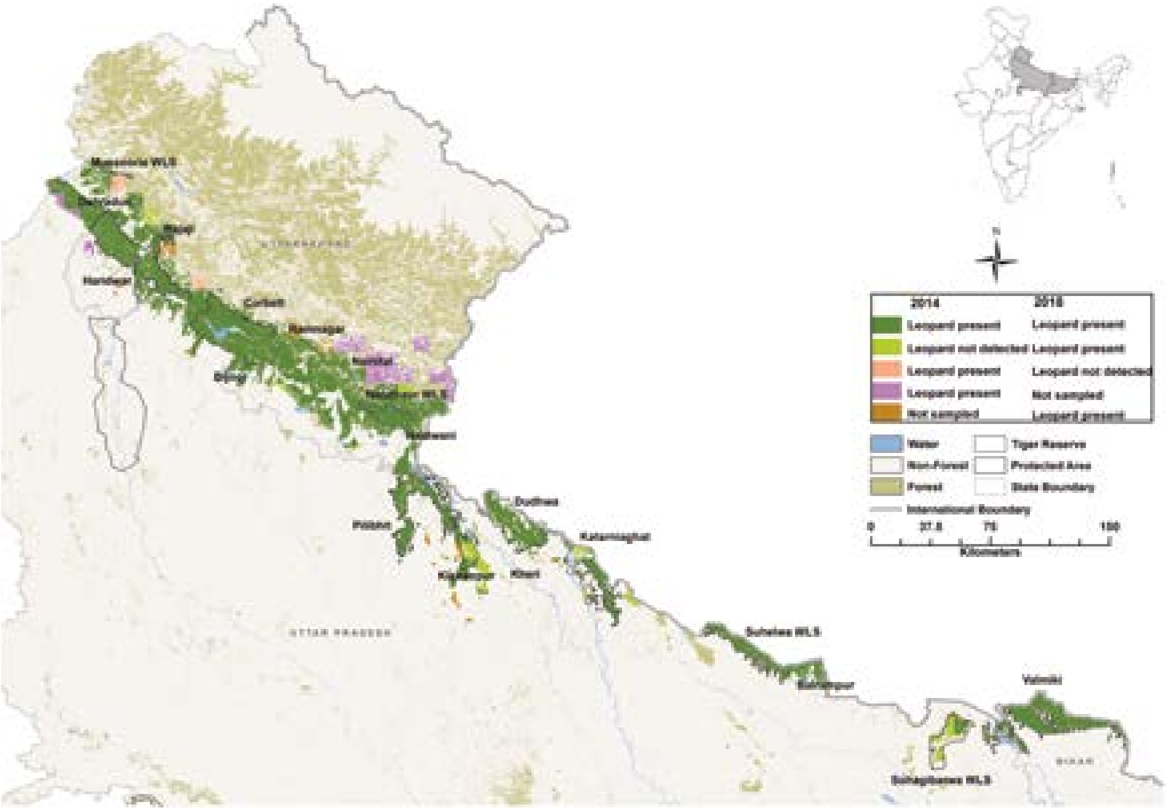
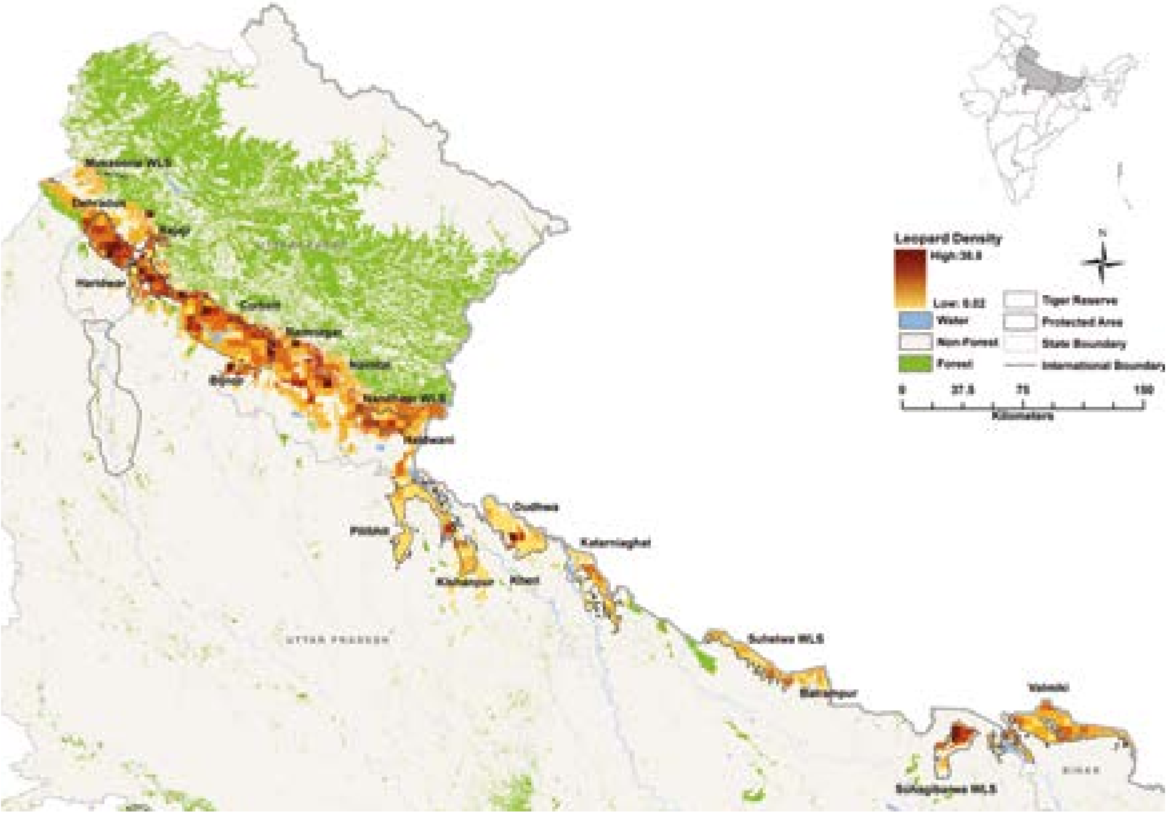


Figure 4.1: Change in leopard distribution in Shivalik Hills and Gangetic Plains Landscape from 2014 to 2018

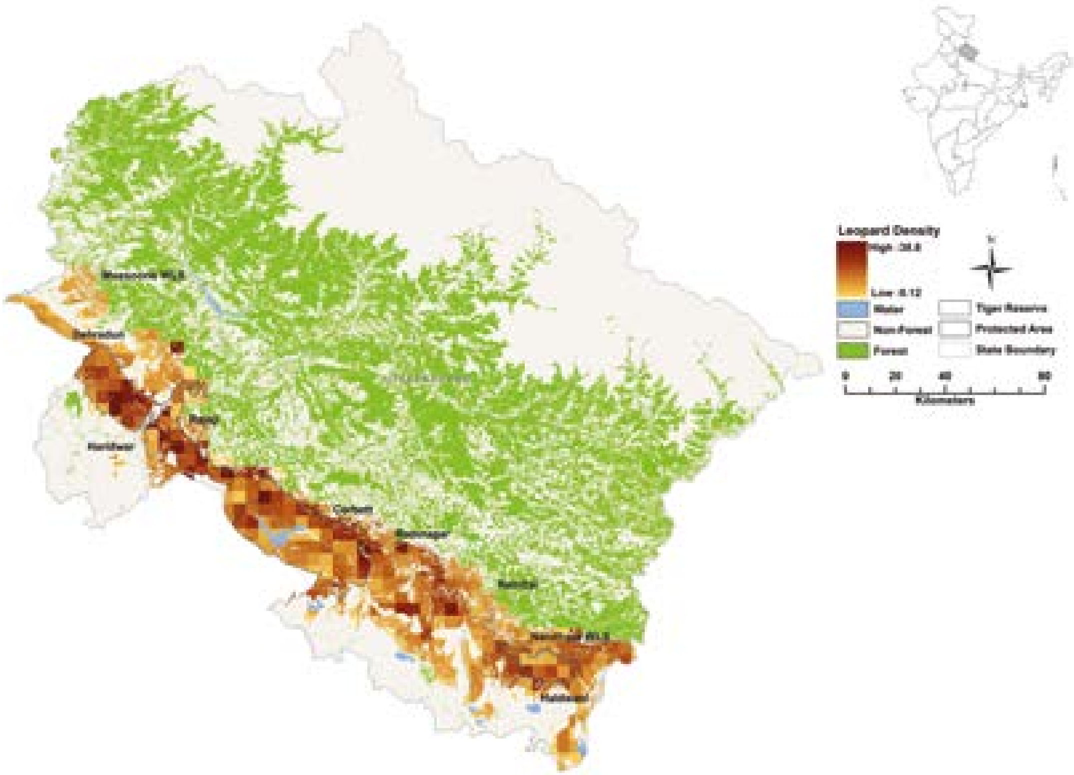
Figure 4.2: Leopard distribution and density (individuals/100 km²) surface for Shivalik Hills and Gangetic Plains landscape, 2018



Uttarakhand

A total of 10 sites were camera trapped in Uttarakhand (Table 4.1) that yielded 2,594 photo-captures of 517 leopard individuals. Like mentioned earlier, we only report leopard numbers from potential tiger habitat of the state. Leopard population of the state was 839 (SE range 791-887) where Western Rajaji Tiger Reserve, Terai areas of the state along with Ramnagar and Haldwani have shown increase in leopard numbers (Figure 4.3). Major concern for leopard conservation in the state is reducing human-leopard conflict.

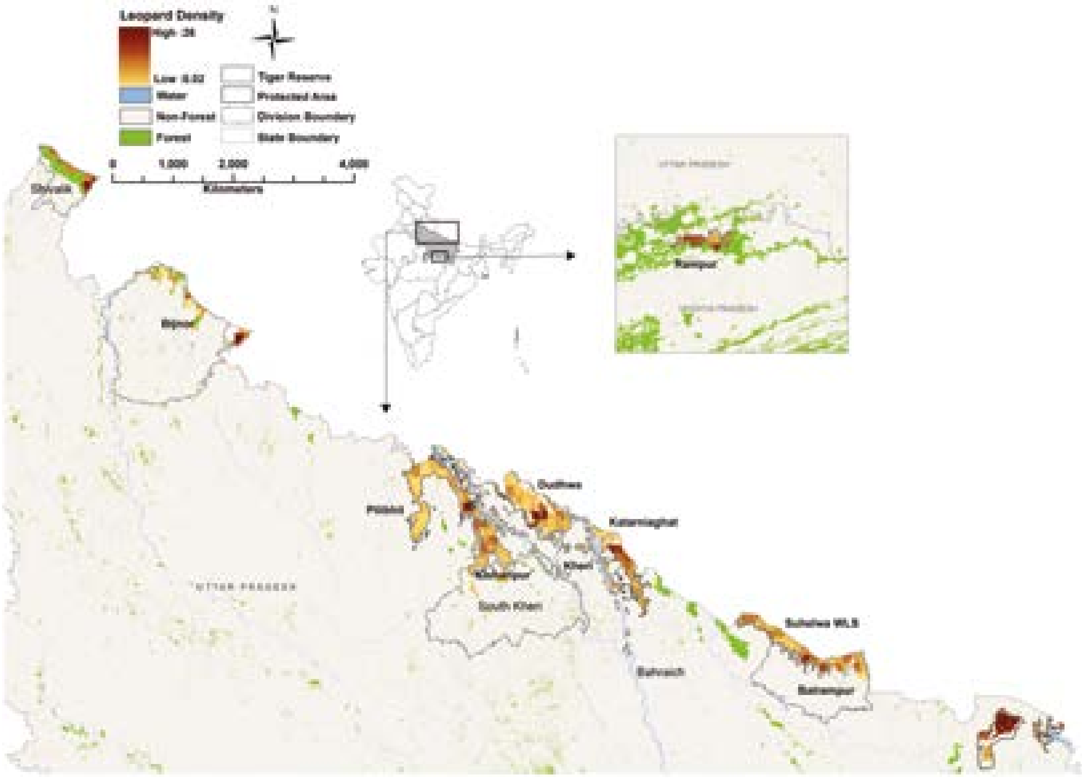
Figure 4.3: Spatially explicit leopard density (individuals/100 km^2) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Uttarakhand



Uttar Pradesh

A total of 8 sites were camera trapped in Uttar Pradesh (Table 4.1) that yielded 1,170 photo-captures of 215 leopard individuals. Leopard population in the state was estimated at 316 (SE range 277-355). Leopard population has shown increase in the tiger reserves of the state, mostly in Kishenpur and Katarniaghat Wildlife Sanctuary (Figure 4.4). Both, tigers and leopards use agricultural areas outside protected areas in this state which leads to a situation of conflict with humans.

Figure 4.4: Spatially explicit leopard density (individuals/100 km²) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Uttar Pradesh



Bihar

Valmiki Tiger Reserve was the only camera trapped site in Bihar, where 1,534 leopard photo-captures yielded 112 leopard individuals (Table 4.1). Leopard population in the state was 98 (SE range 90-106) (Figure 4.5). The leopard population has shown an increase in the tiger reserve (Table 4.1).

Figure 4.5: Spatially explicit leopard density (individuals/100 km²) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Bihar

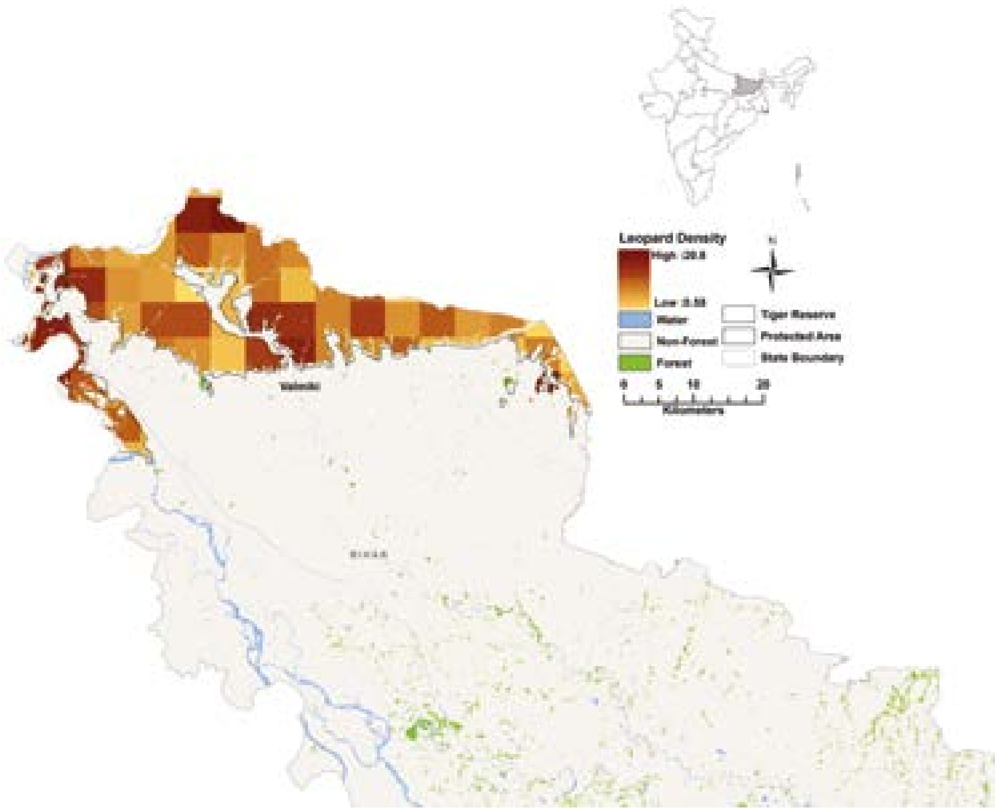


Table 4.1: Sampling details and leopard density parameter estimates using spatially explicit capture mark recapture analysis in a likelihood framework for sites in Shivalik Hills and Gangetic Plains Landscape

State	Site	Model space (km²)	Camera points	Trap nights	M (t+1)	Best fit model	Density/ 100 km² (SE)	g0 Male (SE)	g0 Female (SE)	σ Male (SE) (Km)	σ Female (SE) (Km)	Pmix (SE)
Uttarakhand	Rajaji TR	1309	253	13689	139	σ ~(sex), Pmix~(sex), g^0~(sex)	16.90 (1.44)	0.005 (0.0001)	0.004 (0.0001)	2.35 (0.057)	1.62 (0.011)	0.62:0.38 (0.044)
Uttarakhand	Lansdowne	692.25	187	7252	68	σ ~(.) g^0~(.), Pmix~(sex)	15.29 (1.95)	0.018 (0.003)		1.244 (0.07)		0.44:0.56 (0.076)
Uttarakhand	Corbett TR	1974	529	27425	122	σ ~(.), Pmix~(sex), g0~(sex)	9.06 (0.84)	0.01 (0.001)		1.60 (0.06)	0.99 (0.05)	0.51:0.49 (0.05)
Uttarakhand	Ramnagar	1030	266	9338	45	σ ~(.) g^0~(.), Pmix~(sex)	6.08 (0.92)	0.0217 (0.002)		1.501 (0.07)		0.48:0.52 (0.096)
Uttarakhand	Terai West	691	63	2011	16	σ ~(.) g^0~(.)	4.15 (1.30)	0.0115 (0.004)		3.104 (0.50)		NA
Uttarakhand	Haldwani	1003	203	8930	40	σ ~(.) g^0~(.), Pmix~(sex)	5.68 (0.91)	0.0292 (0.003)		1.668 (0.08)		0.44:0.56 (0.09)
Uttarakhand	Terai Central	NA	17	534	3	NA	NA	NA	NA	NA	NA	NA
Uttarakhand	Terai East	1078	139	7252	45	σ ~(.) g^0~(.), Pmix~(sex)	6.61 (1.03)	0.0054 (0.001)		3.036 (0.19)		0.33:0.67 (0.103)
Uttarakhand	Champawat	273.75	34	1566	15	σ ~(.) g^0~(.)	14.78 (4.32)	0.0240 (0.008)		0.990 (0.14)		NA
Uttarakhand	Nainital	473	70	3072	24	σ ~(.) g^0~(.)	9.66 (2.12)	0.0276 (0.006)		1.292 (0.12)		NA
Uttar Pradesh	Amangarh	216.5	42	1981	10	σ ~(.) g^0~(.)	7.69 (2.61)	0.0183 (0.005)		1.567 (0.20)		NA
Uttar Pradesh	Pilibhit TR	2251	336	16188	38	σ ~(sex), Pmix~(sex), g^0~(sex)	2.96 (0.51)	0.010 (0.002)	0.005 (0.001)	3.60 (0.23)	1.91 (0.24)	0.57:0.43 (0.096)
Uttar Pradesh	Dudhwa	1656	343	12544	35	σ ~(sex), Pmix~(sex), g^0~(sex)	4.06 (0.71)	0.003 (0.0004)	0.006 (0.002)	3.70 (0.25)	1.18 (0.17)	0.32:0.68 (0.08)
Uttar Pradesh	Katarniaghat	1295	283	8891	44	σ ~(sex), Pmix~(sex), g^0~(sex)	5.15 (0.79)	0.021 (0.0025)	0.035 (0.005)	2.46 (0.12)	1.60 (0.09)	00.45:0.55 (0.08)
Uttar Pradesh	Kishenpur	1526	172	5086	11	σ ~(sex), Pmix~(sex), g^0~(sex)	8.57 (0.22)	0.015 (0.004)	0.015 (0.004)	2.86 (0.29)	0.25 (0.25)	0.23:0.77 (0.14)
Uttar Pradesh	South Kheri	NA	8	399	0	NA	NA	NA	NA	NA	NA	NA
Uttar Pradesh	Suhelwa WLS	645	91	3559	44	σ ~(.) g^0~(.), Pmix~(sex)	7.32 (1.11)	0.0493 (0.005)		2.003 (0.08)		0.63:0.37 (0.086)
Uttar Pradesh	Sohagibarwa WLS	486.75	59	1862	33	σ ~(.) g^0~(.)	12.23 (2.63)	0.0034 (0.001)		3.803 (0.57)		NA
Uttar Pradesh	Ranipur	NA	21	1205	18	NA	NA	NA	NA	NA	NA	NA
Bihar	Valmiki TR	2588	492	18170	112	σ ~(sex), Pmix~(sex), g^0~(sex)	6.03 (0.58)	0.006 (0.0004)	0.003 (0.0004)	4.40 (0.13)	2.62 (0.12)	0.59:0.41 (0.052)

SE: Standard error, Mt+1: Number of leopards (> cubs) photo-captured., Dˆ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture, σ : Spatial scale of detection function, g0: Magnitude (intercept) of detection function, Pmix: Detection corrected estimates of proportion of females and males, NA = Information not available

Discussion

Shivalik hills and Gangetic plains landscape has shown a minor increase in the leopard population. The five tiger reserves in this landscape had leopard density varying from 2.95 (SE 0.59) leopards per 100 km² in Pilibhit Tiger Reserve to 16.90 (SE 1.44) leopards per 100 km² in Rajaji Tiger Reserve. Detection corrected sex ratio was female biased in all the tiger reserves except Dudhwa Tiger Reserve. Uttarakhand harbours major portion of the leopard population in the landscape, and the numbers will be more given that the higher hills of the state were not sampled for leopards. Leopards are hard to recapture in a mark recapture study and annual assessment of leopard population along with the tiger population is required to be done by the Tiger Reserves to understand the population dynamics of leopards.

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CHAPTER 5:

CENTRAL INDIA AND EASTERN GHATS

Background

Central Indian and Eastern Ghats landscape consist of the semi-arid zone of Rajasthan, continuous landscape of Deccan plateau (Maharashtra, Madhya Pradesh, Chhattisgarh, Jharkhand and Odisha) and includes parts of the Eastern Ghats (Telangana, Andhra Pradesh and Odisha). Sahyadri Hills of Maharashtra in the northern Western Ghats is included here for convenience so as not to split the state of Maharashtra into two landscapes. Parts of Eastern Ghats of Tamil Nadu and Karnataka are not included here, for the same reason; they are discussed in the Western Ghats landscape chapter. The leopard population for Rajasthan is reported only for the tiger occupied habitats of Mukundara Hills, Ranthambore and Sariska tiger reserves.

Leopards were widely distributed in the Central Indian landscape forests. Heterogeneous terrain and natural vegetation like scrub, moist and dry mixed forests provide an excellent habitat for the leopard within this landscape (Jhala et. al. 2015). In the Central Indian and Eastern Ghats landscape complex, leopards occurred in intact as well as fragmented forests, agro-pastoral landscape and scrub habitats with minimal wild prey (Singh 2005), they are known to switch their prey preference from wild to domestic stock and dogs (Athreya et al. 2011). This adaptive strategy makes it possible for leopards to survive in human dominated areas. Leopards benefit substantially from protection provided under the umbrella of tiger conservation. All the major tiger source sites in this landscape were also major source sites of leopard populations.

Literature on leopard abundances is scarce from this landscape. First detailed study on population assessment and habitat suitability was carried out by Edgaonker (2008) in Satpura Tiger Reserve of Madhya Pradesh. In Rajasthan, Mondal et. al. (2012) studied the abundance and survivorship of leopard in Sariska Tiger Reserve. Population response of leopards to high and low tiger density was studied by Kumar et. al. (2019) in Kanha Tiger Reserve. Dutta et. al. (2013) studied the genetic structure of leopard population in Madhya Pradesh and Maharashtra and found that leopard population is mostly admixed but sub-structured at fine sale of the landscape. Majority of literature available was on human-leopard conflict (Athreya et al. 2013, Dhanwatey et al. 2013, Athreya et al .2014). However, people in this landscape have high forbearance towards leopards in the proximity of their settlements compared to the hilly regions of Uttarakhand and Himachal Pradesh. The diverse and abundant prey base in this landscape could be the reason for low conflict compared to Uttarakhand and Himachal Pradesh (Jhala et al. 2015).

Leopard occupancy, population extent and abundance

Leopard population in central India can be distinguished into four large contiguous patches: (a) the central block which extends across entire Madhya Pradesh, Chhattisgarh, Jharkhand, Odisha, Maharashtra and Northern Telangana. (b) The southern block covering Amrabad Tiger Reserve, Nagarjunsagar Srisailam Tiger Reserve, and extending into Sri Venkateshwara National Park and Wildlife Sanctuary (c) The western block, which comprises of Western Ghats of Maharashtra (Sahyadri hills) and the agricultural areas of adjoining Deccan. (d) The northern block comprises of Sariska, Ranthambore, Mukundara Hills Tiger Reserves and northern Madhya Pradesh comprised by the forests of Kuno-Palpur National Park, Madhav National Park and Sheopur forests.

Total 8,274 grids (100 km²) were sampled in 2018, out of which leopard presence was recorded in 2,265 grids. A total of 7,304 grids (100 km²) were sampled in both 2014 and 2018, out of which leopard presence was consistent in 1,112 grids; leopards were not detected in 423 of previously occupied grids, whereas leopard presence was detected in 1,139 previously unoccupied grids in 2018 (Figure 5.1). Major gain in occupancy was reported from Madhya Pradesh.

Leopard densities were computed from 59 camera-trapped sites within this landscape. A total 26,367 photographs were obtained that yielded 2,601 unique adult individuals and 89 cubs. More than 200 unique leopards were photo-captured from Panna, Sariska and Satpura Tiger Reserves. The total population of leopard within the sampled forest of this landscape was estimated at 8,071 (SE range 7,654-8,488). High densities of leopards were reported mostly from the PAs and major forest tract of corridors between PAs within this landscape (Figure 5.2). Leopard population has increased in all states of central India. The state of Madhya Pradesh was reported to have the largest leopard population [3,421 (3,271-3,571)] in India.

Figure 5.1: Change in leopard distribution in the Central Indian and Eastern Ghats landscape from 2014 to 2018

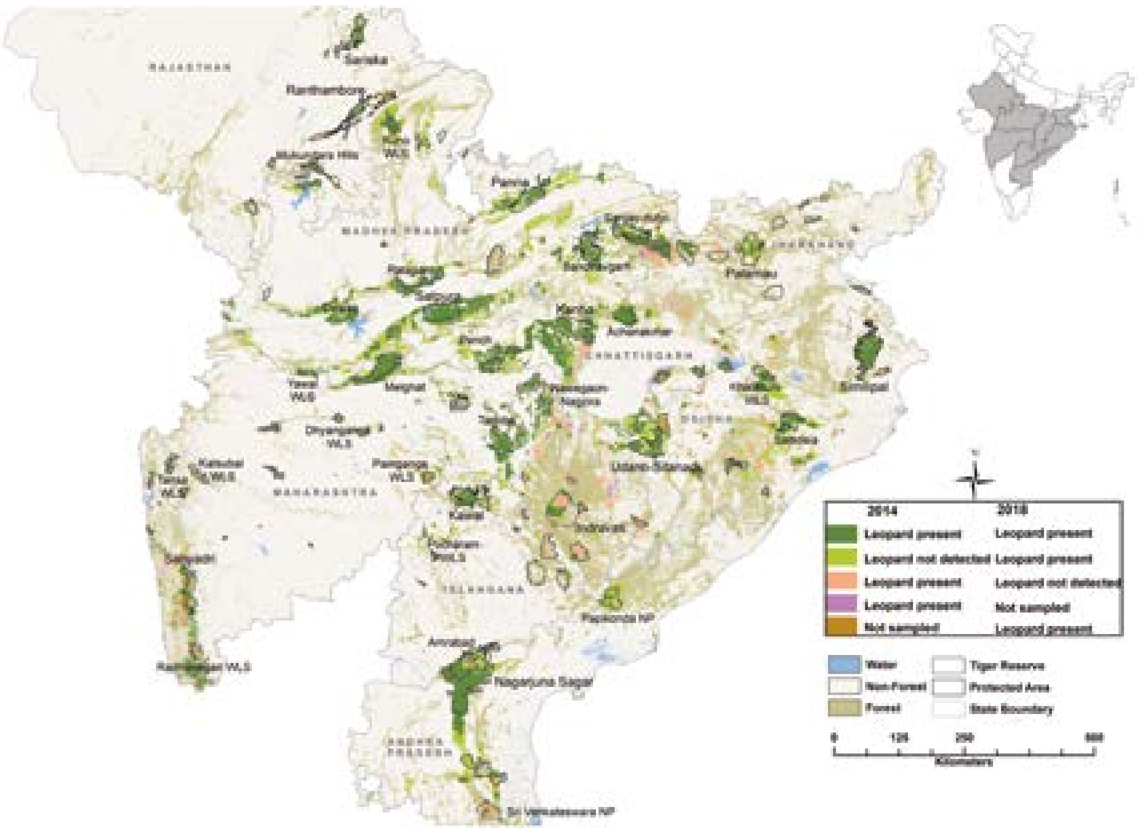
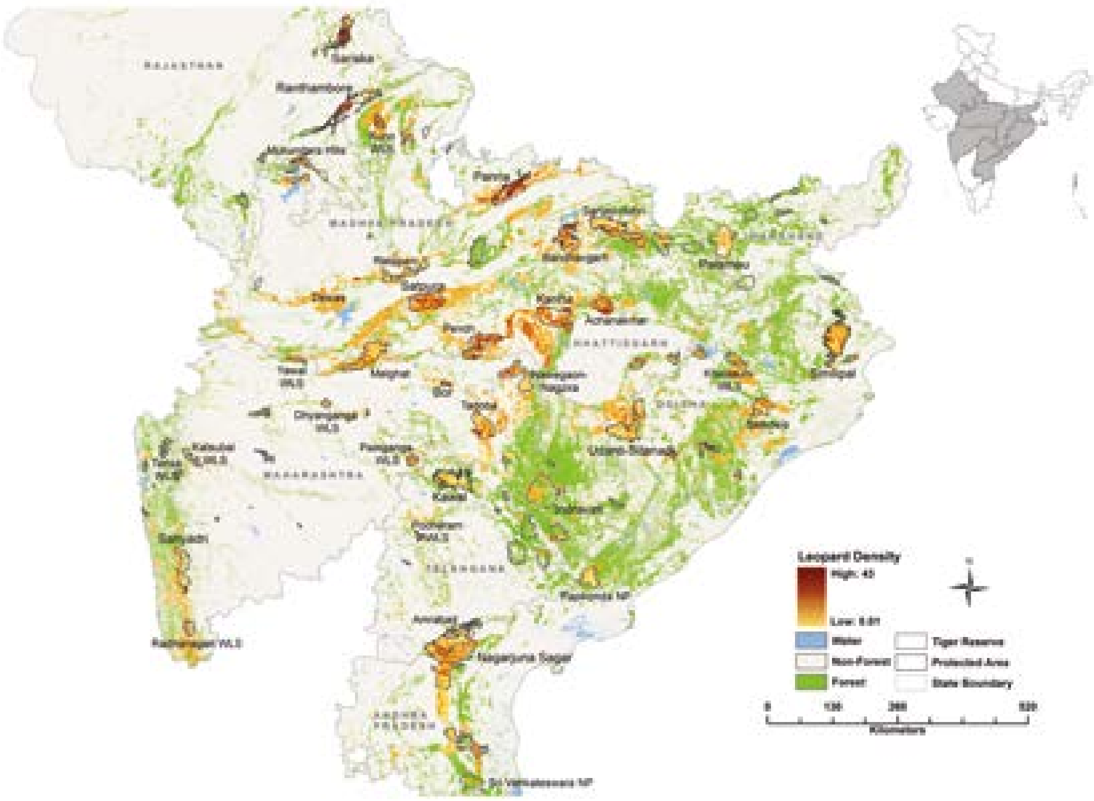


Figure 5.2: Leopard distribution and density (individuals/100 km²) surface for Central Indian and Eastern Ghats landscape 2018



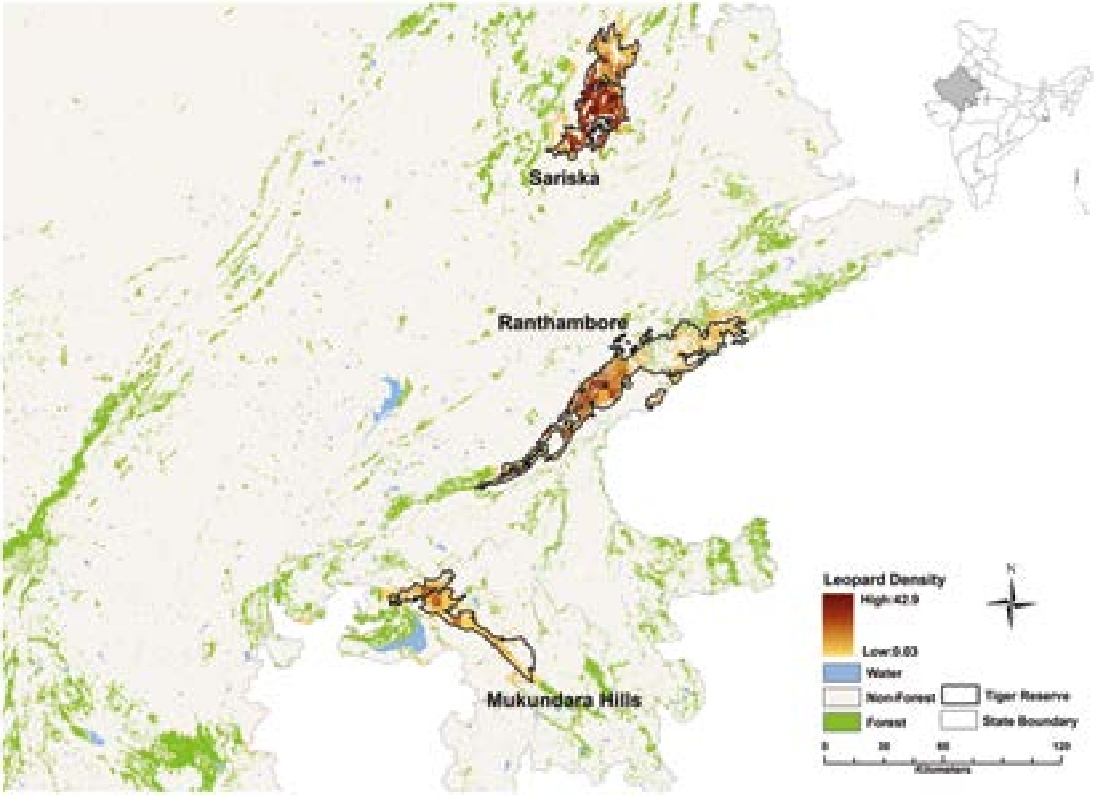
Rajasthan

The semi-arid zone of Rajasthan comprises the westernmost limit of central Indian landscape. This landscape is comprised of rugged hills, steep slopes, and narrow valleys; two ancient mountain ranges, the Aravalli and Vindhya, surround this region. The dry forests are dominated by *Anogeissus pendula* and its associates species (*Acacia, Butea, Lannea*, etc.). Chambal and its tributaries (Banas, Parvati, Kalisindh and Mez) forms the major water sources in this region. Although leopards are distributed widely in the state, the sampling was restricted into only to Tiger Reserves – Ranthambore, Sariska and Mukundara Hills. Major prey species for leopards in the landscape are chital, sambar, nilgai, chinkara, wild pig and livestock.

A total of 1,127 independent photo-captures of leopard were obtained from the sampled area, from which 327 unique leopards were identified. Leopard population of the state was 476 (SE range 437-515) (Figure 5.3).

Site wise densities and parameter estimates of leopards are provided in Table 5.1. The major concern for leopards in this landscape is habitat loss and fragmentation due to mining and developmental projects. Expansion of human land use and increasing anthropogenic activities in leopard habitats need to be mitigated in order to minimise leopard-human conflict in the region.

Figure 5.3: Spatially explicit leopard density (individuals/100 km²) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Rajasthan



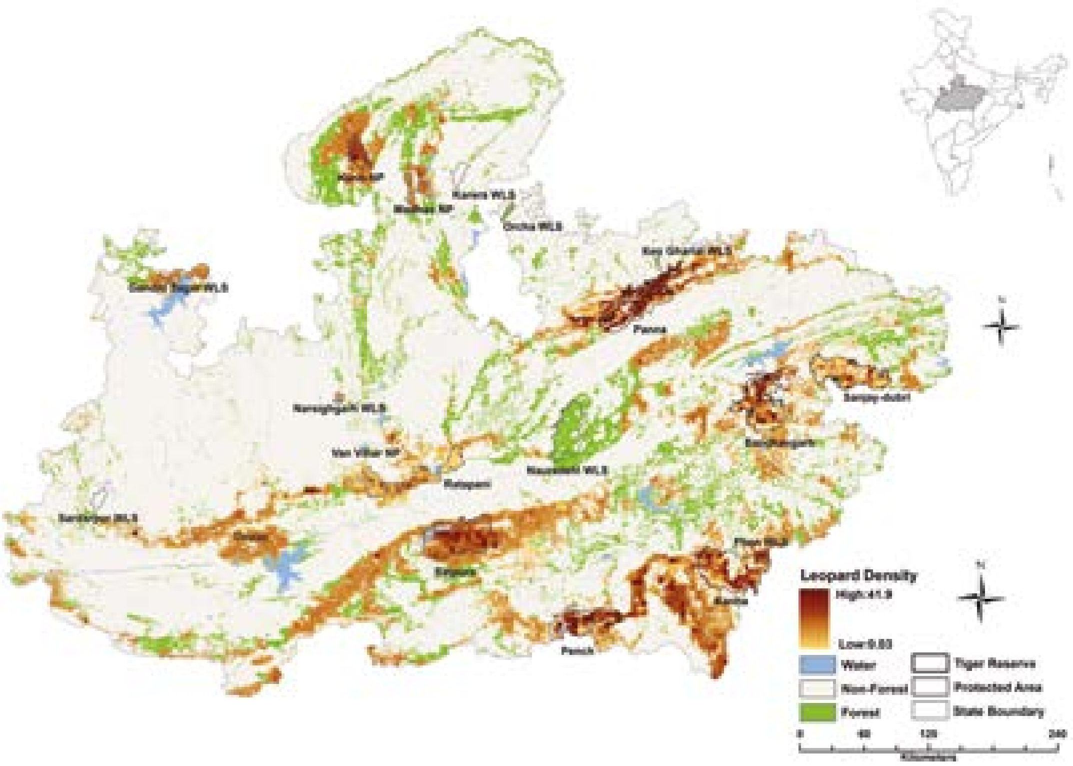
Madhya Pradesh

Parts of Madhya Pradesh are covered by the semi-arid zone and central highlands and plateau biotic provinces of Deccan peninsula biogeographic zones of India. The total forested area is of 94,689 km² (FSI 2019). The state is eco-geographically classified into four zones (1) Malwa plateau-Nimar region (2) Satpura-Maikal (3) Vindhya Region and (4) semi-arid zone of North West, i.e. Gwalior (FSI, 2019). Dry deciduous mixed and teak forests are the dominant forest types in the state, while moist deciduous forest such as peninsular Sal forest is largely restricted to Balaghat-Kanha-Amarkantak – Bandhavgarh landscape. The North-West area of Gwalior region is dominated by *Anogeissus pendula* and Ravines thorn forests (Champion and Seth 196). Madhya Pradesh has 24 wildlife sanctuaries and 11 National parks that includes six Tiger Reserves. Leopards were widely distributed in the state throughout the forested landscape. In the Malwa plateau leopards were distributed throughout from Ratapani wildlife sanctuary to Dhar forest division in the west. High density of leopard was reported from Dewas-Sehore forest divisions along with Ratapani Wildlife Sanctuary, leopard population is continuous and connected with the Betul forest divisions and further towards Satpura Tiger Reserve towards east in the Nimar area. The northern most population of Ujjain-Malwa region, Gandhi Sagar Wildlife Sanctuary is connected to Rajasthan's Mukundara Hills Tiger Reserve. The Satpura Maikal landscape population is well connected to its major source sites such as Kanha-Pench-Satpura- Betul which further connects Melghat in Maharashtra towards south west. Pench Madhya Pradesh population is continuous to Pench Maharashtra Tiger Reserve. The Kanha population is connected to Chhattisgarh state's Achanakmar Tiger Reserve and Bhoramdeo Wildlife Sanctuary towards east and Navegaon Nagzira in Maharashtra towards south-west. High density of leopards was reported from Satpura- Betul, Pench - Balaghat and Kanha Tiger Reserves. This area also holds largest leopard and tiger populations within the central Indian landscape. In Vindhya region the leopard population is distributed in two sub-regions a) Bandhavgarh-Sanjay Dubri: Leopard population is distributed throughout, in tiger reserves as well as adjoining divisions and connected to Chhattisgarh's Guru Ghasidas National Park. High leopard densities were reported from Bandhavgarh and Sanjay Dubri Tiger Reserves. b) Panna-Chhatarpur circle: This area holds the second largest leopard population cluster in the Madhya Pradesh state. Panna tiger reserve was reported with the highest leopard density in the state with the highest number of unique individuals' photo-captured in India (Table 5.1). The adjoining territorial divisions of Panna tiger reserve also have good leopard densities. Interestingly, Nauradehi Wildlife sanctuary did not report leopard signs. Although leopards are known to use this sanctuary their density here is likely very low.

A total of 20 sites were camera trapped in Madhya Pradesh that yielded 5,834 detections of 1,221 leopard individuals. Leopard population of the state was estimated at 3,421 (SE Range 3,271-3,571) (Figure 5.4). Site wise densities and parameter estimates of leopards are provided in Table 5.1. Additional areas such as Shivpuri forest division, Madhav National

Park, Damoh forest divisions, south west ranges of Panna Tiger Reserve and the areas between Satpura to Melghat Tiger Reserves and Kanha to Bandhavgarh Tiger Reserves were reported to have leopard occupancy in 2018 but were unoccupied in 2014. Leopard populations are doing well in the state, however, vigilance should continue for targeted and unintentional poaching, as well as implementation of mitigation measures for linear infrastructure developmental projects.

Figure 5.4: Spatially explicit leopard density (individuals/100 km²) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Madhya Pradesh

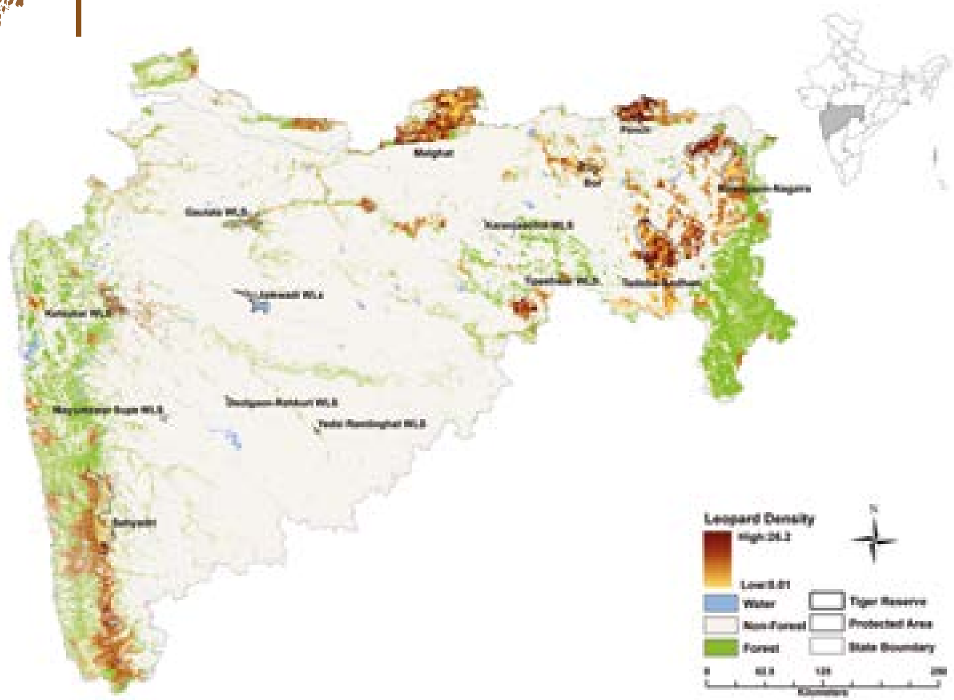


Maharashtra

Maharashtra extends over three bio-geographic zones, namely: Deccan peninsula, Western Ghats and West Coast. The total forested area of the State is of 61,579 km² (FSI 2019). Dry deciduous mixed and dry teak forests are dominant forests in the central plateau region while moist deciduous and evergreen forests dominate the Western Ghat region of the state. Leopards are distributed throughout the forested landscape of Maharashtra with low presence recorded from the large forest patches of Gadchiroli and Bhamagarh forest divisions due to limitation of sampling in these Naxel areas. Leopard population in Maharashtra can be segregated into the three regions 1) Vidarbha: includes most of the tiger reserves i.e. Bor, Tadoba-Andhari, Nawegaon-Nagzira, Pench and Melghat along with sanctuaries like Painganga, Tipeswar, Umred, Karahandla and large forest patches of territorial forest divisions such as Chandrapur, Central Chanda, Wardha, Yavatmal and Gadchiroli. Leopard population is continuous throughout the landscape and connected to major source populations of neighbouring states of Madhya Pradesh, Chhattisgarh and Telangana. High density of leopard was reported from Nawegaon-Nagzira, Melghat and Tadoba-Andhari Tiger Reserves (Figure 5.5). (2) Isolated patches of Nashik and Marathwada region: Leopards were distributed in the forested areas of Junnar, Ahmadnagar, Malegaon, Yawal and Nashik forest divisions. Leopard are known to survive on domestic animals as prey in the agro-pastoral areas of Ahmadnagar forest division (Athreya et al 2014). (3) Western Ghats region of Maharashtra: This region includes Sahyadri Tiger Reserve, Sanjay Gandhi Boriveli National Park, Radhanagri Wildlife Sanctuary, territorial forests of Sindhudurg, Kolhapur and Sawantwadi divisions. A total of 12 sites were camera trapped in Maharashtra that yielded 3,790 detections of 588 adult individual leopards. Leopard population of the state was 1,690 (SE Range 1,591-1,789) (1,712-1,854) (Figure 5.5).

Site wise densities and parameter estimates of leopards are provided in Table 5.1. Leopard occupancy has been reported in 2018 from divisions of Painganga Wildlife Sanctuary and southern Vidarbha regions. In these areas leopards were not detected in 2014. Major concern for leopard conservation in the state is escalating human-leopard conflict and leopard mortality (road kills) as well as population fragmentation by linear infrastructures (Gubbi et al. 2014).

Figure 5.5: Spatially explicit leopard density (individuals/100 km²) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Maharashtra

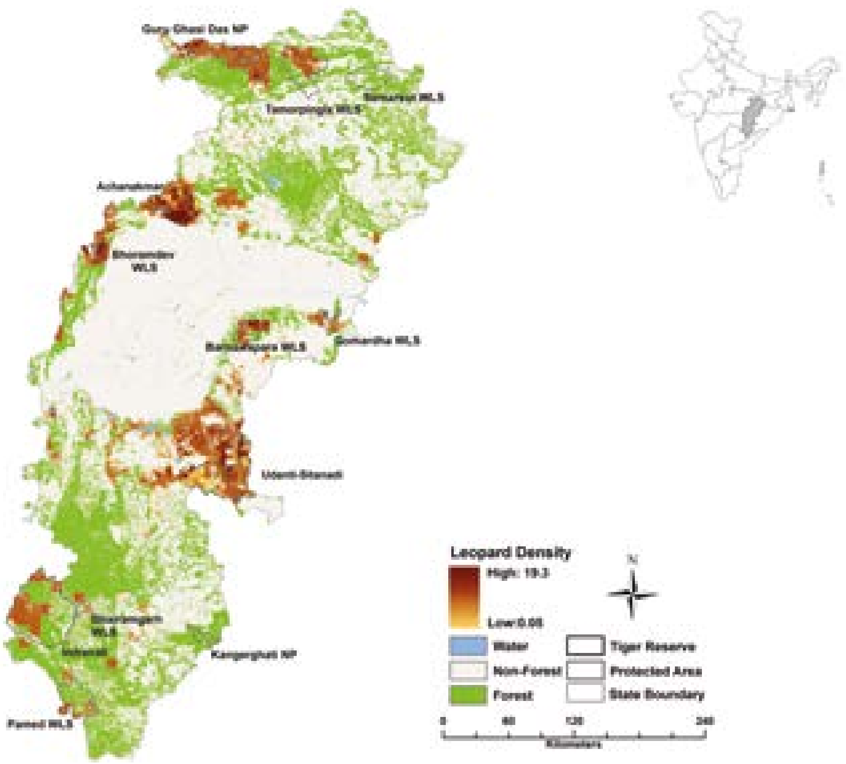


Chhattisgarh

Chhattisgarh is located in the Central highlands, part of Chhotanagpur hills and Eastern highlands biotic provinces of Deccan peninsula biogeographic zone. The total forested area is of 59,772 km^2 (FSI 2019). Dry deciduous mixed, moist deciduous mixed and peninsular Sal forest are the major forest types in the state. The state is divided in to three eco-geographic zone (1) Chhattisgarh Plains: This includes Achanakmar and Udanti-Sitanadi Tiger Reserves, Bhoramdeo, Gobardana and Barnawapara Wildlife Sanctuaries and Mahasamund and Dhamatari forest divisions. Leopard population was mostly distributed inside protected areas (PAs) and adjoining forests of territorial divisions. High density of leopards was reported from Achanakmar Tiger Reserve. Leopard populations are connected to those of Madhya Pradesh in the west and of Odisha in the east. (2) Northern Chhattisgarh Hills: This is located in the northern most part of state, Guru Ghasidas National Park and Timor Pingla Wildlife Sanctuary are the major strongholds of leopard populations in this area. (3) Bastar region: This region included Aboojhmad forests of Chhattisgarh, Indravati Tiger Reserve, Kangad National Park, Pamed and Bhairamghar Wildlife Sanctuaries. This region is affected by left wing extremism hence sampling was limited. Leopards were reported mainly from Indravati and Pamed.

Only Two tiger reserves Achanakmar and Udanti-Sitanadi were camera trapped in Chhattisgarh and yielded 609 detections of 119 adult individual leopards. Leopard population of the state was estimated at 852 (SE range 813-891) (Figure 5.6). Tiger reserves wise densities and parameter estimates of leopards are provided in Table 5.1. Leopard occupancy has declined in the forest divisions of north and central Chhattisgarh. Major concern for leopard conservation in the state is poaching and difficulties with law enforcement in forest areas due to left wing militancy.

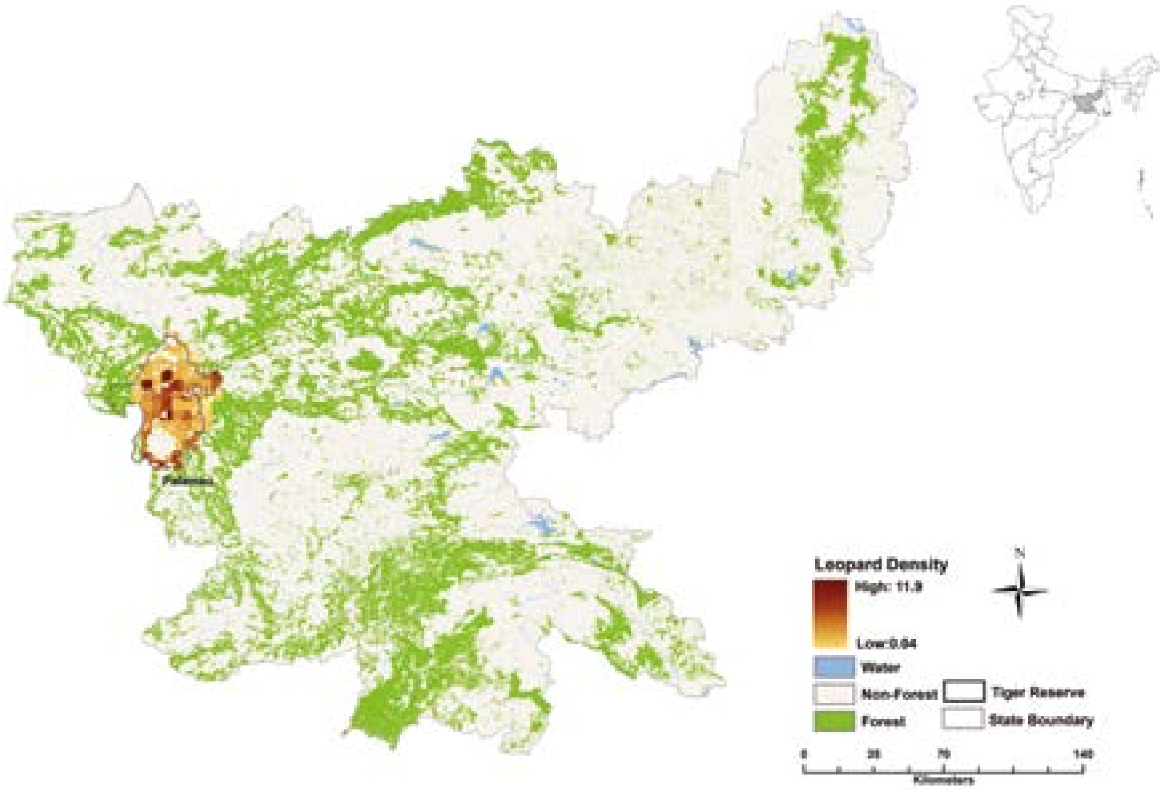
Figure 5.6: Spatially explicit leopard density (individuals/100 km^2) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Chhattisgarh



Jharkhand

Jharkhand is located in the Chhotanagpur hills of the Deccan peninsula biogeographic zone. The total forested area is of 23,605 km² (FSI 2019). Peninsular Sal and dry deciduous mixed forests are the major forest types in the state. During the 2018 survey only Palamau Tiger Reserve was sampled and found to be occupied by leopard. However, leopards are also known to occur in the Hazaribagh and Saranda forest divisions of Jharkhand. Total 16 adult individual leopards with 32 detections were photo-captured in Palamau Tiger Reserve. Leopard population was estimated at 46 (SE range 36- 56) (Figure 5.7) based on the covariate model. Tiger reserve density and parameter estimates of leopards are provided in Table 5.1.

Figure 5.7: Spatially explicit leopard density (individuals/100 km²) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Jharkhand

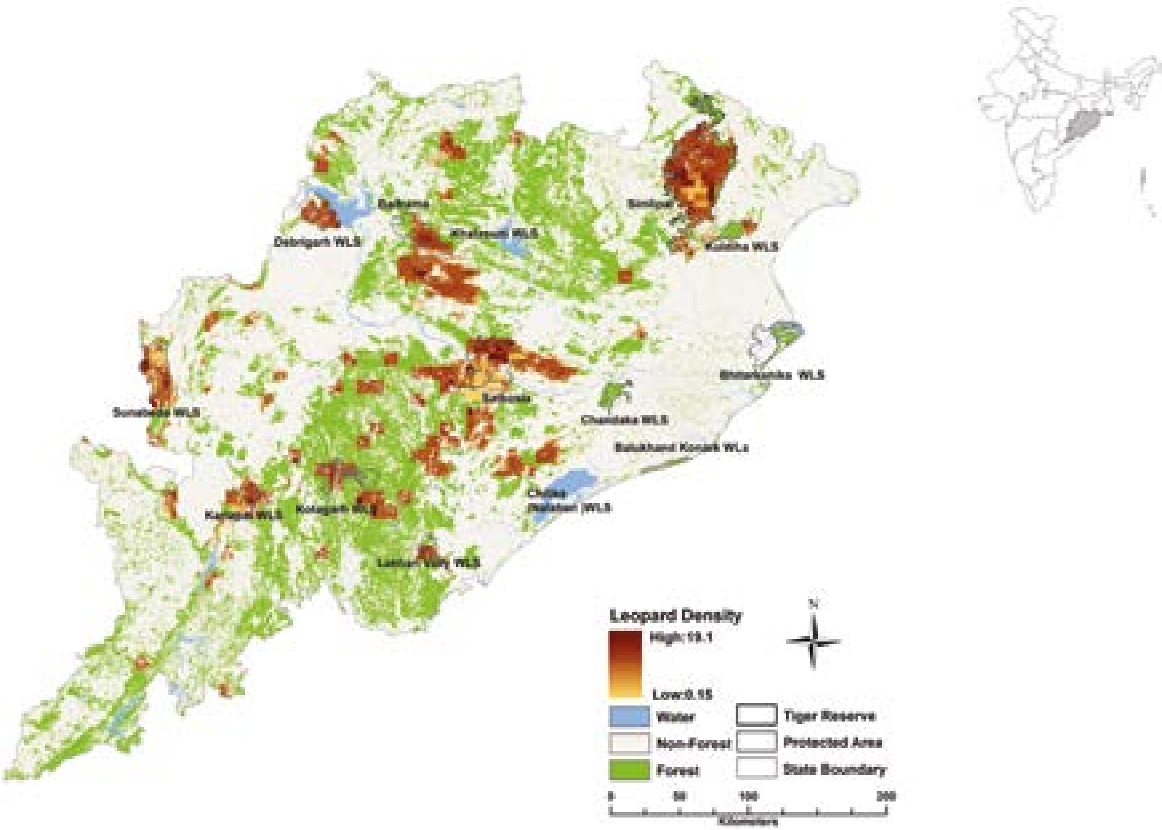


Odisha

Odisha extends over two biogeographic zones *viz.* East coast and Deccan peninsula. The total forested area of the state is of 61,204 km² (FSI 2019). Major forest types are peninsular Sal and dry deciduous mixed forest. Leopard occupancy was reported only from PAs and their adjoining forest divisions. Leopard populations were divided into three regions; 1) North West region that include Similipal Tiger Reserve and adjoining Keonjhar forest division. 2) Central region that include Satkosia Tiger Reserve, Sundargarh, Khalasuni, Badrama and Kotagarh Wildlife Sanctuaries and adjoining forest divisions. (3) West-South that include Karlapat and Sunabeda Wildlife Sanctuaries connected to Udanti-Sitanadi Tiger Reserve of Chhattisgarh.

A total of 14 sites were camera trapped in Odhisa that yielded 200 detections of 63 individual leopard. Leopard population of the state was estimated at 760 (SE range 727-793) (Figure 5.8). Site wise densities and parameter estimates of leopards are provided in Table 5.1. Leopard populations occurred at low density primarily due to lack of prey that was poached for bushmeat consumption. Major concern for leopard conservation in the state is targeted poaching for body parts and habitat fragmentation.

Figure 5.8: Spatially explicit leopard density (individuals/100 km²) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Odisha

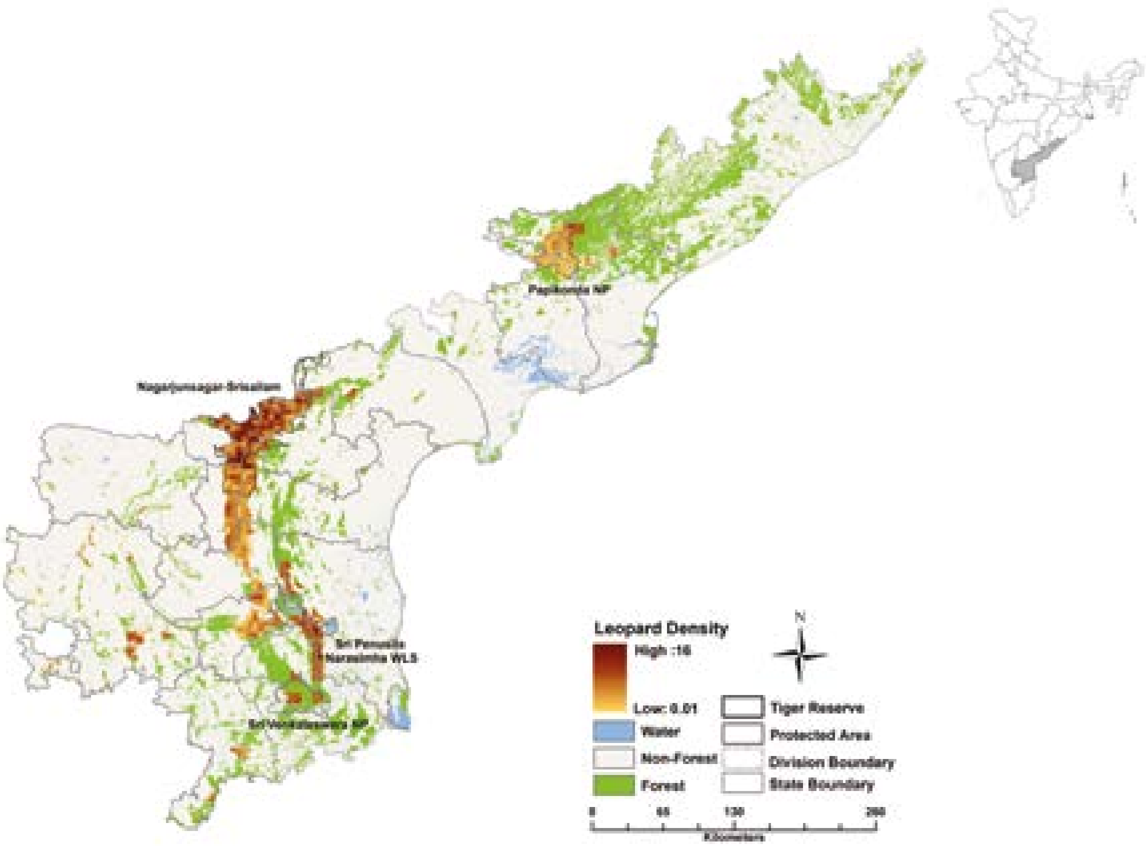


Andhra Pradesh

Andhra Pradesh extends over two biogeographic zones the East coast and south Deccan, and central highlands biotic provinces of Deccan peninsula. The total forested area is of 29,137 km² (FSI 2019). Major forest types are dry deciduous mixed and dry deciduous scrub forests. Eco-geographically, the state is divided in two regions 1) Rayalaseema: This region includes forests of Nagarjuna Sagar Srisailam Tiger Reserve (NSTR), Sri Venkateshwara National Park and Sri Penusila Narasimha Wildlife Sanctuary. A leopard density of ~5 per 100 km² is reported from NSTR. 2) Coastal Andhra: There were no leopard signs reported from this region except in Papikonda National Park, which is located in the Papi hills and Godavari basin and the forested habitat extend into Odisha.

A total of three sites were camera trapped in Andhra Pradesh. Total leopard photos obtained were 836 from which 180 adult individual leopards were identified. Leopard population of the state was estimated at 492 (SE range 461-523) (Figure 5.9). Forests around Sri Venkateswara National Park (Kadapa and Proddatur divisions) where leopard presence was not recorded in previous cycle, was now occupied by leopards. Site wise densities and parameter estimates of leopards are provided in Table 5.1. Major concern for leopard conservation in the state are targeted poaching for body parts, habitat degradation and loss of connectivity in Seshachalam corridor habitats due to developmental activities (NSTR to Shri Venkateshwara NP).

Figure 5.9: Spatially explicit leopard density (individuals/100 km²) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Andhra Pradesh



Telangana

Telangana is located in the Central Plateau biotic province of Deccan peninsula biogeographic zone. The total forested area is of 20,582 km² (FSI 2019). Major forest types are dry deciduous mixed, dry deciduous scrub and dry teak forests. Leopard occupancy was reported in almost all the major forest patches except in the Eturnagaram and Pakhal Wildlife Sanctuaries. Chennur forest division has a few tigers but no leopard presence was recorded either in Phase I or in camera trap survey. Leopard density is generally low across the State with the highest of ~4 leopards per 100 km² reported from Amrabad Tiger Reserve. Leopard population of Telangana is divided into four clusters 1) North Telangana: This included Kawal Tiger Reserve, Adilabad and Kagaznagar forest divisions and is continuous with forests of southern Maharashtra and Chhattisgarh. 2) Eastern Telangana: This population is within the state but connected with Sukma and Bijapur forests of Chhattisgarh state. Leopard occupancy is reported from Kinnersani Wildlife Sanctuary, Bhadrachalam and Mahadevpur forests. 3) Central Telangana: This includes Armoor, Nizamabad, Banswada and Mahbobnagar forests divisions. Leopard occur in these forest divisions at very low density. 4) Amrabad Tiger Reserve: This population is the largest population in Telangana and continuous with the Nagarguna Sagar Srisailam Tiger Reserve of Andhra Pradesh.

Four sites were camera trapped in Telangana that yielded 358 detections of 102 adult individual leopard. Leopard population of the state was estimated at 334 (SE range 318-350) (Figure 5.10). Site wise densities and parameter estimates of leopards are provided in Table 5.1. Major concern for leopard conservation in the state is escalating human-leopard conflict and targeted poaching for their body parts and poaching of wild prey for bush meat consumption.

Figure 5.10: Spatially explicit leopard density (individuals/100 km²) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Telangana

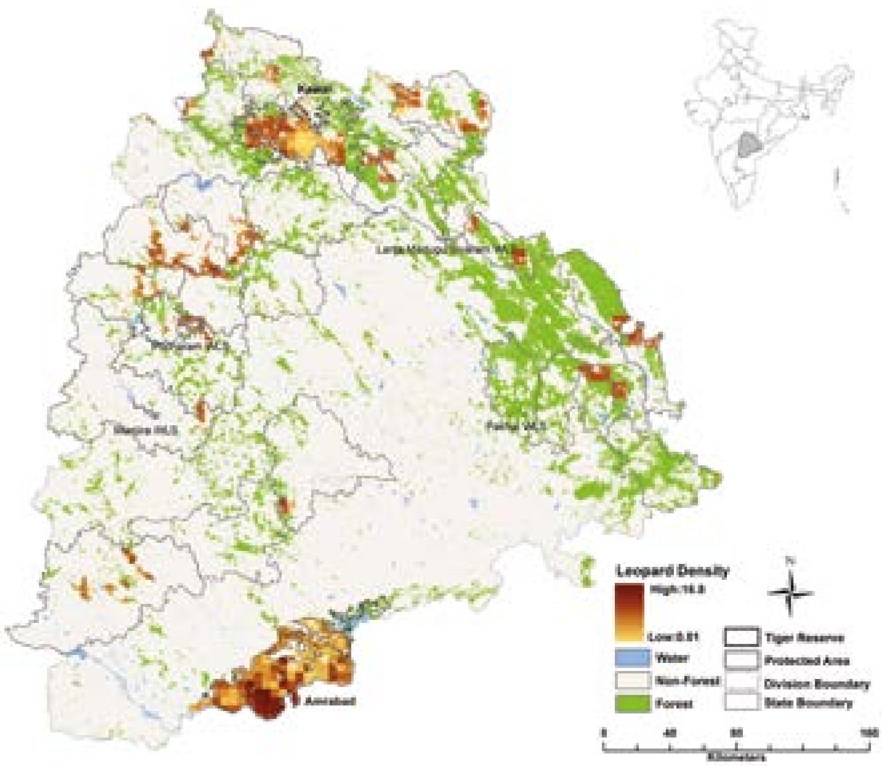


Table 5.1: Sampling details and leopard density parameter estimates using spatially explicit capture mark recapture analysis in a likelihood framework for sites in Central India and Eastern Ghats Landscape

State	Site	Model space (Km^2)	Camera points	Trap nights	Mt+1	Best fit model	Density/ 100 Km^2 (SE)	g^0 Female (SE)	g^0 Male (SE)	σ Female (SE) (km)	σ Male (SE) (km)	Pmix (SE)
Andhra Pradesh	Nagarjuna Sagar Srisailam TR	4455	571	19938	153	g_0 (sex) σ(sex) Pmix (sex)	5.03 (0.4)	0.015	0.004 (0.0001)	2.35 (0.057)	1.62 (0.011)	0.62:0.38 (0.044)
Andhra Pradesh	Papikonda NP	NA	110	2395	10	NA	NA	NA	NA	NA	NA	NA
Andhra Pradesh	Sechachalam	NA	150	3374	17	NA	NA	NA	NA	NA	NA	NA
Chhattisgarh	Achanakmar TR	1735.75	397	10645	81	g_0 (sex) σ(sex) Pmix (sex)	7.11 (0.8)	0.015 (0.002)	0.03 (0.003)	1.67 (0.087)	2.42 (0.01)	NA
Chhattisgarh	Udanti Sitanadi TR	1585.75	283	6630	38	g_0 (.) σ(sex) Pmix (sex)	3.98 (0.66)	0.014 (0.0012)		1.8 (0.113)	3.79 (0.23)	NA
Jharkhand	Palamau TR	1458.25	369	10142	16	g_0 (.) σ(.)	2.10 (0.59)	0.009 (0.003)		1.53 (0.19)		NA
Madhya Pradesh	Balaghat	2304.3	327	12316	81	g_0 (sex) σ(sex) Pmix (sex)	5.87 (0.67)	0.01 (0.002)	0.008 (0.002)	1.84 (0.12)	2.83 (0.18)	0.59:0.41 (0.06)
Madhya Pradesh	Bandhavgarh TR	2166.75	679	23607	135	g_0 (.) σ(sex) Pmix (sex)	8.45 (0.73)	0.02 (0.001)		1.4 (0.04)	2.28 (0.05)	0.66 : 0.34 (0.04)
Madhya Pradesh	Barghat	NA	38	1004	15	NA	NA	NA	NA	NA	NA	NA
Madhya Pradesh	Bhopal	NA	119	2500	9	NA	NA	NA	NA	NA	NA	NA
Madhya Pradesh	Chhatarpur	NA	9	234	3	NA	NA	NA	NA	NA	NA	NA
Madhya Pradesh	Dewas	NA	79	1256	13	NA	NA	NA	NA	NA	NA	NA
Madhya Pradesh	Kanha TR	2566.5	648	21091	134	g_0 (sex) σ(sex) Pmix (sex)	8.06 (0.7)	0.013 (0.001)	0.17 (0.001)	1.46 (0.059)	2.61 (0.07)	0.64 : 0.36 (0.04)
Madhya Pradesh	Kuno NP	1225	85	1792	54	g_0 (.) σ(.)	8.46 (1.28)	0.01 (0.0012)		3.83 (0.25)		NA
Madhya Pradesh	Mandla	1859.5	193	5379	22	g_0 (.) σ(.)	2.00 (0.46)	0.03 (0.005)		2.40 (0.23)		NA
Madhya Pradesh	North Panna	NA	57	1628	15	NA	NA	NA	NA	NA	NA	NA
Madhya Pradesh	Panna TR	2001.5	531	15900	251	g_0 (.) σ(sex) Pmix (sex)	17.49(1.11)	0.19 (0.001)		1.43 (0.037)	2.12 (0.051)	NA
Madhya Pradesh	Pench (MP) TR	1511	421	15291	128	g_0 (sex) σ(sex) Pmix (sex)	13.16 (1.06)	0.005 (0.0005)	0.012 (0.001)	1.6 (0.061)	2.23 (0.05)	NA
Madhya Pradesh	Rampur Bhatodi	NA	36	729	2	NA	NA	NA	NA	NA	NA	NA
Madhya Pradesh	Ratapani/Obdaullaganj	2825.8	582	12618	34	g_0 (.) σ(.)	2.13 (0.39)	0.02 (0.004)		3.86 (0.35)		NA
Madhya Pradesh	Sanjay Dubri TR	2568.5	375	13853	55	g_0 (.) σ(sex) Pmix (sex)	3.53(0.49)	0.004 (0.0004)		2.49 (0.176)	3.94 (0.28)	0.66 : 0.34 (0.07)
Madhya Pradesh	Satpura TR##	NA	791	31972	205	NA	7.38 (range 5.6 to 10.6)*	NA	NA	NA	NA	NA
Madhya Pradesh	Sehore	NA	202	4570	11	NA	NA	NA	NA	NA	NA	NA

State	Site	Model space (Km^2)	Camera points	Trap nights	Mt+1	Best fit model	Density/ 100 Km^2 (SE)	g^0 Female (SE)	g^0 Male (SE)	σ Female (SE) (km)	σ Male (SE) (km)	Pmix (SE)
Madhya Pradesh	Shahdol	986.75	97	3245	22	g_0 (.) σ(.)	4.16 (0.95)	0.014 (0.003)		2.55 (0.24)		NA
Madhya Pradesh	South Panna	NA	49	1412	22	NA	NA	NA	NA	NA	NA	NA
Madhya Pradesh	Umaria	NA	67	1674	10	NA	NA	NA	NA	NA	NA	NA
Maharashtra	Bor TR	875.25	193	8368	32	g_0 (.) σ(.)	4.42 (0.79)	0.01 (0.001)		2.64 (0.13)		NA
Maharashtra	Brahmpuri	2314.5	353	9112	70	g_0 (.) σ(.)	5.17 (0.63)	0.006 (0.0007)		4.43 (0.23)		NA
Maharashtra	Central Chanda	NA	354	8426	18	NA	NA	NA	NA	NA	NA	NA
Maharashtra	Chandrapur	1401.3	250	6157	41	g_0 (.) σ(.)	4.63 (0.74)	0.026 (0.003)		2.23 (0.14)		NA
Maharashtra	Melghat TR	3162.25	890	46784	149	g_0 (sex) σ(sex) Pmix (sex)	5.31 (0.43)	0.008 (0.0005)	0.014 (0.0006)	2.51 (0.065)	3.4 (0.064)	0.63: 0.37 (0.004)
Maharashtra	Nawegaon-Nagzira TR	1336	315	8505	74	g_0 (sex) σ(sex) Pmix (sex)	7.64 (0.89)	0.02 (0.002)	0.027 (0.002)	2.01 (0.09)	3.12 (0.14)	0.64 : 0.36 (0.06)
Maharashtra	Painganga WLS	645	113	4059	22	g_0 (.) σ(.)	4.95 (1.09)	0.004 (0.0009)		3.56 (0.35)		NA
Maharashtra	Pench (MH) TR	1293.75	274	12012	67	g_0 (.) σ(sex) Pmix (sex)	8.23 (1.01)	0.012 (0.001)		1.8 (0.064)	3.45 (0.14)	0.75 : 0.25 (0.05)
Maharashtra	Sahyadri TR	2263.5	120	NA	10	g_0 (.) σ(.)	1.18 (0.54)	0.04 (0.02)		3.14 (0.89)		NA
Maharashtra	Tadoba Andhari TR	1724.5	327	9300	89	g_0 (.) σ(sex) Pmix (sex)	6.9 (0.74)	0.03 (0.002)		1.72 (0.06)	3 (0.11)	0.64 : 0.36 (0.06)
Maharashtra	Tipeswhar WLS	NA	73	2354	5	NA	NA	NA	NA	NA	NA	NA
Maharashtra	Umred WLS	NA	89	4497	11	NA	NA	NA	NA	NA	NA	NA
Odisha	Badrama	NA	23	736	1	NA	NA	NA	NA	NA	NA	NA
Odisha	Bargarh	NA	45	1367	3	NA	NA	NA	NA	NA	NA	NA
Odisha	Bonai	NA	31	814	2	NA	NA	NA	NA	NA	NA	NA
Odisha	Debrigarh	NA	33	697	6	NA	NA	NA	NA	NA	NA	NA
Odisha	Kalahandi	NA	11	183	1	NA	NA	NA	NA	NA	NA	NA
Odisha	Keonjhar	NA	19	456	1	NA	NA	NA	NA	NA	NA	NA
Odisha	Khalasuni	NA	12	411	1	NA	NA	NA	NA	NA	NA	NA
Odisha	Khariar	NA	13	221	3	NA	NA	NA	NA	NA	NA	NA
Odisha	Kuldiha	NA	38	92	0	NA	NA	NA	NA	NA	NA	NA
Odisha	Raulkela	NA	32	941	0	NA	NA	NA	NA	NA	NA	NA
Odisha	Satkosia TR	1411.25	73	2829	12	g_0 (.) σ(.)	1.92 (0.79)	0.014 (0.0057)		2.39 (0.49)		NA
Odisha	Similipal TR	1059	141	4400	21	g_0 (.) σ(.)	3.16 (0.74)	0.012 (0.002)		2.8 (0.26)		NA
Odisha	Sunabeda WLS	NA	11	95	10	NA	NA	NA	NA	NA	NA	NA
Odisha	Sundargarh	NA	40	1726	2	NA	NA	NA	NA	NA	NA	NA
Rajasthan	Mukundara TR	1669.75	236	8316	45	g_0 (.) σ(.)	4.65 (0.71)	0.007 (0.001)		2.08 (0.12)		NA
Rajasthan	Ranthambhore TR	571.5	150	5341	72	g_0 (.) σ(.)	18.23 (2.21)	0.02 (0.003)		1.09 (0.05)		NA

State	Site	Model space (Km^2)	Camera points	Trap nights	Mt+1	Best fit model	Density/ 100 Km^2 (SE)	g^0 Female (SE)	g^0 Male (SE)	σ Female (SE) (km)	σ Male (SE) (km)	Pmix (SE)
Rajasthan	Sariska TR	1077.75	406	11820	210	g_0 (.) σ(.)	24.46 (1.7)	0.006 (0.0003)		1.70 (0.04)		NA
Telangana	Amrabad TR	4112.75	318	7218	87	g_0 (sex) σ(sex) Pmix (sex)	3.88 (0.43)	0.002 (0.0004)	0.005 (0.0005)	3.39 (0.23)	4.78 (0.256)	0.62 : 0.38 (0.05)
Telangana	Chennur	NA	101	2393	0	NA	NA	NA	NA	NA	NA	NA
Telangana	Kagaznagar	NA	118	3852	5	NA	NA	NA	NA	NA	NA	NA
Telangana	Kawal TR	833.25	100	NA	10	g_0 (.) σ(.)	2.01 (0.68)	0.012 (0.004)		2.88 (0.49)		NA

Improper spatial detection histories, hence spatially explicit capture recapture model was not run for Satpura Tiger Reserve. Temporal detection history was used in traditional closed capture-recapture framework to estimate population, subsequently density estimation using Pench Tiger Reserve (MP) leopards ½ MMDM (2.87 SE 0.85) km with an effective area of 2,869.05 (range 2,014.45 – 3,723.65) km^2. Mt+1: Number of leopards (> cubs) photo-captured., SE: Standard error, $\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture, σ : Spatial scale of detection function, g0: Detection probability at home range centre, Pmix: Detection corrected estimate of proportion of females and males, NA = Information not available

Discussion

Leopard population has increased in all states of the central India. The state of Madhya Pradesh had the largest leopard population in India. Leopard population growth rate with annual rate of 15% was reported from high tiger density area of Kanha landscape (Kumar et al. 2019). Due to its adaptive nature and behavioral plasticity they are reported to persist in human dominated landscape, hence, they are more prone to human wildlife conflict. Other major threats for leopard in this landscape are habitat fragmentation and poaching.

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CHAPTER 6:
WESTERN GHATS

Background

Major tiger bearing states of the Western Ghats landscape in India spans across Kerala, Karnataka, Tamil Nadu, Goa and Maharashtra (Sahyadri and Radhanagari landscape). For convenience, the Western Ghats part of Maharashtra State has been included with the Central India and Eastern Ghats landscape (see Jhala et al. 2020 for more details) for convenience of not splitting state estimates into two landscapes. From an ecological perspective, this region with a total forested area of 1,01,467 km² (Qureshi et al. 2006) comprising of eleven notified tiger reserves, 20 national parks and 68 wildlife sanctuaries which together form one of the largest Protected Area networks in India. Originally recognized as among the several global 'hotspots of biodiversity', the Western Ghats along with its geographical extension in the wet zone of Sri Lanka are now also considered one of the eight 'hottest hot spots' of biodiversity (Myers et al. 2000) and is also declared as a UNESCO World Heritage Site. The importance of the Western Ghats in terms of its biodiversity can be seen from the known inventory of its plant and animal groups, and the high levels of endemism in these taxa.

In many places in the Western Ghats hill ranges of southern India, rainforest has been clear-felled in order to convert them into croplands, orchards, tea and coffee plantations. The landscape is thus now predominantly a mosaic of agriculture and commercial plantations surrounded by forest tracts, most of which are protected as wildlife sanctuaries. Wildlife from Protected Areas frequently use these forest fragments and also move through commercial plantations and farmlands making the landscape prone to human–wildlife conflict. Leopards are one of the key species which often come into such conflict (Bali et al. 2007, Gubbi et al. 2017, Sidhu et al. 2017).

Leopard presence was recorded across the forested areas of Western Ghats, Nilgiris, and sporadically recorded across much of the dry forests of Central Karnataka. Leopard population of the Western Ghats landscape occurs in four distinct blocks (Jhala et al. 2020): A) The northern block contiguous with Radhanagari and Goa covering Haliyal- Kali Tiger Reserve- Karwar- Honnavar- Madikeri- Kudremukh- Shettihali Wildlife Sanctuary- Bhadra-Chikmagalur- Hassan. B) The central population covering southern Karnataka, Tamil Nadu, and Northern Kerala covering the forests of Virajpet- Nagarhole- Bandipur- Mudumalai- Sathyamangalam- Nilgiri- Silent Valley- Wayanad- BRT Hills- MM Hills- Cauvery Wildlife Sanctuary- Bannerghhata National Park. C) A cluster south of the Palghat gap, covering central Kerala and Tamil Nadu composed of the Parambikulam-Anamalai-Eravikulum-Vazachal population. D) The southern-most leopard population block in Southern Kerala and Tamil Nadu is comprised of the forests of Periyar-Kalakad Mundanthurai-Kanyakumari. It seems likely that the population blocks of the entire Western Ghats north end south of the Palghat gap are connected forming two single large populations with geneflow within them since intervening habitat is permeable to leopard movement. Leopards occur from low to moderately high densities in various parts of the Western Ghats. Earlier localised studies have shown that leopard densities varied from 2/100 km² in Kalakad

Mundanthurai Tiger Reserve (Ramesh et al. 2012), to 7/100 km2 in BRT Hills Tiger Reserve (Gubbi et al. 2019) to 13/100 km² in Mudumalai Tiger Reserve (Kalle et al. 2011). In Karnataka, leopards occupied around 84,000 km² in 68 out of 175 talukas of the state excluding the designated Protected Areas and their presence was facilitated by topography and extent of vegetative cover- including irrigated croplands, rocky escarpments, and prey base in the form of feral and free-ranging dogs (Athreya et al. 2015). Gubbi et al. 2020a, based on occurrences, delineated four distinct population clusters for leopards in Karnataka: Bandipur-Nagarhole, BRT-MM Hills-Cauvery-Bannerghatta, Bangalore rural, and Tumkur. Leopards were reported from fragmented forests of Bengaluru urban and rural area, which is a major urban sprawl with high human densities (Nagendra et al. 2013). Major prey of leopard in this landscape were barking deer, mouse deer, porcupine, chital, sambar, langur, wild pig, livestock, gaur, poultry and dogs (Ramesh et al. 2009, Sidhu et al. 2015, Krishnakumar et al. 2020). Since leopards often occur in agrarian landscape that are in close proximity of Protected Areas that usually have good number of wild prey, their dependence and attacks on livestock were relatively low compared to other landscapes in India (Sidhu et al. 2015). However, in certain parts of the landscape where leopards solely sustain on human subsidized prey, attacks on humans were common (Navya et al. 2014, Sidhu et al. 2017) and a large number of leopards had to be captured (Athreya et al. 2015, Gubbi et al. 2020b) or eliminated (Anderson 1954) in the region.

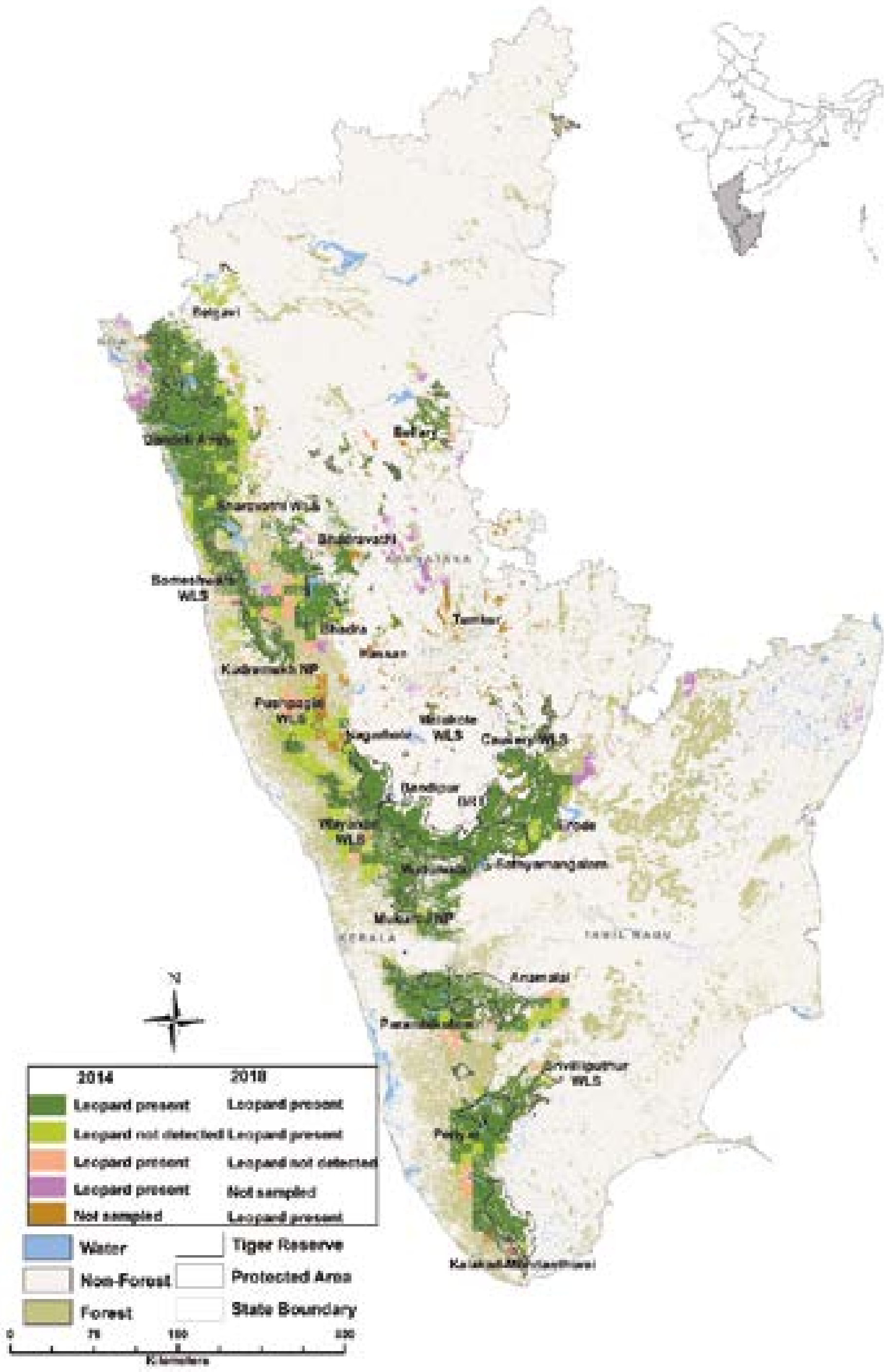
Leopard occupancy, population extent and abundance

As mentioned earlier, leopards in Western Ghats use tea and coffee plantations and other agricultural areas as well which were not sampled during this exercise. Therefore, we report a minimum number of leopard i.e. from only within sampled forests of the Western Ghats landscape.

Leopard density was computed from 46 camera trapped sites within this landscape. A total of 6,757 leopard photo-captures were obtained from which 1,681 adult individuals and 32 cubs were identified. The covariates that best explained leopard density were leopard sign encounter rates and prey dung density. Total population of leopard within the sampled forested landscape of the Western Ghats landscape was estimated at 3,387 (SE range 3,245- 3,529) as compared to 2,487 (SE range 1,846-3,128) in 2014.

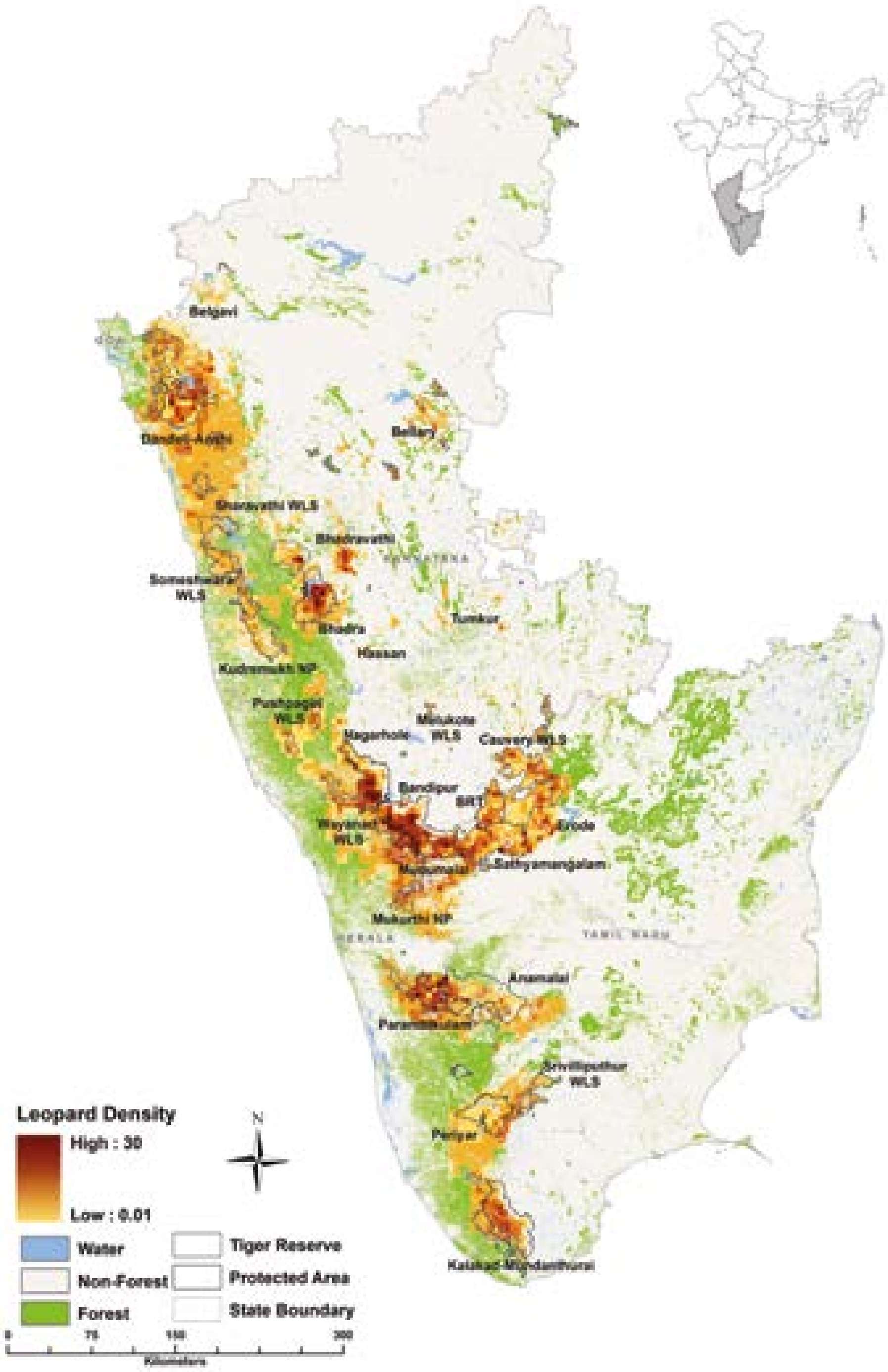
Total 1,335 grids (100 km²) were sampled in 2018, out of which leopard presence was recorded in 826 grids. A total of 1,091 grids (100 km²) were sampled in both 2014 and 2018, out of which leopard presence was consistent in 563 grids; leopards were not detected in 73 of previously occupied grids, whereas leopard presence was detected in 180 previously unoccupied grids (Figure 6.1). Forests of Goa and central Karnataka which had leopard presence in 2014 were not sampled in 2018. Areas adjacent to Pushpagiri Wildlife Sanctuary, Bhadra Tiger Reserve in Karnataka, landscapes connecting Parambikulam Tiger Reserve with Periyar Tiger Reserve and Kalakad Mundanthurai Tiger Reserve showed loss in leopard occupancy in 2018 compared to 2014 (Figure 6.1).

Figure 6.1: Change in leopard distribution in Western Ghats landscape from 2014 to 2018



Leopards occurred at high density in Tiger Reserves/Protected Areas (Figure 6.2, Table 6.1). Nagarhole, Bandipur and Mudumalai Tiger Reserves and Wayanad Wildlife Sanctuary support high density of leopards despite having high tiger densities.

Figure 6.2. Leopard distribution and density (individuals/100 km²) surface for Western Ghats landscape, 2018

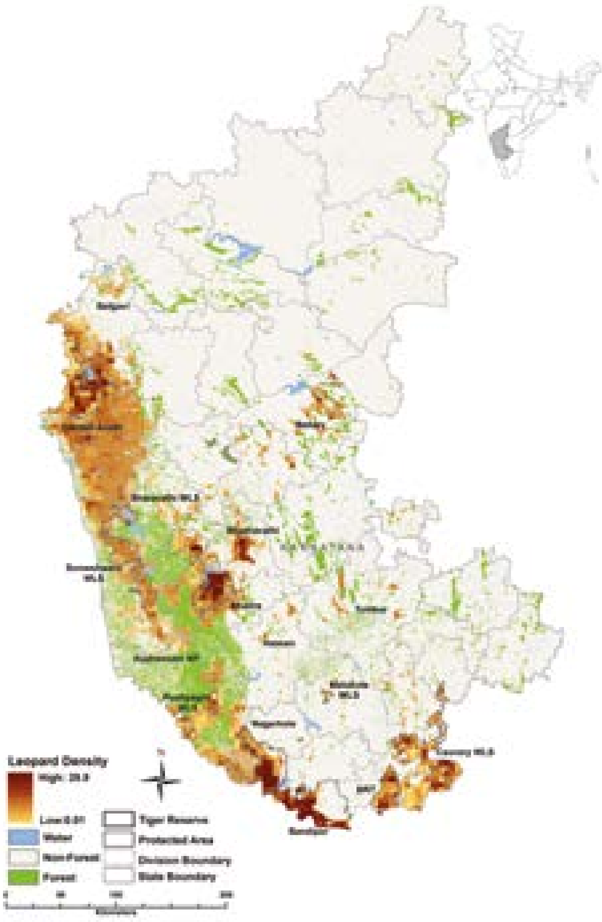


Karnataka

The southern state of Karnataka consists three biogeographic zones i) Coast, ii) Western Ghats and iii) Eastern Plain (Deccan South). Total forested area of the state is 38,575 km² which comprises about 20% of Karnataka's geographical area (FSI 2019). Major forest types of the state include i) evergreen and semi-evergreen forests found in the Western Ghats, ii) moist deciduous forests occurring along the eastern slope of the Western Ghats, iii) dry deciduous forests dominating the lee side of the Western Ghats, iv) scrub and thorn forests in the arid areas of Deccan Plateau and v) grasslands.

A total of 26 sites were camera trapped in Karnataka that yielded 3,564 photo-captures of 836 adult leopard individuals. Like mentioned earlier, leopard numbers from only the sampled forests of the state were estimated (Figure 6.3). Leopard population for Karnataka was estimated at 1,783 (SE Range 1,712-1,854) as compared to 1,129 (SE range 831-1,427) in 2014 (Jhala et al. 2015). Number of grids that were not sampled in 2014 were 199 of which 74 had leopard presence. In 2018 the number of grids sampled decreased by 62. Leopard has been observed to be present from fragmented forests of Ramanagara, Bengaluru urban and rural area, which is a major urban sprawl with high human densities (Figure 6.3). Estimates of leopard density parameters from Tiger Reserves and other camera trapped sites are in Table 6.1.

Figure 6.3: Spatially explicit leopard density (individuals/100 km²) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Karnataka



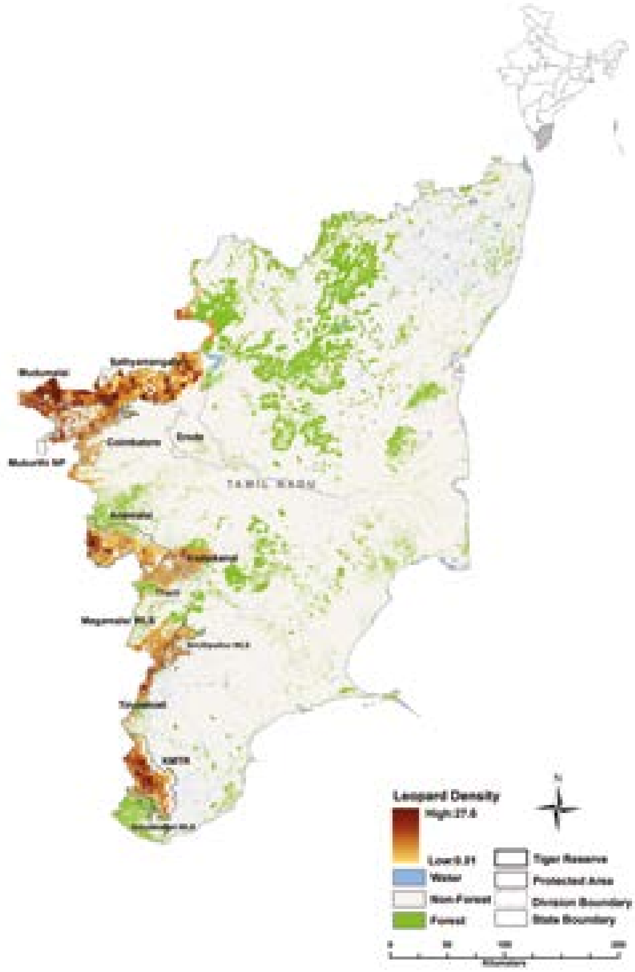
Major concern for leopard conservation in Karnataka is escalating human-leopard conflict and barrier effect of unmitigated linear infrastructures such as roads, railway tracks and irrigation canals (Gubbi et al. 2014).

Tamil Nadu

Of the ten Biogeographic Zones recorded by Rodgers and Panwar (1988), Tamil Nadu encompasses three zones: Western Ghats, Deccan Peninsula and Coastal Zone. Tamil Nadu is the only state which extends over both Western Ghats and Eastern Ghats. Total forested area of Tamil Nadu is 26,364 km² which represents approximately 20% of the state's geographical area (FSI 2019). Nine out of 16 major forest types and 48 sub types of forest recognized by Champion and Seth (1968) occur in Tamil Nadu.

A total of 14 sites were camera trapped in Tamil Nadu that yielded 2,017 photo-captures of 629 leopard individuals. Leopard population of the state was 868 (SE Range 828-908) and similar to the estimate of 2014 (815 leopards, SE range 587-1,043; Jhala et al. 2015). Additional number of 100 km² grids sampled in 2018 that were not sampled in 2014 were 29, out of which 4 had leopard presence. Mudumalai Tiger Reserve, Mukurthi National Park, parts of Sathyamangalam Tiger Reserve and Kalakad Mundanthurai Tiger Reserve support high density of leopards (Figure 6.4). Srivilliputhur Grizzled Squirrel Wildlife Sanctuary had the highest leopard density [20.43 (SE 10.51)/100 km²] in the entire Western Ghats landscape. Estimates of leopard density parameters from Tiger Reserves and other camera trapping sites are in Table 6.1.

Figure 6.4: Spatially explicit leopard density (individuals/100 km²) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Tamil Nadu



Growing human population and increasing fragmentation of the landscape has increased human-wildlife interface and interactions. The coffee-tea estates, and other commercial plantations surrounded by forests, are frequently occupied by leopards, and are the major hubs for human-leopard conflicts in Tamil Nadu (Kumara et al. 2004, Bali et al. 2007).

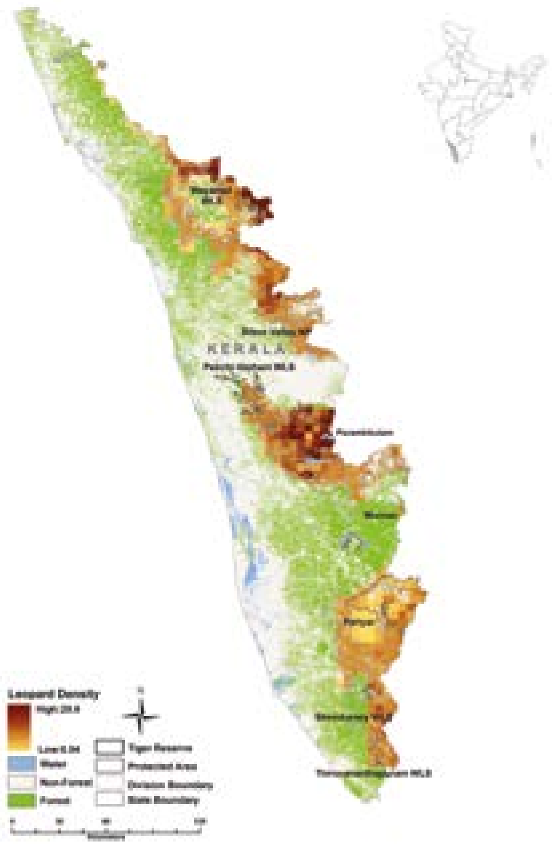
Kerala

Kerala extends over two biogeographic zones: the Western Ghats and the Coasts. Total forest cover of the state is 21,144 km² which represents about 54% of the state's geographical area (FSI 2019). As per the Champion and Seth Classification of Forest Types (1968), the forests in Kerala are divided into seven types which are further divided into 16 sub types. Major forest type includes i) evergreen and semi evergreen forests, ii) dry and moist deciduous forests, iii) shola forests (Southern Montane Wet Grasslands), iv) grasslands and v) mangroves.

A total of 6 sites were camera trapped in Kerala that yielded 1,176 photo-captures of 258 adult leopard individuals. Leopard population of the state was estimated at 650 (SE Range 622-678) as compared to 472 (SE range 367-577) in 2014 (Jhala et al. 2015). Number of grids that were not sampled in 2014 were 7 of which 1 had leopard presence. In 2018 the number of grids sampled decreased by 6. Leopards were concentrated in three clusters within the state: A) Northern population of Wayanad-Kozhikkode-Nilambur-Silent Valley-Palakkad, B) Central population of Parambikulam landscape and C) Southern population of Periyar Tiger Reserve-Ranni-Konni extending up to Thiruvananthapuram (Figure 6.5). Estimates of leopard density parameters from Tiger Reserves and other camera trapping sites are in Table 6.1.

Figure 6.5: Spatially explicit leopard density (individuals/100 km²) modelled from camera traps-based capture-mark-recapture and covariates of leopard sign for Kerala.

Escalating human leopard conflict is a major conservation concern in the state (Govind 2015, Mahanti and Kumar 2018) and most conflict-prone areas are Wayanad, Palakkad, Kannur, Calicut, Thrissur and Malappuram.



Goa

The state of Goa comprises of three biogeographic zones *viz.* coasts, mid-highlands (Malabar Plains) and Western Ghats (Rodgers et al. 2002). Total forest cover of the state is 2,237 km² which represents about 60% of the state's geographical area (FSI 2019). As per Champion and Seth (1968) Classification of Forest types of India, the forests of Goa fall in the following types: i) estuarine vegetation consisting of mangrove species, ii) strand vegetation along the coastal belts, iii) plateau vegetation confined especially to the low altitude and iv) semi-evergreen and evergreen forest of the Western Ghats.

Leopard population in Goa was estimated based on covariate models (Figure 6.6). Minimum leopard population in the state was 86 (SE Range 83-89) in comparison to 71 (SE Range 61-81) in 2014 (Jhala et al. 2015). The forests of Goa are vital in maintaining habitat contiguity between northern Western Ghats and central and southern Western Ghats. It also acts as a connecting link in between Western Ghats and Central Indian landscape permitting gene flow. However, the forests and biodiversity of Goa are under threats from mining and linear infrastructure in the form of upcoming railway tracks and highways in the state that need to be addressed by rationalization and appropriate green mitigation.

Figure 6.6: Spatially explicit leopard density (individuals/100 km²) modelled from covariates of leopard sign for Goa.

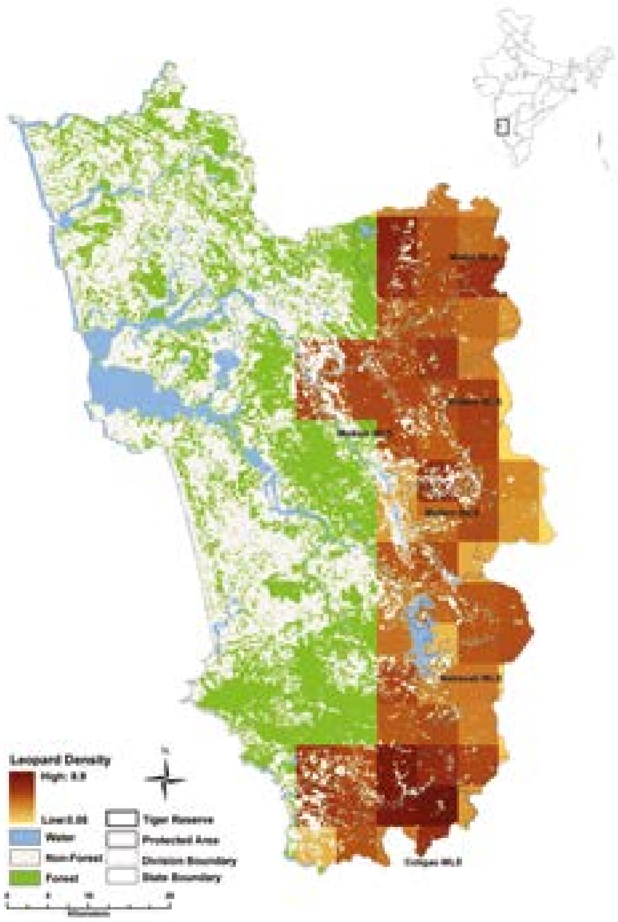


Table 6.1: Sampling details and leopard density parameter estimates using spatially explicit capture mark recapture analysis in a likelihood framework for sites in Western Ghats

State	Site	Model space	Camera points	Trap nights	M (t+1)	Best fit model	Density/ 100 Km² (SE)	g_0 Male (SE)	g_0 Female (SE)	σ Male (SE) (km)	σ Female (SE) (m)	Pmix (SE)
Karnataka	Arabithittu Wildlife Sanctuary	NA	9	164	1	NA	NA	NA	NA	NA	NA	NA
Karnataka	Bandipur Tiger Reserve	1942.75	534	20512	150	σ ~(.) g0~(.)	10.28 (0.84)	0.01 (0.005)		1.99 (0.39)		NA
Karnataka	Bannerghatta National Park	NA	22	1004	2	NA	NA	NA	NA	NA	NA	NA
Karnataka	Belagavi Forest Division	2203.75	183	4642	31	σ ~(.) g0~(.)	4.72 (1.26)	0.13 (0.05)		2.9(0.42)		NA
Karnataka	Bhadra Tiger Reserve	1610.75	212	6653	79	σ ~(sex), Pmix~(sex), g0~(.)	10.05 (1.19)	0.66 (0.05)		2.19 (0.09)	1.34 (0.06)	0.69:0.31 (0.05)
Karnataka	Bhadravati Forest Division	1545.75	133	2468	33	σ ~(sex), Pmix~(sex), g0~(.)	5.43 (1.15)	1 (0.2)		2.6 (0.38)	1.17 (0.18)	0.75:0.25 (0.08)
Karnataka	BRT Tiger Reserve	1655.5	240	8028	35	σ ~(sex), Pmix~(sex), g0~(.)	5.14 (1.02)	0.11 (0.02)		4.08 (0.42)	2.4 (0.33)	0.55:0.45 (0.12)
Karnataka	Cauvery Wildlife Sanctuary	2605.75	502	16924	72	σ ~(sex), Pmix~(sex), g0~(.)	5.52 (0.7)	0.23 (0.02)		4.34 (0.23)	1.94 (0.14)	0.78:0.22 (0.05)
Karnataka	Haliyal Forest Division	2788.5	71	1851	35	σ ~(.) g0~(.)	4.68 (1.26)	0.31 (0.12)		2.7 (0.47)		NA
Karnataka	Honnavar Territorial Division	2659.75	144	4184	27	σ ~(.) g0~(.)	4.61 (1.72)	0.13 (0.07)		2.55 (0.53)		NA
Karnataka	Kali Tiger Reserve	4597	461	11131	107	σ ~(.), g0~(.)	4.81 (0.49)	0.001 (0.0009)		4.32 (0.19)		NA
Karnataka	Karwar Forest Division	NA	60	1500	12	NA	NA	NA	NA	NA	NA	NA
Karnataka	Koppa Wildlife Division	1536.5	32	902	6	σ ~(.) g0~(.)	1.05 (0.55)	0.01 (0.001)		2.37 (0.52)		NA
Karnataka	Kudremukh National Park	1070.25	130	3389	23	σ ~(.) g0~(.)	3.38 (0.82)	0.04 (0.01)		7.89 (1.59)		NA
Karnataka	Madikeri Territorial Division	1738.5	169	2871	5	σ ~(.) g0~(.)	0.56 (0.27)	0.61 (0.18)		2.36 (0.39)		NA
Karnataka	Madikeri Wildlife Division	3544	140	3696	22	σ ~(.) g0~(.)	1.18 (0.31)	0.17 (0.04)		5.69 (0.78)		NA

State	Site	Model space	Camera points	Trap nights	M (t+1)	Best fit model	Density/ 100 Km^2 (SE)	g_0 Male (SE)	g_0 Female (SE)	σ Male (SE) (km)	σ Female (SE) (m)	Pmix (SE)
Karnataka	MM Hills Wildlife Sanctuary	3207.5	447	9808	34	σ ~(sex), Pmix~(sex), g0~(sex)	3.98 (0.91)	0.31 (0.06)	0.07 (0.03)	4.38 (0.47)	2.43 (0.35)	0.36:0.64 (0.03)
Karnataka	Mookambika Wildlife Sanctuary	NA	43	1037	13	NA	NA	NA	NA	NA	NA	NA
Karnataka	Nagarhole Tiger Reserve	1245.25	329	12862	98	σ ~(.), g0~(.)	10.88 (1.10)	0.007 (0.005)		1.73 (0.05)		0.69:0.31 (0.05)
Karnataka	Periyapatna Forest Division	437.75	39	980	5	σ ~(.) g0~(.)	4.22 (2.35)	0.49 (0.38)		1.55 (0.57)		NA
Karnataka	Sakleshpura Forest Division	NA	66	1380	4	NA	NA	NA	NA	NA	NA	NA
Karnataka	Shimoga Wildlife Division	707.25	134	2718	15	σ ~(.) g0~(.)	6.37 (3.02)	0.03 (0.02)		5.36 (1.95)		NA
Karnataka	Sirsi Territorial Division	3004	114	3220	10	σ ~(.) g0~(.)	1.03 (0.64)	0.43 (0.42)		2.44 (0.88)		NA
Karnataka	Someshwara Wildlife Sanctuary	397	17	420	6	σ ~(.) g0~(.)	9.07 (6.3)	0.82 (0.95)		1.12 (0.51)		NA
Karnataka	Virajpet Territorial Division	1757.5	114	2856	8	σ ~(.) g0~(.)	0.87 (0.35)	0.53 (0.14)		3.25 (0.5)		NA
Karnataka	Yellapora Forest Division	NA	27	495	3	NA	NA	NA	NA	NA	NA	NA
Kerala	Malayatoor Wildlife Division	856.5	139	3640	30	σ ~(.) g0~(.)	5.43 (1.02)	0.36 (0.05)		2.92 (0.01)		NA
Kerala	Parambikulam Tiger Reserve	1659.25	254	9823	108	σ ~(sex), Pmix~(sex), g0~(.)	13.31 (1.36)	0.56 (0.05)		2.22 (0.09)	1.27 (0.06)	0.67:0.33 (0.05)
Kerala	Periyar Tiger Reserve	2374.5	390	14080	39	σ ~(.), g0~(.)	4.02 (0.76)	0.0008 (0.0002)		2.89 (0.31)		NA
Kerala	Ranni Wildlife Division	NA	159	3808	4	NA	NA	NA	NA	NA	NA	NA
Kerala	SilentValley National Park	880.5	103	2800	16	σ ~(.) g0~(.)	3.77 (1.05)	0.25 (0.08)		2.48 (0.34)		NA
Kerala	Wayanad Wildlife Sanctuary	2215.5	312	11390	61	σ ~(sex), Pmix~(sex), g0~(sex)	8.57 (1.55)	0.69 (0.07)	0.33 (0.1)	2.28 (0.11)	1.13 (0.16)	0.54:0.46 (0.07)
Tamil Nadu	Anamalai Tiger Reserve	1934	332	11023	59	σ ~(.), g0~(.)	5.95 (0.83)	0.002 (0.003)		2.22 (0.14)		NA

State	Site	Model space	Camera points	Trap nights	M (t+1)	Best fit model	Density/ 100 Km² (SE)	g_0 Male (SE)	g_0 Female (SE)	σ Male (SE) (km)	σ Female (SE) (m)	Pmix (SE)
Tamil Nadu	Coimbatore Wildlife Division	558.75	67	2709	13	σ ~(.) g0~(.)	8.35 (3.14)	0.17 (0.08)		2.01 (0.45)		NA
Tamil Nadu	Erode Wildlife Division	1469.75	366	10866	52	σ ~(sex), Pmix~(sex), g0~(sex)	7.39 (1.53)	0.12 (0.03)	0.28 (0.11)	3.63 (0.31)	1.12 (0.19)	0.71:0.29 (0.1)
Tamil Nadu	Gudalur Wildlife Division	1139.75	106	3699	37	σ ~(sex), Pmix~(sex), g0~(.)	13.39 (2.98)	0.6 (0.16)		2.23 (0.43)	0.99 (0.16)	0.4:0.6 (0.16)
Tamil Nadu	Kanyakumari Wildlife Sanctuary	NA	43	1417	6	NA	NA	NA	NA	NA	NA	NA
Tamil Nadu	KMTR	1581.5	316	12014	90	σ ~(sex), Pmix~(sex), g0~(.)	10.18 (1.28)	0.14 (0.02)		4.33 (0.25)	2.09 (0.16)	0.69:0.31 (0.06)
Tamil Nadu	Kodaikanal Wildlife Sanctuary	NA	152	2788	4	NA	NA	NA	NA	NA	NA	NA
Tamil Nadu	Meghamalai Wildlife Sanctuary	1130	109	2402	10	σ ~(.) g0~(.)	4.06 (2.3)	0.08 (0.07)		2.55 (0.94)		NA
Tamil Nadu	Mudumalai Tiger Reserve	3267	391	12482	120	σ ~(sex), Pmix~(sex), g0~(.)	12.11 (1.18)	0.01 (0)		2.5 (0.03)	1.27 (0.03)	0.69:0.31 (0.04)
Tamil Nadu	Mukurthi National Park	1304.5	44	1452	5	σ ~(.) g0~(.)	0.66 (0.41)	0.31 (0.14)		5.22 (1.5)		NA
Tamil Nadu	Nellai Wildlife Sanctuary	NA	81	1876	11	NA	NA	NA	NA	NA	NA	NA
Tamil Nadu	Nilgiri Forest Division	2008.5	273	10731	82	σ ~(sex), Pmix~(sex), g0~(.)	12.57 (1.82)	0.3 (0.04)		3.09 (0.32)	1.37 (0.15)	0.43:0.57 (0.09)
Tamil Nadu	Sathyamangalam Tiger Reserve	2740	707	22806	115	σ ~(sex), Pmix~(sex), g0~(.)	7.05 (0.68)	0.19 (0.02)		2.42 (0.12)	2.08 (0.13)	0.5:0.5 (0.08)
Tamil Nadu	Srivilliputhur Wildlife Sanctuary	908.75	136	3342	25	σ ~(.) g0~(.)	20.43 (10.51)	0.05 (0.03)		1.94 (0.63)		NA

Mt+1: Number of leopards (> cubs) photo-captured. SE: Standard error, D^ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture, σ : Spatial scale of detection function, g_0: Detection probability at home range centre, Pmix: Detection corrected estimate of proportion of females and males, NA = Information not available

Discussion

Western Ghats landscape have shown an increase in the leopard population since 2014. Highest leopard density was observed in Srivilliputhur Grizzled Squirrel Wildlife Sanctuary of Tamil Nadu [20.43 (SE 10.51)/ 100 km²] which is proposed as a tiger reserve. Leopard density in 11 Tiger Reserves of the landscape varied from 5.07 (SE 1.17) leopards/100 km² in Periyar to 13.43 (SE 1.45) leopards/100 km² in Nagarhole. Detection corrected sex ratio was female biased in all the tiger reserves. Fragmentation of continuous forest patches due to plantation, agriculture and linear infrastructure is the biggest threat to the leopard population and other wildlife of the Western Ghats. Despite their ubiquitous presence in the entire landscape, leopard habitats are being increasingly fragmented, and such small fragmented areas with low wild prey densities are a recipe for human-leopard conflict. Robust conflict mitigation policy is required to minimize such interfaces. Linear infrastructures causing further fragmentation of leopard habitats need appropriate mitigation measures and greener technology. In a landscape with high density of tigers and leopards, periodical assessment of their status along with their prey and habitat as well as detailed study of their ecology is required so as to understand their population dynamics which in turn would assist informed decision making and policy formulation.

CHAPTER 7:
BRAHMAPUTRA FLOOD PLAINS AND NORTH EAST HILLS

Background

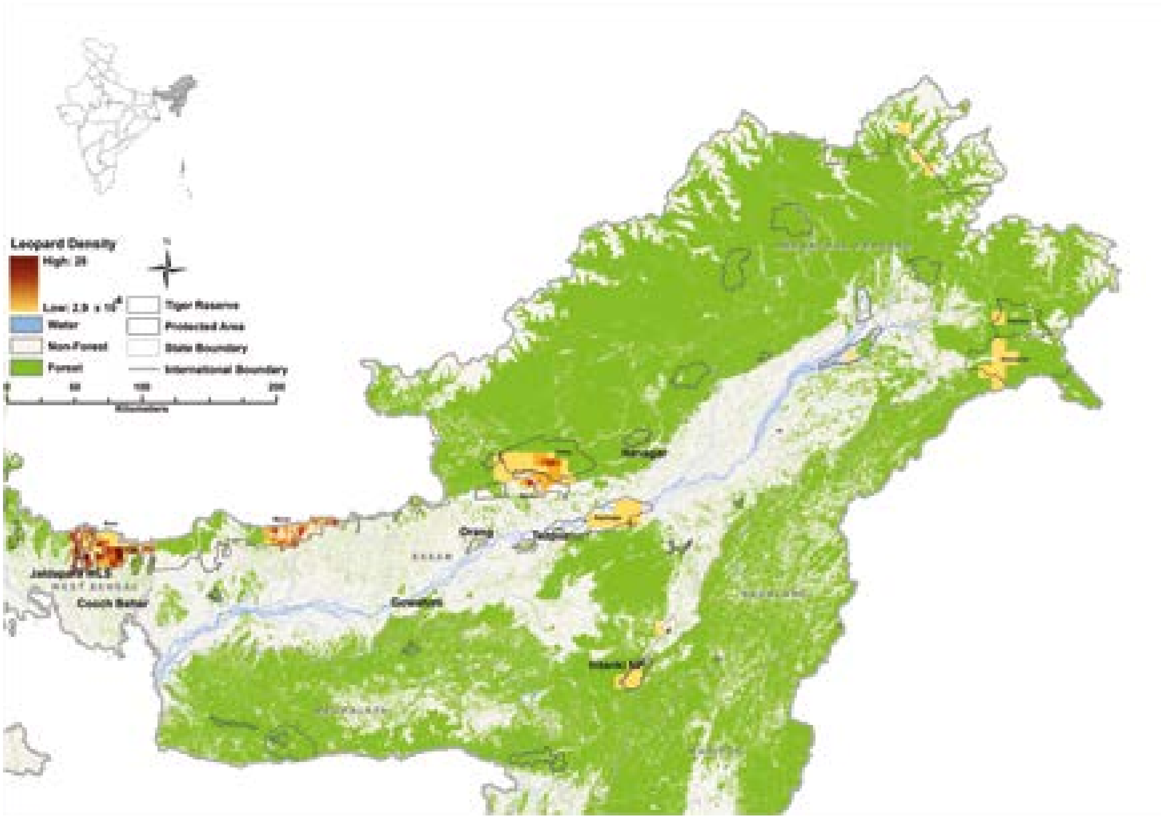
Spanning across the eastern Himalaya and its foothills and as an extension of Indo-Gangetic alluvial plain, North east hills, North Bengal Dooars and Brahmaputra flood plain harbour rich faunal and floral assemblage (Chhetri et al. 2001) and often considered as "geographical gateway" to the Indo-Malayan biodiversity hotspot (Chakravarty et al. 2012). Though there are number of Protected Areas situated in this landscape, but much of the original habitat is lost due to extensive land-use changes for tea plantation, cultivation and several developmental projects (Chatterjee 2008). Although, leopards are reported across the landscape, sampling was limited to tiger presence states and was sparse. Therefore, covariate information was not reliable for extrapolation and leopard population estimation for the Brahmaputra Flood Plain and North Eastern Hills was limited to camera trapped areas and cannot be considered as a landscape population estimate but used for monitoring specific sampled sites here.

In this landscape that provides ample cover, leopards were present in most forested areas and reported from outside protected areas as well, including tea plantations, agricultural fields and near human habitation (Kshettry et al. 2017). However, literature on estimation of leopard population is very scarce in this landscape. A study by Borah et al. 2013 estimated density of 3.4 (SE 1.9) leopards/ 100 km² in Manas Tiger Reserve, Assam. Borthakur et al. 2017 recorded sign encounter rates of leopard in various Protected Areas of north Bengal. Apart from these, most of the literature addresses human-leopard conflicts and food habit of leopard (Kshettry et al. 2017, Kshettry et al. 2018, Naha et al. 2018), since human leopard conflict is a major concern here.

Leopard occupancy, population extent and abundance

Due to inadequacy of Phase I sampling, landscape scale analysis was not feasible. From camera trapped sites total leopard population of 147 (SE range 118-176) was estimated for the landscape (Figure 7.1). Leopard population estimation was done for the first time in Buxa Tiger Reserve, Gorumara National Park and Jaldapara Wildlife Sanctuary of northern West Bengal.

Figure 7.1: Leopard distribution and density (individuals/100 km²) surface for North Bengal and North Eastern landscape 2018



Arunachal Pradesh

Systematic sampling in mark-recapture framework was done in southern valley of Pakke Tiger Reserve and opportunistic camera trap sampling was done in Dibang Wildlife Sanctuary, Kamlang, and Namdapha Tiger Reserves in Arunachal Pradesh. However, leopards were photo-captured only from Namdapha and Pakke Tiger Reserves. There were 39 images of melanistic leopards obtained from Pakke Tiger Reserve which were not included in the estimation as individual leopards could not be identified from those images. Pakke Tiger Reserve shares 5 individual leopards with adjacent Nameri Tiger Reserve of Assam. Estimates of leopard density parameters from Tiger Reserves and other camera trapping sites are in Table 7.1.

Table 7.1: Sampling details and leopard density parameter estimates using spatially explicit capture mark recapture analysis in a likelihood framework for sites in Brahmaputra flood plains, North Bengal and North East hills

State	Site	Model space	Camera points	Trap nights	M (t+1)	Best fit model	Density/ 100 Km^2 (SE)	g_0 Male (SE)	g_0 Female (SE)	σ Male (SE) (km)	σ Female (SE) (km)	Pmix (SE)
Arunachal Pradesh	Pakke TR	962	111	3561	13	$g_0(.)\sigma(.)$	1.6 (0.45)	0.02	NA	NA	NA	NA
Arunachal Pradesh	Namdapha TR**	NA	36	1725	4	NA	NA	NA	NA	NA	NA	NA
Assam	Nameri TR	NA	91	2572	10	NA	NA	NA	NA	NA	NA	NA
Assam	Manas TR	658.25	240	11407	30	$g_0(.)\sigma(.)$	3.69(0.68)	0.02 (0.002)	NA	NA	NA	NA
Assam	Kaziranga TR**	NA	204	14465	6	NA	NA	NA	NA	NA	NA	NA
West Bengal	Buxa TR	709.75	161	4176	32	$g_0(sex)\sigma(sex)$ pmix (sex)	5.38(1)	0.02 (0.002)	0.01 (0.001)	2.4(0.1)	1.76 (0.14)	0.6:0.4 (0.1)
West Bengal	Jaldapara WLS	283.25	65	1404	24	$g_0(.)\sigma(.)$	11.3 (2.4)	NA	NA	NA	NA	NA
West Bengal	Gorumara NP**	NA	25	576	4	NA	NA	NA	NA	NA	NA	NA
Nagaland	Intanki NP**	NA	25	1188	2	NA	NA	NA	NA	NA	NA	NA

Mt+1: Number of leopards (> cubs) photo-captured., SE: Standard error, D̂ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture, : Spatial scale of detection function, g_0: Magnitude (intercept) of detection function, Pmix: Detection corrected estimate of proportion of females and males. ** These individuals were not included in the population estimates of the landscape, as those areas were not adequately sampled and these could be minimal individual numbers.

Assam

Systematic sampling in mark-recapture framework were done at five sites namely Kaziranga, Manas, Nameri and Orang Tiger Reserves and Nagaon Wildlife Division. However, no leopards were photo-captured from Orang Tiger Reserve and Nagaon Wildlife Division and only six individuals were photo-captured from Kaziranga Tiger Reserve. A total of 365 photo-captures of 46 leopards were obtained from Assam, out of these 46 leopards, 5 individuals were common with Pakke Tiger Reserve, Arunachal Pradesh. There were 183 images of melanistic leopards obtained from Manas Tiger Reserve which were not included in the estimation as individual leopards could not be identified. While leopard presence was sporadically reported from the state, extrapolation of leopard population outside tiger reserves was not feasible in absence of adequate Phase I sampling by the State Forest Department. Since, there is a void of published literature on estimation of population of leopard and human-leopard conflict from the state, this estimation acts as a baseline information of density estimates for the sampled areas of the state. An extensive Phase I data collection throughout the state is required which will provide a spatial extent of leopards in the state and assist in a proper population estimate. With growing urban built-up progressively shrinking the suitable habitats for leopards, frequent interfaces and conflicts between man and leopard even within the urban landscapes are one of the major conservation challenges for the managers in the state.

West Bengal

For the first time, Jaldapara Wildlife Sanctuary, Gorumara National Park and Buxa Tiger Reserve of north Bengal Dooars have been systematically sampled with camera traps. A total of 389 photo captures of 60 individual leopards were obtained in the sampled area. Estimates of leopard density parameters from Tiger Reserves and other camera trapping sites are in Table 7.1. Published reports on human leopard conflict and diet of leopard indicate the presence of leopard almost everywhere, including tea plantations, agricultural land and near human habitation in this landscape. However, due to inadequacy of sampling (Phase I) across the State it was not possible to estimate the leopard population except from within camera trapped areas. With continued fragmentation of forested habitats, escalating leopard human conflict, particularly in the tea gardens of north Bengal is a major conservation challenge in the state (Vyas and Sengupta 2014).

Discussion

The estimates provided herein for camera trapped areas provide baseline density estimates of leopards for Northern West Bengal, Brahmaputra floodplains and North east hills. An estimate of 11.3 (SE 2.4) leopard/ 100 km^2 is reported from Jaldapara Wildlife Sanctuary. After adequate sampling it would be possible to estimate leopard numbers for the entire State and the landscape.

CHAPTER 8:
GENETIC STRUCTURE OF LEOPARD, DHOLE, AND SLOTH BEAR, AND ITS IMPLICATION FOR CONSERVATION

Introduction

The basic unit of biological diversity is within species diversity. Conservation efforts need to first take stock of genetic variation present in extant populations (gene pool diversity), understand processes that have resulted in differential distribution of this diversity, assess its loss within historical times and plan strategies to minimize human induced losses (Moritz 2002, Frankham 2010). Rarely is this basic tenet of species conservation considered for formulation of policy and management strategies, primarily because of lack of information on the quantum and distribution of genetic diversity across the geographical range of a species and amongst its populations. An attempt to understand and incorporate this important conservation tenet at a National scale was with tigers in India (Kolipakam et al. 2019) and at a global scale (O'Brien et al. 2017) for many species including tiger (Liu et al. 2018), lions (Bertola et al. 2016) and cheetah (Prost et al. 2020) amongst other studies. The study by Kolipakam et al. (2019) provided the baseline for understanding the extant genetic diversity, its distribution, and the identification of conservation priority populations based on vulnerability to extinction, genetic distinctiveness, divergence, and diversity. Subsequently, the NTCA has issued a standard operative procedure for sourcing tigers for reintroductions and supplementation based on the findings of this study *(https://ntca.gov.in/documents/#sop1)*. The geographic distribution of genetic diversity depends, amongst other factors, the historic colonization/evolutionary events, vicariant events, and isolation caused by natural or manmade barriers (Saunders et al. 1991, Fahrig 2003, Henle et al. 2004). Since the Indian sub-continent lies at the confluence of Ethiopian, Malayan, and Palearctic zoogeographic realms (Mani 1974), species have either colonised India from the east (tigers, dhole, etc.), from the west (leopards, lions, etc.) or have evolved within the subcontinent (sloth bears, blackbuck, nilgai, four horned antelope, etc.). The current quantum of genetic diversity and its spatial structuring would depend on the species founding gene pool, entry points/ evolutionary history, and their ability to cross natural and man-made barriers.

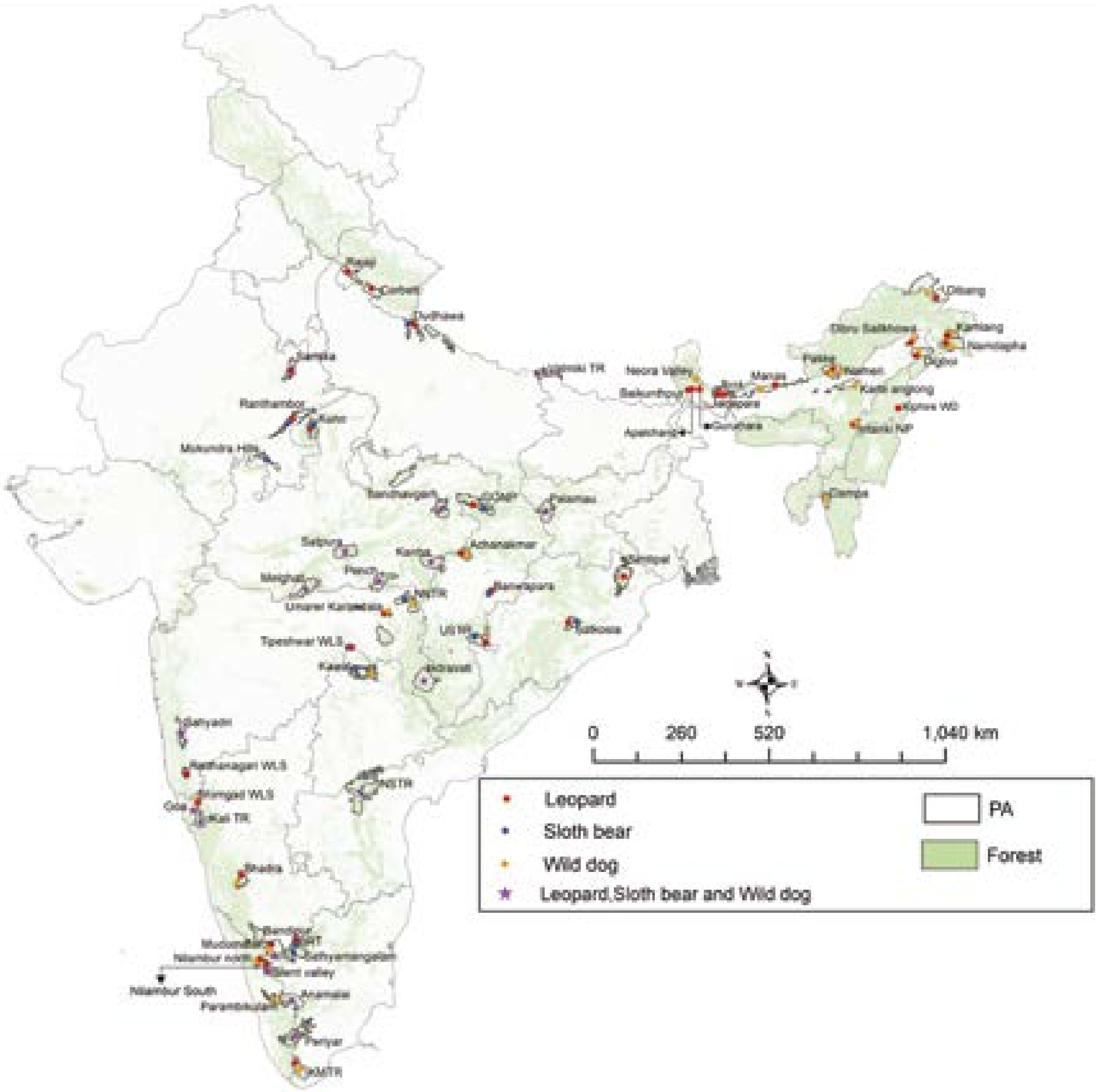
Project tiger was envisioned as a conservation programme to not only safeguard tiger populations across the country, but to also garner conservation support and direct concerted effort to secure forested habitats and their encompassing biodiversity, by using the tiger as an charismatic icon. Small tiger (or other species) populations have a better chance to survive for the long-term when they remain connected and function as metapopulations (Hanski et al. 1996) decreasing their vulnerability to extinction. This also ensures that the genetic variation inherent in the population does not erode due to drift or isolation and result in inbreeding depression (Moritz 2002). The model of corridor conservation is also driven by the needs of the tiger (Gopal et al. 2007, Qureshi et al. 2014), it is important to understand how these corridors serve the umbrella function of catering to other species as well. Only then will investments made for tigers, result in a holistic approach to conservation.

Currently only limited information is available on the genetic diversity and its spatial distribution for leopards, dhole and sloth bear (Iyengar et al. 2005, Dutta et al. 2013, Dutta et al. 2015, Bhatt et al. 2020). Herein, we address this void by collecting non-invasive samples for these three species from across India through a NTCA funded project on "Genetic Connectivity across Landscapes" and the AITE exercise to study their genetic diversity and spatial distribution using microsatellite markers.

Method

To understand the genetic structure of leopards, dholes and sloth bears across tiger habitats in the country, putative carnivore scats were collected during the National tiger monitoring exercise. DNA from scats was extracted and assigned as belonging to either leopard, wild dog or sloth bear, based on molecular identification through species specific primer amplification (Figure 8.1; Maroju et al. 2016; Thatte et al. 2018, Singh et al. in prep). These species identified samples were then identified to individuals using microsatellites described in Kolipakam et al. (2019) for leopards, Iyengar et al. (2005) and Modi et al. (2018) for wild dogs and black bear microsatellites designed for sloth bears (Paetkau et al. 1998, Kitahara et al. 2000, Shih et al. 2009). Lab and analytical protocols followed to identify individuals are described in detail in Kolipakam et al. (2019). Following identification of individuals, we used package ADEGENET in R (Jombart et al. 2008), to summarise the genetic diversity statistics of each species, and populations within each landscape. To understand how populations of each species are genetically structured across India, we used a Bayesian clustering approach applied through the program STRUCTURE (Pitchard et al. 2000). To understand the extent of distinctiveness of each landscape population in terms of shared allelic space, a Discriminant Analysis of Principal Components implemented through the package ADEGENET in R (Jombart et al. 2008) was used.

Figure 8.1: Map depicting locations of leopard, dhole and sloth bear samples positively identified to species using species specific markers, used for genetic analysis



Leopards

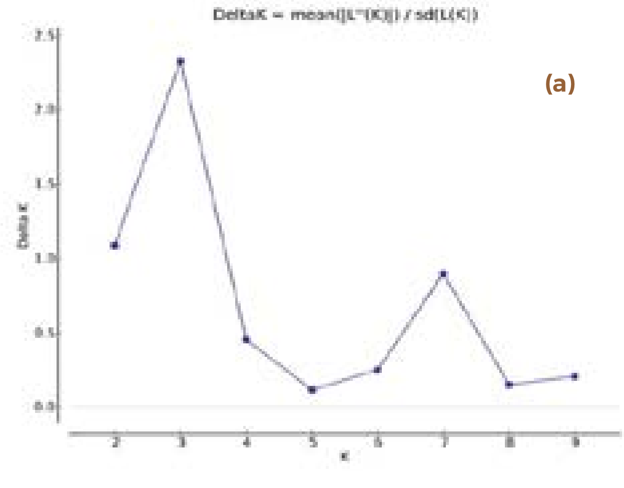
Of a total of 1,871 carnivore scat samples from which DNA was extracted, 704 were positively identified as belonging to leopards. From 704 leopard positive samples, we were able to identify 317 unique individuals, after removing samples that did not amplify, as well as recaptures of individuals. Leopard individuals identified, comprised of 45 leopards from the North-East, 21 from Terai, 108 from Central India, 53 from Eastern Ghats and 90 from Western Ghats (Table 8.1).

Table 8.1: Sample size (N), Mean number of Alleles (MNA), Mean Allelic Richness (AR), Observed Heterozygosity (H_{OBS}), Expected Heterozygosity (H_{EXP}), Probability of Identity (P_{ID}) and Probability of identifying siblings (P_{SIBS}) of the 317 individual leopards sampled across India.

Landscape	N	MNA	AR	H_{OBS}	H_{EXP}	P_{ID}	P_{SIBS}
India	317	10.7	9.89	0.49	0.88	6.53×10^{-19}	3.09×10^{-6}
Northeast	45	12.45	9.50	0.47	0.82	3.5×10^{-14}	1.70×10^{-5}
Terai	21	7.91	9.41	0.52	0.83	1.02×10^{-13}	1.86×10^{-5}
Western India	20	9.91	9.09	0.41	0.83	7.73×10^{-16}	8.64×10^{-6}
Central India	88	15	11.52	0.46	0.87	3.26×10^{-19}	4.07×10^{-6}
Eastern Ghats	53	6.64	9.66	0.32	0.83	5.37×10^{-19}	7.90×10^{-6}
Western Ghats	90	11.73	10.15	0.43	0.81	3.79×10^{-14}	1.61×10^{-5}

The genetic diversity as measured by mean number of alleles and allelic richness, was maximum in central India, while variation in all other landscapes was comparable (Table 8.1). Genetic analysis indicates that leopard populations across the country were not strictly structured, as opposed to tiger populations which showed strong structuring across landscapes (Kolipakam et al. 2019). Bayesian clustering approach, when sample location information was not incorporated, resolves two clusters, and when apriori sample location information was added, the number of clusters inferred was three (Figure 8.3a). The discriminant analysis of principal components reveals largely overlapping clusters, where landscapes share allelic space (Figure 8.2). Both these analysis reveal that leopards populations across the country are genetically not distinctly structured. At both statistically inferred population divisions (K=2 and 3) we do not observe any uniqueness or genetically distinct populations. At further levels of population divisions (K=3 to 8), the Terai and parts of Central Indian leopards show up as distinct from Western Ghats and North Eastern leopard populations (Figure 8.3b). There was a clear signal of shared affinity of genes between leopards of Eastern Ghats, and those of West and North Bengal (assigned under North East in the analysis). The leopard population throughout the Western Ghats is genetically contiguous. The Eastern Ghat populations also share allelic space with Western Ghat populations. It is interesting to note that while tigers across the same space are genetically structured, leopard populations are genetically similar, with structuring seemingly driven only by separation in space.

Figure 8.2: Discriminant analysis of principal components of 317 leopard individuals from the five landscapes (Terai, CI = Central India, NE = NorthEast, EG = Eastern Ghats, WG = Western Ghats.)



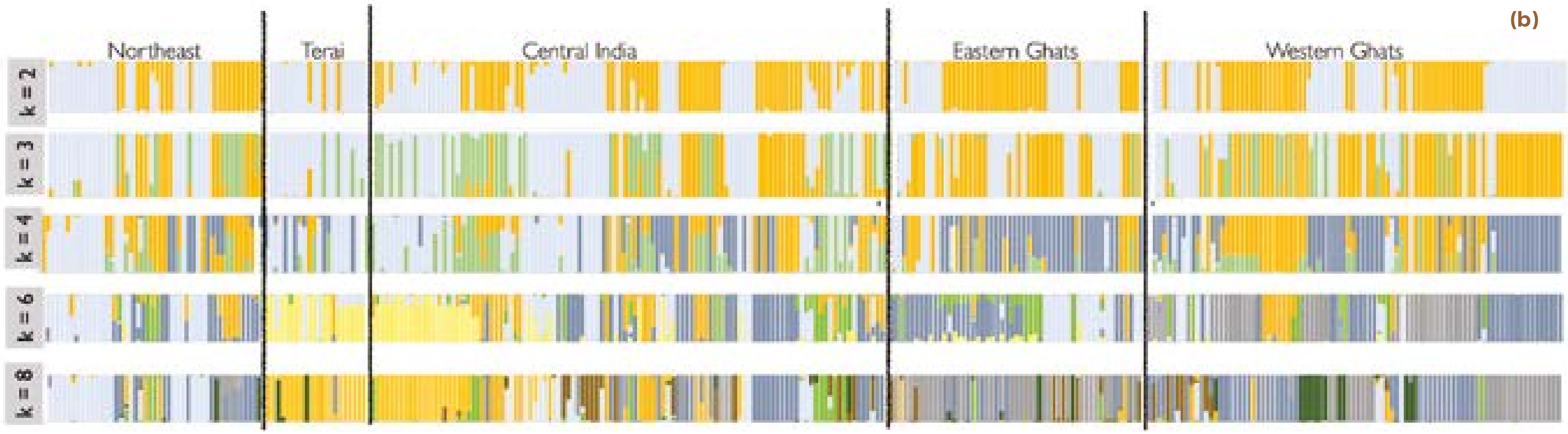


Figure 8.3: (a) Delta K value indicating k=3 to be the hierarchically most plausible number of clusters. (b) Barplots indicating genetic structure of 317 individual leopards across landscapes at K=2, 3, 4, 6, and 8. Each individual is represented by a vertical bar, and the coloured length of each bar indicates the probability of membership in each cluster. Associated Delta K plot for loc prior, where K-3 is the most likely hierarchically top most cluster is depicted.

Wild dog

DNA was extracted from a total of 980 putative canid samples, of which 493 were identified as Dholes. From 493 dhole positive samples, we were able to identify 397 unique individuals, after removing samples that did not amplify and samples that were recaptures of individuals. Dhole individuals identified comprised of 133 individuals from North East, 12 from Terai, 30 from Eastern Ghats, 107 from Central India, 115 from Western Ghats (Table 8.2).

Table 8.2: Sample size (N), Mean number of Alleles (MNA), Mean Allelic Richness, Observed Heterozygosity (Hobs), Expected Heterozygosity (Hexp), Probability of Identity (PID) and Probability of identifying siblings (Psibs) of the 397 individual dholes sampled across India

Landscape	N	MNA	AR	H_{OBS}	H_{EXP}	P_{ID}	P_{SIBS}
India	397	13.83	6.44	0.4	0.87	$1.01x10^{-19}$	$1.22x10^{-6}$
Northeast	133	12.75	7.82	0.41	0.87	$1.68x10^{-19}$	$1.16x10^{-6}$
Terai	12	4.75	4.51	0.36	0.71	$5.88x10^{-11}$	$6.11x10^{-5}$
Central India	107	10.67	6.58	0.44	0.82	$2.06x10^{-16}$	$3.59x10^{-6}$
Eastern Ghats	30	8.92	6.58	0.34	0.82	$5.52x10^{-16}$	$4.14x10^{-6}$
Western Ghats	115	10.25	6.69	0.42	0.83	$7.15x10^{-17}$	$3.06x10^{-6}$

The mean number of alleles was highest for Dhole populations from the North East, followed by comparable diversity in both Eastern Ghats and Western Ghats. After correcting for sample size however, the allelic richness of Central Indian dholes is comparable with that of both Eastern Ghats and Western Ghats (Table 8.2). The Bayesian clustering algorithm to understand population genetic structure of Dholes, resolved two major clusters with and without incorporating location priors, largely differentiating the North-East and Terai populations from the rest of the country (Figure 8.4a and 8.4b). Current structure results indicate Terai to be a unique cluster, sharing genetic similarity with North-Eastern populations. With increasing K, there is evidence of sub-structure within each landscape, but this requires further investigation. Even the discriminant analysis of principal components echoes the inference made from STRUCTURE results, with North-Eastern and Terai populations separating out from the rest of the Indian wild dog populations (Figure 8.5). Preliminary analysis to understand population genetic structure in the rest of the country using DAPC, after removing the North-East and Terai from the analysis (Figure 8.6), shows that there is structure within each landscape, where each landscape forms a distinct cluster, with a low amount of gene flow, unlike leopard populations. Central India and Western Ghats share allelic space a pattern similar to what is seen in the case of tiger populations (Kolipakam et al. 2019).

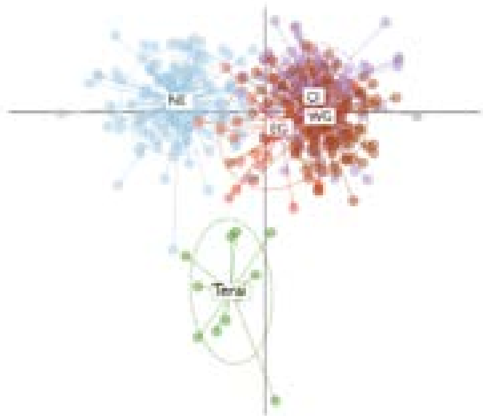
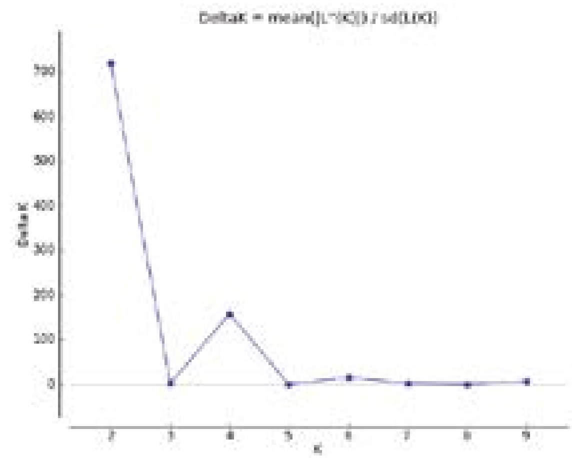
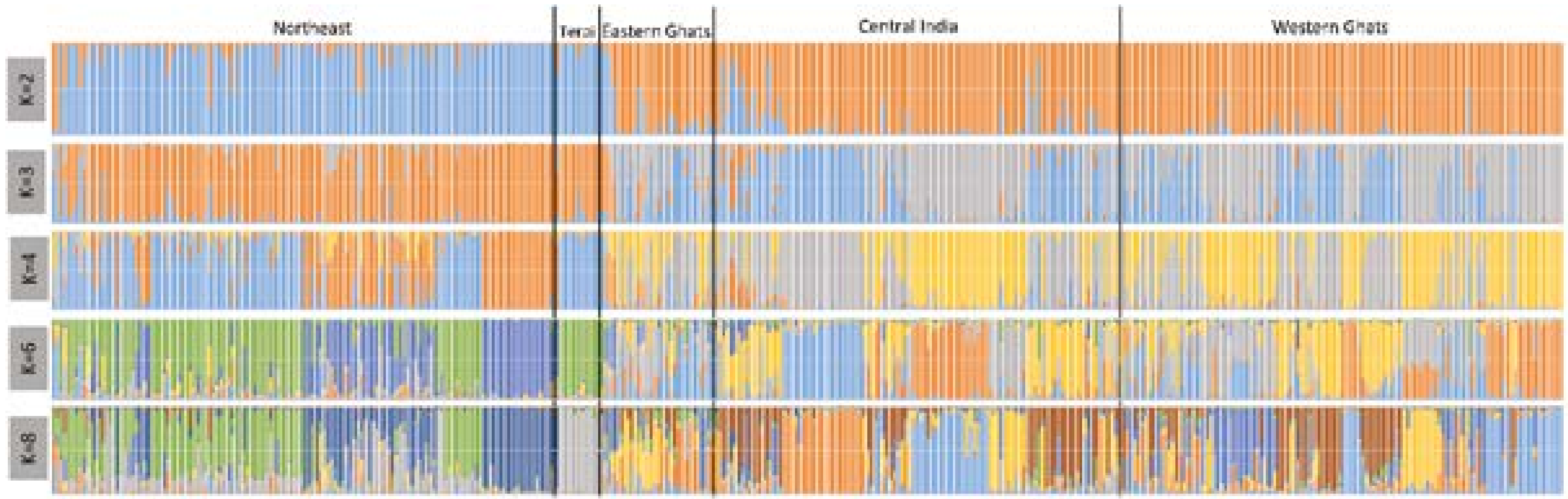


Figure 8.4: Discriminant analysis of principal components of 397 dhole individuals from NorthEast(NE), Terai, Central India (CI), Eastern Ghats (EG) and Western Ghats (WG)



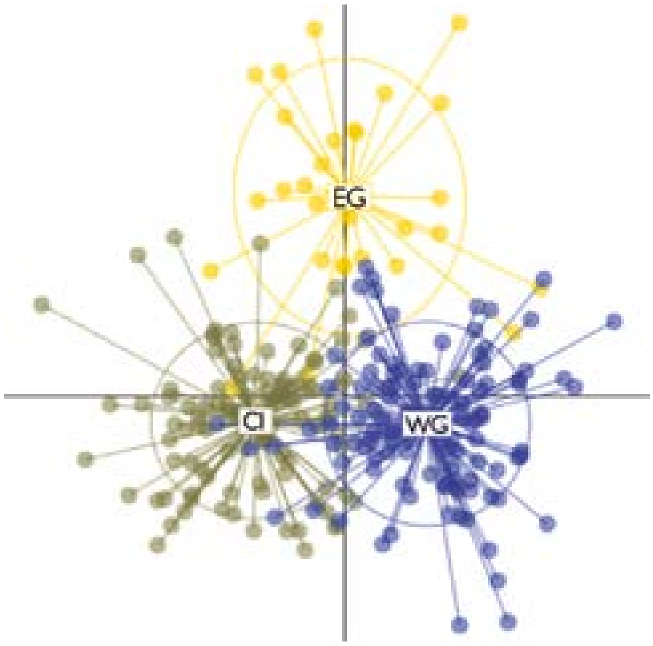
(a)



(b)

Figure 8.5: (a) Barplots indicating genetic structure of 397 individual leopards across landscapes at K=2, 3, 4, 6, and 8. Each individual is represented by a vertical bar, and the coloured length of each bar indicates the probability of membership in each cluster. (b) Delta K plot depicting two major populations of wild dogs.

Figure 8.6: Discriminant analysis of principal components of dhole individuals Central India (CI), Eastern Ghats (EG) and Western Ghats (WG)



Sloth bear

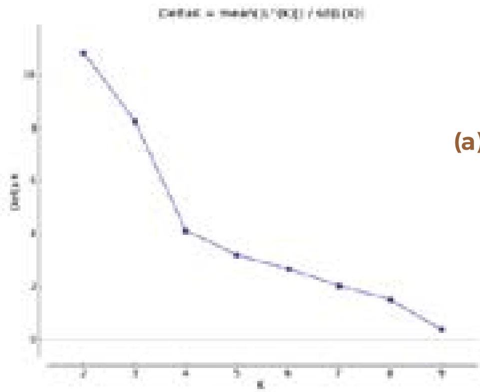
A total of 531 putative bear samples were collected during the National Tiger Estimation Exercise of 2014 (Jhala et al. 2015) and 2018 (Jhala et al. 2020). Species identification of sloth bear was carried out using a species specific marker amplifying a ~243bp region of mitochondrial Cytochrome Oxidase II gene (Thatte et al. 2018). Out of the 531 scats, 255 sloth bear samples were successfully amplified and were identified to 146 unique individuals after removal of samples that did not work during microsatellite amplification and recaptures of same individuals. There were a total of 11 individuals from Terai, 79 from Central India (including Western India), and 56 from Western Ghats (Table 8.3). We do not include samples of bears from the North-East, since work on definitively differentiating between Sun Bear and Sloth Bear is ongoing.

Table 8.3: Sample size (N), Mean number of Alleles (MNA), Mean Allelic Richness (AR), Observed Heterozygosity (Hobs), Expected Heterozygosity (Hexp), Probability of Identity (PID) and Probability of identifying siblings (Psibs) of the 146 individual sloth bears sampled across India

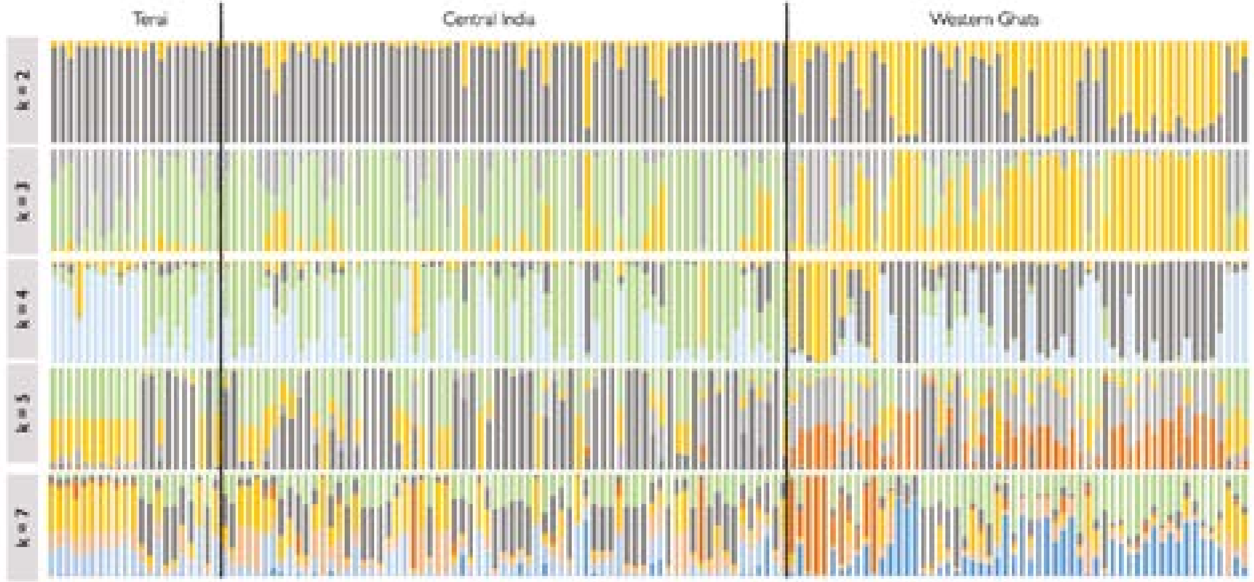
Landscape	N	MNA	AR	Hobs	Hexp	PID	Psibs
India	146	10	3.65	0.38	0.80	1.55×10^{-11}	1.26×10^{-4}
Central India	79	9	3.25	0.40	0.79	2.97×10^{-11}	0.000143
Terai	11	4.56	3.84	0.44	0.66	6.40×10^{-8}	0.00091
Western Ghats	56	8.11	3.86	0.33	0.78	2.56×10^{-11}	0.0001445

While mean number of alleles was highest for Central India, after correcting for sample sizes, the diversity of all three landscapes was comparable. Bayesian analysis approach used to understand the highest hierarchical genetic clustering between these landscapes revealed three major clusters corresponding to the three landscapes, when no location prior information is provided (Figure 8.7a and 8.7b).

Figure 8.7: Discriminant analysis of principal components of 146 sloth bear individuals Terai, Central India (CI) and Western Ghats (WG)



(a)



(b)

Figure 8.8: (a) Barplots indicating genetic structure of 146 individual sloth bears across landscapes at K=2, 3, 4, 5, and 7. Each individual is represented by a vertical bar, and the coloured length of each bar indicates the probability of membership in each cluster. (b) Delta k plot depicts lack of structure in sloth bears

Genetic structure of sloth bear at k=3 and at k=5 showed weak genetic structuring, due to differing allele frequencies between the clusters (Figure 8.9). Amongst sloth bears individuals were seen to be more admixed in terms of population assignment. Central India encompassed the variation present across all the sampled populations. The discriminant function analysis was able to cluster Terai population into one cluster, but there was ample amount of sharing of allelic space between Central India and Western Ghats (Figure 8.8). There was evidence of sub-structuring of populations within the Western Ghats.

Figure 8.9: Cluster memberships of sloth bear individuals of each landscape at. putative five populations (K=5)

Discussion

We find that genetic diversity amongst all study carnivores was high and comparable to that observed in other large carnivore populations (e.g. lions in Africa (Curry et al. 2021); Puma and Jaguar (Wultsch et al. 2016)). The panel of microsatellites used for all carnivores had a high cumulative PID values and was found to be appropriate for the analysis as well as for individual identification (Tables 8.1, 8.2, and 8.3). The genetic structure observed for leopards, dhole and sloth bear seems to be governed by their phylogenetic history, species biology, and dispersal ability. Our results reveal that leopard populations shared a common genepool and had poor genetic structuring at the country scale. Whatever structuring was seen could likely be explained with geographical distance between landscapes (isolation by distance). Leopards entered into India from the western corridor and therefore would have colonised western Central India and Terai first. We would have expected the allelic representation from these landscapes to be present across all populations. However, at higher population division (K=6-8) the populations of Terai and CI separate out as the only distinct populations – such a result is indicative of multiple or recent geneflow from the western corridor into India. Analysis of leopard populations from Persia and Afghanistan along with the Indian samples would provide definitive answers to this hypothesis. Human dominated landscapes are permeable to leopard movement (Odden et al. 2014) but act as barriers to tigers

(Smith 1993). However, population structuring would also depend on founding and vicariant events and subsequent geneflow between populations. Therefore, it seems clear that Indian habitat matrix was more permeable to leopard geneflow compared to that of tigers. An important point to note is that protected areas centred around tiger conservation have served as source populations for leopards as well and allowed them to colonise surrounding human dominated landscapes at lower densities **(Figure 3.1)**. Population genetic connectivity is promoted and maintained by dispersing individuals produced in these source populations. Dutta et al. 2012 hint at contemporary genetic structuring in progress in leopard populations of central India, and the need for maintaining connectivity to ensure long-term persistence of the species along with retaining its current genetic diversity. Therefore, it is of utmost importance to focus on this aspect of conservation under the ambit of project tiger for the conservation of leopards. It is important to point out that geographic scale of genetic studies using the same data and same markers will give different results. At large country scale analysis leopards lack structuring, but analysis at local scale may give another picture and point to recent barriers in gene flow (Dutta et al. 2013, Biswas et al. 2020).

Unlike leopards dhole colonised India from the east and gene frequencies observed in the NE should be represented across India if there was a single colonization event. However, dhole populations from the North-East and Terai separate out from the rest of the populations. This is suggestive of more than one colonization event or continued genetic mixing of the NE populations with dhole from the Malayan realm while some form of genetic isolation/lowered gene flow occurred towards central India and Western Ghats but not towards the Terai landscape. Iyengar et al. (2005) based on mitochondrial sequence data suggests two phylogeographic groupings of the Asiatic dhole populations, one that are present in the southern part of India and spread till the Ganges river (Western Ghats and Central Indian), and the other spread across the north of the Ganges up until Myanmar (NE and Terai). Our nuclear microsatellite data supports such a hypothesis. However, like suggested for leopards if samples from Myanmar, Thailand and Malaysia were included along with Indian samples in a single analysis, a holistic picture regarding colonization events into India could be obtained. Nevertheless, when the aforementioned Terai and North-East populations are removed from the analysis, the discriminant function segregates the three remaining landscapes of Central India, Eastern Ghats and Western Ghats into separate clusters. Thus, there seems to exist inherent structuring within the landscapes, which requires further investigation. Dhole populations seem to mimic the genetic structure of tigers that share the same entry route into India. Also in comparison to tigers and leopards, permeability of human dominated habitat matrix for dhole is somewhere in between the two felids. Dhole being able to disperse across some human impacted landscapes better than tigers but not as much as leopards. Therefore, corridors delineated for tigers would be useful for conservation of dholes as well.

A weak genetic structuring was observed in sloth bears across all landscapes, and this is in consonance with a landscape-wide study focussed in central India by Thatte et al. 2018, where a weak genetic differentiation between populations was found. Central India encompassed entire diversity present in the sampled sloth bear populations. This is not surprising, given that the evolution of sloth bear was thought to have occurred in the Peninsular region of India (Erdbrink 1953). Continuous and rapid decline in forest extent and quality can become a big threat to a forest dependent species like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sloth bear (Puri et al. 2015, Thatte et al. 2018). Further analysis to understand effective population size and phylogeography would help in determining the efforts required to sustain sloth bears in the landscape, and also to mitigate any process of structuring within the landscapes.

All the three large carnivores showed less genetic structuring compared to tigers, suggesting that tigers were the most conservation investment dependent species compared to the other large carnivores. If conservation strategies of maintaining geneflow in tigers were implemented through corridors then genetic connectivity for all the other carnivores would be ensured. Our results reinforce the need for restoration and protection of existing and delineated tiger corridors across all source populations. Often, it is argued that it would be much easier to move individual tigers between populations than to maintain natural corridors so that genetic diversity is maintained and inbreeding avoided. This easier route to metapopulation management of tigers would compromise the need and umbrella role of natural tiger corridors for other species. Also, animals that disperse naturally and survive natural perils are better adapted and more fit, thereby ensuring the evolutionary potential of future generations. Such selection cannot be achieved by artificial management which should only be used as a last resort.

FELIDS

CHAPTER 9:
CARACAL *(CARACAL CARACAL)*

INTRODUCTION

Conservation status

IUCN Red List: Least concern (LC)

Wildlife (Protection) Act, 1972: Schedule I

The caracal derived its name from a Turkish word "Karakulak" which refers to one of this cat's prominent features viz. black ear (Buffon 1761). In Pakistan and northern India, it is vernacularly known as 'Siya Gosh', originated from a Persian word for 'Black Ear' (Harting 1883). The species is among the most widespread of small wild cats, distributed across at least 20 million km² including 42 African and 18 Asian countries across Africa, Central Asia, and south-west Asia and into India (Avgan et al. 2016, Veals et al. 2020). North African populations are disappearing (Ray et al. 2005, Stuart and Stuart 2013), but caracals are still abundant in other African regions (Thorn et al. 2011). Their range limits are the Saharan desert and the equatorial forest belt of Western and Central Africa. On the Arabian Peninsula, the Caracal is widespread and seems to be stable with rediscovery of the species from Abu Dhabi (Gubiani et al. 2020). In Asia, the caracal's historical range mirrors with that of cheetah *(Acinonyx jubatus)* and overlaps with small ungulate species such as blackbuck *(Antilope cervicapra)* in India (Sunquist and Sunquist 2002) and chinkara *(Gazella gazella bennettii)* in Iran and India (Sunquist and Sunquist 2002, Farhadinia et al. 2007, Ghoddousi et al. 2009, Moqanaki et al. 2016). In India the species historically occurred across north-western and central India upto the states of Jharkhand and Odisha in the east with a country wide occupancy of about 793,927 km² till 1947 (Khandal et al. 2020). Since 2001, the Caracal's presence has been reported in three states viz. Rajasthan (areas near Ranthambhore, Sariska Tiger Reserves, Udaipur and Chittorgarh districts), Gujarat (Kutch landscape) and Madhya Pradesh (ravines of Chambal) spreading over an area of 16,709 km² (Singh et al. 2014, Khandal et al. 2020) making it the most endangered cat in India (Kolipaka 2011).

Major threat faced by the species is human persecution in retaliation for predating on livestock, especially in South Africa and Namibia (Stuart 1982, Nowell and Jackson 1996). Habitat destruction (agriculture, desertification, urbanization) is a significant threat in central, west, north and northeast Africa and Asia where the species is naturally sparsely distributed. Linear infrastructure, especially roads with moving vehicles in caracal habitats take their silent toll and local low density populations are pushed towards extinctions with even a few road kills.

SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Caracal have brown to red coats, with colour varying among individuals. Females are typically lighter than males. Caracal fur is short, dense and provides effective insulation from extreme temperatures that characterize much of the species' range (Smithers 1983). Seasonal variation occurs in coat thickness and degree of underfur (Pocock 1939). Their undersides are white and, similar to African golden cats, are adorned with many small spots (Smithers 1983). The face has black markings on the whisker pads, tear marks around the eyes as seen in the cheetah, and faintly down the center of the head and nose. Its most striking feature is its long, narrow, blacktufted ears (Menon 2014). Melanistic individuals have been recorded in Kenya and Uganda (Rosevear 1974) and from central Africa in tropical habitat (Happold 1987).

Body size:
Head and body length: >60 cm, Tail length: 23 cm (Prater 1971, Menon 2014)

Body weight:
8-12 Kg (Prater 1971)

Gestation period:
70-90 days (Prater 1971, Bernard and Stuart 1987)

Litter size:
2-4 (Bernard and Stuart 1987)

Life span:
Up to 15 years (Prater 1971). The maximum captive longevity reported was 20.3 years for a wild-born female raised in captivity (de Magalhaes et al. 2009).

ECOLOGY AND BEHAVIOUR

The caracal occupies a wide variety of habitats from semi-desert to relatively open savanna and scrubland to moist woodland and thicket or evergreen/montane forest (as in the Western Cape of South Africa), but favours drier woodland and savanna regions with lower rainfall and some cover (Stuart and Stuart 2013). Compared to servals, caracal can tolerate much drier conditions. However, they seldom inhabit deserts and are usually associated with some form of vegetative cover (Sunquist and Sunquist 2002). They generally range up to 2,500 m but their occurrence at an elevation of 3,300 m has been recorded from the Ethiopian Highlands (Ray et al. 2005). However, caracal space use was found to decrease as elevation increased and they preferred areas at elevations of < 1,200 m in south Africa (Ramesh et al. 2017).

Caracal are opportunistic predators, documented predating on a broad range of prey, that include rodents, lagomorphs, hyraxes, small to mid-sized ungulates, small carnivores birds and reptiles (Smithers 1971, Skinner 1979, Grobler 1981, Moolman 1984, 1986, Weisbein and Mendelssohn 1989, Stuart and Hickman 1991, Mukherjee et al. 2004, Farhadinia et al. 2008, Braczkowski et al. 2012). Diet is primarily mammal-based but varies by region, habitat, or locale (Moolman 1986). Caracal habitat use is positively correlated with density of mammalian prey (Avenant and Nel 1998). Mammalian prey ranges in size from small rodents to large antelope such as springbok *(Antidorcas marsupialis)*, with mass of prey items typically averaging 45% the mass of the caracal (Kok and Nel 2004). Avian prey ranges from quail to ostrich *(Struthio camelus)* (Smithers 1971), and reptilian prey ranges from small lacertid lizards to large varanids (Sunquist and Sunquist 2002). Like cheetahs, caracal were captured and trained to hunt for Indian royalty, but although it is capable of taking the larger ungulates it was mainly used for small game and birds (Divyabhanusinh 1995).

Caracal are solitary, except for the duration of mating and rearing of kits. Eight individuals were recorded at a fishpond in Israel (Hoath 2003). Both sexes are territorial and maintain an active home range. Home ranges are large in arid areas, with the home ranges of three males averaging 316.4 km^2 on a Namibian ranchland (Marker and Dickman 2005). In South Africa male home ranges were 5.1-48 km^2 and female ranges were 3.9-26.7 km^2 (TAWIRI 2009). In Saudi Arabia, a radio-tracked male ranged over 270 km^2 to 1,116 km^2 in different seasons (Van Heezik and Seddon 1998), while in an Israeli study, home ranges of males averaged 220.6 km^2 (Weisbein and Mendelssohn 1990). Male home ranges in better-watered environments of South Africa are smaller (two males averaged 26.9 km^2 in West Coast National Park (Avenant and Nel 1998), and female ranges were considerably smaller than the ones of males (Stuart and Stuart 2013). Caracal are active during both day and night except for late morning and around midnight (İlemin and Gürkan 2010). They were significantly more active on colder nights (< 20° C; Avenant and Nel 1998).

RESULTS

A total of 37 presence points from photo-captures of caracal were used to build up the species distribution model. During the 2018 field survey only one photo-capture of caracal was recorded from Ranthambhore tiger reserve, rest of the points used in the analysis were collated from long-term tiger ecology project in Ranthambhore TR and from earlier observations in Kachchh, Gujarat (Y.V. Jhala, unpublished data). Photo-capture and observation location data used for subsequent modeling are given in Figure 9.1. Data and parameters of the MaxEnt model are provided in Table 9.1 and modelled distribution of caracal in the potential historical distributional range (model extent) are given in Figure 9.2.

According to MaxEnt estimates of relative contribution of predictor variables (Table 9.2), human pressure contributed the most (60.9 ± 6.26%) to caracal habitat model. The response curve suggests that caracal avoid highly disturbed landscapes, but can tolerate low human disturbances (Figure 9.3). Caracal habitat was further defined by ruggedness (19.07±4.17%), where species used areas with moderate rugged terrain (Figure 9.3). The third most important variable was aridity index (13.19 ±2.06%) wherein the semi-arid areas were found most suitable for caracal (very arid regions of the Thar Desert of Rajasthan were not included as model space for MaxEnt). The response curves of precipitation of driest month (model contribution 5.17±2.28%) and NDVI of April (model contribution 9.87±5.45%) suggests that the caracal occurs in areas with low rainfall (less than 5cm in the driest month) and less vegetation cover (dry forest/savanna habitats) (Figure 9.2). These model responses are in consonance with available literature on the historical and the present distribution of caracal in India (Khandal et al. 2020).

Figure 9.1. Caracal occurrence locations from camera trap photo-captures 2010 to 2018 and Jhala Pers. Comm.

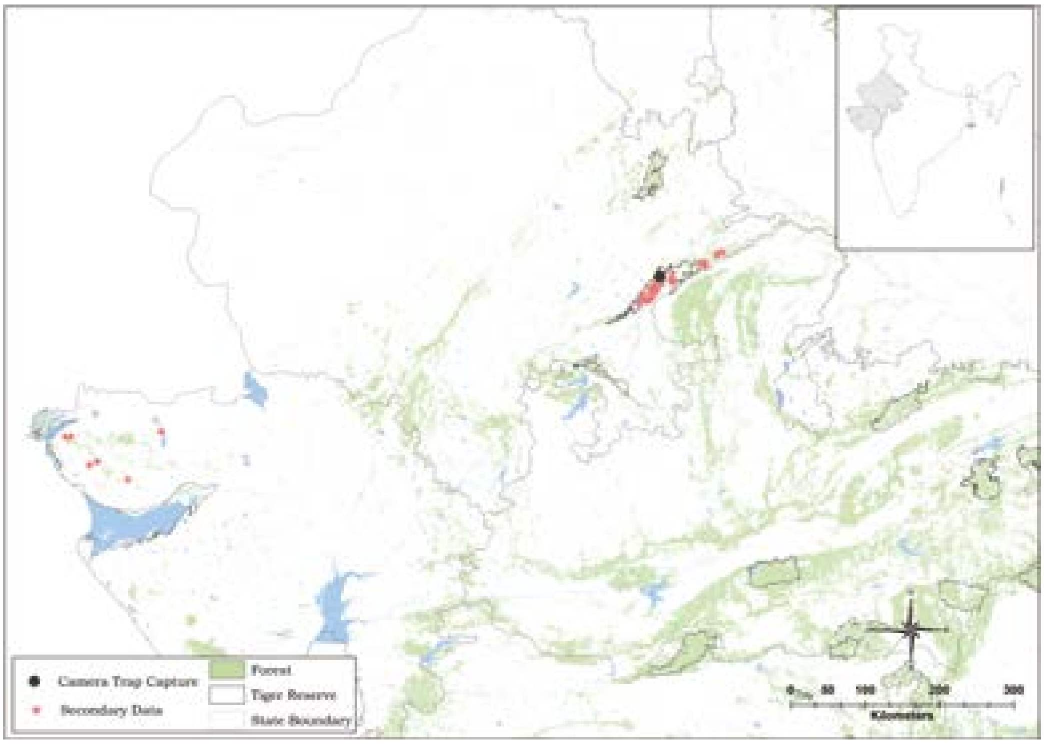


Figure 9.2: Distribution of caracal across the forested areas of India developed from the presence obtained by camera trapping and environmental covariates

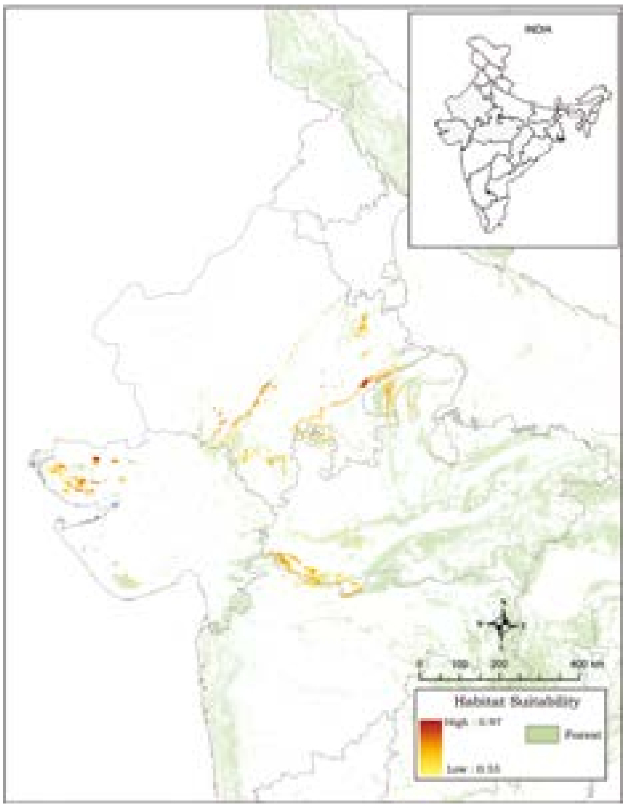


Figure 9.3: Relationship of caracal with A) Human disturbance, B) Ruggedness, C) Aridity index, D) Precipitation of the driest month (cm) and E) Normalized Difference Vegetation Index (NDVI) April

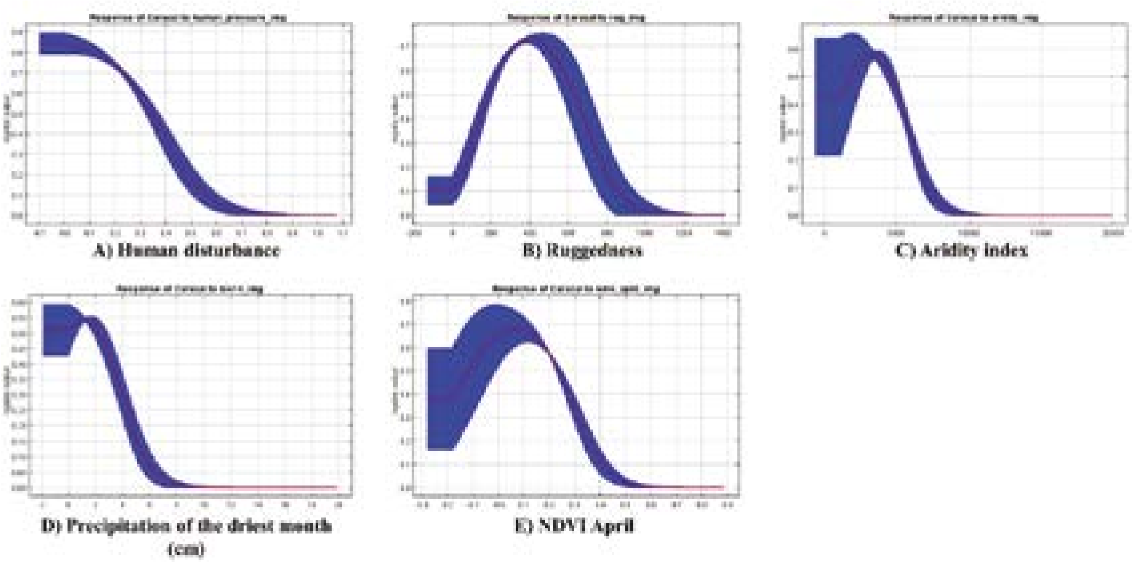


Table 9.1: Parameters used in MaxEnt setting for modelling the Caracal distribution/habitat in the study area

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.54
Area under the ROC* Curve (AUC)	0.96

Table 9.2: Contribution percentage of every covariate (± SD) to the best model explaining distribution of caracal

Covariates	Percent contribution (SD)	Permutation contribution (SD)
Human disturbance	60.9 (6.26)	57.51 (11.63)
Ruggedness	19.07 (4.17)	9.87 (5.45)
Aridity index	13.19 (2.06)	29.08 (7.42)
Precipitation of the driest month	5.17 (2.28)	0.21 (0.51)
NDVI April	1.66 (1.35)	9.87 (5.45)

Conservation significance

The caracal is probably the most endangered cat in India. If focused conservation efforts are not commenced on the species the caracal is likely to become extinct in India within this decade. Due to their large home ranges, caracal naturally occur at low density making conservation of large areas necessary to hold viable populations. Adult mortality caused by humans (poisoning, road kills) is mostly non-compensatory and pushes small populations into the extinction vortex. Strict protection needs to be enforced in their known range (Ranthambore National Park, Kailadevi parts of Ranthambore Tiger Reserve, and in Abdasa, Nakhatrana, Bhuj, Mandvi and Bhachau taluka's of Kachchh). Here the illegal use of poison for killing wolves also kills non target species like the caracal. Development of highways in caracal habitats of Kachchh and Rajasthan have been a major cause of population declines not only of caracal but also of wolves. Any new roadways in the caracal habitat will be like a death knell for the species. Animal passages can be designed and implemented for forest dwelling wildlife to reduce the impact of roads on them. However, caracal and wolves are likely to cross roads anywhere and no amount of mitigation can prevent mortality of these species caused by speeding traffic. A study on genetic differences between African/Arabian and Indian caracal needs to be undertaken urgently. If differences are not substantial then African caracal preferably from Northern Africa or Arabian Peninsula (Israel) need to be sourced to supplement Indian populations at secure caracal conservation designated areas (well protected and devoid of fast traffic roads). Areas being developed for cheetah reintroduction would do very well for caracal conservation as well. However, if African/Arabian caracal cannot be used for supplementation (due to genetic or logistical reasons) then a conservation breeding program of Indian caracal needs to commence urgently. Care should be taken to source individuals from the wild in a manner that will not result in jeopardizing the survival of the already depleted source populations. Professional biologists need to be involved for this assessment as well as for capture and breeding of caracal. Once a founding population is established, the conservation bred kittens meant for release into the wild should be >1 year of age and trained to hunt and avoid humans and predators. A dedicated conservation breeding facility in the caracal's range that has been made safe for the species reintroduction/supplementation needs to be established.

CHAPTER 10:
CLOUDED LEOPARD
(NEOFELIS NEBULOSA)

INTRODUCTION

Conservation status

IUCN Red List: Vulnerable (VU)

Wildlife (Protection) Act, 1972: Schedule I

The clouded leopard is a locally endangered semi-arboreal medium size felid with a wide distribution in tropical forests of southern and southeast Asia, including the islands of Sumatra and Borneo in the Indonesian archipelago (Nowell and Jackson 1996). They are found south of the Himalayas in Nepal, Bhutan, some areas of northeastern India and southeastern Bangladesh, Myanmar, southern China, Taiwan, Vietnam, Laos, Cambodia, Thailand, and Malaysia make up its geographic range (Grassman et al. 2016). Clouded leopards from the Sunda islands were classified as a distinct species *(Neofelis diardi)* (Buckley-Beason et al. 2006).

In India, clouded leopards occur in the states of Sikkim, Bihar, northern West Bengal. Assam, Meghalaya, Manipur, Tripura, Nagaland, and Arunachal Pradesh (Katti et al. 1990, Choudhury 1992, 1996, 1997, 2003, Ghose 2002, Borah et al. 2010, 2014, Sathyakumar et al. 2011, Mukherjee et al. 2019, Shafi et al. 2019).

Clouded leopards are a common species involved in illegal wildlife trade (Oswell 2010, Nijman and Shepherd 2015). Poaching and hunting for pelt and body parts and live animals for the pet trade (Hunter 2011) are common. Clouded Leopards prefer closed forests (Grassman et al. 2005, Austin et al. 2007), and their habitats in Southeast Asia are undergoing rapid deforestation for the agriculture timber industry, and oil palm plantations (1.2-1.3% a year since 1990: FAO 2007).

SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Clouded leopard, a felid of intermediate size between large and small cats, is the smallest of the big cats in the Indian subcontinent. Two distinct morphological groups primarily differing in their size of cloud markings have been reported by Kitchener et al. (2006). Several features in the clouded leopard skull hitherto considered exclusive characteristic of sabertooth felids have been reported by Christiansen (2006). Coat color of the clouded leopard varies from warm ochraceous or pale rich yellowish to grey or earthy brown. The coat has a distinctive elliptical cloud-like pattern, which is formed by dark blotches bordered by black. Two broad cheek stripes are associated with narrower bands or elongated spots running from between the ears to the shoulders. A very long tail, equal to the head and body length, is patterned with imperfect rings and a black tip (Hunter 2011, Menon 2014, Grassman et al. 2016).

Body size:

Head and body length: 68.6 - 94 cm, Tail length: 60- 92 cm (Hunter 2011)

Body weight:

11-23 kg (Holmes 2009)

Gestation period:

87-99 days (captivity) (Nowell and Jackson 1996, Mukherjee 1998)

Litter size:

2-3 (Holmes 2009)

Life span:

11 years in the wild (Holmes 2009), maximum 17 years in captivity (Hunter 2011)

ECOLOGY AND BEHAVIOUR

Earlier considered to be restricted in primary evergreen tropical rainforest, recent studies have recorded occurrence of clouded leopards from much broader habitat range viz. tropical dry and deciduous forest, moist deciduous forest, secondary and logged forest, mangroves, and scrub (Mukherjee 1998, Menon 2014, Grassman et al. 2016). Generally, they occur up to an elevation of 3,000 m; however, they have been camera trapped at an altitude of 3,720 m in Sikkim (Sathyakumar et al. 2011).

Diet of this felid includes a variety of arboreal and terrestrial mammals such as slow loris and other primates, Asiatic brush-tailed porcupine, ground squirrel, and other rodents, hog deer, barking deer, etc. (Davies 1990, Nowell and Jackson 1996, Mukherjee 1998, Grassman et al. 2005, Feng et al. 2008).

Believed to be solitary animals; although groups of three individuals were recorded from Arunachal Pradesh in recent camera traps (Jhala et al. 2020) which were likely mother and grown up cubs. They are primarily nocturnal with crepuscular activity peaks (Grassman et al. 2005, Austin et al. 2007). Radio-telemetry studies in national parks in Southeast Asia have found that male and female clouded leopards have ranges that are similar in size. Clouded leopards have a home range that is of 30 to 40 km², with a core area of 3 to 5 km² (Grassman et al. 2005, Austin et al. 2007). Male and female home ranges overlap substantially.

RESULTS

A total of 77 independent photo captures were recorded during the camera-trap field sampling revealing their higher encounters in moist deciduous evergreen forests habitats of Buxa, Manas, Pakke, Nameri, Kaziranga, Dibang, Kamlang, Namdhapa, Intanki, and Dampa (Figure 10.1) covering biogeographic provinces 8A (Bramhaputra valley), 8B (Assam hills), 2D (Eastern Himalayas) and 7B (Lower Gangetic plains). Proportion of time spent active by clouded leopard was 0.56 (SE 0.08) and it had photo-captures throughout the day but had activity peak at dawn and a drop in activity at noon (Figure 10.2), majority of the activity being nocturnal. Data used and parameter settings of MaxEnt that used photo-capture intensity and eco-geographical covariates to model occurrence of rusty spotted cat are provided in Table 10.1.

Figure 10.1: Presence locations and intensity of photo-captures of clouded leopard obtained from camera traps in 2018-19

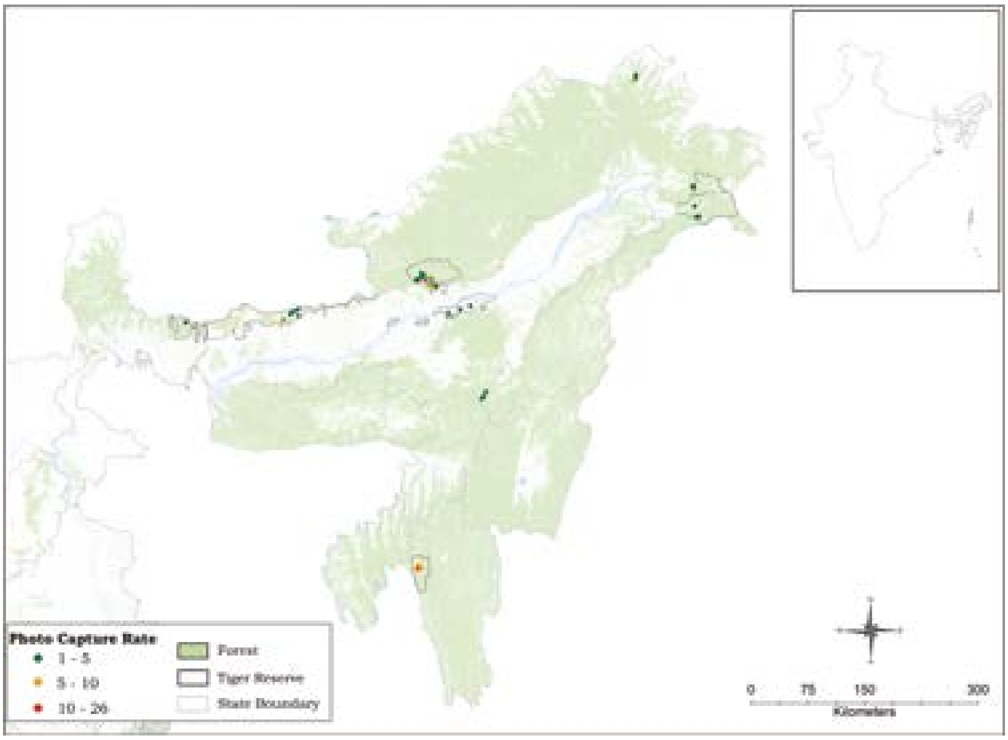
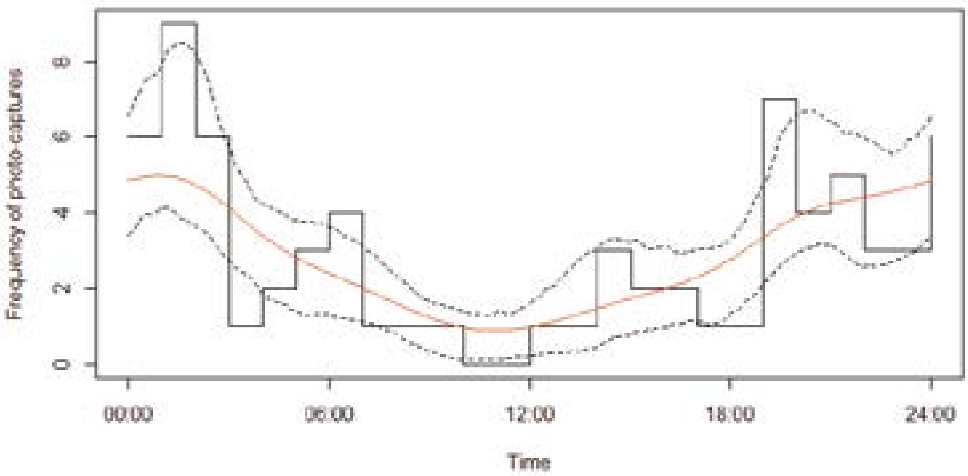


Figure 10.2: Activity pattern of clouded leopard obtained from camera trap photo-captures (N= 77) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day



Maximum contribution (57.5 SD 10.52%) to clouded leopard habitat model was by elevation (Digital Elevation Model) shows Clouded leopards preferred productive valley habitats compared to higher elevations. The species occurrence/habitat was further defined by areas that have low human pressure (25.5 SD 11.11%), and evergreen forests - NDVI April (17 SD 11.58%) (Table 10.2, Figure 10.3). Probability of occurrence within the forested habitats of tiger states based on the best MaxEnt model is given in Figure 10.4.

Table 10.1: Parameters used in MaxEnt setting for modeling clouded leopard distribution/habitat in the forested landscapes of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.60
Area under the ROC* Curve (AUC)	0.825

**receiver operating characteristic*

Table 10.2: Contribution percentage of every covariate (SD) to the best model explaining clouded leopard distribution

Covariates	Percent contribution (SD)	Permutation Importance (SD)
DEM (Digital Elevation Model)	57.5 (10.52)	66 (8.61)
Human pressure	25.5 (11.11)	27.4 (8.73)
NDVI April	17 (11.58)	6.6 (6.45)

Figure 10.3: Relationship of clouded leopard with A) DEM (Digital Elevation Modelling), B) Human pressure, C) The Normalized Difference Vegetation Index (NDVI April)

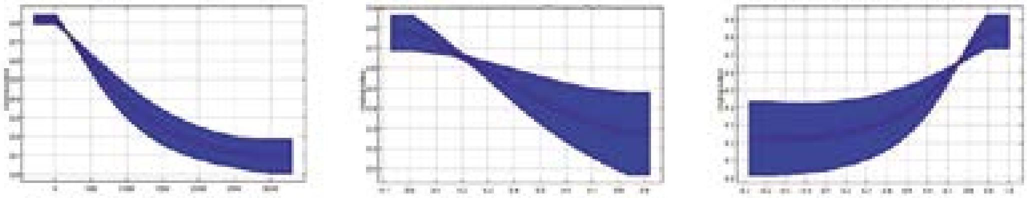
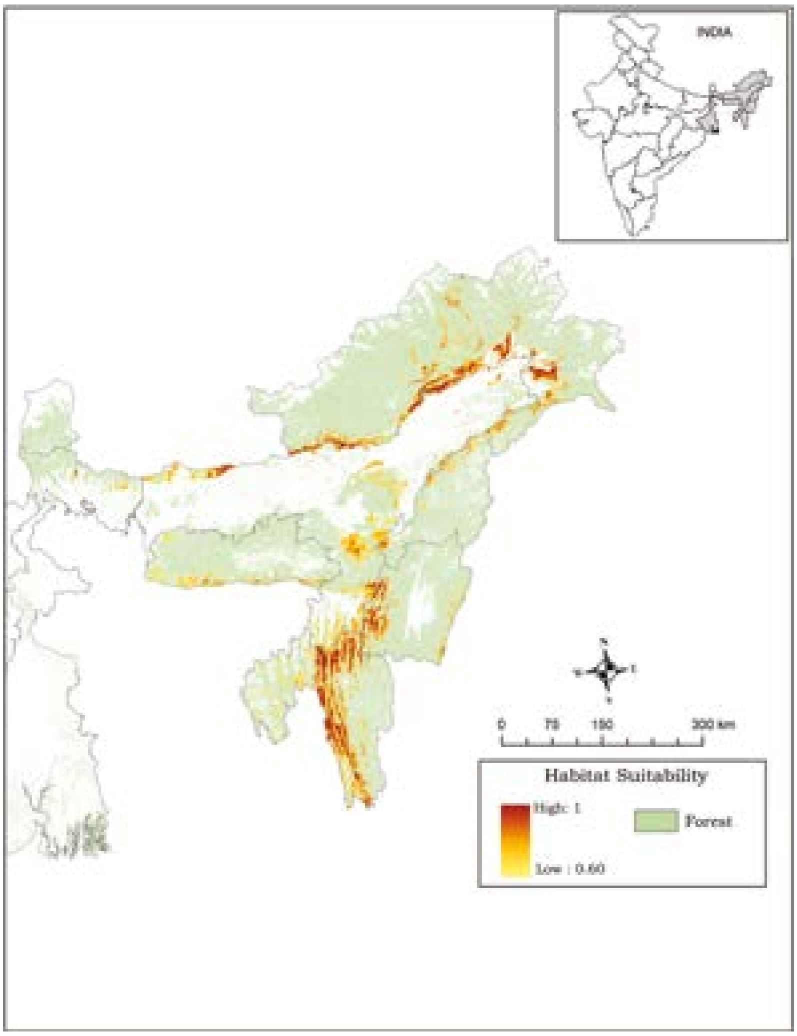
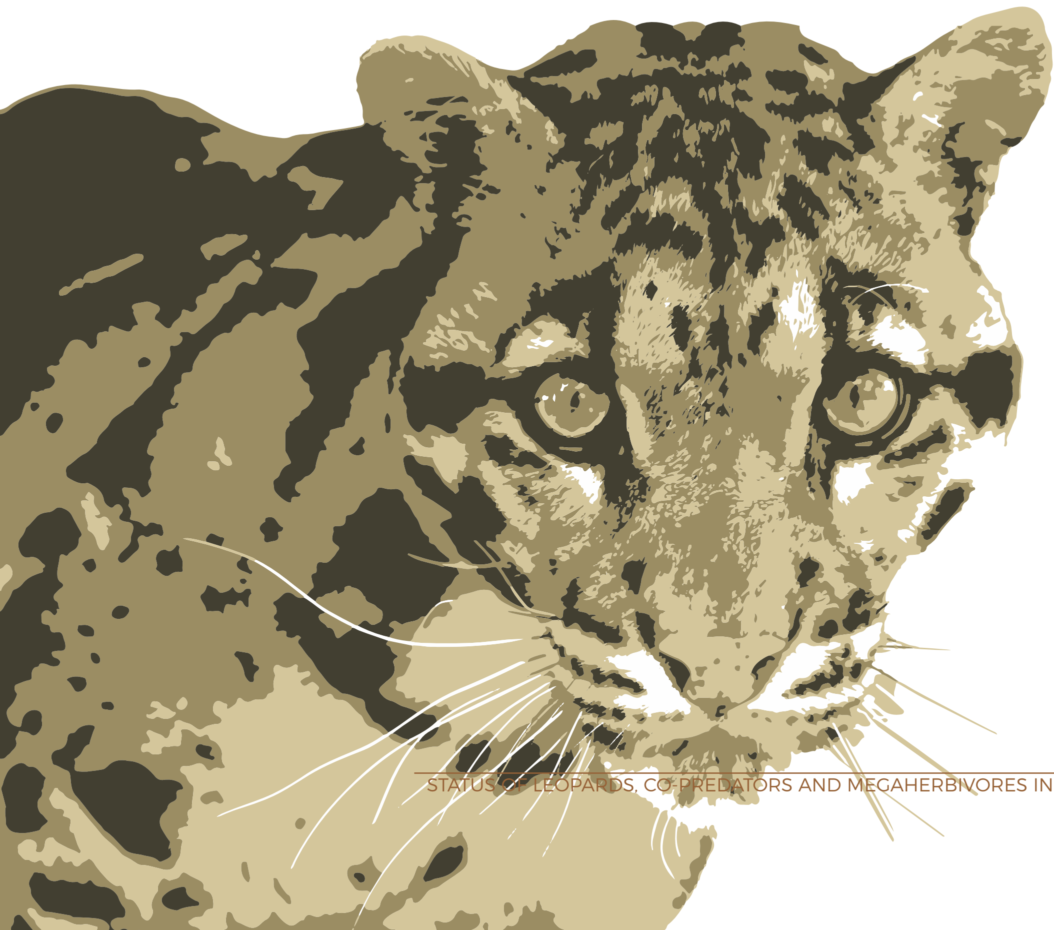


Figure 10.4: Distribution of clouded leopard across the forested areas of India estimated from presence obtained by camera traps and environmental covariates



Conservation significance

Clouded leopards were found to be more common than previously believed; this was due to the modern technique for obtaining occurrence data through camera traps. Though the camera traps were designed to maximize photo-captures of tigers, still reasonable images of the arboreal clouded leopards were obtained. Focused camera trap and telemetry based studies are required to better understand the local densities and ecology of the species for planning conservation strategies.



CHAPTER 11:
DESERT CAT/ ASIATIC WILD CAT *(FELIS SILVESTRIS)*

INTRODUCTION

Conservation status
IUCN Red List: Least Concern (LC)
Wildlife (Protection) Act, 1972: Schedule I

Asiatic wild cats (also known as desert cat) are found in the Middle East, southern Russia, Kazakhstan, western China, southern Mongolia and western India (Nowell and Jackson 1996, Driscoll et al. 2007). The species is distributed throughout the central Indian highlands (Jhala et al. 2020), especially the semi-arid and arid zone of central and western India (Mukherjee 1998, Sharma et al. 2003, Dookia 2007, Gajera and Dharaiya 2011, Mukherjee 2013, Pande et al. 2013).

One of the biggest threats to Asiatic wildcat is hybridization with domestic cats (Yamaguchi et al. 2015). Feral domestic cats also compete with wild cats for prey and space, and there is a high potential for disease transmission between domestic cats and wild cats (Nowell and Jackson 1996, Yamaguchi et al. 1996, Daniels et al. 1999, Macdonald et al. 2004). In the past Asian wild cats were trapped in large numbers for their fur, although at present there is little international trade (Nowell and Jackson 1996). Other threats include significant human-caused mortality, especially road kills (Nowell and Jackson 1996).

SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Asiatic wild cat's fur is light sandy with small rounded spots covering its upper body (Mukherjee 1998). The cat has a long, tapering tail, ending with a short black tip and with spots at the base. The tail appears much thinner, as the hair are shorter and more close-fitting. The forehead has a pattern of four well-developed black bands (Menon 2014). Two clear, black markings are present on its cheeks and the inner sides of the forelimbs (Menon 2014). On the whole, the cat is long-legged, long-tailed and long-bodied compared to domestic cats (Wilson and Mittermeier 2009).

Body Size:
Head and Body Length 47-60cm, Tail Length; 30cm (Menon 2014)

Body Weight:
2.7-5 kg (Dewey 2005), 3-4 kg (Menon 2014)

Gestation period:
60-70 days (Dewey 2005)

Litter Size:
2-4 (Nowell and Jackson 1996)

Life Span:
11 years (Nowell and Jackson 1996), 18 years in wild (Dewey 2005)

ECOLOGY AND BEHAVIOUR

Wild cats are solitary (Menon 2014) and found in a wide variety of habitats, from deserts and scrub grassland to dry and mixed forest; absent only from rainforest and coniferous forest. It prefers to be in close proximity to water sources. It can be found in ranges up to 2,250 m above mean sea level in mountain areas with dense vegetation (Yamaguchi et al. 2015).

This species' varied diet includes hare, desert gerbils, birds, small rodents, insects and reptiles (Dewey 2005). It has been found to kill even cobras, vipers and sand boas (Abdukadir et al. 2010). Although a variety of small prey is taken, wildcats also scavenge (Nowell and Jackson 1996, Sunquist and Sunquist 2002).

For European wild cats in Italy, their home range size varied from 7-23 km² for adult males and 6 km² for adult females (Anile et al. 2017). Phelan and Sliwa (2006) found large home ranges (52.7 km² for a radio-collared female) in desert habitats of the United Arab Emirates. The species is primarily diurnal (Yamaguchi et al. 2015).

RESULTS

A total of 541 independent photo captures of Asiatic wild cat were recorded during the field sampling with high encounters in semi-arid habitats and dry mixed deciduous forests especially in Protected Areas like Ranthambhore, Sariska, Mukundara and Bandhavgarh Tiger Reserves (Figure 11.1). A total of 22 direct observations of desert cat in Thar and Kutch area were obtained from secondary data sources (Sharma and Sankhala 1984, Y.V. Jhala unpublished data). Proportion of time spent active in a day was 0.49 (Se 0.03) for Asiatic wild cat , it was most active from 19:00hrs to early dawn (05:00 hrs), showing nocturnal activity pattern (Figure 11.2). Data used and parameters of the MaxEnt model are provided in Table 11.1.

Open dry forests (i.e., moderate NDVI April) explained 59% (SD 5.78) of the variation in occurrence fo Asiatic wild cat (Table 11.2). The second most important variable was distance to nightlight (18.6, SD 7.41 %), where the Asiatic wild cat occurrences peaked at ~5km distance from night lights but declined at further distances (Table 11.2, Figure 11.3). This result suggests that Asiatic wild cats are not averse to using cultivated landscapes and can occur in proximity to human settlements. Within this climatic extent, desert cats were found in areas that have warm temperature throughout the year (11.5, SD 3.49 %) (i.e., high BIO5) and in areas nearby grasslands, (10.8, SD 4.55 %); as these in total contributed (22.3, SD 8.04 %) to the distribution model (Figure 11.3, Table 11.2). The response curves (Figure 11.3) illustrate that habitat suitability of Asiatic wild cat increase in areas with drier and warm climate having maximum temperatures beyond 400C. This result is in consonance with available literature suggesting their major distribution in central India and semi-arid regions of western India. The modeled distribution of Asiatic wild cat across the forested areas of India developed from the camera trapped presence obtained and environmental covariates in MaxEnt is given in Figure 11.4.

Figure 11.1: Presence locations and intensity of photo-captures of Asiatic wild cat obtained from camera traps in 2018-19 and secondary data.

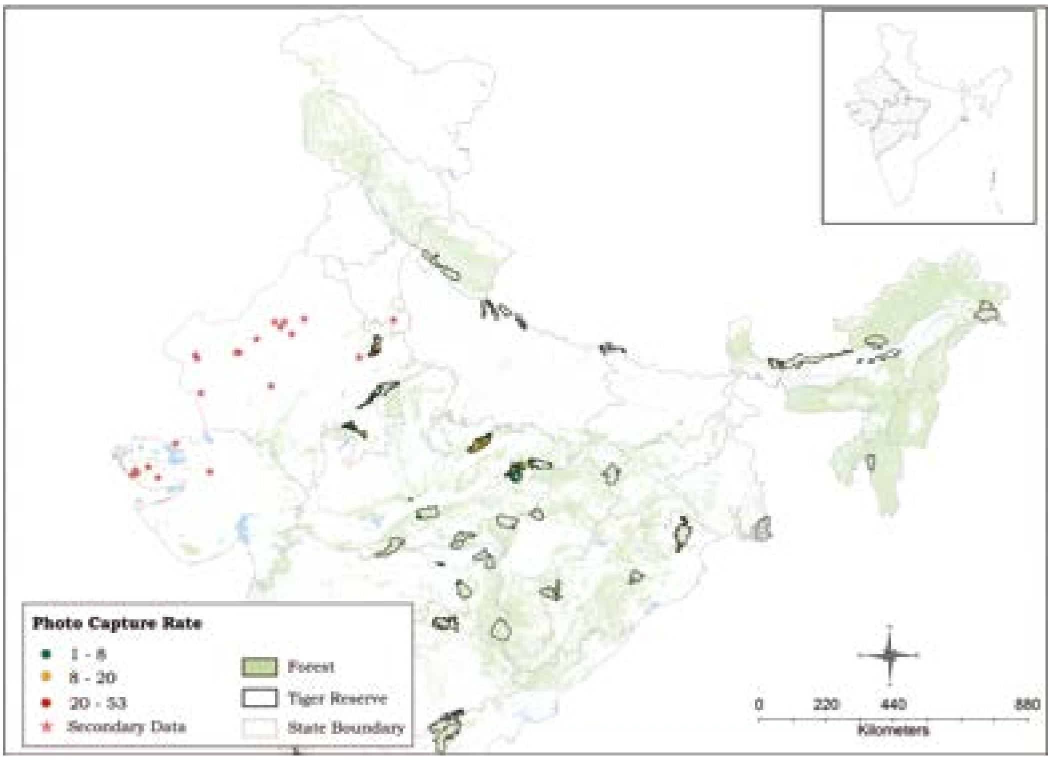


Figure 11.2: Activity pattern of Asiatic wild cat obtained from camera trap photo-captures (N=541) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

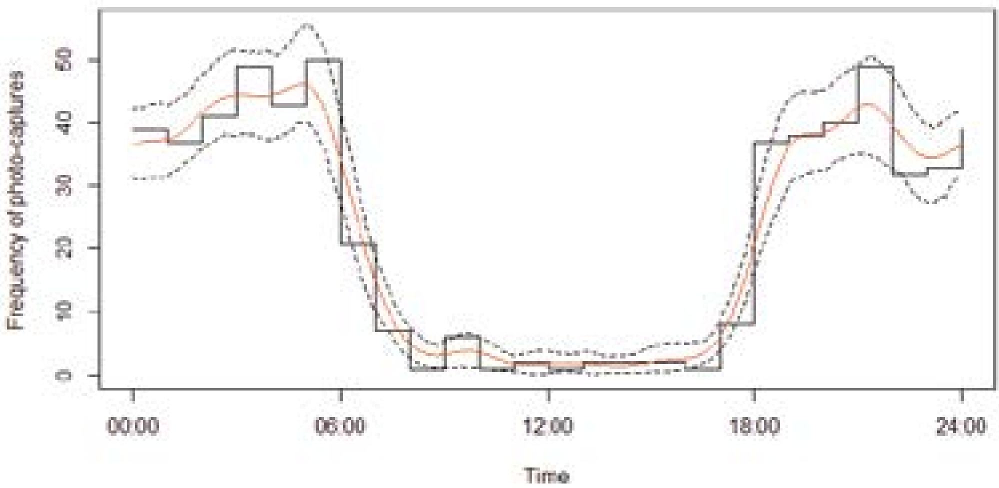


Table 11.1: Parameters used in MaxEnt setting for modelling the Asiatic wild cat distribution/habitat in the forested landscape of India

Model setting	Values
Model features	Linear and quadratic
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.54
Area under the ROC* Curve (AUC)	0.77

**receiver operating characteristic*

Table 11.1: Parameters used in MaxEnt setting for modelling the Asiatic wild cat distribution/habitat in the forested landscape of India

Covariates	Percent contribution (SD)	Permutation contribution (SD)
NDVI April (pre-monsoon)	59 (5.78)	53.6 (3.39)
Distance to nightlight (away from urban centers)	18.6 (7.41)	8.5 (3.43)
Maximum temperature of the warmest month (BIO5)	11.5 (3.49)	24.4 (4.10)
Distance to grassland	10.8 (4.55)	13.4 (4.65)

Figure 11.3: Relationship of Asiatic wild cat with A) Normalized Difference Vegetation Index (NDVI) -April (Deciduousness of forests pre monsoon), B) Distance to night light (m) (away from urban center), C) BIO5; Maximum temperature of the warmest month (°C), D) Distance to grassland (km)

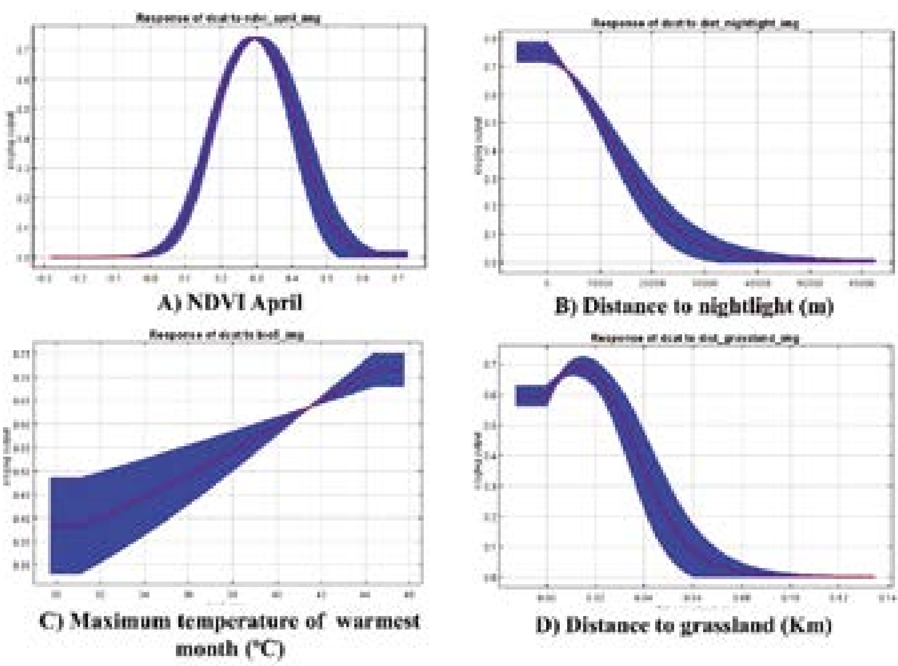
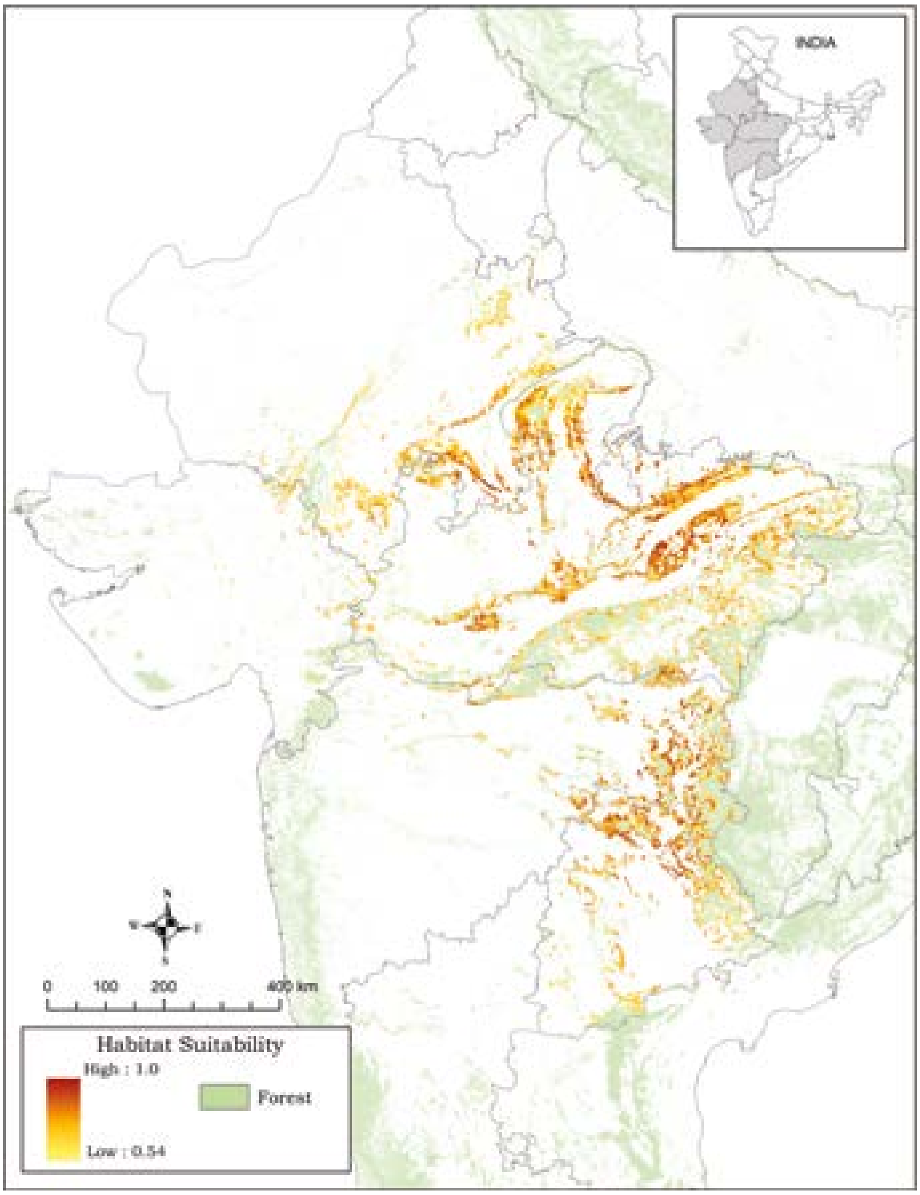


Figure 11.4: Distribution of Asiatic wild cat across the forested areas of India estimated from presence obtained by camera traps, secondary data and environmental covariates.



Conservation significance

Asiatic wild cat often referred to as the desert cat found in the Thar Desert ranges across the all-semi-arid regions of central and western India. A genetic study to identify its extent and zones of hybridization with domestic cats is required. Subsequently, conservation efforts to conserve wild genepool populations needs to be initiated. The Asiatic wild cat populations though declining are not under severe threat.

CHAPTER 12:
FISHING CAT
(PRIONAILURUS VIVERRINUS)

INTRODUCTION

Conservation status
IUCN Red List: Vulnerable (VU)
Wildlife (Protection) Act, 1972: Schedule I

The fishing cat is widely distributed in South and Southeast Asia from Pakistan in the west to Cambodia in the east, and from the Himalayan foothills in the north to Sri Lanka and peninsular Thailand in the south (Sody 1936, Melisch et al. 1996, Dahal and Dahal 2011, Edwards et al. 2012, Gray et al. 2012, Mukherjee et al. 2012, Pandey et al. 2012, Buatip et al. 2013, Than Zaw et al. 2014, Islam et al. 2015, Mishra 2016, Mukherjee et al. 2016, Ratnayaka 2016). Its distribution was probably always patchy because of its strong association with wetlands. In India, historically the species was reported from the Western Ghats and the western coast of (Pocock 1939). A molecular analysis of population connectivity in India suggested that in the past fishing cat populations within India were connected from the Terai region of the Himalayan foothills to the Coringa mangroves in Andhra Pradesh on the east coast (Mukherjee et al. 2012). Currently the species distribution is widespread but patchy, occurring inside and outside the Protected Areas from Bharatpur in Rajasthan, along the Himalayan foothills, through eastern India into Andhra Pradesh (Kolipaka 2006, Adhya et al. 2011, Mukherjee et al. 2012, Sadhu and Reddy 2013, Malla and Sivakumar 2014, Kantimahanti 2016, Jhala et al. 2020).

Destruction of wetland and floodplain habitat due to development activities and illegal hunting, commercial aquaculture and prawn farm (Mukherjee et al. 2012) are some of the threats to fishing cat around its distribution range in India. A very recent report from Howrah district of West Bengal, India reveals rampant killing of the species outside protected areas in human-dominated landscapes for consumption as part of a cultural practice (Adhya 2015). In some parts of its range, the species is killed in retaliation for damaging fishing nets (Thaung and Herranz Muñoz 2016).

SPECIES DESCRIPTION & LIFE HISTORY TRAITS

Fishing cat is a mid-sized cat with short legs, a big broad head and an olive grey coat. It has black elongated spots running in parallel lines over its back, forming stripes along the spine and neck. It has two darker stripes on the cheeks and its eyes are ringed with white fur. The ears are round and short with black backs and prominent white spots in the middle (Phillips 1984). This species has a short thick muscular tail as compared to domestic cats. The tail is marked with series of incomplete black ring and has a black tip (Menon 2014).

Body Size:
Head and Body Length: 57–115 cm, Tail Length: 24–40 cm (Menon 2014).

Body Weight:
5–16 kg (Wilson and Mittermeier 2011).

Gestation period:
63-70 days (Sunquist and Sunquist 2002).

Litter size:
1 –4 (Sunquist and Sunquist 2002).

Life Span:
12 years (in captivity) (Cat Specialist Group 1996)

ECOLOGY AND BEHAVIOUR

Fishing cats live primarily in wetland areas, both marshes and swamps. These cats can be found in forested regions adjacent to rivers or near ponds (Hamlin 2004). They can also be found in scrub areas, reed beds, and tidal creek areas. Fishing cats have been reported in Himalayan forests at an elevation of 1,800 m. (Mukherjee et al. 2016), they have also been found at elevations as high as ~ 2,100 m. in the hilly wetlands of Sri Lanka (Thudugala 2016). Silva et al. (2020) suggests that with a tropically restricted geographic range, fishing cats will likely be able to maintain and increase their range with global warming.

The species predominantly feeds on fish and shellfish. Birds, insects, rodents, and snakes also constitute a small portion of its diet (Haque and Vijayan 1993). A conservative estimate of rodent consumption by the fishing cat suggests that each individual eats between 365 and 730 rodents per year (Adhya 2015). Fishing cats have been recorded to feed on carcasses of dogs, sheep and cattle (Finn 1929, Haque 1988).

Fishing cats are solitary and primarily nocturnal (Mukherjee 1989, Sunquist and Sunquist 2002, Lynam et al. 2013). Home range size varies in between 4-8 km^2 in females and 16-22 km^2 in males (Sunquist and Sunquist 2002).

RESULTS

A total of 2087 independent photo captures were recorded during the camera trapping exercise with high encounters in Subtropical/Tropical Mangrove Forest, Subtropical/Tropical Moist Lowland Forest (Figure 12.1). Proportion of time spent active in a day by fishing cat was 0.51 (SE 0.01), where it had maximum photo-captures from late evening to dawn, showing nocturnal activity (Figure 12.2). Data used and parameter settings of MaxEnt that used photo-capture intensity and eco-geographical covariates to model occurrence of fishing cat are provided in Table 12.1.

Maximum contribution to fishing cat' habitat model was by elevation (57.90±1.38%) and human pressure (16.10±0.64%) where predicted occurrence of the species appears in lowland areas with low human pressure (Table 12.2, Figure 12.3). Fishing cat habitat was further defined by areas that have minimum temperatures of coldest month (BIO6) (4.90, SD 0.311%), NDVI difference (9.20, SD 1.76%) and NDVI April (6.70, SD 0.77%) (Table 12.2, Figure 12.3). The response curves illustrate that habitat suitability of fishing cat decreases with high elevation, distance to water, deciduousness and human disturbances (Figure 3). Probability of occurrence within the forested habitats of tiger states based on the best MaxEnt model is given in Figure 12.4.

Figure 12.1: Presence locations and intensity of photo-captures of fishing cat obtained from camera traps in 2018-19 and published records.

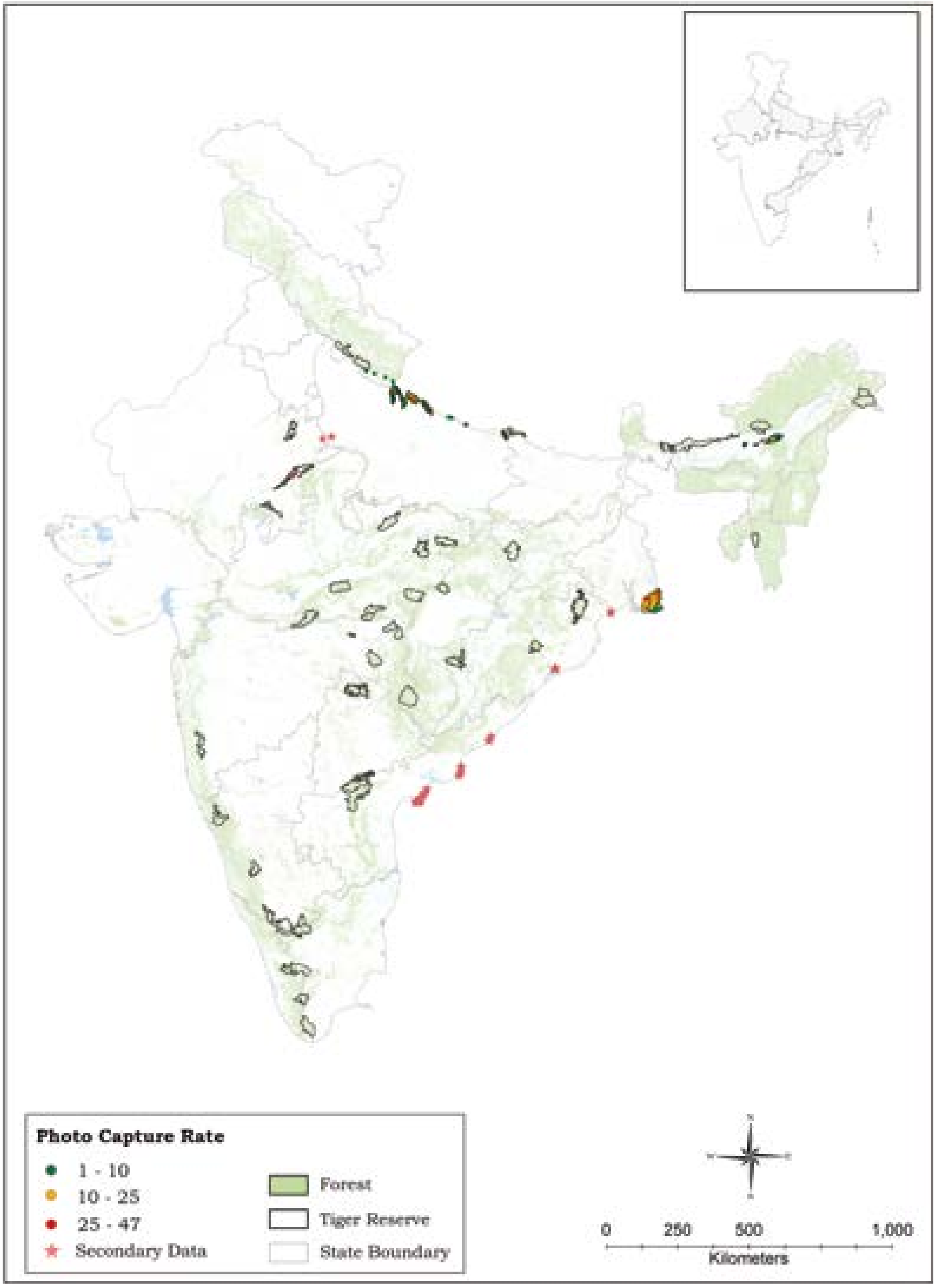


Figure 12.2: Activity pattern of fishing cat obtained from camera trap photo-captures (N= 2087) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day.

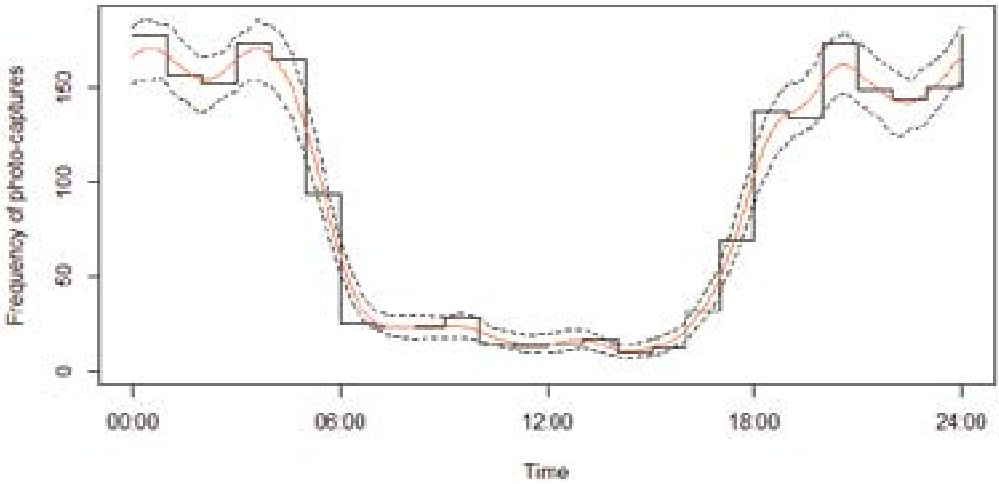


Table 12.1: Parameters used in MaxEnt setting for modelling the fishing cat distribution/habitat in forested landscapes of India

Model setting	Values
Model feature	Linear, Quadratic
Output formats	Logistic
Threshold of "maximum sensitivity plus specificity"	0.29
Area under the ROC* Curve (AUC)	0.90

**receiver operating characteristic*

Table 12.2: Contribution percentage of every covariate (SD) to the best model explaining distribution of fishing cat

Covariates	Percent contribution (SD)	Permutation contribution (SD)
Digital Elevation Model (DEM)	57.90 (1.38)	75.10 (0.42)
Human Pressure	16.10 (0.64)	8.90 (0.31)
NDVI difference (deciduousness)	9.20 (1.76)	0.10 (0.04)
NDVI April	6.70 (0.77)	3.60 (0.33)
Distance to water	5.20 (0.52)	4.30(0.27)
Minimum temperature of coldest month (BIO6)	4.90 (0.31)	8.00 (0.27)

Figure 12.3: Relationship of fishing cat with A) BIO6; Minimum temperature of the coldest month, B) Digital Elevation Model, C) Distance to water, D) Human Pressure, E) NDVI April, F) NDVI difference

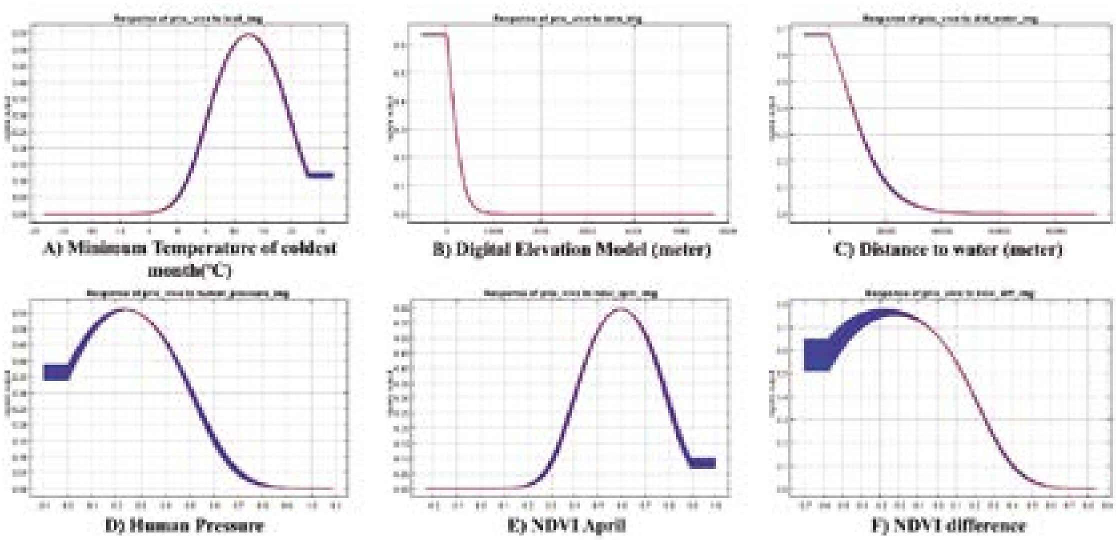
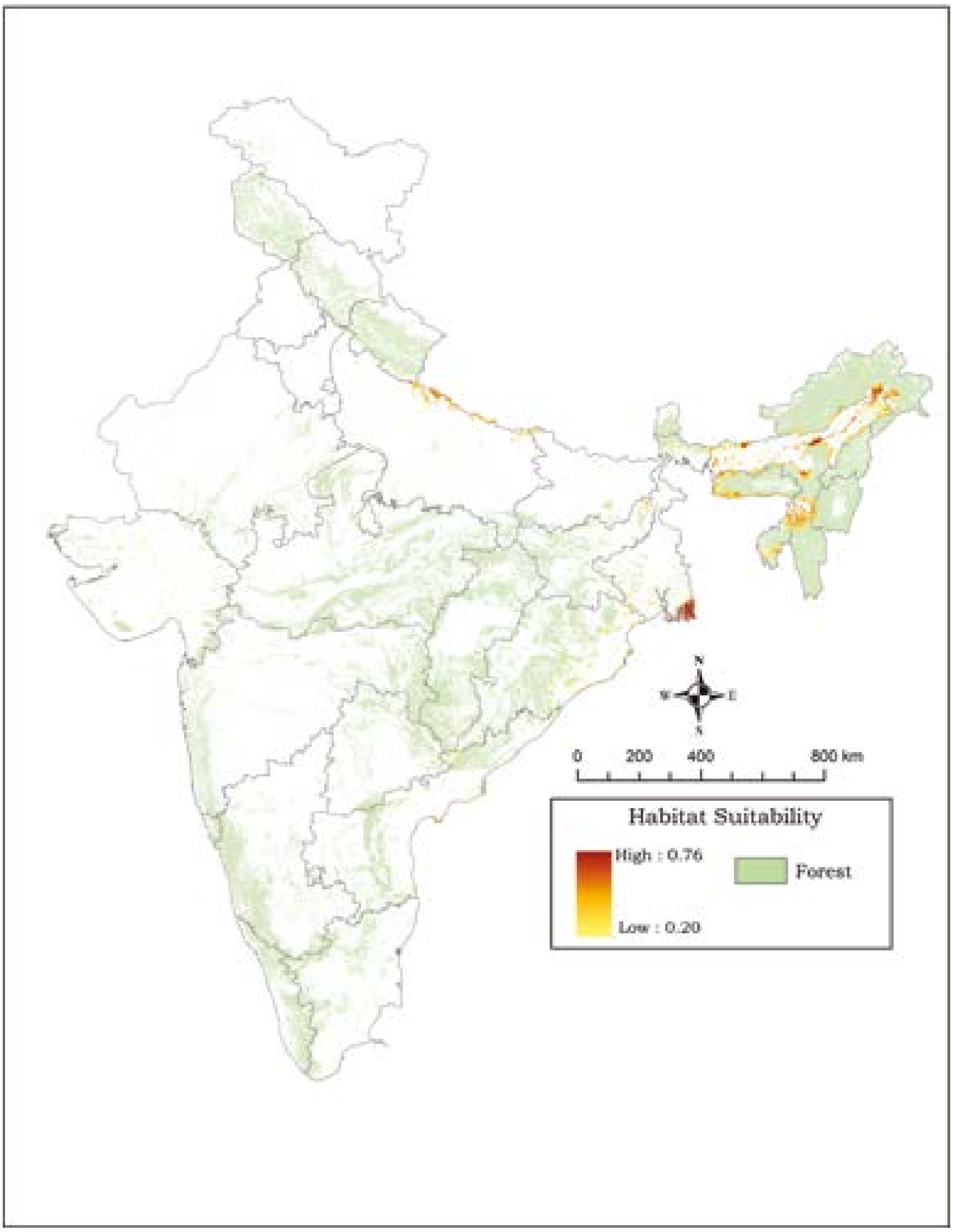


Figure 12.4: Distribution of fishing cat across the forested areas of India estimated from presence obtained by camera traps and environmental covariates.



Conservation significance

The fishing cat is primarily threatened by habitat destruction and its patchy distribution. Draining of swamps, wetlands and training of water ways for human needs will either eliminate habitat or isolated and reduce local population's sizes that will become inbred and prone to extinction events. Targeted surveys and population level study should direct conservation investments to secure populations for long-term viability.

CHAPTER 13:
ASIATIC GOLDEN CAT *(CATOPUMA TEMMINCKII)*

INTRODUCTION

Conservation status
IUCN Red List: Near Threatened (NT)
Wildlife (Protection) Act, 1972: Schedule I

The Asiatic Golden Cat is the largest wild cat among the smaller Oriental Felines except the clouded leopard *(Neofelis nebulosa)* (Bashir et al. 2011). This felid has wide distribution across twelve south and southeast Asian countries, from Nepal (Schaller 1980, Ghimrey and Pal 2009, Jnawali et al. 2011, Koju et al. 2020) and parts of China to peninsular Malaysia and Sumatra (Mukherjee 2013). Recent records within Asia and South Asia include photo-captures from Thailand (Grassman et al. 2005, Simcharoen et al. 2014), Bhutan (Wang 2007, Vernes et al. 2015, Dhendup 2016, Wangyel et al. 2020), Cambodia (Gray et al. 2014), Myanmar (Zaw et al. 2014), Lao PDR (Coudrat et al. 2014), Vietnam (Willcox et al. 2014), Sumatra and Indonesia (Pusparini et al. 2014). In India the species has been reported from central and eastern Himalayan states of West Bengal (Chatterjee et al. 2018, Ghose et al. 2019), Sikkim (Bashir et al. 2011), Assam (Chodhury 2007, Borah et al. 2013), Nagaland (Joshi et al. 2019), Mizoram (Lalthanpuia et al. 2012, Gouda et al. 2016), Arunachal Pradesh (Datta et al. 2008, Lyngdoh et al. 2011, Nijhawan et al. 2019), Meghalaya (Nadig et al. 2016) and Manipur (Government of Manipur 2018).

Poaching and hunting for consumption of meat, trade of pelt and body parts and retaliatory killing in response to poultry depredation are some of the major threats faced by the species (McCarthy 2013, McCarthy et al. 2015). Being a forest dependent species, habitat loss due to several developmental activities and hydroelectric projects and fragmentation and land conversion for agriculture also pose significant threat to the survival of the species (Nowell and Jackson 1996, Duckworth et al. 1999, Choudhury 2007, Aiyadurai et al. 2010, Pusparini et al. 2014, McCarthy et al. 2015).

SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Golden cats are medium sized wild felids with rich-russet brown pelage, however, a variety of coats have been reported, including grey, ocelot, melanistic, cinnamon and tightly rosette (Nijhawan et al. 2019). Except in the melanistic morph, a conspicuous white or buff cheek stripe often edged with dark brown to black run vertically from the crown and nostrils towards the medial side of the eye. Coat pattern of tail and legs are grey to black at distal ends (McCarthy et al. 2015).

Body size:
Head and Body Length: 66-94 cm (female), 75-105 cm (male) Tail Length: 42.5-58 cm (Hunter 2011)

Body weight:
8-15.7 kg (Menon 2014)

Gestation period:
78-80 days (in captivity) (Hunter 2011)

Litter size:
2- 4 (in captivity) (Hunter 2011)

Life span:
17 years in captivity (Hunter 2011)

ECOLOGY AND BEHAVIOUR

Asiatic golden cat inhabits a wide variety of habitat which includes tropical and subtropical moist evergreen forests, mixed evergreen forests, broad-leaved forests and dry deciduous forests, (Nowell and Jackson 1996, McCarthy 2013, Tempa et al. 2013, McCarthy et al. 2015). Several studies have reported occurrence of golden cat from more open areas such as scrub or grasslands, or open rocky areas over 3,500 m altitude and from degraded or fragmented forested habitats (Grassman et al. 2005, Wang 2007, Bashir et al. 2011, Hunter 2011, McCarthy 2013, Nijhawan et al. 2019) and human modified landscapes (Suzuki et al. 2019).

Diet of Asiatic golden cat includes rodents, ground squirrels, birds, reptiles, (Lekagul and McNeely 1977, Lim 2002) and it purportedly can hunt small ungulates such as goral and barking deer, monkeys and livestock calves (Pocock 1939, Grassman et al. 2005, Kawanishi and Sunquist 2008, Hunter 2011).

They are mainly solitary but recent camera trap photographs have shown a pair of them together (Vernes et al 2015). Home ranges of two radio collared individuals in Thailand's Phi Khieu National Park were estimated 33 km^2 and 48 km^2 for female and male respectively (Grassman et al. 2005). Earlier golden cats were thought to be nocturnal, but recent remotely sensed camera trap images from different protected areas across the globe show a diurnal and crepuscular activity pattern for the species (Grassman et al 2005, Jigme 2011, Vernes et al. 2015, Mukherjee et al. 2019, Suzuki et al. 2019)

RESULTS

A total of 36 photo-captures were recorded during the field sampling from the evergreen and broadleaved forests of north eastern hills (Figure 13.1). Proportion of time spent active in a day was 0.52 (SE 0.10) and most of the photo-captures were during early morning to noon (06:00 hrs to 12:00 hrs) (Figure 13.2). The known distribution of the species is restricted to the north-eastern India, therefore, we have considered the same extent for running species distribution model. Data used and parameter settings of MaxEnt that used photo-capture intensity and eco-geographical covariates to model occurrence of golden cat are provided in Table 13.1.

Maximum contribution to golden cat's habitat model was by human pressure (60.95, SD 15.69%) and NDVI April (15.60, SD 13.18%) where predicted occurrence of the species was influenced by forest cover and low human pressure (Table 13.2, Figure 13.3). Golden cat habitat was further defined by elevation (DEM, 9.16, SD 5.04%), minimum temperatures of coldest month (BIO6) (20.62, SD 13.89%), and ruggedness (5.82, SD 8.82%) (Table 13.2, Figure 13.3). The response curves for human pressure and NDVI April explains species preference of high canopy forests with low human disturbances (Figure 13.3). Moderately high elevation areas where temperature of the coldest month ranges from -5 to 5˚C were preferred by the species (Figure 13.3). Probability of occurrence within the forested habitats of tiger states based on the best MaxEnt model is given in Figure 13.4.

Figure 13.1: Presence locations and intensity of photo-captures of Asiatic golden cat obtained from camera traps in 2018-19

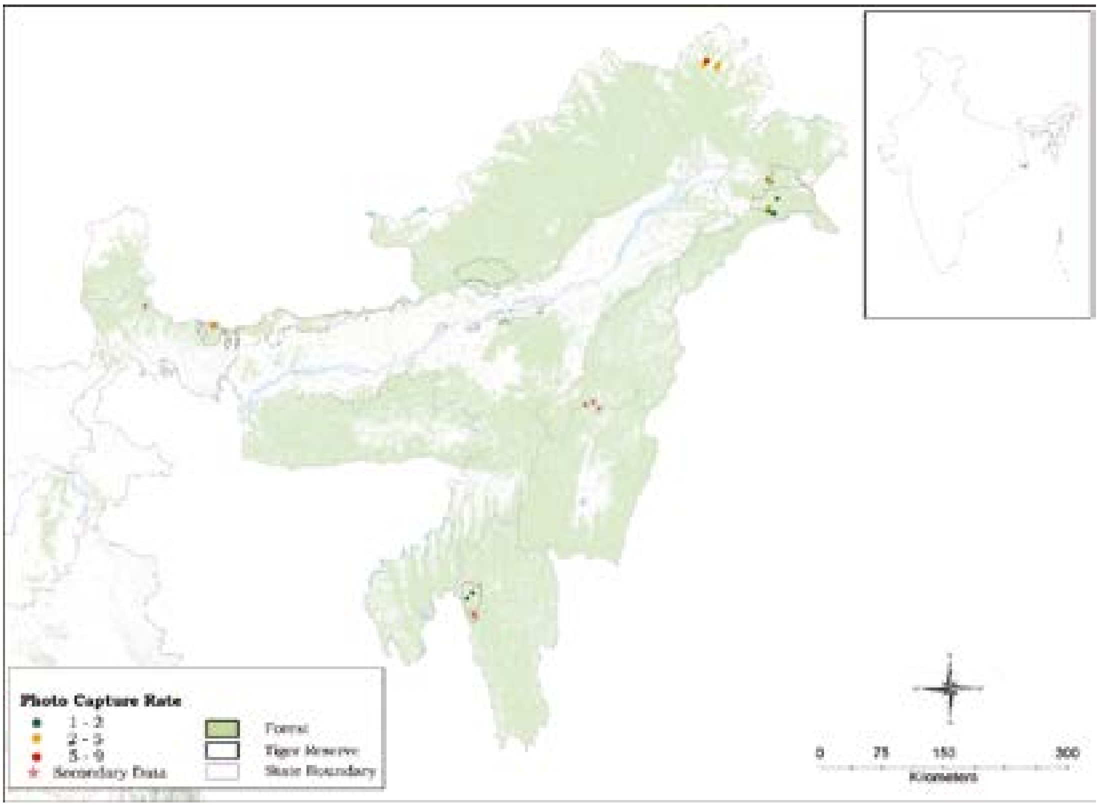


Figure 13.2: Activity pattern of Asiatic golden cat obtained from camera trap photo-captures (N= 36) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

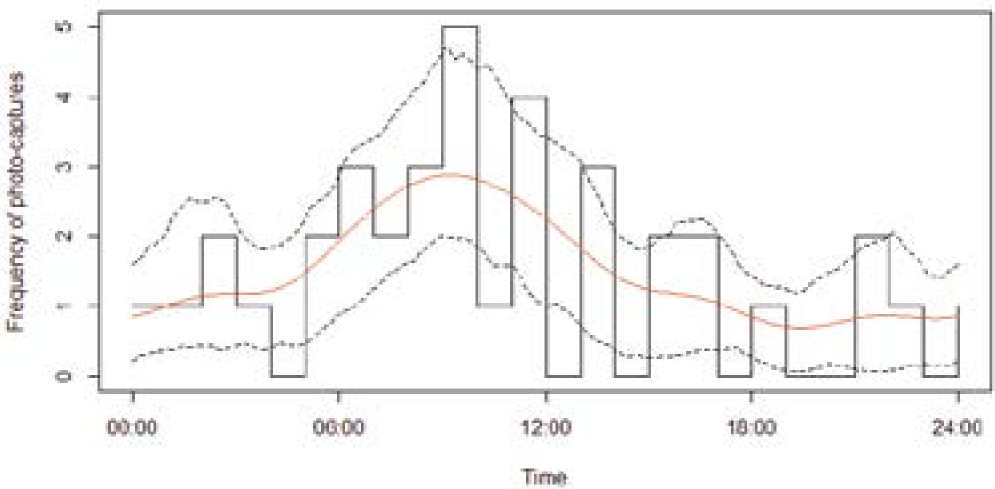


Table 13.1: Parameters used in MaxEnt setting for modelling the distribution/habitat of Asiatic golden cat in the forested landscape of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.42
Area under the ROC* Curve (AUC)	0.76

**receiver operating characteristic*

Table 13.2: Contribution percentage of every covariate (SD) to the best model explaining distribution of Asiatic golden cat

Covariates	Percent contribution (SD)	Permutation Importance (SD)
Human pressure	60.95 (15.69)	54.20 (24.25)
NDVI April	15.60 (13.18)	12.88 (18.95)
Digital Elevation Model (DEM)	9.16 (5.04)	14.82 (9.36)
Minimum Temperature of Coldest Month (BIO6)	20.62 (13.89)	9.76 (18.69)
Ruggedness	5.82 (8.82)	8.31 (13.42)

Figure 13.3: Relationship of golden cat with A) Human pressure, B) NDVI April, C) Digital Elevation Model (m), D) Minimum temperature of the coldest month (˚C), and E) Ruggedness

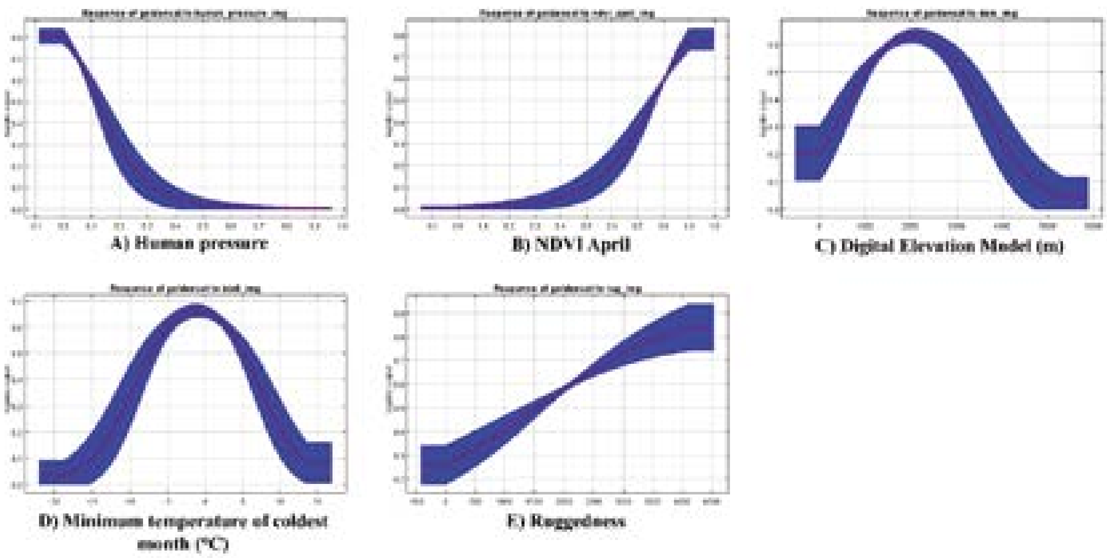
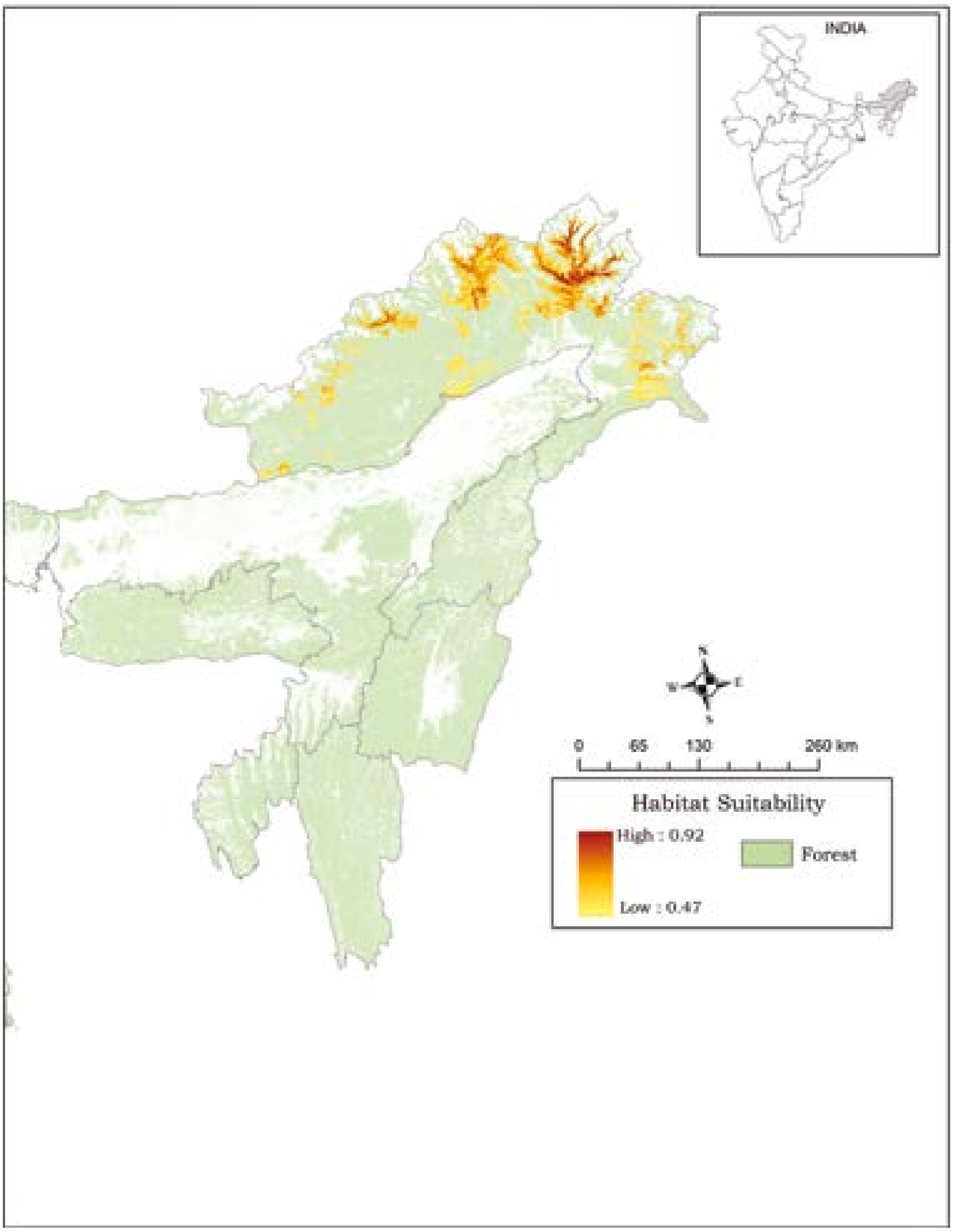


Figure 13.4: Distribution of golden cat across the forested areas of India estimated from presence obtained by camera traps and environmental covariates.



Conservation significance

An immense knowledge gap exists on Asiatic golden cat in India since no specific study has ever been conducted on this species. More targeted detailed research using modern tools and focusing the species' status, abundance, ranging, habitat use, diet and threats is required so that species specific conservation action plan can be formulated.

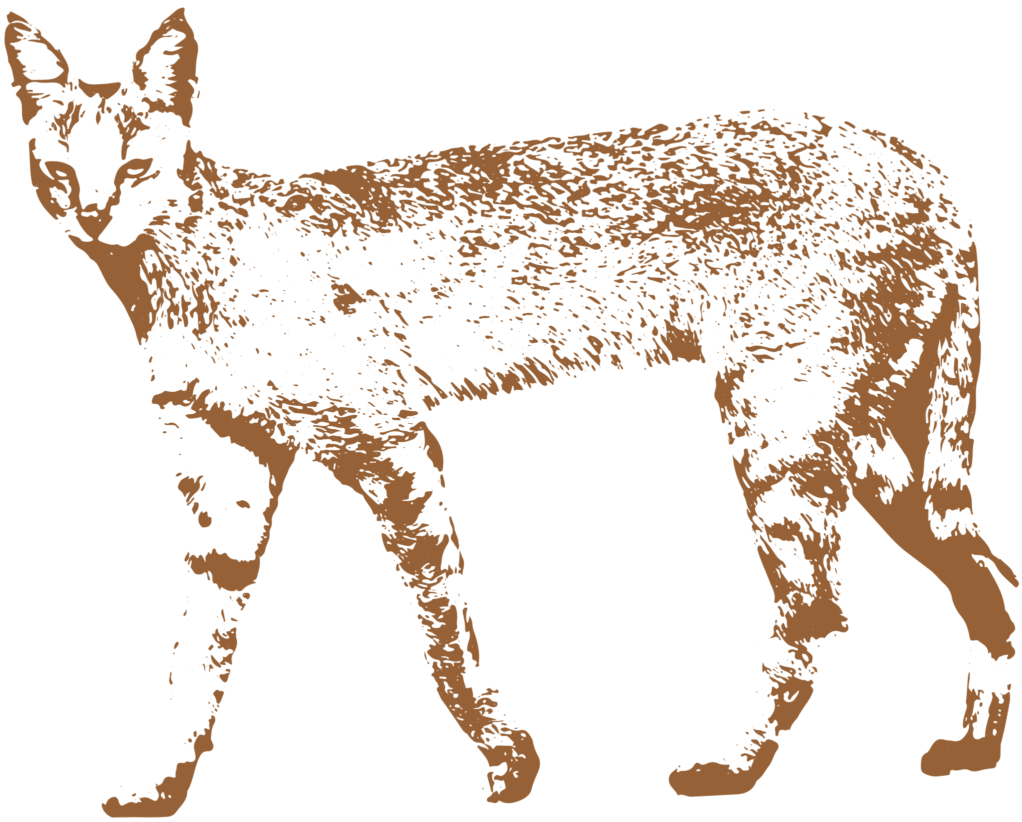
CHAPTER 14:
JUNGLE CAT *(FELIS CHAUS)*

INTRODUCTION

Conservation status
IUCN Red List: Least concern (LC)
Wildlife (Protection) Act, 1972: Schedule II, Part II

Jungle cat has a wide distribution that extends from Egypt, Israel, Jordan, northern Saudi Arabia, Syria, Iraq, Iran, to the shores of the Caspian Sea and the Volga River delta, east through Turkmenistan, Uzbekistan, Tadzhikistan, Kazakhstan and to western Xingjian (China), Afghanistan, Pakistan, Nepal, India, Sri Lanka, Myanmar, Laos, Thailand, Cambodia, Vietnam, and south-western China (Sunquist and Sunquist 2002, Mukherjee 2013).

The biggest threat for jungle cat is habitat loss due to urbanization and industrialization of low intensity agricultural landscapes and scrublands (Gray et al. 2016). Farmers often hunt and poison jungle cat for attacking and killing poultry. Reports of road mortality are also known from Iran, India, Nepal and Sri Lanka (Sanei et al. 2016, Joshi et al. 2018). Intermediate morphs between domestic and jungle cats are often encountered in rural areas and outskirts of townships giving rise to the possibility of interbreeding between these two species.



SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

The most common amongst all wild cats in India, jungle cat has generally a sandy brown, reddish or grey coloured coat without any pattern beside conspicuous stripes on the legs and occasionally on the throat. The fur has black tips while the face is slim and the muzzle has some white on it (Menon 2014). The ears are reddish on the back and tipped with small black tufts which can reach up to 15 mm in length (Prater 1971). The tail measures one third of the cat's total head and body length and has usually black rings near the posterior end; it is brownish grey on the upper and yellowish brown on the lower sides respectively. Melanistic individuals have also been reported from western India (Sahu et al. 2017).

Body size:
Head and Body Length: 60-85 cm, Tail Length 20-30 cm (Menon 2014)

Body weight:
2.5 – 12 kg (Mukherjee 2013); 4 kg (Menon 2014)

Gestation period:
63-68 days (Green 1991)

Litter size:
3-6 (Prater 1971, Heptner and Sludskii 1992)

Life span:
14-15 years in captivity (Green 1991, Weigl 2005)

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ECOLOGY AND BEHAVIOUR

Although jungle cat distribution has been reported upto 4,178 m elevation across its geographical range (Gray et al. 2016), it's occurrence up to 3,300 m in the Nepal Himalayas has been reported by Shrestha et al. (2020). However, jungle cats are common in the plains (Mukherjee 2013). A habitat generalist, it prefers habitats near water with some vegetative cover and is found in a variety of habitats including deserts, grasslands, shrubby woodlands and dry deciduous forests, as well as cleared areas in moist forests (Prater 1971, Nowell and Jackson 1996, Baker et al. 2003, Chatterjee et al. 2020a). It is commonly found in tall grass, thick brush, riverside swamps, and reed beds. It also adapts well to cultivated land and can be found in many different types of semi-urban landscapes such as agriculture, villages and forest plantations (Tikader 1983, Sunquist and Sunquist 2002, Ogurlu et al. 2010, Menon 2014). Silva et al. (2020) identified following factors to best explaining occurrence of jungle cats in India – tropical moist deciduous forest, distance to human population density, distance to railways, elevation, rodent richness and presence of larger bodied rodents.

Jungle cat primarily preys on animals that weigh less than 1 kg and commonly consume rodent, lizards, snakes, frogs, birds, hare, fish, insects, livestock, and even fruit (Baker et al. 2003, Duckworth et al. 2008, Majumder et al. 2011) Rodents are its primary prey which account for up to 70% of its daily energy intake (Mukherjee et al. 2004). Although it specializes on small prey, jungle cat has been known to kill porcupine, wild pig and chital fawn (Prater 1971, Mukherjee 2008).

The species is not social and occurs as solitary (Hunter 2015) with home ranges varying between 45-180 km² (Sunquist and Sunquist 2002, Ogurlu et al. 2010). Jungle cats are primarily crepuscular (Prater 1971) to nocturnal (Majumder et al. 2011) in their activity patterns.

RESULTS

A total of 26363 independent photo-captures were recorded during the field sampling with majority of the locations in the moderately dense forests, followed by open forests and grasslands. It was found in almost all of the sampled forests across India (Figure 14.1). Proportion of time spent active by the cat was 0.47 (SE 0.01), with maximum photo-captures during the night hours and peak in activity between 19:00hrs and 21:00 hrs, showing nocturnal activity pattern (Figure 14.2). Data and parameters of the MaxEnt model are provided in Table 14.1.

NDVI Difference (deciduousness of forests) explained (44.5, SD 2.19 %) of the occurrence data, human pressure explained (19.5, SD 1.15%) (Table 14.2). Jungle cat habitat was further defined by areas that have low or moderate NDVI April (19.2, SD 2.04 %), low ruggedness (12.7, SD 0.68 %) and aridity (4.1, SD 0.92 %) (Table 14.2). The resultant distribution was thus restricted by very arid areas in the western parts, higher human pressure across the peninsula and high terrain ruggedness (Figure 14.3). Potential suitability of smaller forest patches, savannas and grasslands in areas without protection in the semi-arid areas and Deccan peninsula shows the ability of the species to accommodate itself in the proximity to humans, provided the mosaic of its suitable habitat and human land use could co-occur. The modeled probability of jungle cat occurrence across the forested areas of India developed from photo-captures and environmental covariates are given in Figure 14.4. Jungle cat occurrence probability was high amongst tropical dry and moist deciduous forests (Figure 14.4).

Figure 14.1: Presence locations and intensity of photo-captures of jungle cat obtained from camera traps in 2018-19

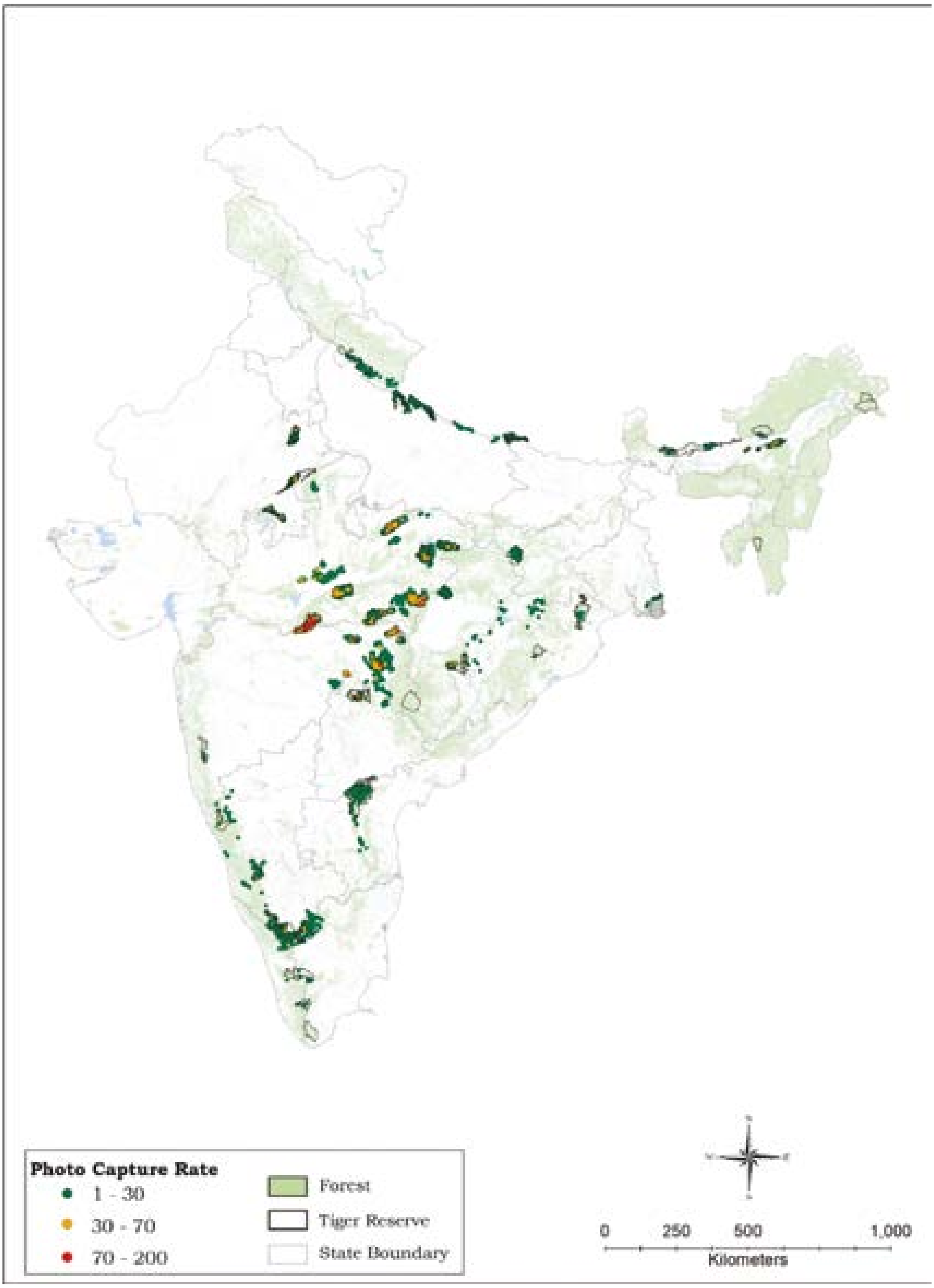


Figure 14.2: Activity pattern of jungle cat obtained from camera trap photo-captures (N= 26363) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day.

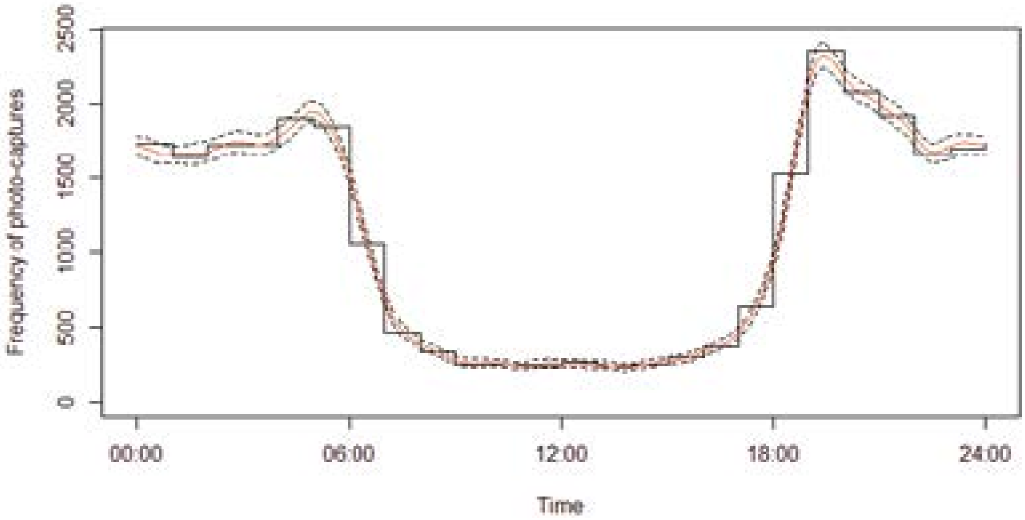


Table 14.1: Parameters used in MaxEnt setting for modelling jungle cat distribution/habitat in forested landscapes of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.43
Area under the ROC* Curve (AUC)	0.73

**receiver operating characteristic*

Table 14.2: Contribution percentage of every covariate (± SD) to the best model explaining jungle cat distribution

Covariates	Percent contribution (SD)	Permutation Importance (SD)
NDVI Difference (deciduousness)	44.5 (2.19)	29.8 (2.00)
Human pressure	19.5 (1.15)	32.1 (1.88)
NDVI April	19.2 (2.04)	1.1 (0.47)
Ruggedness	12.7 (0.68)	21.1 (1.18)
Aridity Index	4.1 (0.92)	15.9 (1.78)

Figure 14.3: Relationship of jungle cat with A) NDVI difference (deciduousness), B) Human pressure, C) NDVI April, D) Ruggedness and E) Aridity index

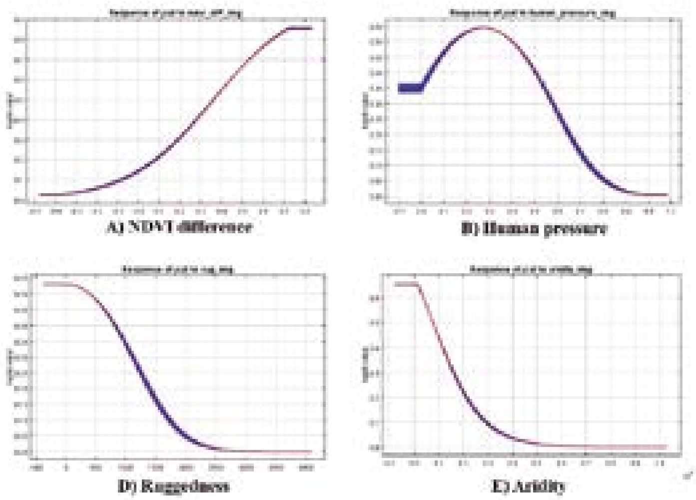
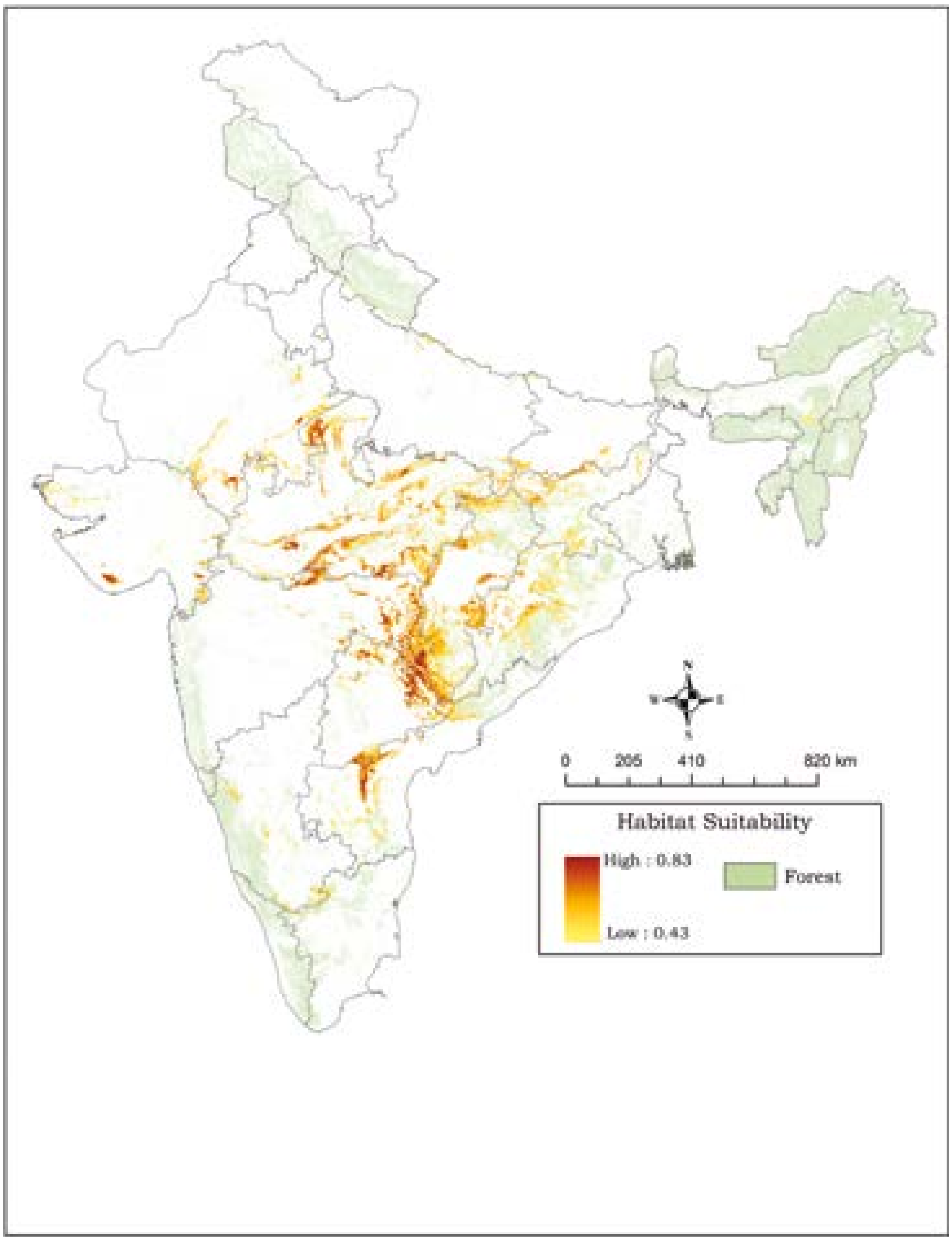


Figure 14.4: Distribution of jungle cat across the forested areas of India estimated from presence obtained by camera traps and environmental covariates.



Conservation significance

Due to a wide habitat and diet spectrum and its ability to adapt to human modifications of their habitat, jungle cats are under no major threat. A study on their genetics and potential problem of hybridization with domestic cats needs to be investigated to identify extent and populations with hybridization. Due to their close proximity to humans, jungle cats would be susceptible to diseases contracted from feral cats and dogs and could potentially act as dispersal agents for these pathogens between wildlife and domestic/feral animals.

CHAPTER 15:

LEOPARD CAT *(PRIONAILURUS BENGALENSIS)*

INTRODUCTION

Conservation status
IUCN Red List: Least Concern (LC)
Wildlife (Protection) Act, 1972: Schedule I

Leopard cat is one of the most widespread felids in Asia, and can be found throughout most of south and southeast Asia, Sunda Islands, and up to the Amur region in north. It ranges across eastern Afghanistan, northern Pakistan, northern and coastal India, Nepal, Eastern China, Korea, Myanmar, Lao PDR, Thailand, Cambodia, Vietnam, Taiwan, parts of the Philippines, Borneo, Malaysia, Sumatra, Java, Bali, and Indonesia (Ross et al. 2015). Within India, the species is distributed throughout the Himalayan foothills and Terai, across the entire Northeast, along the coastal areas of Bengal (Sundarbans), Odisha, Andhra Pradesh and in the Western Ghats. It is absent in the arid parts of Rajasthan and Gujarat and most parts of the Deccan Peninsula (Menon 2014). The Western Ghats population is geographically isolated due to a climate barrier (Mukherjee et al. 2010) but holds good density of leopard cats (Srivathsa et al. 2015).

Leopard cats are poached for fur (coat) and bones (used for local traditional medicine) (Nowell and Jackson 1996) and often kept as pets and interbred with domestic cats, particularly in the Western countries, to make the popular Bengal breed (Ross et al. 2015).

SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Leopard cat is about the size of a large domestic cat. In general, it has brownish buff to ochre coat with a white belly (Menon 2014). Body and tail are covered with rosettes and the tail is often ringed at the tip. The small head is marked with two prominent dark stripes, while the muzzle is short, narrow and white. There are two dark stripes running from the eyes to the ears, and smaller white streaks running from the eyes to the nose (Phillipps and Phillipps 2016). Melanistic forms have been reported from the Sundarbans.

Body size:
Head and Body Length: 45-75cm, Tail Length:19.5-31.5cm (Menon 2014)

Body weight:
2-7 kg (Mohamed et al. 2013)

Gestation period:
65 to 72 days (Fauzi et al. 2018)

Litter Size:
1-4 (Fauzi et al. 2018)

Life span:
4 years in wild and up to 20 years in captivity (Nowak 2005, Miller 2011).

ECOLOGY AND BEHAVIOUR

Leopard cats range up to 3,240 m above sea level (Ghimirey and Ghimire 2010) and occur in a wide variety of habitats from tropical rainforest to temperate broadleaf and, marginally in coniferous forest, as well as shrub forest and successional grasslands (MacDonald and Loveridge 2010, Ross et al. 2015). Their distribution is limited to areas with less than 10 cm of snow annually, and they are not found in steppe, arid and hot climates (Sunquist and Sunquist 2002). It mostly prefer moist, relatively thick canopied forests which are protected from human disturbances (Silva et al. 2020). It is an exceptional swimmer, possibly explaining its distribution on islands, and is intolerant of high temperatures (exceeding 40˚ C), possibly explaining its absence from central India (Miller et al. 2011, Mukherjee 2013).

Leopard cats mainly subsists on small mammals such as rodent, but it also feeds on reptiles, amphibians, birds and insects (Rabinowitz 1990, Grassman et al. 2005, Rajaratnam et al. 2007). Eels and fish have also been reported in its diet, as well as occasional scavenging of carcasses (Nowell and Jackson 1996). Adults are capable of catching larger prey, such as hare and fawns (Miller 2011).

Leopard cats are solitary (Nowak 2005) with home range sizes of about 4.1 km² to 2.5 km² for males and females respectively (Grassman 2000). Large home ranges of ~13 km² have also been reported (Grassman et al. 2005). Leopard cats are predominantly nocturnal (Lynam et al. 2013, Mukherjee 2013, Chen 2016), with crepuscular peaks in some areas (Grassman et al. 2005). In the Indian Terai, diurnal activity has also been recorded (Saxena and Rajvanshi 2014).

RESULTS

A total of 4404 independent photo-captures were recorded during the field sampling with higher captures in moist deciduous forest, open semi-evergreen forests, moist grasslands, and mangrove forests. Predominantly occurring in protected areas like Corbett, Valmiki, Kaziranga, Sundarbans, and Nilgiri Forest Division (Figure 15.1). Proportion of time spent active in a day was 0.46 (SE 0.01) for leopard cat and it was primarily found to be active at night with maximum activity between 20:00 hrs and 02:00 hrs (Figure 15.2), showing nocturnal behaviour.

Data used and parameter settings of MaxEnt that used photo-capture intensity and eco-geographical covariates to model occurrence of rusty spotted cat are provided in Table 15.1. Maximum contribution (51.4 ± 2.70%) to species habitat model was by deciduousness (NDVI difference) where the species occurrence was high in the forests having no change in vegetation during pre-monsoon and post-monsoon, mainly evergreen kind of forest with high rainfall (Table 15.2, Figure 15.3). Species habitat was further defined in areas that have a high normalized difference vegetation index during April (NDVI of April month) (30.6 ± 3.01 %) and less disturbance (distance to nightlight, 8.9 ± 1.45 %). Within this climatic extent, leopard cats were found in forests that are moist with milder temperature and high rainfall (Table 15.2, Figure 15.4). The resultant distribution was thus restricted to the wet forests of the Western Ghats, moist deciduous forests of the Central India, and the Shivalik-Terai forests; within the northeastern parts of India, species occurred in alluvial grasslands of the Brahmaputra plains, wet tropical forests, and mountain top grasslands (Figure 15.4). Probability of occurrence within the forested habitats of tiger states based on the best MaxEnt model is given in Figure 15.4.

Figure 15.1: Presence locations and intensity of photo-captures of leopard cat obtained from camera traps in 2018-19

Figure 15.2: Activity pattern of leopard cat obtained from camera trap photo-captures (N= 4404) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

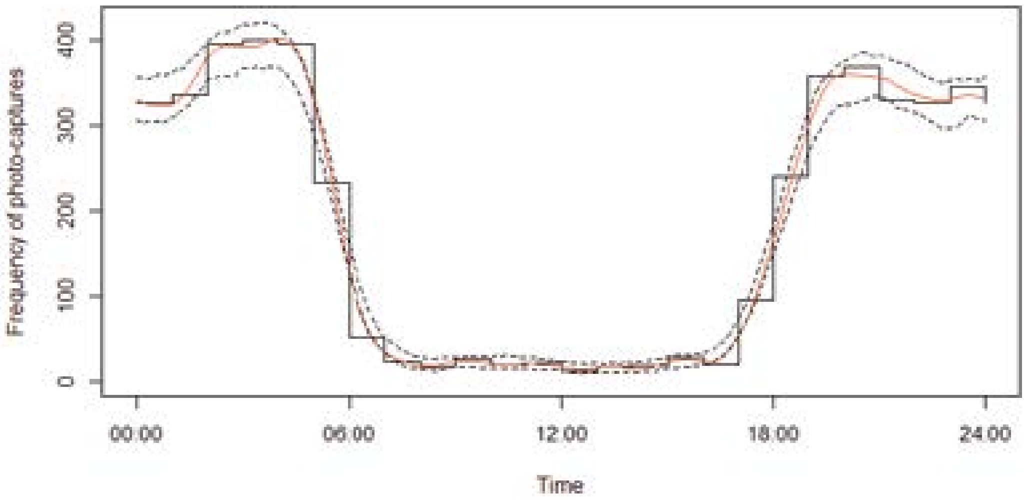


Table 15.1: Parameters used in MaxEnt setting for modelling the distribution/habitat of leopard cat in the forested landscape of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.41
Area under the ROC* Curve (AUC)	0.70

**receiver operating characteristic*

Table 15.2: Contribution percentage of every covariate (SD) to the best model explaining distribution of leopard cat

Covariates	Percent contribution (SD)	Permutation contribution (SD)
NDVI difference (deciduousness)	51.4 (2.70)	50.1 (1.64)
NDVI April	30.6 (3.01)	22.6 (1.73)
Distance to nightlight	8.9 (1.45)	10.6 (0.91)
Annual Precipitation (BIO12)	8.6 (1.43)	14.9 (1.61)
Maximum Temperature of Warmest Month (BIO5)	0.2 (0.41)	0 (0.04)
Distance to roads	0.2(0.18)	1.9 (0.45)

Figure 15.3. Relationship of leopard cat with A) BIO5; maximum temperature of the warmest month, B) BIO12; annual precipitation, C) distance to night light (away from urban centre), D) distance to road, E) Normalized Difference Vegetation Index (NDVI) –April and F) NDVI difference (deciduousness)

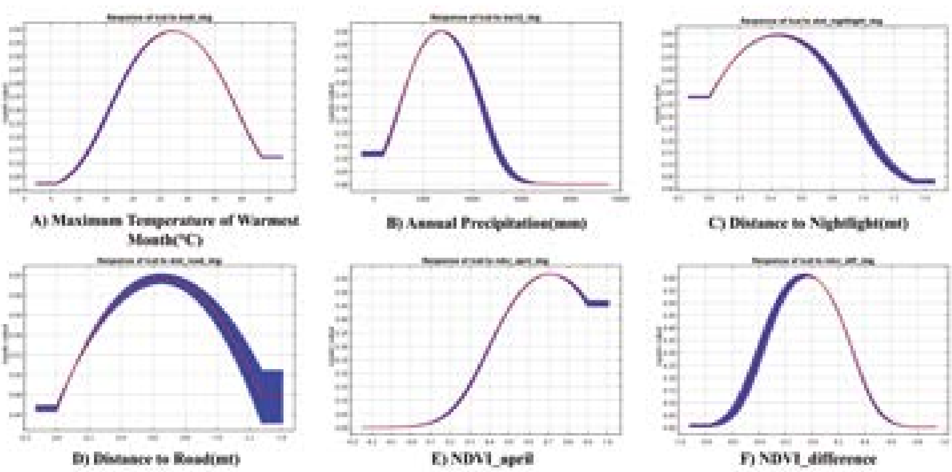
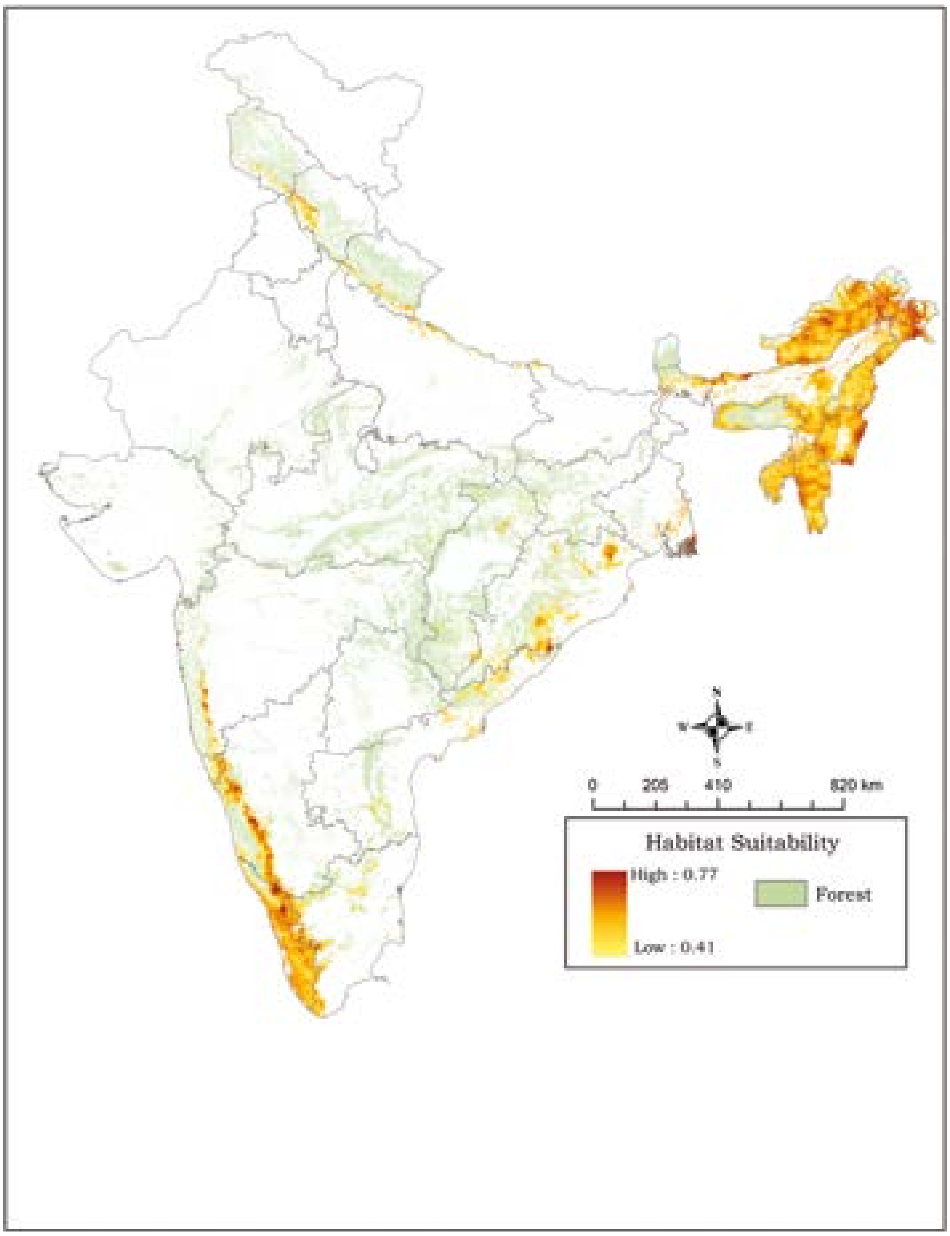


Figure 15.4: Distribution of leopard cat across the forested areas of India estimated from presence obtained by camera traps and environmental covariates.



Conservation significance

Our results are in consonance with the distribution maps provided by the IUCN (Ross et al. 2015) as well as the hypothesis of high temperature and aridity being the determinants of distribution (Mukherjee et al. 2010). The wide distribution of photo-captures with reasonable RAI's of leopard cats within the known range of the species indicates good population status. However, leopard cats avoided human disturbance and therefore the Protected Areas especially tiger reserves were good refuges and harbor source populations for the species.

CHAPTER 16:
MARBLED CAT
(PARDOFELIS MARMORATA)

INTRODUCTION

Conservation status
IUCN Red List: Near Threatened (NT)
Wildlife (Protection) Act, 1972: Schedule I

Marbled cat is a poorly known wild cat that has a broad distribution across much of the Indo-Malayan eco-realm. The species is distributed throughout Southeast Asia, from the Himalayan foothills of India and Bhutan to China and then southwards through to Malaysia and Indonesia. Marbled cat has been recorded in Bangladesh (Khan 2015), Bhutan (Tempa et al. 2013), Nepal (Lama et al. 2019), Brunei Darussalam (Ross et al. 2016), Cambodia (Gray et al. 2014), China (Wang and Wang 1986), India (Choudhury 1996), Indonesia (Cheyne and Macdonald 2010), Lao PDR (Johnson et al. 2009), Malaysia (Azlan and Sharma 2006), Myanmar (Zaw et al. 2014), Thailand (Grassman et al. 2005), Vietnam (Nowell and Jackson 1996), Borneo and Sumatra (Hunter 2011, Ross et al. 2016). In India, the species is distributed in north Bengal (Mukherjee 2013), Assam (Borah et al. 2013), Arunachal Pradesh (Lyngdoh et al. 2011, Velho 2013), Mizoram (Lalthanpuia 2012, Sethy et al. 2017, Singh and Macdonald 2017) Nagaland (Grewal et al. 2011, Longchar 2013, Joshi et al. 2019) and Meghalaya (Samrakshan Trust 2007).

Restricted to forests primarily, degradation of forest and habitat loss due to increasing logging activities, human settlements, agriculture including oil palm plantations across its distributional range are the major threats for this cat. Even though poaching and illegal trade of this cat is underreported compared to other species, but records of hunting and poaching of marbled cat for pelt, meat and bones are reported from several areas of the north eastern states of India (Mishra et al. 2006, Grewal et al. 2011, Lyngdoh et al. 2011, Selvan et al. 2013).

SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Marbled cat is a miniature version of the clouded leopard (about one third the size of the latter) with dark bordered cloud like blotches on thick rich ochraceous- brown to rufous brown coat. It has stripes on the crown, neck and back and has a tubular bushy tail (Menon 2014). The tail has obscured pattern of blotches and is darker in tone and proportionally very long compared to head-body length. It has a broad and more rounded skull, short, rounded wide set of ears and short, heavily spotted legs with larger padded feet (Pocock 1932, Prater 1971, Sunquist and Sunquist 2002). Melanistic forms have been reported from Sumatra (Wibisono and Mccarthy 2010).

Body size:

Head and Body Length: 45-62 cm, Tail Length: 35.6 53.5cm (Hunter 2011)

Body weight:

2.5- 5 kg (Hunter 2011)

Litter size and gestation period:

2-4 (in captivity); 66-82 days (in captivity) (Mukherjee 1998, Hunter 2011)

Life span:

12 years (in captivity) (Hunter 2011)

ECOLOGY AND BEHAVIOUR

Marbled cat mostly occurs in the north-eastern hills moist and mixed deciduous-evergreen tropical forests, and might have preference for hill forests (Nowell and Jackson 1996, Duckworth et al. 1999, Holden 2001, Grassman et al. 2005). The species occurs upto an altitude of 2,750 m (Lama et al. 2019). The increasing use of camera traps throughout its range is revealing detections from disturbed areas (Mohamed et al. 2009, Mathai et al. 2010), including recently logged forest (Ross et al. 2010), but not in oil palm plantations (Ross et al. 2010, Yue et al. 2015, Hearn et al. 2016). In India, the species is mostly present in the eastern foothills of Himalayas, in moist deciduous and semi-evergreen forests (Dhendhup 2016).

Diet of marbled cat is poorly known, but the arboreal nature of the cat indicates that the diet probably includes small vertebrates, including rodents and squirrels, and birds (Nowell and Jackson 1996, Wilson and Mittermeier 2009).

They are mainly solitary but recent camera trap photographs have shown a pair of them together as well (Grassman and Tewes 2002). Marbled cat has never been intensively studied, but Grassman et al. (2005) reported a preliminary home range estimate of 5.3 km^2 for an adult female who was radio-collared and tracked for one month in Thailand's Phu Khieu National Park. Earlier thought to be nocturnal and crepuscular, recent remotely sensed camera trap images from different protected areas show a diurnal activity pattern for marbled cats (Ross et al. 2010, Lynam et al. 2013).

RESULTS

A total of 33 independent photo-captures of marbled cat were recorded from the semi-evergreen and evergreen forests of north eastern India (Figure 16.1). Proportion of time spent active in a day by the species was 0.47(SE 0.08) and it showed primarily diurnal activity pattern, where activity peaks were between 13:00 to 18:00 hours (Figure 16.2). Data used and parameter settings of MaxEnt that used photo-capture intensity and eco-geographical covariates to model occurrence of marbled cat are provided in Table 16.1.

Maximum contribution to marbled cats' habitat model was by normalised difference vegetation index (NDVI) difference (deciduousness of forests) (41.80, SD 27.11%), and minimum temperature of the coldest month (BIO6) (27.80, SD 18.57%) where predicted occurrence of the species appears in areas with moist and evergreen forests with moderate temperature (5-120C) (Figure 16.3). Low human pressure (18.50, SD 13.97%) and areas with moderate annual rainfall (1000 to 3000 mm within the species extent) were preferred by the species (Table 16.2, Figure 16.3). Probability of occurrence of marbled cat within the forested habitats of the north eastern states based on the best MaxEnt model is given in Figure 16.4.

Figure 16.1: Presence locations and intensity of photo-captures of marbled cat obtained from camera traps in 2018-19

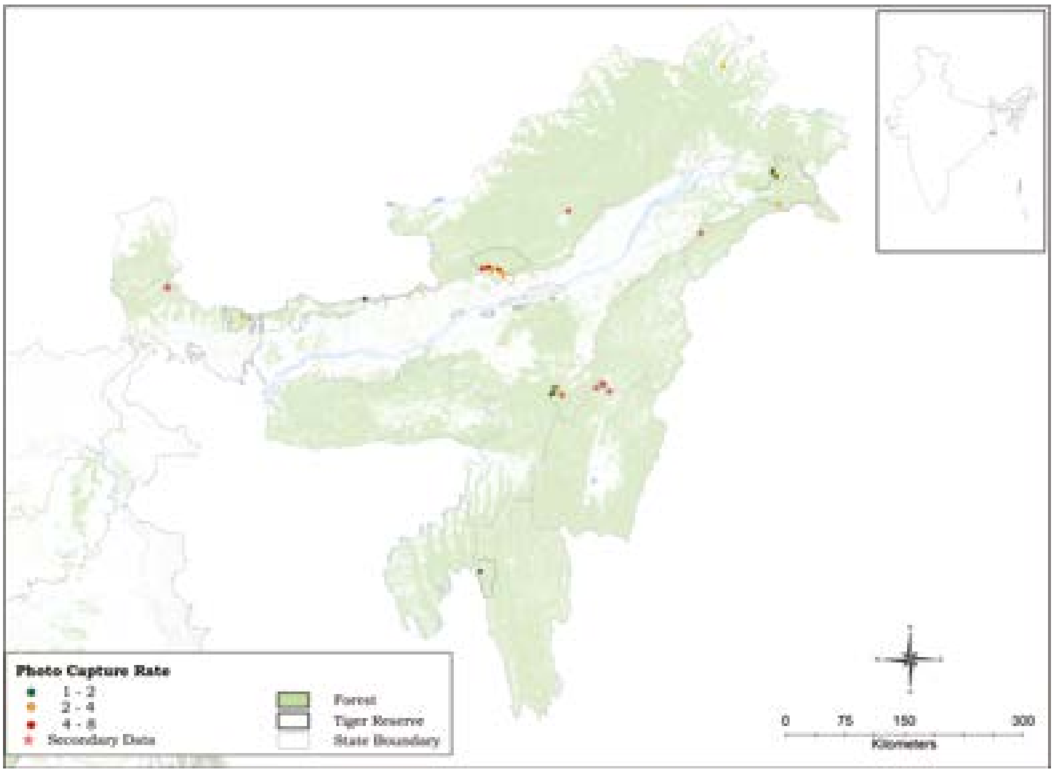


Figure 16.2: Activity pattern of marbled cat obtained from camera trap photo-captures (N= 33) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

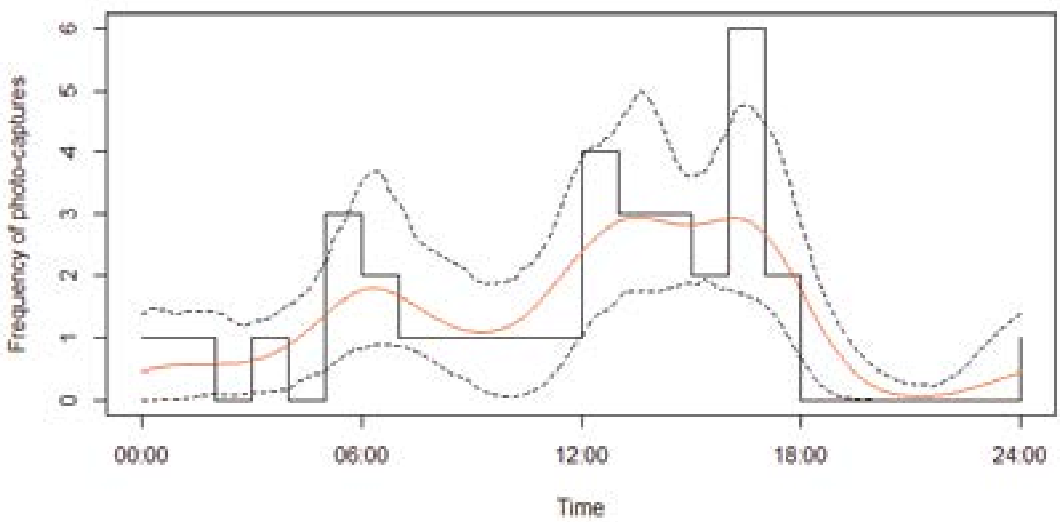


Table 16.1: Parameters used in MaxEnt setting for modelling distribution/habitat of marbled cat in the forested landscapes of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.573
Area under the ROC* Curve (AUC)	0.733

**receiver operating characteristic*

Table 16.2: Contribution percentage of every covariate (SD) to the best model explaining distribution of marbled cat

Covariates	Percent contribution (SD)	Permutation Importance (SD)
NDVI difference (deciduousness)	41.80 (27.11)	33.60 (23.30)
Minimum Temperature of Coldest Month (BIO6)	27.80 (18.57)	28.40 (16.29)
Human pressure	18.50 (13.97)	21.40 (12.96)
Annual precipitation (BIO12)	11.80 (11.33)	16.60 (13.79)

Figure 16.3: Relationship of marbled cat with A) NDVI difference (Deciduousness of forests), B) Minimum temperature of the coldest month (˚C) (BIO_6), C) Human pressure, D) Annual precipitation (mm) (BIO_{12})

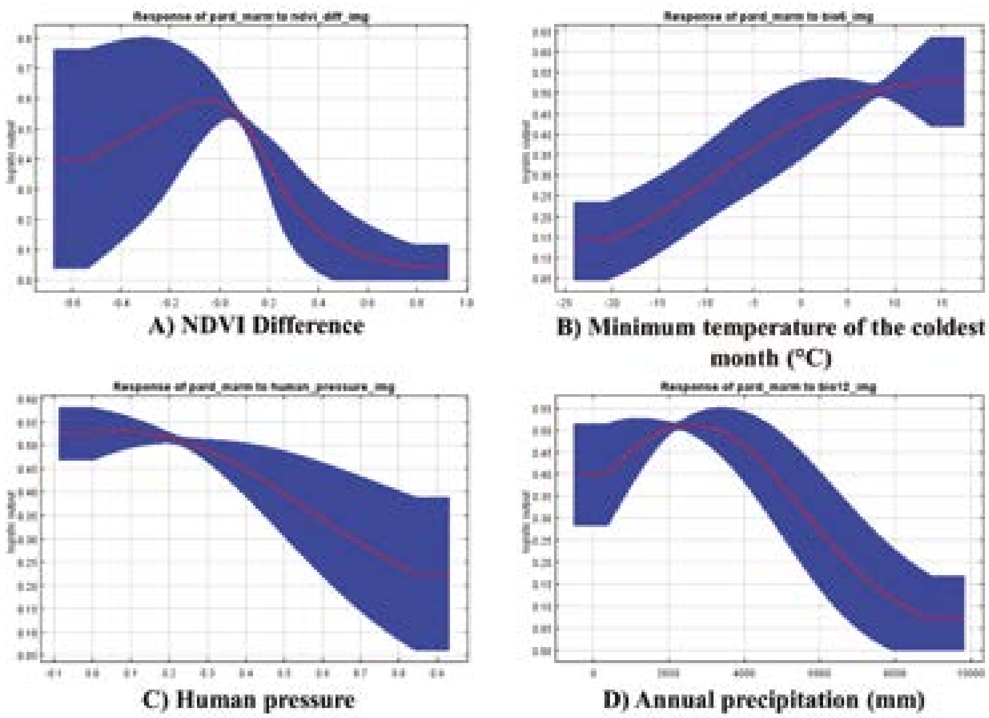
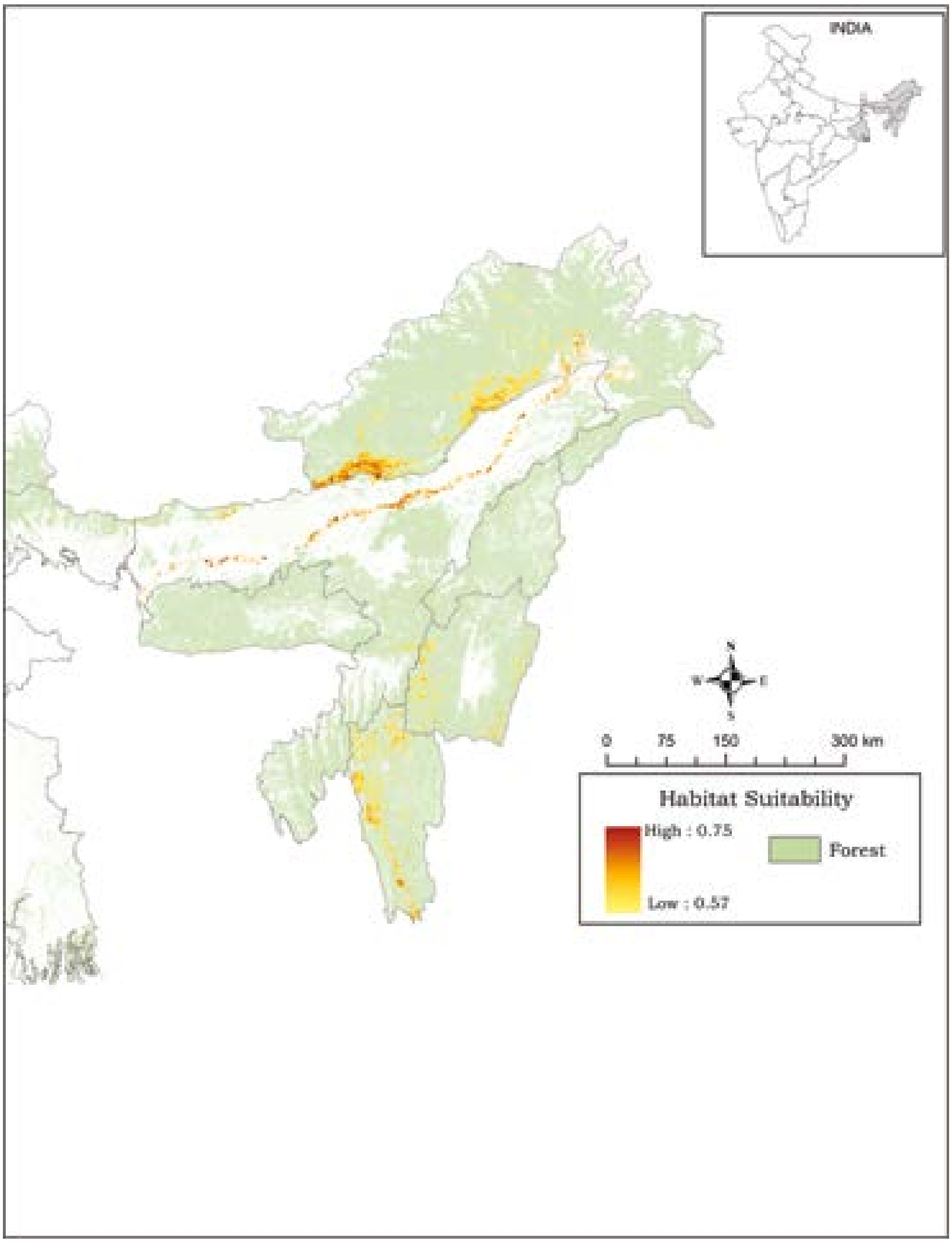


Figure 16.4: Distribution of marbled cat across the forested areas of India estimated from presence obtained by camera traps and environmental covariates.



Conservation significance

The marbled cat needs an in-depth study of its ecology with the use of modern technology (intensive camera trapping with individual identification from their spot patterns and radio-telemetry). Based on proper studies, future conservation policy and management strategies need to be formulated for these cats.

CHAPTER 17:
RUSTY SPOTTED CAT *(PRIONAILURUS RUBIGINOSUS)*

INTRODUCTION

Conservation status
IUCN Red List: Near Threatened (NT)
Wildlife (Protection) Act, 1972: Schedule I

Rusty spotted cat is endemic to India, Nepal and Sri Lanka (Mukherjee et al. 2016). Earlier, the distribution of this secretive nocturnal cat was believed to be rare and sparse, with very little published literature. But recently, the species has been recorded from many Indian states, except the north-eastern. The following publications confirm its widespread distribution across the country (Nowell and Jackson 1996), including Pondicherry (Geoffroy Saint-Hilaire 1831), Maharashtra (Abdulali 1945, Patel 2010, Chatterjee et al. 2020a), Tamil Nadu (Web-Peploe 1946, Kalle et al. 2014, Guptha and Ramanujam 2017), Saurashtra, Kutch, Gir and southern parts of Gujarat (Digveerendrasinh 1964, Pathak 1990, Chavan et al. 1991, Patel and Jackson 2005, Vyas and Upadhyay 2014, Vyas et al. 2018), Odisha (Behura and Guru 1969), Jammu and Kashmir (Chakraborty 1978), Rajasthan (Tehsin 1994, Sharma 2007, Nayak et al. 2017), Kerala (Jackson 1998), Andhra Pradesh (Rao et al. 1999, Aditya and Ganesh 2016), Karnataka (Kumara and Singh 2005), Uttar Pradesh (Anwar et al. 2010), Uttarakhand (Jhala et al. 2020), Madhya Pradesh (Patel 2010, Vasava et al. 2012, Jena et al. 2016, Bora et al. 2020) and Haryana (Ghaskadbi et al. 2016).

Rapid loss and fragmentation of habitat, disease and mortality due to linear infrastructure (roadways) are some threats faced by the species (Mukherjee et al. 2016). There are concerns regarding possible hybridization of rusty-spotted cat with domestic cats (Kittle and Watson 2004) but these have yet to be substantiated.

SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Rusty spotted cat is the smallest wild cat in the world. The russet coloured coat is short and soft with rust coloured patches along the body. The eyes are large and rounded. The back and sides are marked with blotches that join as a line in the flank portion. Other characteristics include white underside of its neck, four vertical stripes on its forehead, cheeks marked with two streaks of darker rusty coloured fur, small and rounded ears, fawn coat with rusty-brown pots arranged in lines on the back, black paws and a long unmarked tail equalling about half the combined length of the head and body (Sunquist and Sunquist 2002, Menon 2014).

Body size:
Head and body length: 35-48cm, Tail length: 15-30 cm (Menon 2014).

Body weight:
Average female: 1.1 kg, Average male: 1.6 kg (Phillips 1980)

Gestation period:
65-70 days (Dmock 1997)

Litter size:
1-3

Life span:
16-18 years in captivity (Sunquist and Sunquist 2002)

ECOLOGY AND BEHAVIOUR

A range-wide, ecological niche modelling study has shown that the rusty-spotted cat occurs in dry and moist deciduous forests in three broad biogeographic regions: Western Ghats, southern Deccan peninsula and the Himalayan foothills upto an elevation of 2,480 msl (Silva et al. 2015, Mukherjee et al. 2016). These prime regions correspond with dry and moist deciduous forests showing relatively low forest fragmentation. However, the species also occurs in in scrub, thorn, and grassland habitats; but are likely absent from evergreen forests (Nowell and Jackson 1996). It prefers mostly thick vegetation, bamboo and rocky areas with rugged terrain and is largely arboreal in nature (Pathak 1990, Mukherjee 1998, Athreya 2010, Menon 2014, Bora et al. 2020, Chatterjee et al. 2020a). It often coexists with humans, occurring near agricultural fields like sugar cane, tea, and coconut plantations (Phillips 1980, Mukherjee 2013). The rusty spotted cat also seems to be cave-dwelling in some parts of its range.

Rusty spotted cat is solitary and primarily nocturnal (Patel 2011, Bora et al. 2020). Rusty spotted cat feeds on small-sized birds and mammals (Dmock 1997, Mithathapala 2006). This cat persists successfully in human-dominated and agricultural areas where it mostly feeds on rodents (Athreya 2010).

RESULTS

A total of 1773 independent photo-captures were recorded during the field sampling with higher captures from tropical dry and moist deciduous forests (Figure 17.1). Proportion of time spent active in day was 0.43 (SE 0.02) and rusty spotted cat was primarily nocturnal with activity sharply declining with day break (05:00 hrs) and commencing after dark (19:00 hrs) (Figure 17.2). The rusty spotted cat was recorded across India in four biogeographic regions: the western Ghats, southern Deccan peninsula, the Himalayan foothills and semi-arid regions (Figure 1). Among the sampling areas it was not found in the wet evergreen forests of western Ghats, Sundarbans and north-east India. Data used and parameter settings of MaxEnt that used photo-capture locations and eco-geographical covariates to model occurrence of rusty spotted cat are provided in Table 17.1.

Maximum contribution to rusty spotted cats' habitat model was by human pressure (53.30, SD 4.40%) and NDVI difference (deciduousness of forests) (20.00, SD 3.90%). Where predicted occurrence of the species was in areas with predominant deciduous forests and low human pressure (Table 17.2, Figure 17.3). Rusty spotted cat habitat was further defined by areas that have moderate (8-200C) minimum temperatures of coldest month (BIO6) (6.80, SD 1.91%), miscellaneous forests with moderate summer canopies (NDVI April, 12.70, SD 2.60%) and high potential evapotranspiration (7.20, SD 1.32%) (Table 17.2, Figure 17.3). The response curve for NDVI April explains that the species' suitable habitats are in moderately dense forests (excluding the evergreen forests and the arid deserts where the species is not found) (Figure 17.3). This is also supported by the response curve for potential evapotranspiration (Figure 17.3) which depicts that extreme climatic conditions were not suitable for the rusty-spotted cat. Probability of occurrence within the forested habitats of tiger states based on the best MaxEnt model is given in Figure 17.4.

Figure 17.1: Presence locations and intensity of photo-captures of rusty spotted cat obtained from camera traps in 2018-19

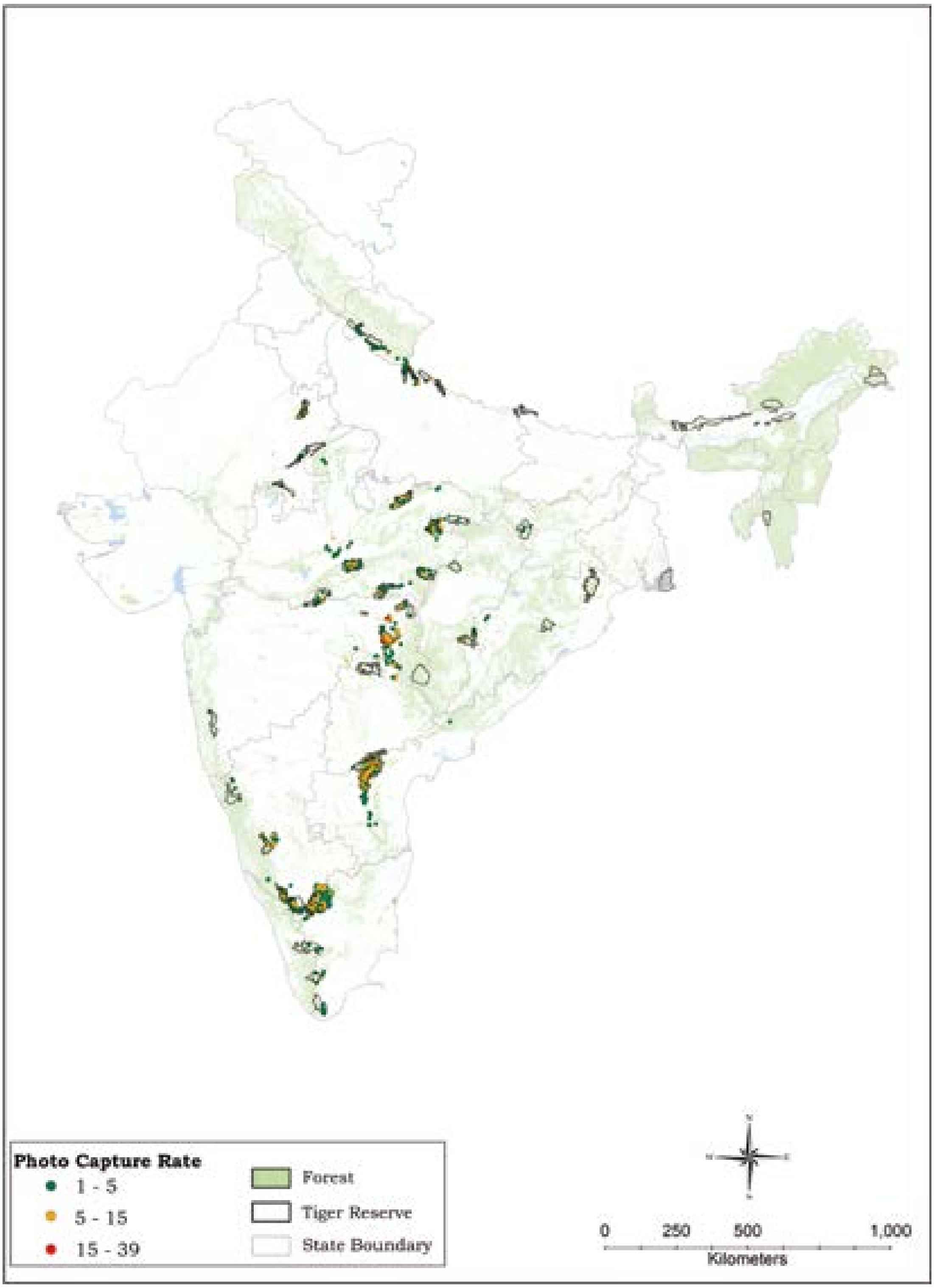


Figure 17.2: Activity pattern of rusty spotted cat obtained from camera trap photo-captures (N= 1773) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

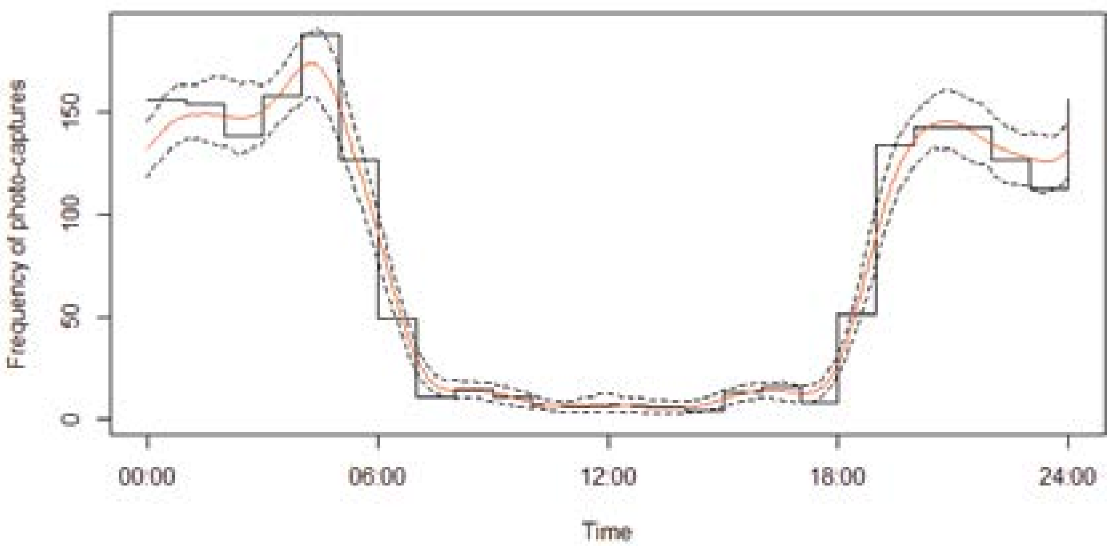


Table 17.1: Parameters used in MaxEnt setting for modelling the rusty-spotted cat distribution/ habitat in forested landscapes of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.42
Area under the ROC* Curve (AUC)	0.76

**receiver operating characteristic*

Table 17.2: Contribution percentage of every covariate (SD) to the best model explaining distribution of rusty spotted cat

Covariates	Percent contribution (SD)	Permutation Importance (SD)
Human pressure	53.30 (4.40)	35.90 (4.30)
NDVI difference (deciduousness)	20.00 (3.90)	13.40 (3.48)
NDVI April	12.70 (2.60)	22.30 (2.59)
Potential evapotranspiration	7.20 (1.32)	22.90 (2.48)
Minimum Temperature of Coldest Month (BIO6)	6.80 (1.91)	4.40 (1.77)

Figure 17.3: Relationship of rusty-spotted cat with A) NDVI difference (Deciduousness of forests), B) Human pressure, C) Minimum temperature of the coldest month (˚C), D) NDVI April, and E) Potential evapotranspiration

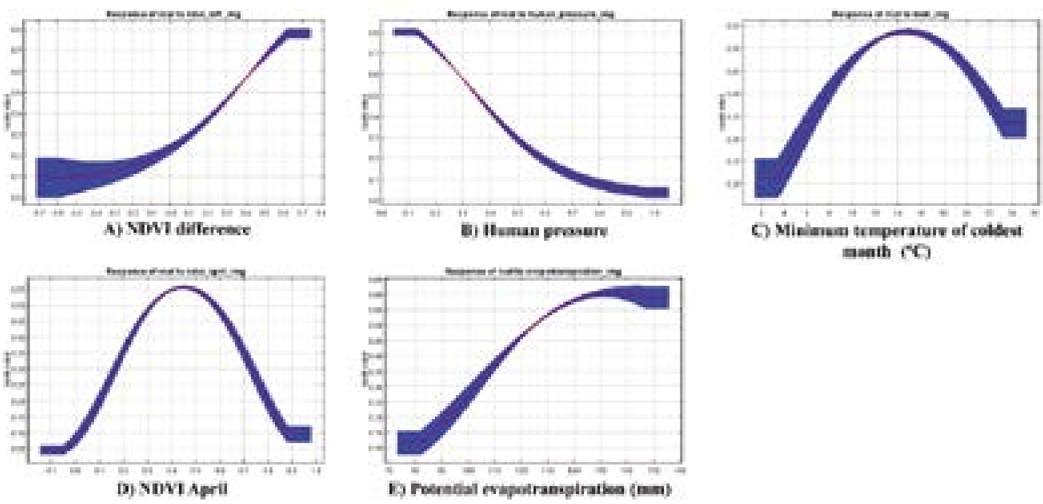
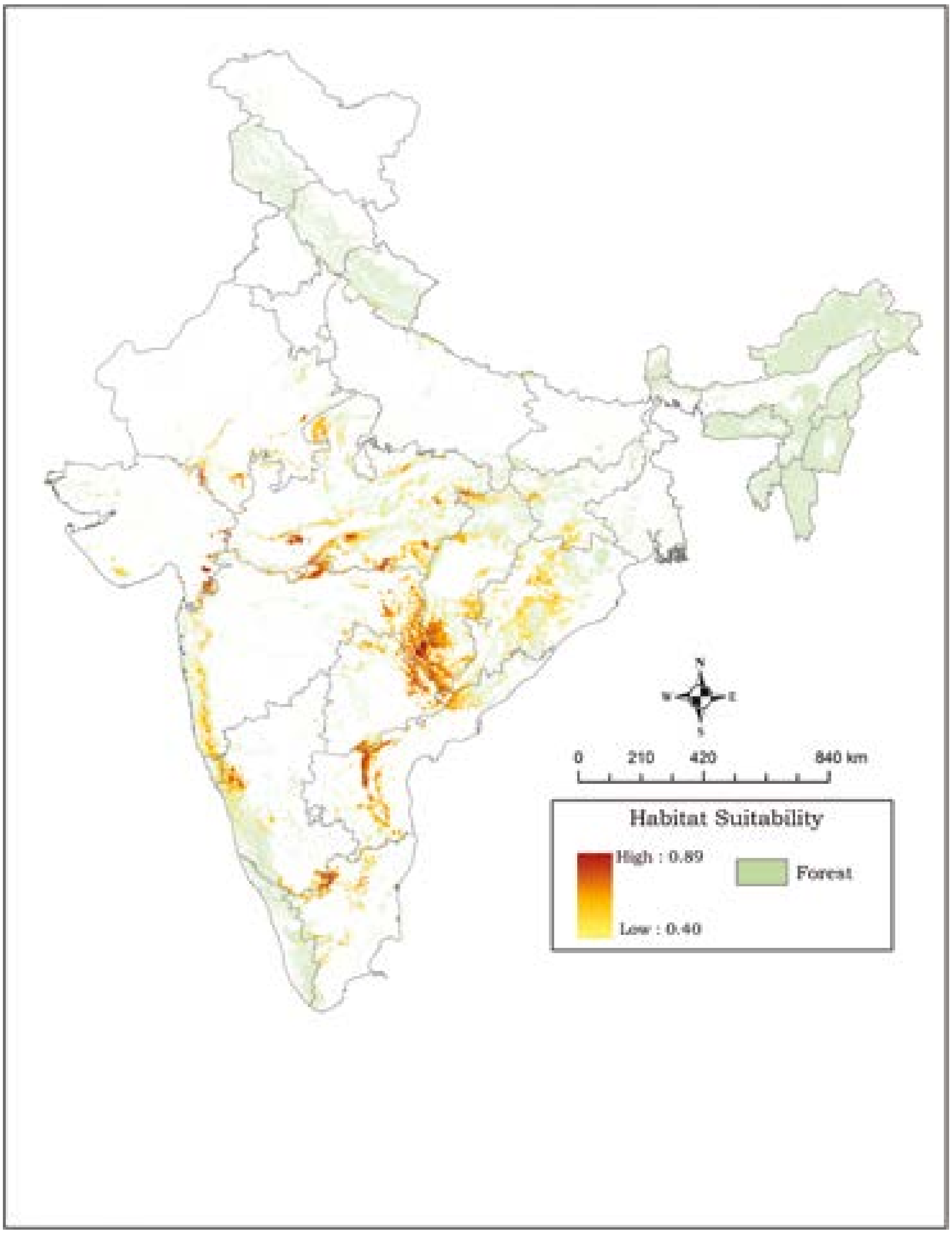


Figure 17.4: Distribution of rusty-spotted cat across the forested areas of India estimated from presence obtained by camera traps and environmental covariates.

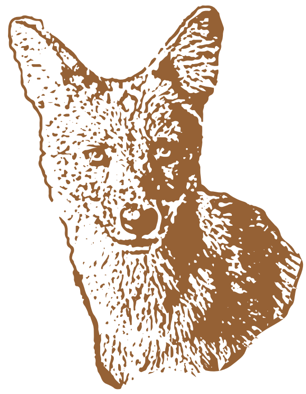


Conservation significance

The rusty spotted cat needs an in-depth study of its ecology using modern technology (intensive camera trapping with individual identification from their spot patterns and radio-telemetry). The world's smallest wild cat is doing well in India and the ambit of Tiger Reserves and Protected Areas seem sufficient to secure viable populations of this cat. Based on proper studies, future conservation policy and management strategies need to be formulated for these cats.

CANIDS & HYENID

CHAPTER 18:
DHOLE OR ASIATIC WILD DOG *(CUON ALPINUS)*



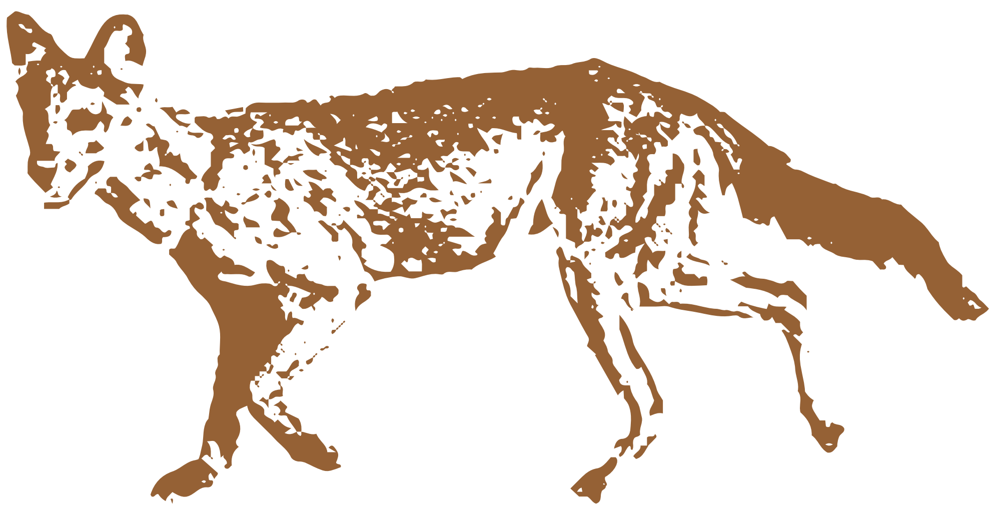
INTRODUCTION

Conservation status
IUCN Red List: Endangered (EN)
Wildlife (Protection) Act, 1972: Schedule II

The term "Dhole" is probably having an ancient Asiatic origin indicating "recklessness and daring" (Mivart 1890). Dholes are the most widespread canids of the Indian, the Indo-Malayan and the Indo-Chinese sub-regions of the Oriental region. Dhole historically ranged across South, East and South-East Asia including the former USSR nations. Presently dholes have a geographical range stretching from Siberia in the north, Afghanistan in the west, Java in the south, and China in the east (Fox 1984, Johnsingh 1985) with the current range nations include Afghanistan, Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Kazakhstan, Korean peninsula, Kyrgyzstan, Laos, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Russia, Tajikistan, Thailand, Vietnam (Kamler et al. 2015).

In India, until the recent past dhole distribution was recorded across Indo-Gangetic plains, *Terai* region, Western Ghats, central India, Eastern Ghats, and in the north eastern states of Assam, Meghalaya, Arunachal also in West Bengal (Johnsingh 1985, Durbin et al.2004). Dholes were treated as 'vermin' and bounty-hunted in India during British Raj and post-independence until the 1970s when they were brought under protection in 1972 with the Wild Life (Protection) Act (Jones 1907, Champion 1927, Phythian-Adams 1949, Fox 1984). Their current range is reduced due to habitat loss and human persecution based on unfounded myths and negative public sentiment (Burton 1899, Witt 1907, Cohen 1977). However, in recent times, presence of dholes has been recorded in the high altitudes of Sikkim, Ladakh, western Himalaya and Kashmir regions (Bashir et al. 2013, Pal et al. 2020).

Depletion of prey base, habitat change and loss, persecution through poisoning, trapping and killing of pups, competition for prey and risk of disease and pathogens from feral dogs (Fox 1984, Durbin et al. 2004) have been the major cause for their declining populations. As mentioned earlier, they have been extirpated from 60% of their former range in the last century due to human persecution and loss of forest cover, and now occur primarily in protected wildlife reserves embedded within larger multiple-use landscapes (Karanth et al. 2010). Canine distemper and rabies are also responsible for substantial dhole mortality (Morris 1942, Davidar 1975).



SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Dhole are large canids (typically 12-20 kg) with shorter legs, more bushy tail and shorter, thicker muzzle when compared to wolves or domestic dogs (Durbin et al. 2004). The dorsal and lateral pelage is red to brown while the undersides, chest, inner legs and lips have varying amounts of white or cream fur on them. Ognev (1931) reported occurrence of distinct summer and winter coats in dholes of the former USSR. The ears are triangular, relatively large and lined with white fur inside especially in dominant adult individuals. The tail is only russet at its base and is almost fully black (Menon 2014).

Body Size:
Head and body length: 135.5cm Tail length: 42.1cm (Durbin et al. 2004).

Body Weight:
10 – 20kg (Cohen 1978, Durbin et al. 2004).

Gestation Period:
63 days (Durbin et al. 2004).

Litter Size:
4-10 (Venkataraman et al. 1995, Durbin et al. 2004).

Life Span:
16 years in captivity, 7-8 years in wild (Durbin et al. 2004).

ECOLOGY AND BEHAVIOUR

Dhole is a habitat generalist and can occur in a wide variety of vegetation types, including primary, secondary and degraded forms of tropical dry and moist deciduous forest; evergreen and semi-evergreen forests; dry thorn forests; grassland–scrub–forest mosaics; and alpine steppe (Krishnan 1972, Davidar 1975, Durbin et al. 2004). Their elevation range varies from sea level to as high as 5,300 m asl in Ladakh (Kamler et al. 2015). They are not recorded from desert regions. In India, dhole prefers dry deciduous, moist deciduous and tropical dry forest under the protected wildlife reserves with relatively low human disturbances (Srivatsha et al. 2014).

Prey of dhole vary from place to place with the latter's distributional range. Brander (1923) was of the opinion that nearly every species of forest animal within the dholes' range has at one time or other served as their prey. Medium and large sized ungulates have been reported as the principal prey of dhole in the Indian subcontinent (Davidar 1974, Fox and Johnsingh 1975, Johnsingh 1983, Venkataraman et al. 1995, Karanth and Sunquist 1995, 2000, Acharya 2008, Wang and Macdonlad 2009, Gopi et al. 2010, Selvan et al. 2013, Hayward et al. 2014, Srivastha et al. 2020).

Dhole are social animals living in packs of 5–10 individuals, but groups of as many as 18 (Alas Purwo, Java, Indonesia), 24 (Kanha, India), and 25 (Mudumalai Sanctuary, India) have been recorded (Durbin et al. 2004). In tropical evergreen forests of Southeast Asia, dhole occur in smaller packs and have smaller litters, probably due to low prey biomass and small size of ungulate prey in these habitats (Kawanishi and Sunquist 2008).

The home range of dholes varies depending on habitat characteristics, prey populations, and pack size (Srivathsa et al. 2017). Home range size of ~85 km² was reported from Mudumalai (Venkataraman et al. 1995), 40 km² in Bandipur (Johnsingh and Acharya 2013) while size of the home ranges varied in between 66 and 203 km² in Pench Tiger Reserve, Madhya Pradesh (Acharya 2008). Recent telemetry study in Kanha TR on three packs has reported a larger home range of 60.9 km² to 248.9km² (Jhala et al. UnPub Data).The species is predominantly diurnal with hunting peaks during early morning and evening (Johnsingh 1983, Kamler et al. 2012, Ramesh et al. 2012).

RESULTS

A total of 10,541 independent photo-captures events were recorded during the field sampling with higher encounters in tropical forests, deciduous forest, shola grasslands from protected areas of Nilgiri Biosphere Reserve, Tadoba Andhari Tiger Reserve, Valmiki Tiger Reserve amongst others (Figure 18.1). Proportion of time dhole was active in a day was 0.30 (SE 0.01) and had peaks in photo-captures during early morning (5:00 to 9:00 hours) and evenings (17:00 to 20:00 hours) (Figure 18.2), showing diurnal activity pattern. Data details and parameters of the MaxEnt model are provided in Table 18.1. Since prey encounter rate is an important contributor in explaining dhole presence, and was not avaible from the North East, this region was not modeled using MaxEnt. Covariate contribution to dhole’s habitat model are given in Table 18.2.

Maximum contribution to dhole’s habitat model was by human pressure (91.01, SD 0.37%), where highly disturbed areas were avoided by the species. The species distribution was further explained by NDVI April (7.48, SD 0.36%) and prey encounter rate (1.41 SD 0.10%), however their contribution to the model were less (Figure 18.3). The overall model suggested, dholes prefers undisturbed forested areas with ample amount of ungulate (large bodied) prey. Probability of occurrence of dhole within the forested habitats of tiger states based on the best MaxEnt model is given in Figure 18.4.

Figure 18.1: Presence locations and intensity of photo-captures of dhole obtained from camera traps in 2018-19

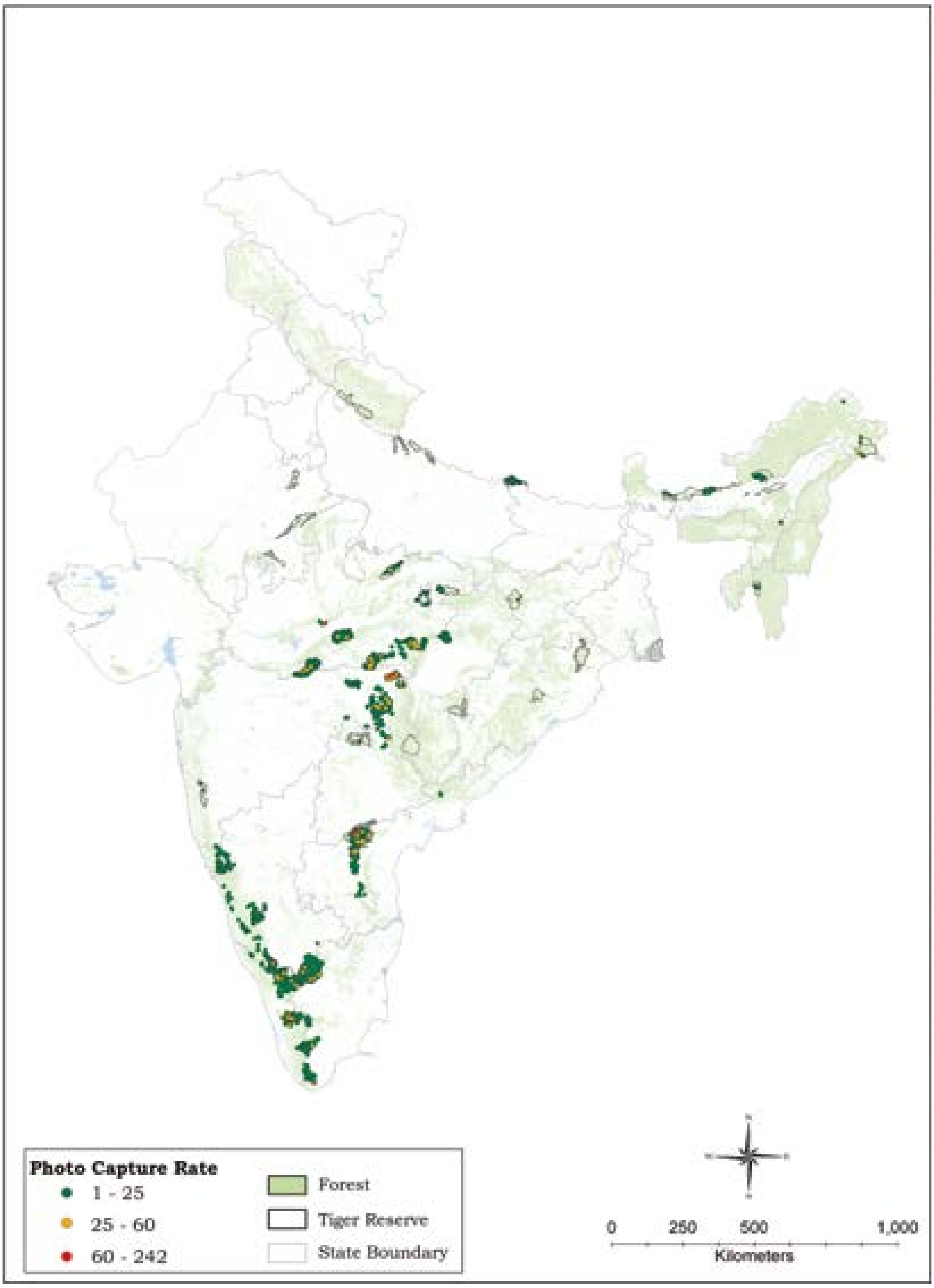


Figure 18.2: Activity pattern of dhole obtained from camera trap photo-captures (N= 10541) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

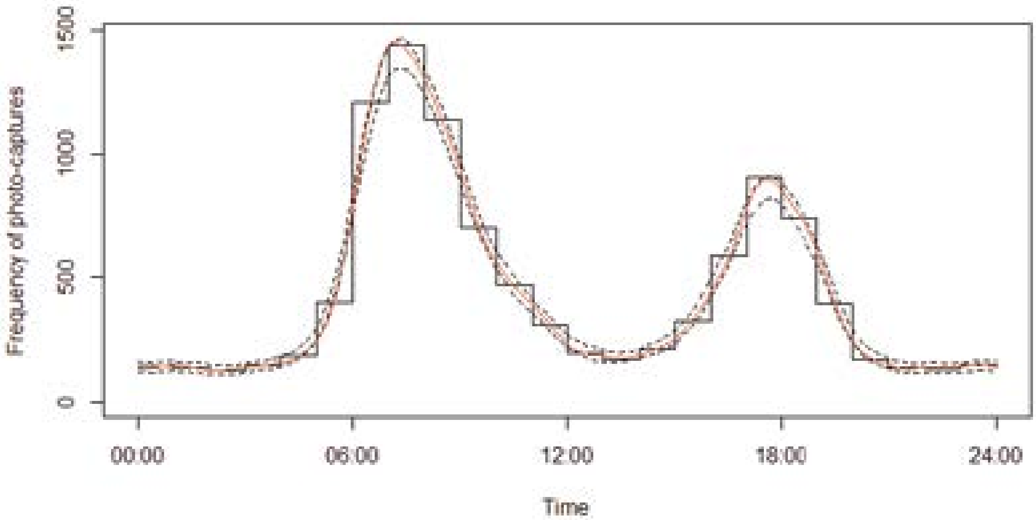


Table 18.1: Parameters used in MaxEnt setting for modelling the dhole distribution/habitat in the forested landscape of India

Model setting	Values
Type of features used to model relationship in covariates and presence	Linear, quadratic
Output formats used	Logistic
Threshold of “maximum sensitivity plus specificity”	0.44
Area under the ROC* Curve (AUC)	0.63

**receiver operating characteristic*

Table 18.2: Contribution percentage of every covariate (± SD) to the best model explaining distribution of dhole

Covariates	Percent contribution (SD)	Permutation contribution (SD)
Human Pressure	91.01 (0.37)	87.97 (0.55)
NDVI April	7.48 (0.36)	9.59 (0.50)
Encounter rate of prey	1.41 (0.10)	2.42 (0.21)

Figure 18.3: Relationship of dhole with A) Human pressure, B) Normalized Difference Vegetation Index (NDVI) April and C) Prey encounter rate

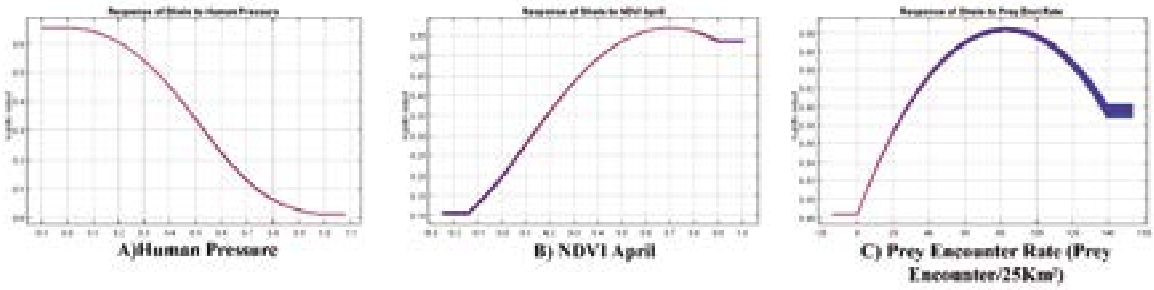
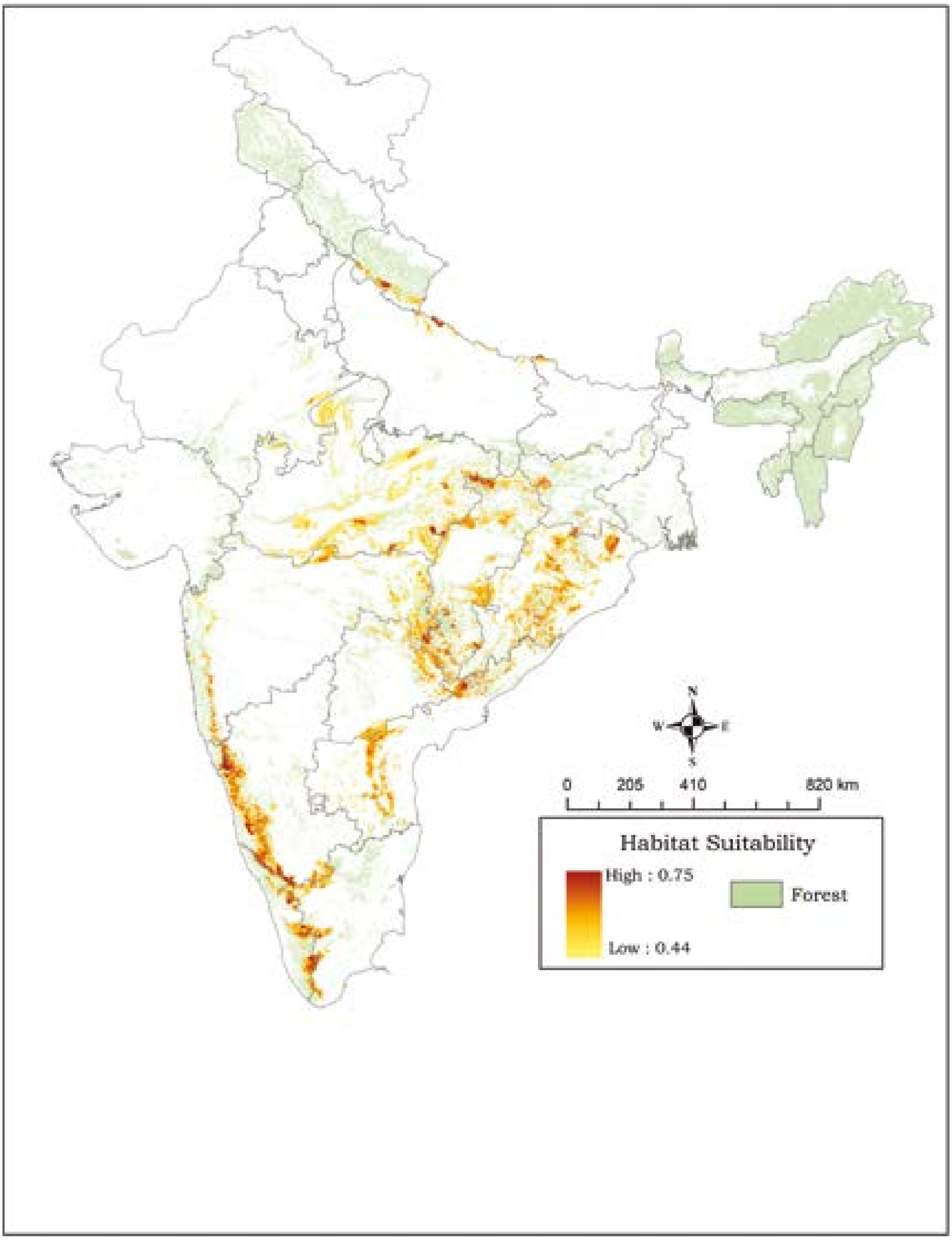


Figure 18.4: Distribution of dhole across the forested areas of India estimated from presence obtained by camera traps and environmental covariates,



Conservation significance

Even with such a wide range, dhole remain poorly studied. No population estimates or local density estimates are available. During the 2018-19 exercise not a single photo-capture of dhole was recorded in western Terai (west of Valmiki Tiger Reserve), confirming their local extinction from this region of India and Nepal. Dhole has also been exterminated from Rajasthan and western Madhya Pradesh (Kuno-Sheopur-Shivpuri landscape). MaxEnt models suggest suitable habitat in Rajasthan, Western Madhya Pradesh and Terai. Dhole populations were genetically more structured compared to leopards but less than those observed for tigers in India (see chapter 8 for details). This suggests that dhole require habitat connectivity (corridors) like those needed for tigers to maintain geneflow and prevent inbreeding. It seems likely that dhole are extremely vulnerable to poisoning and disease like distemper, parvovirus, and rabies contracted from feral dogs, both these factors can wipe out entire packs and cause local extinctions. Dhole are an integral part of the ecosystem since they, unlike large felids, predate ungulates after testing them for weaknesses. Dhole predation is therefore a major selective force that keeps ungulate populations healthy by weeding out diseased, infirm, old and young individuals. Active interventions in the form of planned reintroductions are required to re-establish dhole from areas where they have been extirpated (western Terai and western thorn forests). There are no known records of dhole attacks on humans in India and their depredation on livestock is not of major concern compared to conflicts with tigers and leopard. Therefore, the misconception about dhole in the minds of managers and decision makers needs to be addressed and conservation efforts commenced in all earnest.

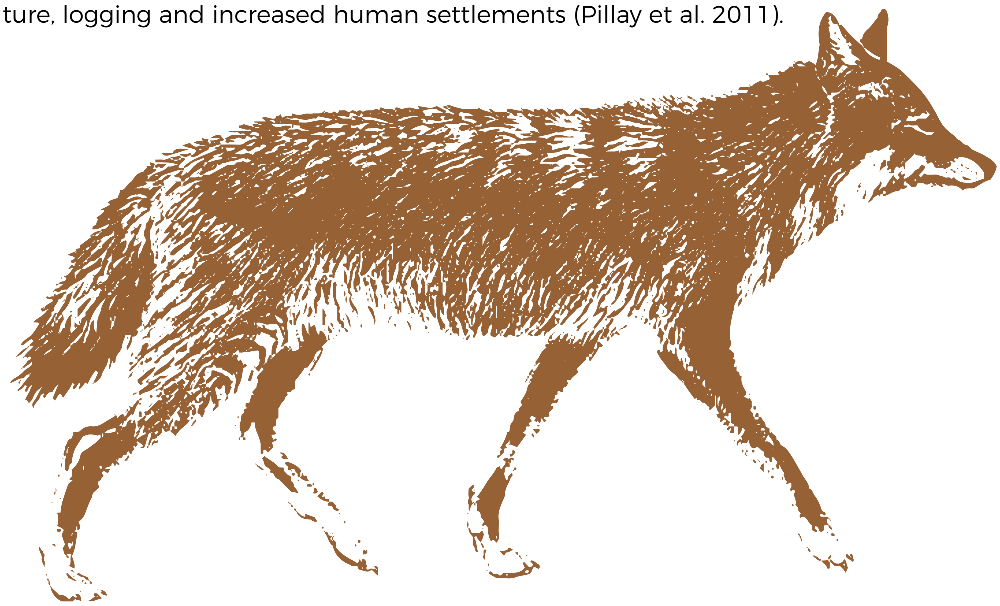
CHAPTER 19:
GOLDEN JACKAL *(CANIS AUREUS)*

INTRODUCTION

Conservation status
IUCN Red List: Least Concern (LC)
Wildlife (Protection) Act, 1972: Schedule III

Golden jackal is the most widespread canid that is fairly common throughout most of its range with medium to high densities observed in areas with abundant food and cover (Jhala and Moehlman 2013). The species ranges throughout the Indian subcontinent, Sri Lanka, Myanmar, parts of Indo China, Iran and Central Asia (Jhala and Moehlman 2004). In the southern Arabian Peninsula, golden jackal is restricted to the eastern parts of Saudi Arabia, Turkey, Syria and Iraq (Mallon and Budd 2011). This species was historically believed to be restricted to the coastal regions of Europe (Krofel et al. 2017). In the 19th century, it was sighted in the south-eastern Europe and by 20th century, its range expanded to the northern and western Europe (Krofel et al. 2017). The current range countries include Afghanistan, Albania, Armenia, Austria, Azerbaijan, Bangladesh, Bhutan, Bosnia, Bulgaria, Cambodia, Croatia, Czech, Georgia, Greece, Hungary, India, Iran, Iraq, Israel, Italy, Jordan, Kazakhstan, Lao PDR, Lebanon, Macedonia, the former Yugoslav Republic, Moldova, Montenegro, Myanmar, Nepal, Pakistan, Qatar, Romania, Russian Federation, Saudi Arabia, Serbia, Slovakia, Slovenia, Sri Lanka, Syria, Tajikistan, Thailand, Turkey, Turkmenistan, Ukraine, Uzbekistan, Vietnam (Hoffmann et al. 2018). The golden jackal in Africa (Moehlman and Jhala 2013) has now been recognised as a distinct wolf species Canis lupaster (Rueness et al. 2011, Hoffman and Atickem 2019). The species features in mythological and cultural accounts of several civilizations spanning Africa, India and Europe (Jhala and Moehlman 2013).

Despite being locally abundant, the population is declining almost across its entire range, except in protected areas, primarily due to human modifications of traditional land-use patterns (Jhala and Moehlman 2013). Since golden jackals often live in close proximity to human habitations they come in contact with feral dog population which transmit disease and can potentially hybridise. Diseases such as canine distemper, rabies, mange are common in areas where they occur in high densities in India. Heavy persecution in some parts of its range (Lao PDR, Vietnam, Thailand, Cambodia) has been reported. Localized decline has been reported in Southern Western Ghats of India due to agriculture, logging and increased human settlements (Pillay et al. 2011).



SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Golden jackal has a buff-grey coat which can change from pale creamy yellow to a dark tawny hue depending on the season (Menon 2014). The pelage on the back is often a mixture of black, brown, and white hairs such that they can appear to have a dark saddle (Moehlman and Jhala 2013) The belly and underparts are light pale-ginger to creamish in colour. The tail is bushy with a tan to black tip. Melanistic individuals have also been reported from Turkey (Ambarli and Bilgin 2013).

Body size:
Head and Body Length:60-80 cm, Tail length: 20-27 cm (Prater 1971, Menon 2014).

Body weight:
6.5–9.8 kg (Moehlman and Jhala 2013).

Gestation period:
60 - 63 days (Sheldon 1992)

Litter Size:
1-9 (Sheldon 1992)

Life span:
8 - 9 years in wild, Up to 18 years in Captivity (Sheldon 1992).

ECOLOGY AND BEHAVIOUR

Due to its tolerance of dry conditions and its omnivorous diet, the golden jackal can live in a wide variety of habitats ranging from semi-arid environments to forested, mangrove, agricultural, rural and semi-urban habitats in India and Bangladesh (Clutton-Brock et al. 1976, Prater 1971, Poche et al. 1987, Hoffmann et al. 2018). Jackals mostly occur up to elevations of 2,000 m (Prater 1971) although they have been recorded at elevations of 3,800 m in the Bale Mountains of Ethiopia (Ginsberg and Macdonald 1990). In India, the golden jackal is found in most protected areas, semi-urban and rural landscapes of the country, except in the high elevation regions of the Himalaya. Aiyadurai and Jhala (2006) reported the presence of golden jackal in grasslands, *Prosopis* patches, village outskirts, saline wastelands, halophytic scrubs, fallow fields, mud flats and road edges. Srivathsa et al. (2020) reported high probabily of golden jackal occurrence clustered around large settlements with high density of humans and free-ranging dogs, attributed to high availability of provisioned food resources and the species' ability to adapt to human-modified areas.

Golden jackal is an opportunistic forager with its diet varying across the geographical range it occurs. This species is capable of hunting but also subsists by scavenging (Sheldon 1992). It feeds primarily on rodents, birds as well as fruits (Mukherjee et al. 2004). It is also known to hunt and scavenge on fawns of herbivores like chital, sambar, nilgai, cattle and barasingha (Chourasia 2015). An especially important source of food for jackals in Europe are slaughter remains and other animal waste from livestock, which represents approximately 40% of jackal diet across the continent (Ćirović et al. 2016). In India, golden jackals are opportunistic and often venture into human habitations at night to feed at garbage dumps, or scavenge on livestock carcasses (Jhala and Moehlman 2008).

Golden jackal can be considered as moderately social canids (Sheldon 1992) with solitary/pairs/ small groups of 3-5 comprising of females, their offspring or previous litter (Moehlman 1989, Menon 2014). Jackals are not strictly territorial with a significant overlap in their home ranges (Aiyadurai 2001) with home range sizes ranging between 3 to 30 km² (Aiyadurai and Jhala 2006). However, core areas of jackal home ranges were exclusive. The species shows diurnal activity where there is low anthropogenic disturbance (Gupta et al. 2016), however, it is strictly nocturnal in areas close to human habitations (Sheldon 1992).

RESULTS

A total of 21,709 independent photo-captures were recorded during the field sampling with higher encounters in deciduous forest, savannas, grasslands and agro-pastoral areas in India and secondary sources availed us of 271 presence records (Yumnam et al. 2015, de Vries et al. 2021) (Figure 19.1). Proportion of time spent active by jackal in a day was 0.62 (SE 0.01), jackals showed diurnal activity pattern where they had activity peaks in morning and evening (Figure 19.2). Data used and parameters of the best model are provided in (Table 19.1) and distribution of golden jackal across the India developed from the presence obtained by camera trapping, published occurrences, and environmental covariates are given in (Table 19.2, Figure 19.3).

Maximum contribution (81.1, SD 0.68%) to golden jackal MaxEnt model was by human pressure index, wherein jackals occurred in areas with low to moderate human pressure (Table 19.2, Figure 19.3) in consonance with the known ecology of the species. Jackal habitat was further defined by areas that have open to moderate canopy (Table 19.2, Figure 19.3) i.e. NDVI April (15.6, SD 0.77%), moderate evapotranspiration (3.3 SD 0.30%). The resultant distribution indicated higher distribution in areas outside protected areas, but without high human modifications (e.g. agro-pastoral landscape of western Madhya Pradesh, and Kutch) and in parts of southern Western Ghats and Northeast hills where rainfall was not very high. The probability of occurrence of jackal in India based on the best MaxEnt model is given in the Figure 19.4.

Figure 19.1: Presence locations and intensity of photo-captures of golden jackal obtained from camera traps in 2018-19 and secondary sources.

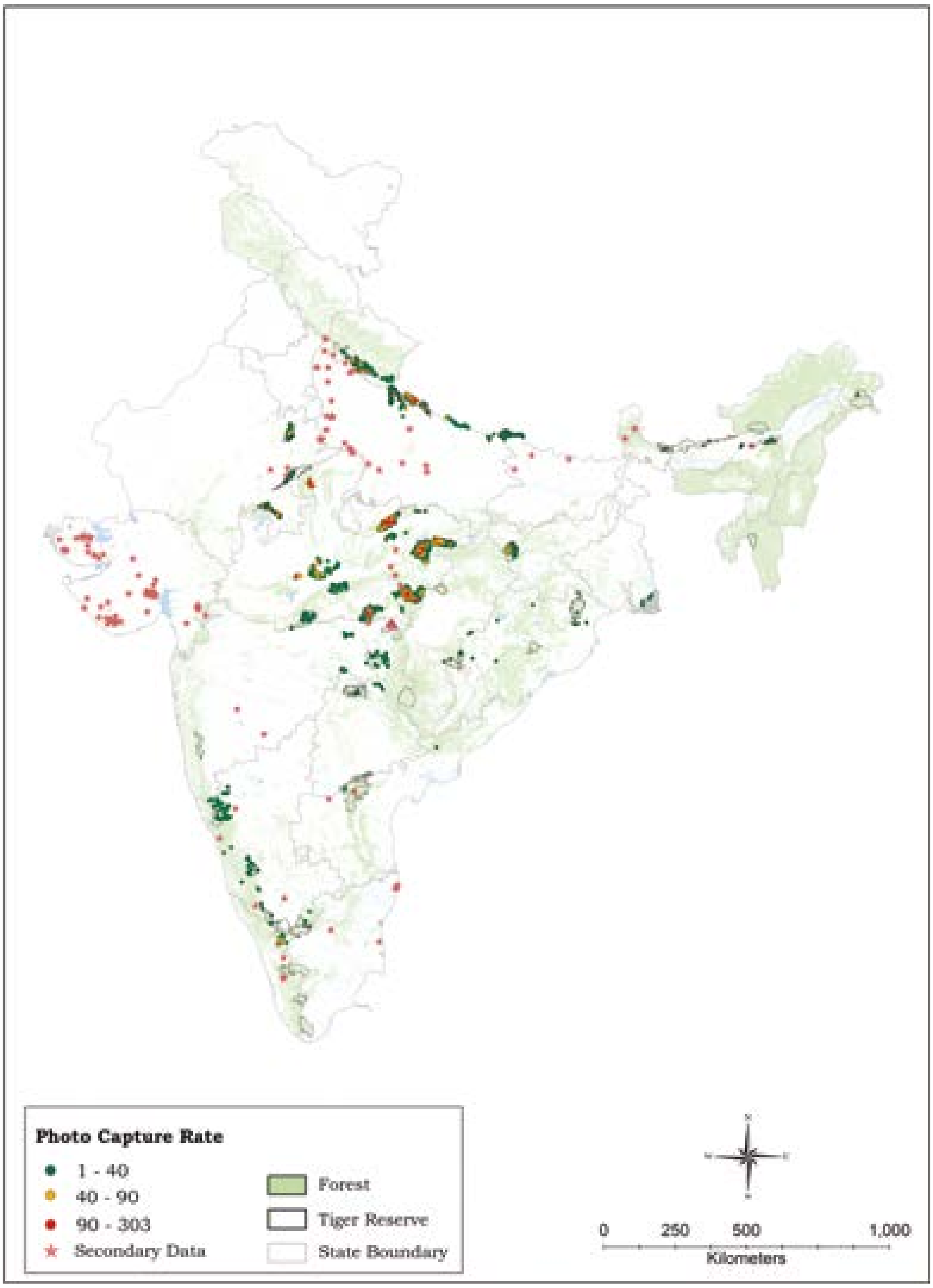


Figure 19.2: Activity pattern of golden jackal obtained from camera trap photo-captures (N = 21709) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

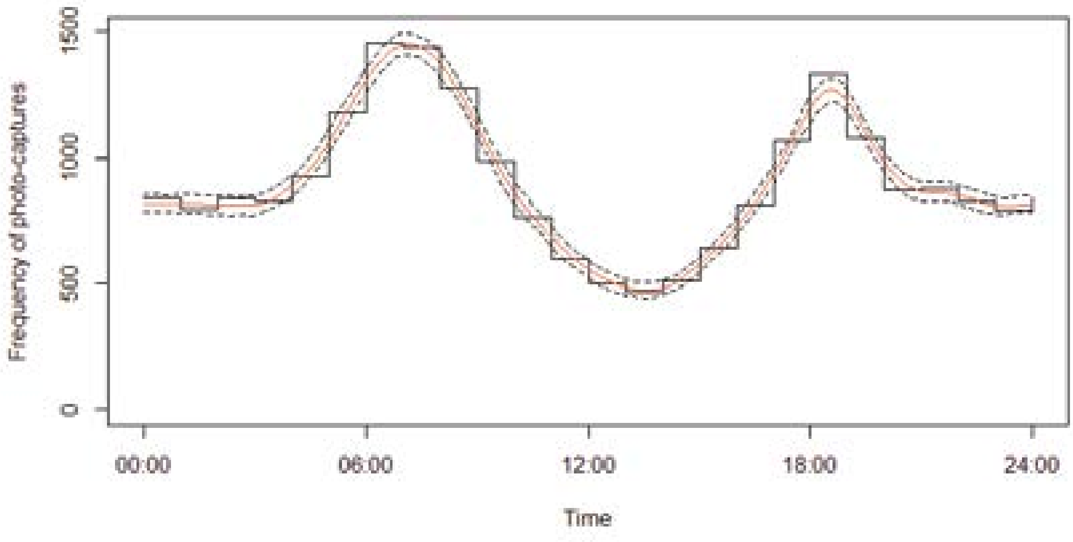


Table 19.1: Parameters used in MaxEnt setting for modelling the golden jackal distribution/habitat in India

Model setting	Values
Model features	Linear, Quadratic
Output formats	Cloglog
Threshold of 'maximum sensitivity plus specificity'	0.49
Area under the ROC* Curve (AUC)	0.81

**receiver operating characteristic*

Table 19.2: Contribution percentage of every covariate (SD) to the best model explaining golden jackal distribution

Covariates	Percent contribution (SD)	Permutation contribution (SD)
Human Pressure	81.1 (0.68)	80.2 (0.79)
NDVI April	15.6 (0.77)	10.5 (0.66)
Evapotranspiration	3.3 (0.30)	9.3 (0.75)

Figure 19.3: Relationship of golden jackal with environmental covariates: A) Human pressure, B) NDVI of April, C) Potential evapotranspiration

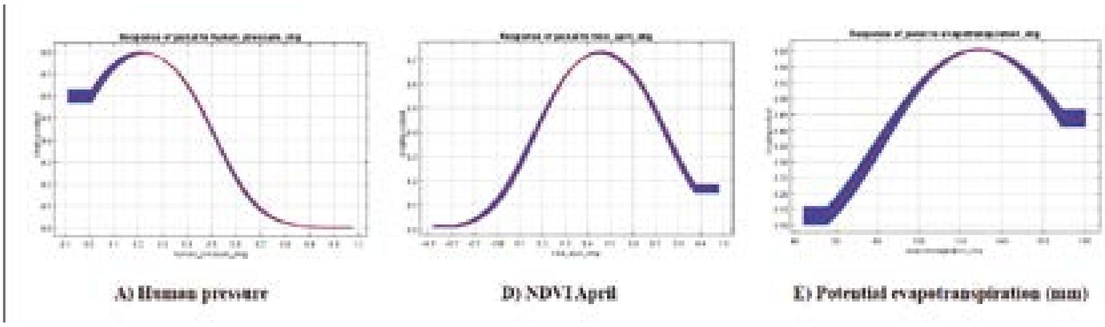
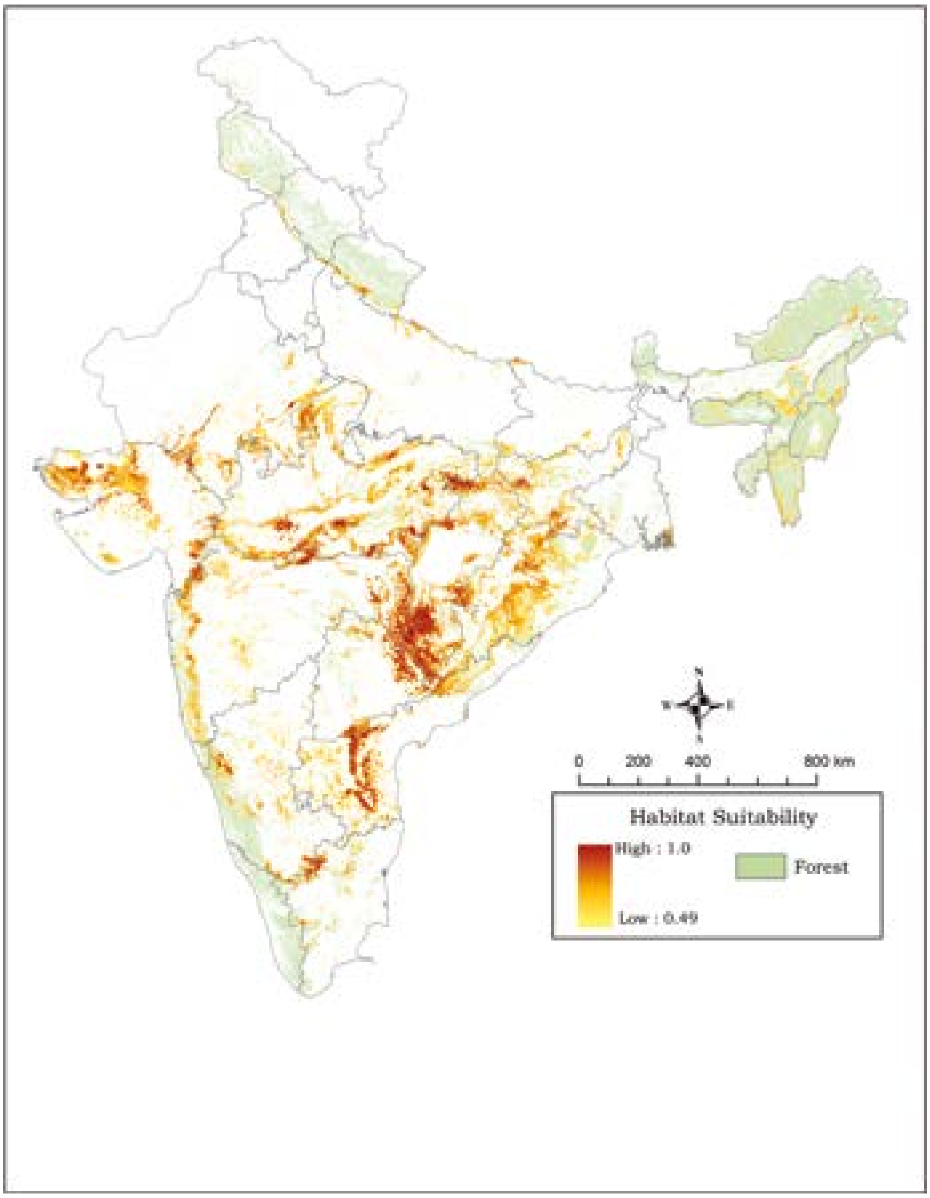


Figure 19.4: Distribution of golden jackal across India estimated from presence obtained by camera traps, secondary data and environmental covariates.



Conservation significance

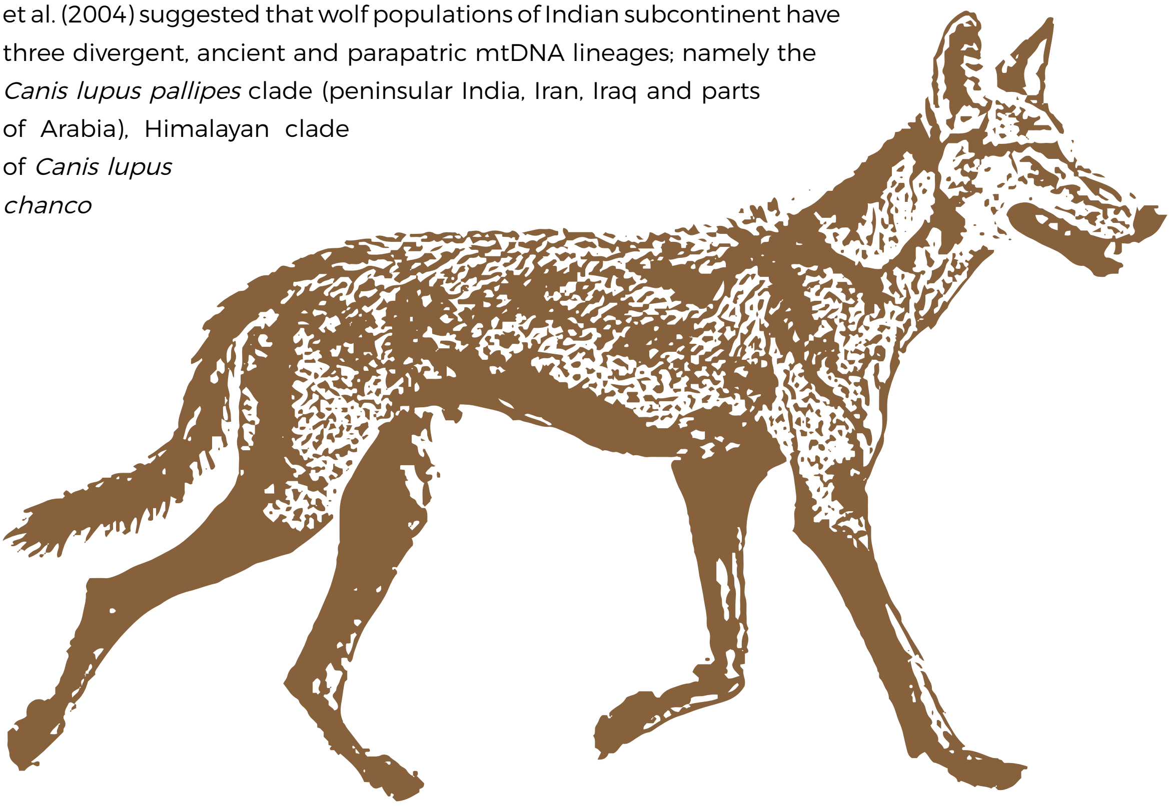
India is believed to be the origin from where golden jackals spread westwards into middle east and to Europe (Yumnam et al. 2015). The golden jackal is still widely distributed and occurs in reasonable numbers across its range. However, photo captures were not recorded from Maharashtra which is a matter of concern and further investigation is required on the causes of decline of jackal populations in this region. Species specific disease or targeted poaching seems to be likely causes. High speed roads are a major threat to the species which result in high mortality and extermination of local populations. Diseases and competition from feral dogs is another major concern for golden jackals as well as other wild canids.

CHAPTER 20:
INDIAN WOLF
(CANIS LUPUS PALLIPES)

INTRODUCTION

Conservation status
IUCN Red List: Least concern (LC)
Wildlife (Protection) Act, 1972: Schedule I

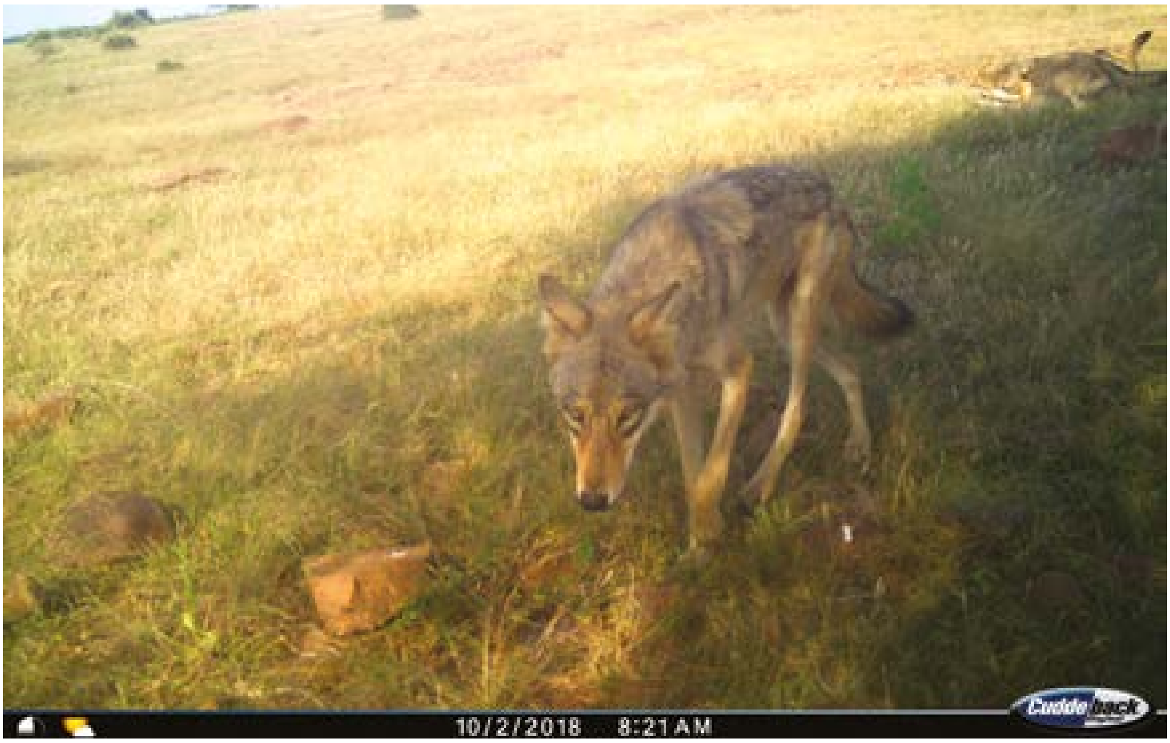
The Indian wolf *(Canis lupus pallipes)* is a subspecies of grey wolf inhabiting semi-arid and arid areas. Variations in physical features, behavioral aspects and geographical distribution suggest the presence of up to 32 subspecies of grey wolf globally (Mech 1974), of which 10 extant subspecies are from Eurasia (Aggarwal et al. 2007). Indian subcontinent is home to two subspecies of wolf i.e., Tibetan Wolf *(Canis lupus chanco)* and Indian wolf; the Tibetan Wolf inhabits the higher mountain ranges of trans-Himalayas ranging from 3,000-4,000 m and occupies an alpine niche in Tibet, China, Manchuria and Mongolia (Jhala 2013). In contrast, Indian wolf having evolved during the Pleistocene epoch (Sharma et al. 2004, Mech and Boitani 2010), with a relatively different climatic envelop and is adapted for semi-arid regions of the Indian subcontinent including degraded plains, semi-arid grasslands and scrublands. Traditional taxonomy considers them as distinct relatives of other grey wolves; however, recent molecular genetics studies contest this and suggest that the wolves from the Himalayas (Tibetan wolf) are the basal form that gave rise to the Indian wolf. Further, the two are distinct enough to be treated as full species (Aggarwal et al. 2003). Sharma et al. (2004) suggested that wolf populations of Indian subcontinent have three divergent, ancient and parapatric mtDNA lineages; namely the *Canis lupus pallipes* clade (peninsular India, Iran, Iraq and parts of Arabia), Himalayan clade of *Canis lupus chanco*



(Ladakh, Spiti, Tibet and Nepal) and the wolf-dog clade of *Canis lupus chanco* (northwest Jammu and Kashmir, i.e. Gilgit and Baltistan). The Indian wolf, possibly diverged from the grey wolf sub species (wolf-dog clade) about 400,000 years ago.

The subspecies *C. l. pallipes* has a wide distribution range, extending from India in the east toTurkey in the west, with populations reported from Pakistan, Iran, Iraq, Syria andIsrael (Mendelssohn 1982, Shahi 1982, Mech and Boitani 2010, Boitani et al. 2018). Once believed to be extinct, the species has been recently recorded in Bangladesh (Akash et al. 2020). However, genetic evidence suggests that the wolves *(C. l. pallipes)* in Indian and Pakistan may be entirely a different subspecies (Sharma et al 2004). In India, they inhabit three biogeographic zones that include the hot desert, the semiarid zone and the Deccan plateau (Jhala 2013) covering the states of Karnataka, Maharashtra, Gujarat, Madhya Pradesh, Rajasthan, Haryana, Uttar Pradesh, Bihar, Jharkhand, Odisha and West Bengal (Pocock 1941, Shahi 1982, Jhala 1991, 2003, Kumar and Rahmani 1997, Singh and Kumara 2006, Habib 2007, Dey et al. 2010, Saren et al. 2019, Shankar et al. 2019, Sharma et al. 2019, Gubbi et al. 2020) occupying an area of about 293,947 km² of peninsular India (Srivatsha et al. 2020). Shahi (1982) estimated that there were 500–800 wolves surviving in peninsular India. Later, Ginsberg and Macdonald (1990) estimated that the wolf population was between 1,000 and 2,000. A detailed study by Jhala and Giles (1991) estimated the population of Indian wolf between 190 and 270 in Gujarat and 253 and 350 in Rajasthan. In another study, Kumar and Rahmani (1997) estimated 53–85 wolves in Solapur in Maharashtra. Jhala (2000) reported that 2,000–3,000 wolves for the entire Indian peninsula that seemed a more realistic population estimate.

The major threat to surviving wolf populations in India is direct persecution by herders who often smoke wolf dens to kill pups and poison carcasses to kill entire packs. Other threats includeloss of habitat, combined with poaching of wild prey, resulting in depletion of natural prey populations and non-availability of appropriate denning and rendezvous sites. Wolves have a bad reputation for incidences like child lifting or attacking humans (Blanford 1891, Jhala and Sharma 1997, Rajpurohit 1999, Krithivasan et al. 2009) which often result in retaliatory killings (Kumar and Rahmani, 1997, 2008). Diseases such as canine distemper, rabies, hepatitis, parvovirus, parasitic infection such as mange are also common among wolf populations (Mech 1970, Goyal et al. 1986, Jhala 1991, 2008).



SPECIES DESCRIPTION & LIFE HISTORY TRAITS

A large canid, the Indian wolf superficially looks like aslim Alsatian with a big head, long limbs, large feet, a slightly curved tail and broad ears (Menon 2014). It has a long muzzle. Its pelage varies greatly with tones of red and grey fur intermingled with black, especially on the dorsal crest, forehead and tip of the tail. The undersides are buff or creamish in colour. They develop under-fur during winter and resemble a German Shepherd dog (Jhala 2013). In summer, most of the fur is shed and only sparse long hairs remain. Records of melanistic wolves have been reported by Lokhande and Bajaru (2013) from Solapur district of Maharashtra.

Body Size:
Head and body length: 65-75 cm, Tail length: 125-145 cm (Jhala 2013)

Body Weight:
18-27 kg (Jhala 2013)

Gestation period:
62-63 days (Mech 1970)

Litter size:
2-6 (Jhala 2013)

Life Span:
12-15 years (Jhala 2013)

ECOLOGY & BEHAVIOUR

Indian wolf in general prefers scrublands, grasslands and semi-arid agro-pastoral landscapes (Jhala 2013). However, the eastern population of Indian wolf found in Odisha, Bihar, Jharkhand and parts of West Bengal occurs in moister forested habitats, (but not in thick forests, Shahi 1982). In Maharashtra, wolves are found to using forestry plantations, human settlements and industrial areas (Kumar 1998, Habib 2007) while in Velavadar National Park (Gujarat), they use moderately dense *Prosopis juliflora* patches. In western Maharashtra, wolf presence is strongly favored by abundance of medium sized prey and presence of areas with seasonal agricultural cover (both irrigated and non-irrigated) but negatively favored by dry forests and built-up areas (Majgaonkar et al. 2019). In Madhya Pradesh, scrublands are important for wolf and its presence is influenced by terrain ruggedness and drier areas (Srivatsha et al. 2019). Wolves are extremely selective in their denning and rendezvous site choices as they require specific habitat pockets that offer refuge without human disturbances (Jhala 2013). They shift dens often and den shifting is not entirely governed by disturbance levels at den sites; rather increasing age of pups is one of the main factors associated with den shifting (Habib and Kumar 2007).

Indian wolf is known to hunt prey larger than its body size, as it hunts in pack and is able to digest large quantities of food in a shorter time (Mech 1970). Wolves are the top predators of blackbuck *(Antilope cervicapra)* and chinkara *(Gazella gazella)* in much of the arid and semi-arid areas of India (Sharma 1978, Jhala 1991, 1993, Kumar 1998, Habib 2007, Maurya et al. 2011). Majority of wolf populations in India occur outside the protected areas and therefore subsist on small livestock (goats and sheep) (Shahi 1982, Jhala and Giles 1991, Kumar and Rahmani 2000, Krithivasan et al. 2009, Palei et al. 2013). Wolves have been estimated to consume 4.62 (SE 0.11) kg of blackbuck per wolf per kill. The average feeding interval is 3.6 (SE 0.7) days and the average consumption/wolf/day is1.8 (SE 0.3) kg (Jethva and Jhala 2004). Wolves are also known to feed on rodents, locusts, other insects, reptiles and plant matters such as pods of *Prosopis juliflora* and fruits of *Ziziphus sp.* (Sharma 1978, Jhala 1993, Habib 2007).

Wolves have a highly developed social system and function as packs (Mech 1970). Packs usually contain 5 to 8 members comprising of alpha pair and their offspring of several litters (Mech 1974), but packs of up to 36 have been reported (Rausch 1967). A pack stakes out and defends a resource territory from other packs by scent marking, howling and by actual territorial strife (Mech 1970). Food, water and availability of denning habitat and rendezvous sites determine the territory sizes in wolves (Fuller 1989, Jhala 1991). Wolves subsisting on wild prey in areas of high prey density have been observed to have small home range sizes (<150 km^2), while wolves subsisting primarily by scavenging and predation of livestock reported large range sizes (300-700 km^2) covering grazing lands of several villages (Habib 2007, Jhala 2013). Although wolves are predominantly nocturnal but they remain active throughout the day (Jhala 2013).

RESULTS

A total of 839 independent photo-captures were used to build up the species distribution model, obtained from 360 camera trap sampling sites (Figure 20.1) and 180 locations from secondary information from Gujarat, Rajasthan, North Karnataka, Solapur, Maharashtra, Nauradehi, Madhya Pradesh and eastern Uttar Pradesh (Y.V. Jhala, unpublished data). High photo-captures of Indian wolf were obtained from the tropical dry forests of Mukundara, Panna, Amrabad, however, it does not reflect actual preference as the sampling was biased towards tiger occupied forests. Proportion of time Indian wolf was active in a day was 0.54 (SE 0.03) and had peaks in photo-captures during morning (7:00 to 9:00 hours) andlate afternoon to evening (15:00 to 18:00 hours) (Figure 20.2), showing diurnal activity pattern. However, since camera trap data was only obtained from forested habitats and wolves are known to occur in agro-pastoral systems, their activity in these human use areas is crepuscular and nocturnal (Jhala 2013). Data details and parameters of the MaxEnt model are provided in Table 20.1. In the case of Indian wolf MaxEnt models, we predicted its distribution only in the forested habitats. Human pressure (65.05, SD 2.43) and NDVI April (15.80, SD 2.83) contributed maximum to the model in predicting suitable habitats for the Indian wolf (Table 20.2, Figure 20.3). Wolf distribution was further defined by mild winters (4-20ºC) with BIO_6 (minimum temperature of the coldest month) contributing 8.23, SD 1.74 to the model and hot summers >40 ºC as shown by the variable BIO_5 (maximum temperature of the warmest month) (4.28 SD 2.06). The modelled distribution of Indian wolf across India, developed by the presence points and environmental covariates is given in Figure 20.4.

Figure 20.1: Presence locations and intensity of photo-captures of Indian wolf obtained from camera traps in 2018-19 and secondary data.

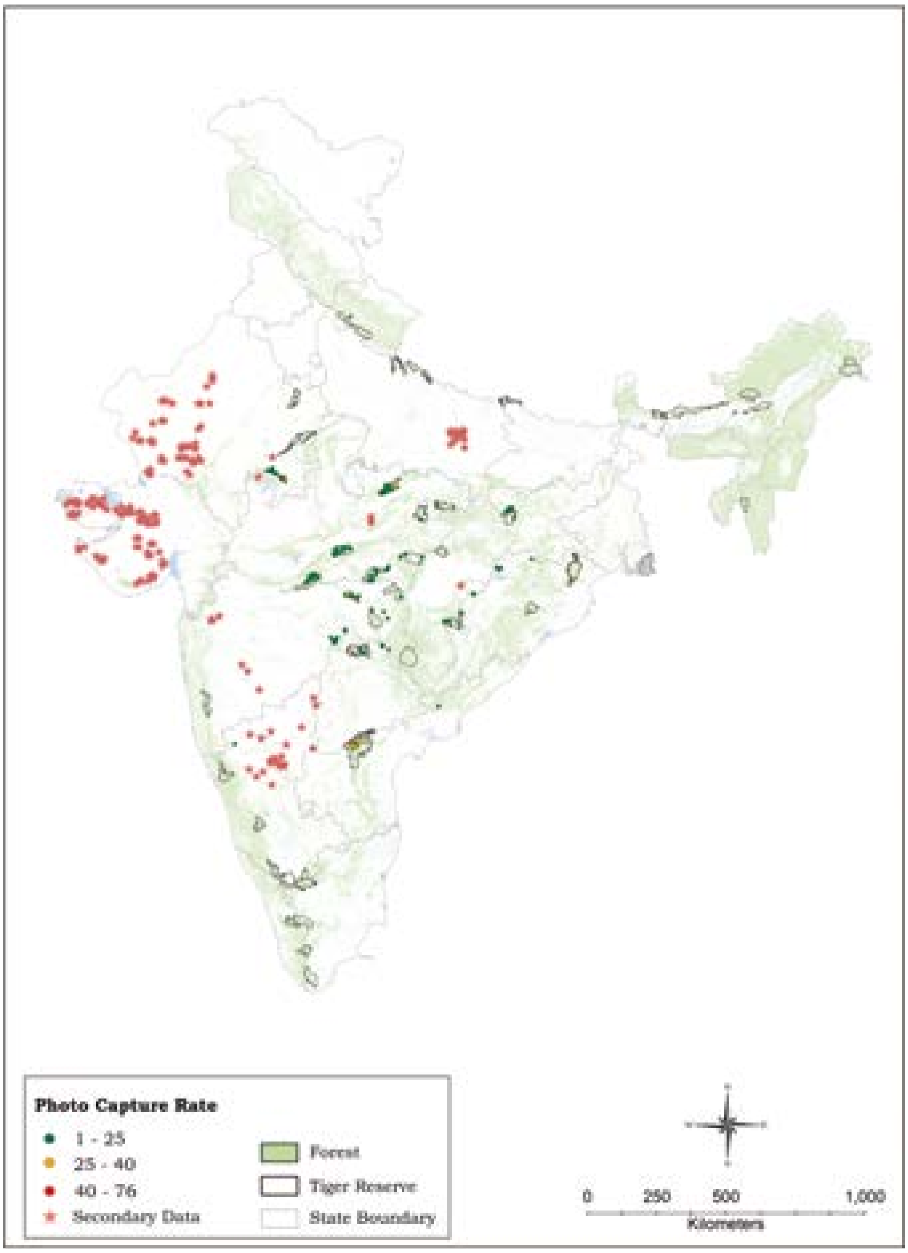


Figure 20.2: Activity pattern of Indian wolf obtained from camera trap photo-captures (N=839) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

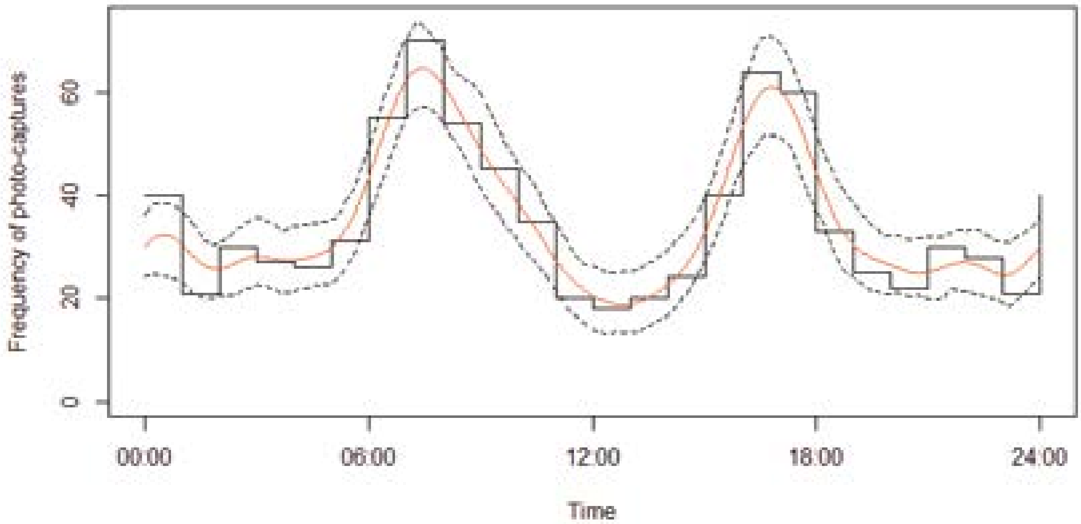


Table 20.1: Parameters used in MaxEnt setting for modelling Indian wolfdistribution/habitat in forested landscapes of India

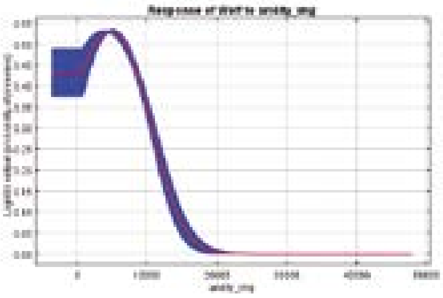
Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.34
Area under the ROC* Curve (AUC)	0.864

**receiver operating characteristic*

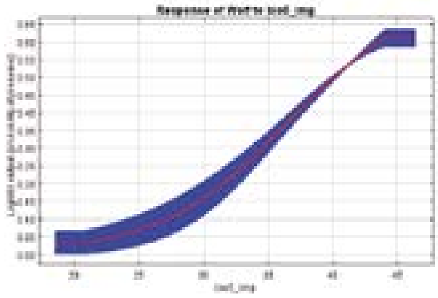
Table 20.2: Contribution percentage of every covariate (± SD) to the best model explaining distribution of Indian wolf

Covariates	Percent contribution (± SD)	Permutation contribution (± SD)
Human Pressure	65.05 (2.43)	56.41 (3.55)
NDVI April	15.80 (2.83)	7.56 (2.63)
Minimum temperature of coldest month (BIO6)	8.23 (1.74)	14.60 (2.29)
Maximum temperature of warmest month (BIO5)	4.28 (2.06)	0.32 (0.47)
Aridity Index	3.62 (1.11)	19.42 (1.97)
Ruggedness	2.99 (1.63)	1.67 (1.22)

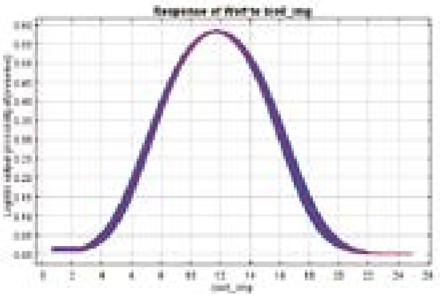
Figure 20.3: Relationship of Indian wolf with A) Aridity, B) Maximum temperature of warmest month, C) Minimum temperature of coldest month (°C), D) Human Pressure, E) NDVI and F) Ruggedness



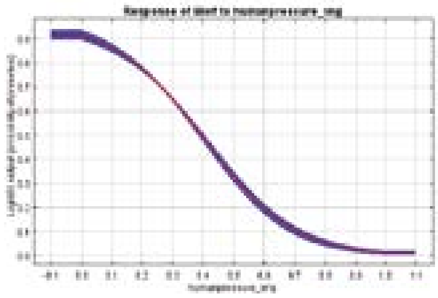
A) Aridity



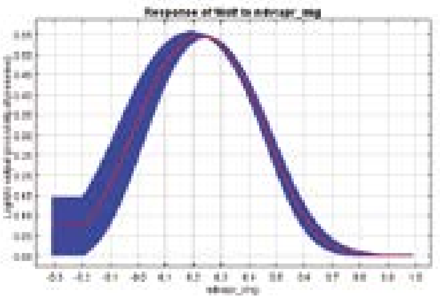
B) Maximum temperature of warmest month



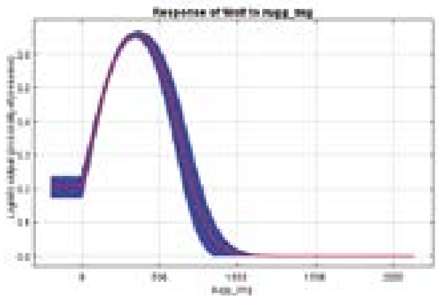
C) Minimum temperature of coolest month



D) Human pressure

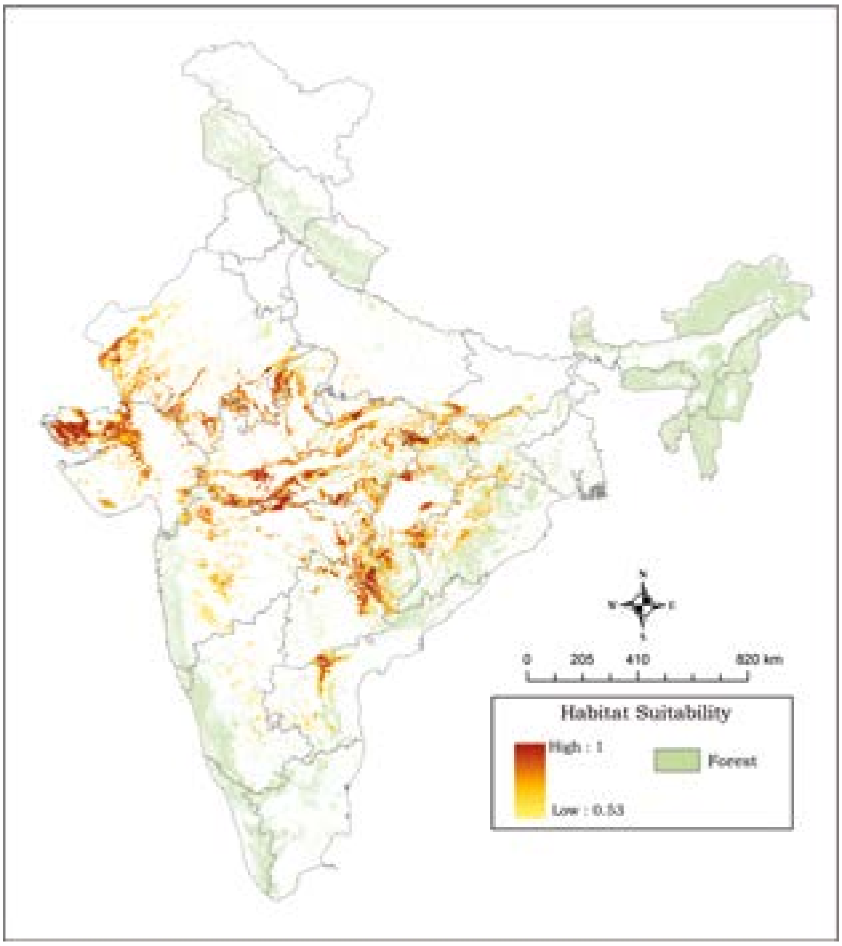


E) NDVI



F) Ruggedness

Figure 20.4: Distribution of Indian wolf across India estimated from presence obtained by camera traps, secondary data and environmental covariates.



Conservation significance

Despite heavy biotic interferences on semi-arid landscapes by humans and livestock populations and escalating conflicts, wolves continue to survive in India primarily because of tolerant and cultural attitudes of human communities towards all forms of life, coupled with low density of fire arms and no systematic use of poisons. However, this old value system of reverence and cultural tolerance is rapidly altering in an agrarian country like India under bourgeoning pressure of economic development. With rapid conversion of fallow lands and communal grazing lands for agriculture and industries, the major threat to surviving wolf populations in India is loss of habitat resulting into low recruitment due to non-availability of appropriate denning and rendezvous sites. This combined with depletion of natural prey for wolves, conflicts with humans due to livestock depredation and diseases such as Canine Distemper and rabies due to increasing interface with feral dogs may further endanger this canid in India. There is an urgent need for implementing a National Wolf Conservation Strategy (Jhala 2003) by amalgamating i) adequate protection, ii) appropriate land use policy securing breeding habitats for wolves, iii) balancing local livelihood economics, iv) eradicating feral dogs from wolf conservation areas, v) more targeted research on wolf ranging, population dynamics, habitat use, diet, disease and, vi) educating and creating awareness amongst local communities eliciting better public support for wolf conservation. The Indian wolf population is threatened most by hybridization with dogs in semi-arid agro-pastoral landscapes and seems to be increasing in and around Protected Areas composed by dry deciduous, and thorn forest.

CHAPTER 21:
STRIPED HYENA
(HYAENA HYAENA)

INTRODUCTION

Conservation status
IUCN Red List: Near threatened (NT)
Wildlife (Protection) Act, 1972: Schedule III

Striped hyena has an extensive range which extends from parts of Northern and Eastern Africa; Arabian Peninsula; Asia Minor up to the Mediterranean coast and in the Caucasus Mountains; southern Afghanistan; Pakistan, and much of India (AbiSaid and Dloniak 2015). Hyenas are not found in Bhutan, Sri Lanka, and east West Bengal and Assam (Mills and Hofer 1998). In the Indian subcontinent, striped hyena is reported from much of the peninsular India, especially in the semi-arid areas of Rajasthan, Gujarat, Madhya Pradesh, Chhattisgarh, Maharashtra, Karnataka, and Tamil Nadu (Jhala 2013) covering a minimal forested area of about 94,500 km^2 of the country (Jhala et al. 2020). Kumar (2012) reported a minimum hyena occupancy of approximately 4,500 km^2 in the arid and semi-arid regions of Gujarat and Rajasthan. The terai habitat in the Himalayan foothills limits the northern range of the species (Jhala 2013), however, in recent times there have been very few records of the striped hyena from much of this landscape (Jhala et al. 2020).

Hyenas are often persecuted for their occasional habit of livestock predation, sometimes accused of lifting children and robbing graves (AbiSaid and Dloniak 2015). They are often killed by poisoning directed towards other predators like wolves (Jhala 2013). Road kills have also been identified as a significant threat for hyenas (Mousavi 2010, Mandal 2018). The skins of this species are illegally traded and body parts are used in traditional medicine (AbiSaid and Dloniak 2015). Road kills of hyenas are quite common since they often feed on road killed carcasses of other animals and fall victim to headlights of fast moving vehicles (Jhala 2013).

SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Striped hyena is characterised by a shaggy buff-coloured coat with black stripes and bushy tail and a robust forequarter. Relatively shorter hind-legs give a sloping posture to the animal. There are 5-9 vertical black stripes on the flanks, two prominent cheek stripes, and broken horizontal stripes on the legs. The muzzle is broad and grey, while the throat has a characteristic black patch (Jhala 2013). The pelage can vary geographically from a very light buff to grey and sometimes even pale cream (Pocock 1934).

Body size:
Head and body length: 100-115cm, Tail length: 26 to 47cm (Rieger 1981, Menon 2014).

Body weight:
Male- 26-41 kg, Female- 26-34 kg (Wilson and Mittermeier 2009, Jhala 2013)

Gestation period:
90 days (Pocock 1941, Nowak 1999, Wagner 2006)

Litter size:
Average 2-3 (Davidar 1985, Alam 2011, Bopanna 2013)

Life span:
23 to 24 years in captivity (Rieger 1981)

ECOLOGY AND BEHAVIOUR

Generally striped hyena favours open or thorn bush country in arid to semi-arid environments (Rosevear et al. 1974, Kruuk 1976, Rieger and Ruppert 1978, Leakey et al. 1999) where water is available within 10 km (Rieger and Ruppert 1978). Striped hyenas have been found upto altitudes of 3,300 m in Pakistan (Rieger and Ruppert 1978) and at least to 2,300 m in the Ethiopian Highlands (Yalden et al. 1996). Striped hyenas seek out relatively heavy vegetative cover or rocky depressions, particularly large caves, for resting (Kruuk 1976, Rieger and Ruppert 1978, Leakey et al. 1999, Wagner et al. 2008). The terrain ruggedness provides optimal refuges and denning sites that are relatively free of anthropogenic activity (Singh et al. 2010, Singh et al. 2014). In India, the species occurs mostly outside the Protected Areas in semi-arid agro-pastoral landscapes with large livestock population such as areas of Deccan Plateau, Kutch, Saurashtra and parts of Rajasthan and Madhya Pradesh (Jhala 2013).

Striped hyena is primarily a scavenger, feeding on ungulate carcasses predated by large carnivores as well as on dead livestock in human dominated landscape (Jhala 2013). However, it opportunistically hunts small to medium sized ungulates including livestock.

Earlier reports of striped hyenas made them out to be solitary or operating in pairs (Finn 1929, Rieger 1979, Hofer et al. 1998). However, recent studies revealed complex social systems for hyenas in semi-arid regions of India (Bopanna 2013, Mandal 2018). Home range sizes of hyenas varied between 60-125 km² in Kutch, India (Bopanna 2013) while in Laikipia, Kenya, the same has been reported to vary between 44 to 72 km² (Wagner 2006). They are strongly nocturnal spending the day in deep burrows (Jhala 2013).

RESULTS

A total of 10422 independent photo-captures of striped hyena were used to build up the species distribution model, (Figure 21.1) and 24 additional sighting records were obtained from Kachchh, Gir, and Velavadar region of Gujarat, and Kumbhalgarh WLS of Rajasthan (Y.V. Jhala, unpublished data). High photo-captures of striped hyena were obtained from the dry forests of Aravalli and Vindhyan hills. Proportion of time spent active by Striped hyena in a day was 0.51 (SE 0.01) and was primarily nocturnal with a sharp decline in activity with daybreak 06:00 hours until dark (Figure 21.2). This separation of activity from human use of the landscape and the habit of spending daylight hours in deep burrows, allows the stripe hyena to persist even in human dominated parts of the landscapes. Details of the parameters used in MaxEnt for modelling the striped hyena distribution are provided in Table 21.1. In the case of striped hyena MaxEnt models, we excluded higher elevations of the Himalayan region (Msl > 1,000m) and the entire north-eastern region, as the species has never been reported from these regions.

According to MaxEnt estimates of relative contribution of predictor variables (Table 21.2), maximum % contributions to striped hyena habitat model were from NDVI difference (October to April) and aridity index, where species preferred dry deciduous habitats of the semi-arid region (within the modelling extent). Species habitat further defined by human pressure, annual mean temperature (BIO 1), and ruggedness. The striped hyena distribution model showed its preferences towards moderately rugged areas with moderate to low human disturbances, annual mean temperature ranges from 22-25 °C (Table 21.2, Figure 21.3). The modelled distribution of striped hyena across India, developed by the presence points and environmental covariates is given in Figure 21.4.

Figure 21.1: Presence locations and intensity of photo-captures of striped hyena obtained from camera traps in 2018-19 and secondary data.

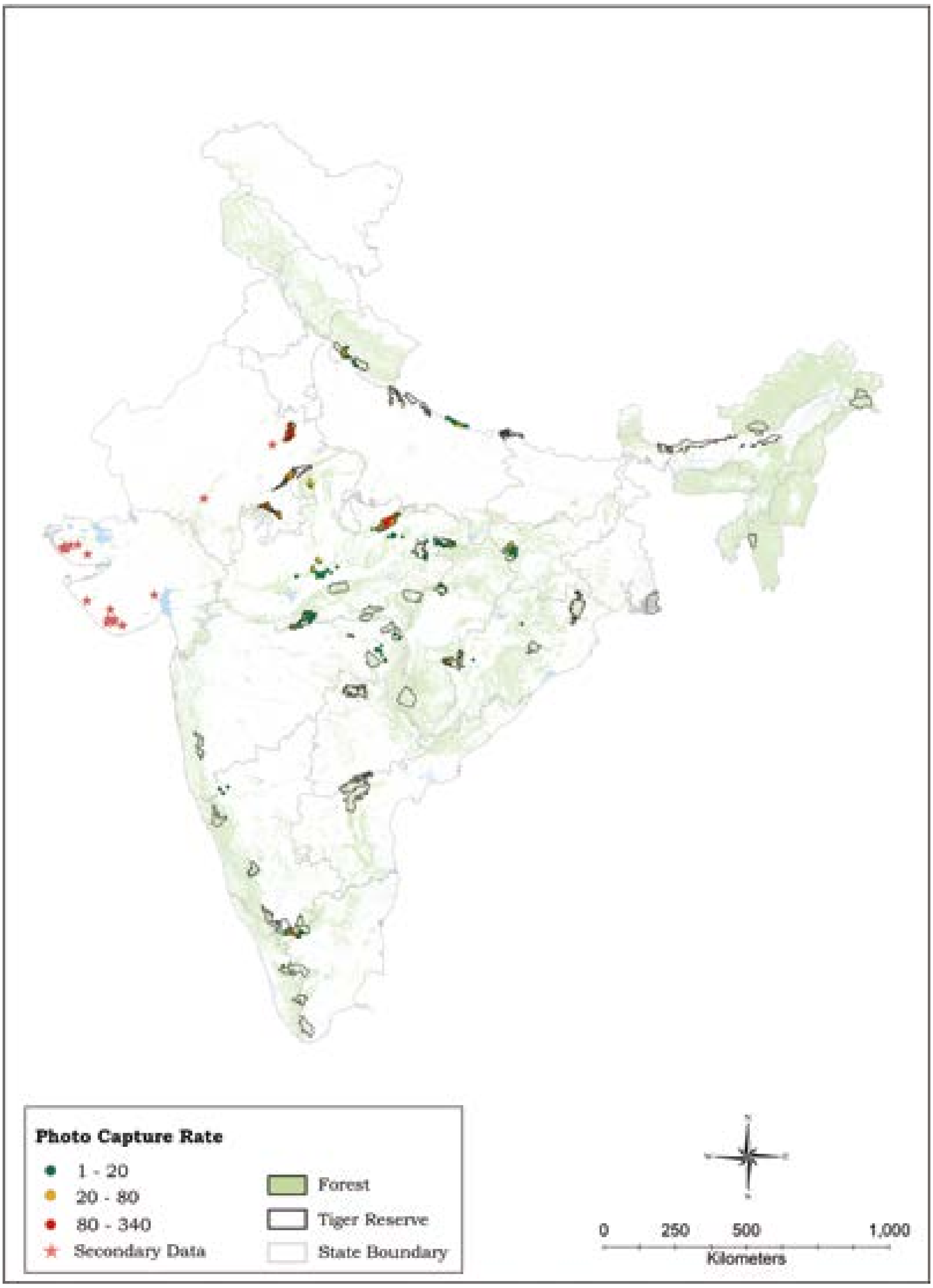


Figure 21.2: Activity pattern of striped hyena obtained from camera trap photo-captures (N=10422) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

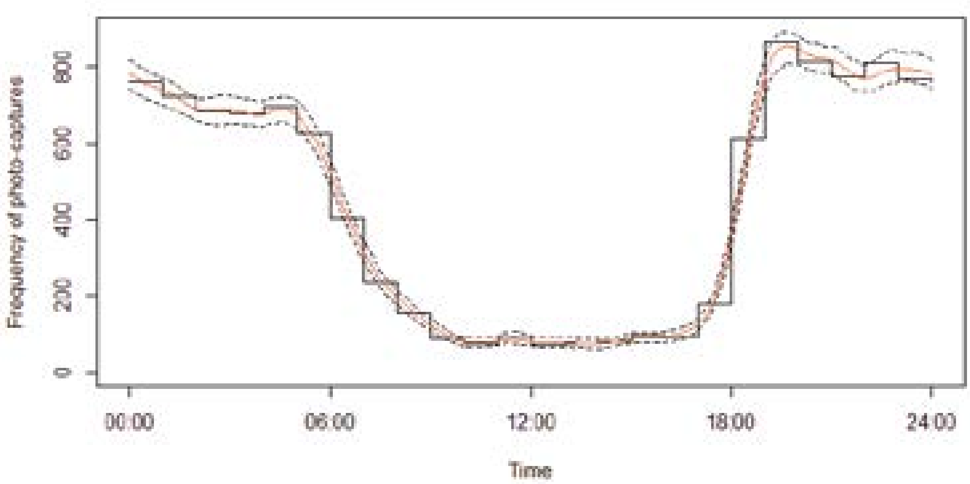


Table 21.1: Parameters used in MaxEnt setting for modelling striped hyena distribution/habitat in forested landscapes of India

Model setting	Values
Model features	Linear and quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.38
Area under the ROC* Curve (AUC)	0.80

**receiver operating characteristic*

Table 21.2: Contribution percentage of every covariate (SD) to the best model explaining striped hyena distribution

Covariates	Percent contribution (SD)	Permutation contribution (SD)
NDVI Difference	31.4 (2.24)	15.93 (1.45)
Aridity index	31.1(1.80)	35.01 (1.34)
Human pressure	17.43(2.23)	14.4 (1.60)
Annual mean temperature (BIO 1)	13.99 (0.89)	22.89 (1.04)
Ruggedness	6.03 (0.72)	11.67 (1.21)

Figure 21.3: Relationship of striped hyena with A) NDVI difference, B) Aridity index, C) Human pressure, D) Annual Mean Temperature (BIO1) (°C) and E) Ruggedness index

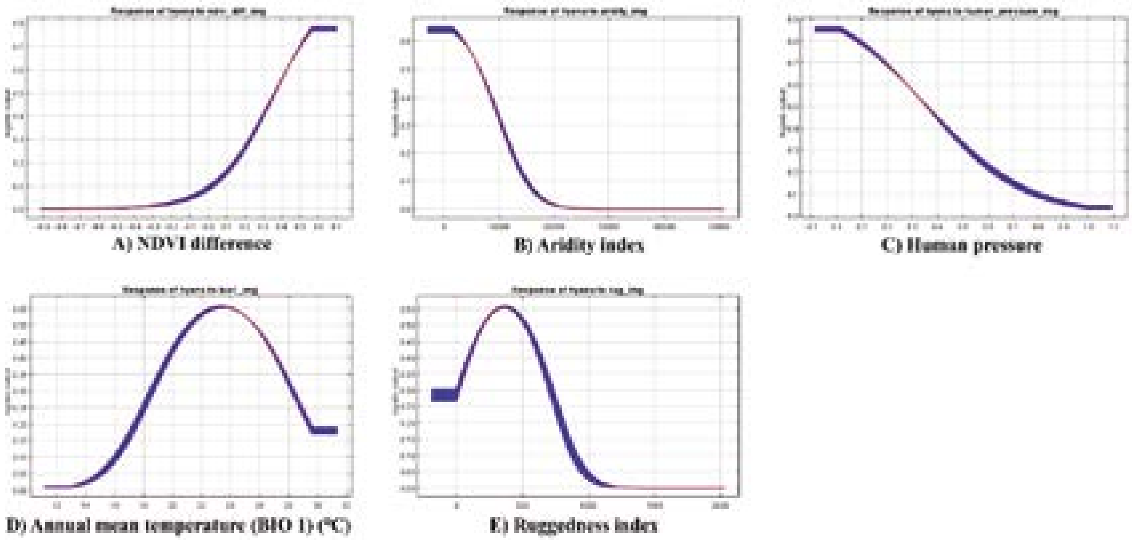
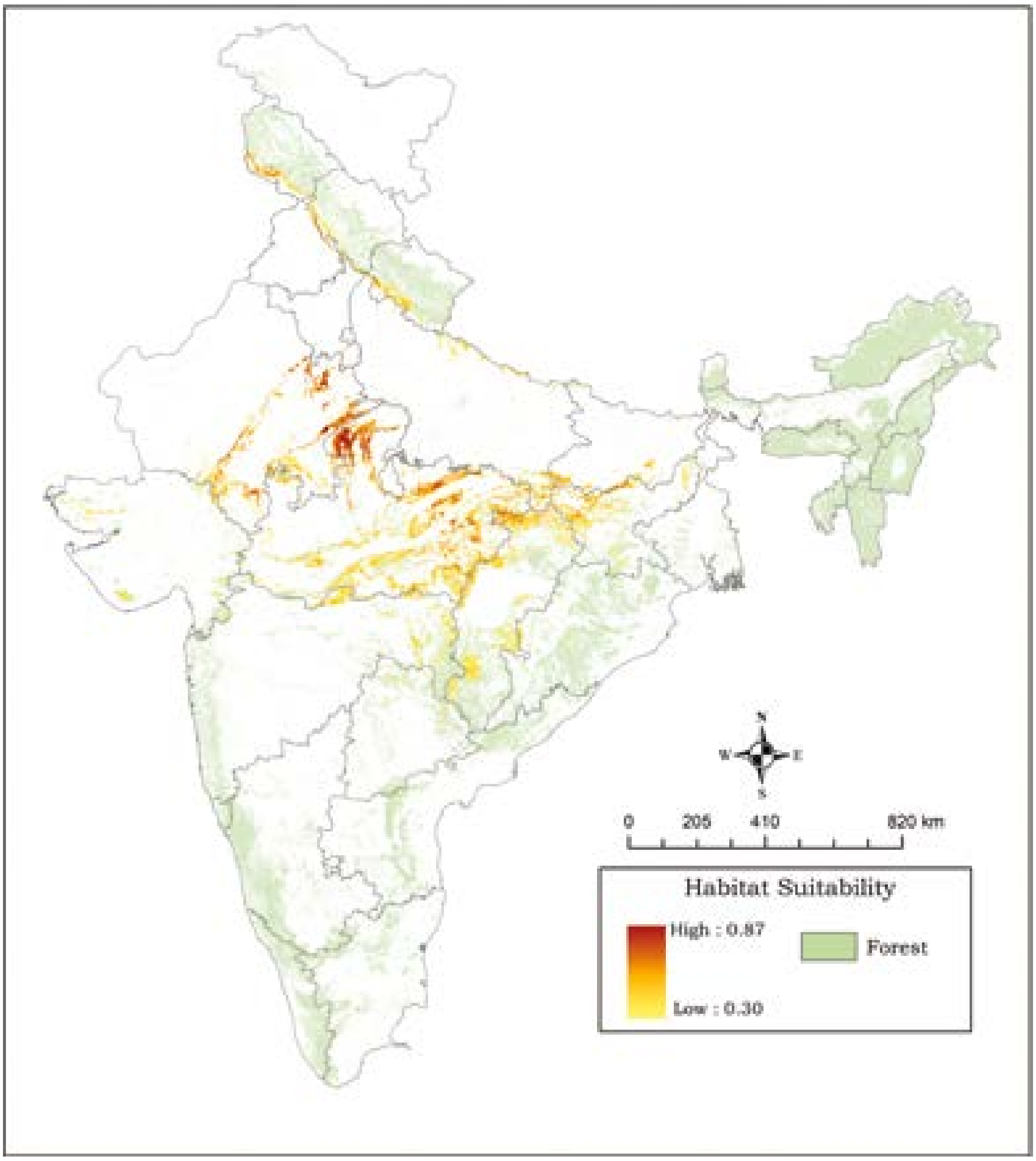


Figure 21.4: Distribution of striped hyena across the forested areas of India estimated from presence obtained by camera traps, secondary data and environmental covariates.



Conservation significance

Hyenas are not considered endangered due to their widespread distribution in India. However, considering the patchy, low-density distributions of hyenas, their extreme vulnerability to poisoning episodes and continuous loss of habitats, their status should be upgraded as threatened in India. Conservation measures such as identification of population strongholds of hyenas, protection of their denning habitats, enforcing strict punishment for use of poison against the carnivores, public education and targeted research on hyena's population dynamics, ranging, diet and social organization should be undertaken so as to formulate appropriate conservation management strategies.

BEARS, MUSTELIDS & VIVERRIDS

CHAPTER 22:
SLOTH BEAR
(MELURSUS URSINUS)

INTRODUCTION

Conservation status
IUCN Red List: Vulnerable (VU)
Wildlife (Protection) Act, 1972: Schedule I

Sloth bears are endemic to Indian subcontinent, viz., India, Sri Lanka, Nepal, Bhutan and Bangladesh. Once abundant across the lowlands of the Indian subcontinent (McTaggart-Cowan 1972, Krishnan 1972, Brander 1982), sloth bear has now become confined mainly to protected areas and its surrounds within its historical range. About 90% of the current range of the species occurs in India with the total occupied area varying between 200,000 km^2 (Johnsingh 2003, Akhtar et al. 2004, Chauhan 2006, Jhala et al. 2014, Jhala et al. 2018) and 400,000 km^2 (Sathyakumar et al. 2012) with an estimated population of 7,000-13,000 individuals (Jaffeson 1975, Yoganand et al. 1999). In India its distribution can be divided into five distinct regions namely northern, north eastern, central, south eastern and south western (Johnsingh 2003, Yoganand et al. 2006, Sathyakumar et al. 2012). Northern region includes states of Uttarakhand, Uttar Pradesh and Bihar and also includes transboundary population with Nepal. This population is believed to be geographically completely isolated from other populations in India due to large scale forest fragmentation as a result of agricultural expansion, urbanization and industrialization (Bargali et al. 2012). Assam holds the bulk of sloth bear population in the north eastern region (Choudhury 2011), though the species is known from Manipur, Mizoram, Meghalaya and Arunachal Pradesh as well (Yoganand et al. 1999, Dharaiya et al. 2020) and their distribution here overlaps with that of both Asiatic black bears and Malayan sun bears. In the central region, the bulk of the distribution occurs in the states of Madhya Pradesh and Chhattisgarh, but also includes the states of Odisha, Andhra Pradesh, Telangana, Maharashtra, Uttar Pradesh, Bihar, Jharkhand and West Bengal. South eastern population is distributed along the Eastern Ghats in the southern parts of Andhra Pradesh. The southwestern area follows the Western Ghats and covers the states of Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu. Sloth bear have been observed up to 2,000 m elevation in the Western Ghats (Garshelis et al. 1999a). They also stretch northwestward into Gujarat and Rajasthan with the westernmost distribution limited by the deserts (Yoganand et al. 2013).

Apart from loss of habitats (Garshelis et al. 1999a), other major threats for the species include hunting for bile that is used in traditional Chinese medicine, claws, meat, and skin (Yoganand 2005, Bargali et al. 2012), conflict with humans and retaliatory killing (Rajpurohit and Krausman 2000, Bargali et al. 2005, Dharaiya and Ratnayeke 2009, Mardaraj 2014).

SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Sloth bear is characterized by its black shaggy coat, a prominent 'V' or 'U' shaped whitish or buff-coloured patch on the breast and muzzle covered with thin and short greyish white hairs. A rare brown morph had also been reported from peninsular India (Pocock 1933, Prater 1971, Brander 1982). From behind the ears to shoulder, the entire neck region is covered with dense and long hair (up to 30cm). The longer snout, exceptionally extensible lips and tongue, long claws, presence of rhinarium (furless skin that helps to keep the nostrils closed while feeding) and absence of front two incisors make the species a highly adapted insectivore (Pocock 1933).

Body size:

Head and Body Length: 140-190 cm; Tail Length: 8-17 cm (Menon 2014), Shoulder height: 60-92 cm (Hunter 2011)

Body weight:

Adult males 80-150 kg, adult females 60-100 kg (Prater 1971, Garshelis et al. 1999a)

Gestation period:

95-97 days in captivity (Joshi et al. 1999)

Litter size:

1-3 (Joshi et al. 1999)

Life span:

40 years (in captivity) (Hunter 2011).

ECOLOGY AND BEHAVIOUR

In Indian subcontinent sloth bear is found in wide variety of habitats. Among all those habitats, this species has been observed at high densities in moist deciduous forests followed by dry deciduous, scrublands and evergreen forests (Yoganand et al. 1999). Sloth bear prefers dense vegetation cover, escarpment areas and dense shrub patches for resting in daytime and foraging (Yoganand 2005). In the Terai Arc landscape, sloth bear prefers highly productive alluvial grasslands in dry season and move upland to sal forests during the wet season possibly to facilitate feeding on termites. In southern India sloth bear signs have been frequently encountered in dry deciduous forest perhaps due to higher abundance of fruiting trees and termites (Baskaran 1990). Sloth bear usually avoids human presence as it has been found in low densities or altogether absent in areas with high anthropogenic activities despite having preferred food availability (Garshelis et al. 1999b).

Sloth bears are the only myrmecophagous ursid. Their diet consists mostly of social insects like ground living ants, termites, and bee hives that are common and found in large colonies. Fruits that contain high sugar are also an attractive food for sloth bear (Laurie and Seidensticker 1977, Yoganand 2005).

Sloth bears are solitary, but territoriality has not been observed (Laurie and Seidensticker 1977, Joshi et al. 1999). Joshi et al. 1995 reported home range sizes of 9.4 km² and 14.4 km² for females and males respectively in Chitwan National Park, Nepal. Yoganand (2005) reported much higher home range sizes (25-100 km²) for sloth bears in Panna. Several studies have shown that sloth bear are active throughout the day but is most active at night (Sunquist 1982). This species also shows crepuscular activity pattern (Yoganand 2005).

RESULTS

A total of 20375 independent photo-captures were recorded during the field sampling with higher photographs from habitats like moist deciduous forest, dry deciduous forest, evergreen forests, scrublands and grasslands (Figure 22.1). Proportion of time active in a day for sloth bear was 0.47 (SE 0.01), its photo-captures shows bimodal peaks inactivity; late evening to night (18:00 hrs to 21:00 hrs) and small peak during early morning (05:00hrs to 08:00hrs) (Figure 22.2). Sloth bear distribution was across all protected areas and tiger reserves in northern, south-eastern, south-western and central parts of India except Sariska Tiger Reserve and in north-eastern region only found in Kaziranga Tiger Reserve (Figure 22.1). Data used and parameter settings of MaxEnt that used photo-capture intensity and eco-geographical covariates to model occurrence of sloth bear are provided in Table 22.1.

Maximum contribution to sloth bear habitat model was explained by human pressure (64.4 SD 1.62%) to species occurrence data was explained by human pressure and distance to forest (17.8 SD 1.23%) where predicted occurrence of the species appears in areas with intact forest patches and less human disturbance (Table 22.2, Figure 22.3). Sloth bear habitat was further defined by areas that have moderate elevation (less than 2500m) digital elevation model (9.1 SD 1.07%), moderate aridity (5.4 SD 0.57%) and NDVI April (3.2 SD 0.51%) (Table 22.2, Figure 22.3). The response curve for NDVI April explains that the species' suitable habitats are in moderately dense forests (excluding the Sundarban and the arid deserts where the species is not found) (Figure 22.3). This is also supported by the response curve for aridity (Figure 22.3) which depicts that extremely arid areas like trans Himalayas and deserts are not suitable for the sloth bear. The probability of occurrence within the forested habitats of tiger states based on the best MaxEnt model is given in Figure 22.4.

Figure 22.1: Presence locations and intensity of photo-captures of sloth bear obtained from camera traps in 2018-19

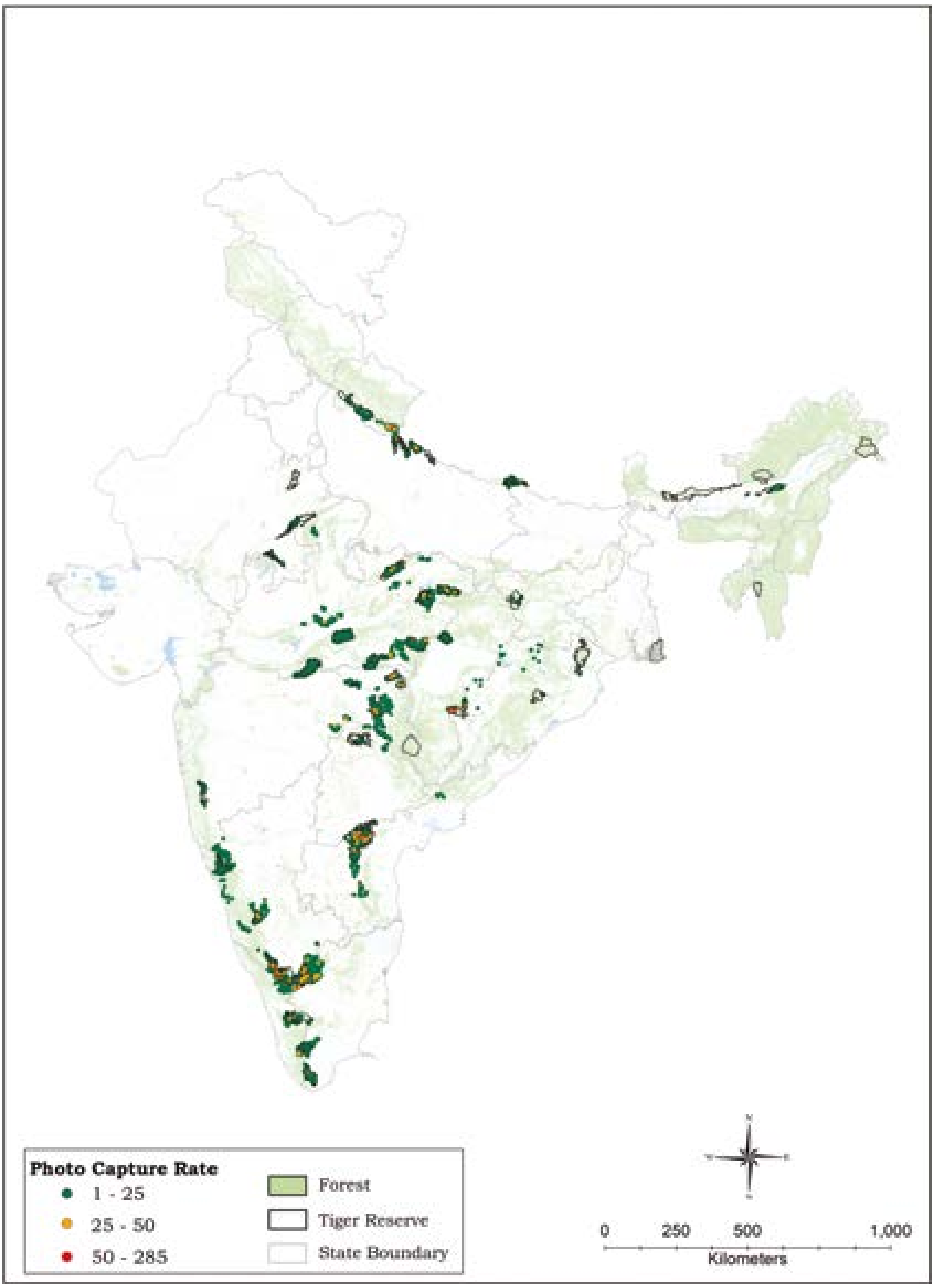


Figure 22.2: Activity pattern of sloth bear obtained from camera trap photo-captures (N= 20375) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

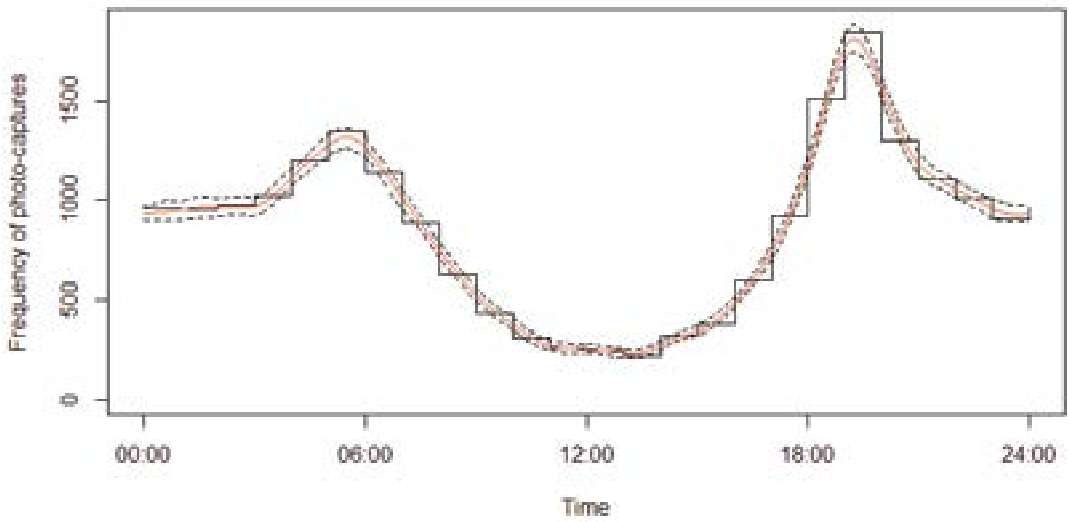


Table 22.1: Parameters used in MaxEnt setting for modelling sloth bear distribution/habitat in forested landscape of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.42
Area under the ROC* Curve (AUC)	0.68

**receiver operating characteristic*

Table 22.2: Contribution percentage of every covariate (SD) to the best model explaining sloth bear distribution

Covariates	Percent contribution (SD)	Permutation contribution (SD)
Human pressure	64.4 (1.62)	50.9 (1.70)
Distance to forest	17.8 (1.23)	17.1 (1.34)
Digital Elevation Model (DEM)	9.1 (1.07)	17 (0.70)
Aridity Index	5.4 (0.57)	4.2 (0.76)
NDVI April	3.2 (0.51)	10.8 (0.93)

Figure 22.3. Relationship of sloth bear with A) Human pressure, B) Distance to forest (meter), C) Digital Elevation Model (meter), D) Aridity and E) NDVI April

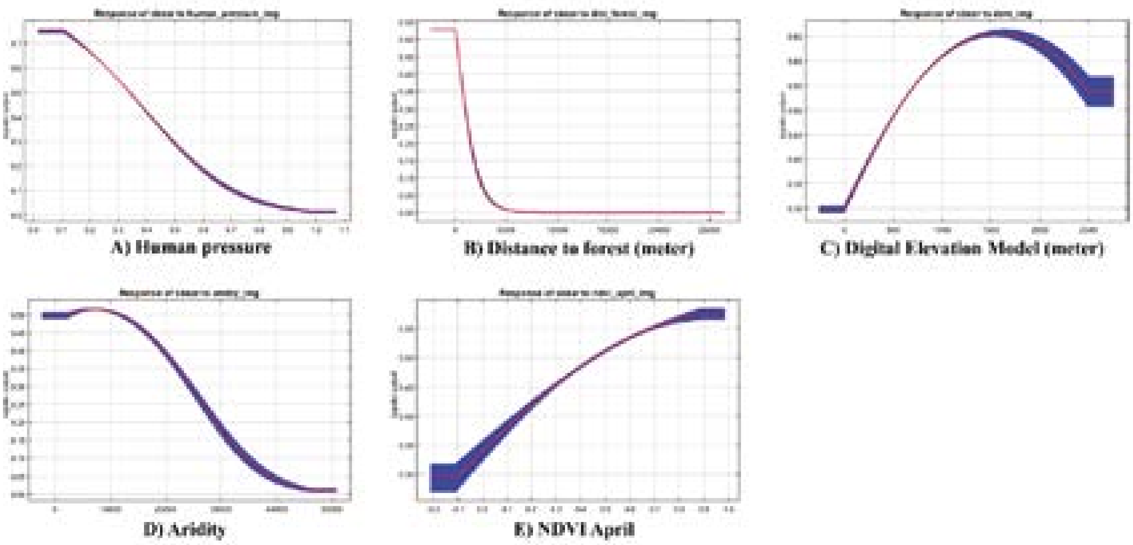
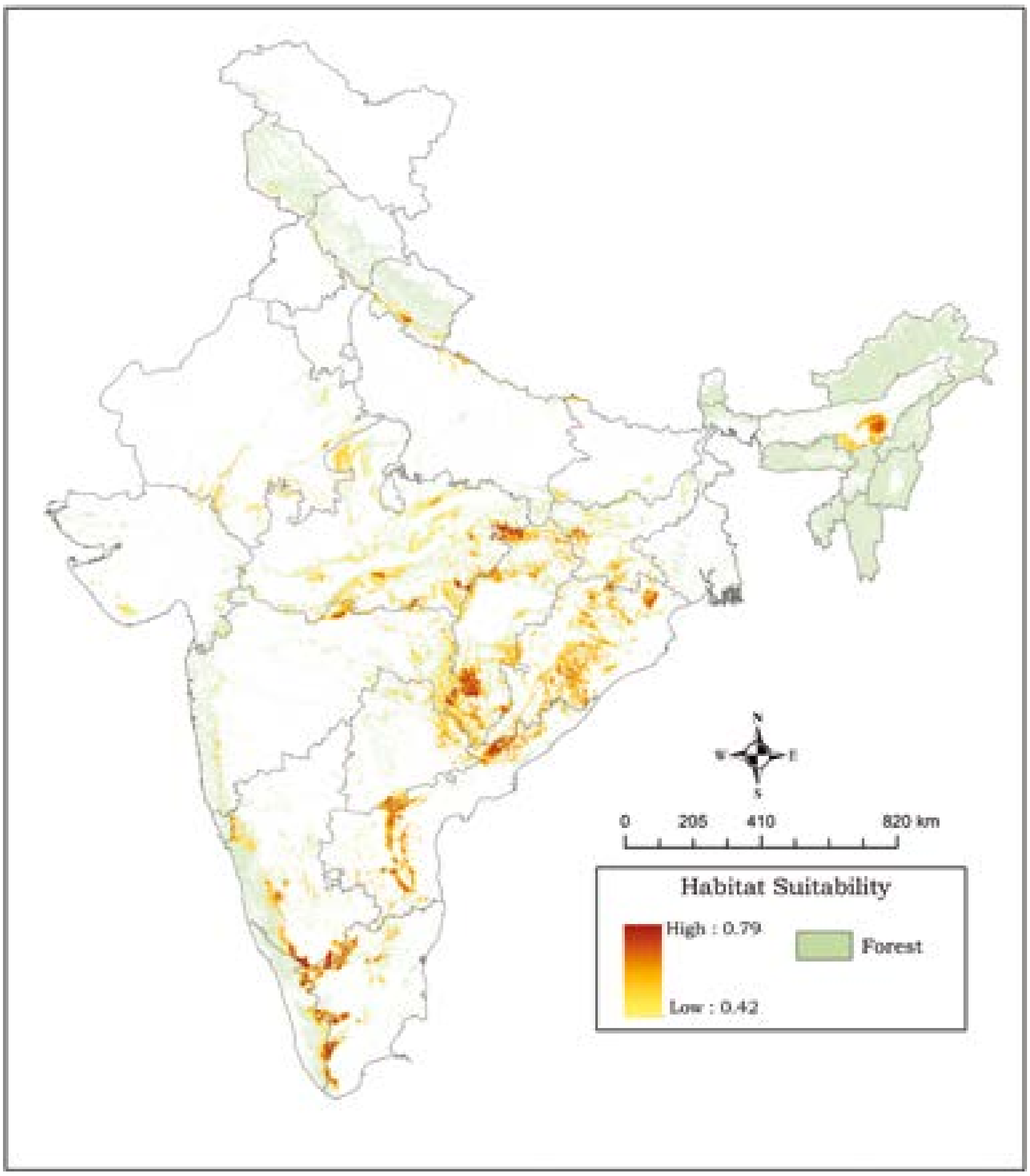


Figure 22.4: Distribution of sloth bear across the forested areas of India estimated from presence obtained by camera traps and environmental covariates.



Conservation significance

The sloth bear like other large carnivores requires vast areas to harbour viable populations. Its specialised diet ensures abundance of food supply in undisturbed ecosystems. Tiger reserves serve the purpose for conserving viable sloth bear populations. Also sloth bears have less genetic structuring across the India compared to tigers and therefore tiger corridors would serve the purpose of maintaining genetic connectivity for sloth bear as well. Control of illegal trade of bear bile will substantially reduce the direct threat of poaching. The future of sloth bear conservation in India seems secure under the current ambit of protected areas and tiger reserves.

CHAPTER 23:
HONEY BADGER
(MELLIVORA CAPENSIS)

INTRODUCTION

Conservation status

IUCN Red List: Least Concern (LC)

Wildlife (Protection) Act, 1972: Schedule I

Honey badger also known as ratel, is a medium sized, widely distributed mustelid. It is native to Africa and Asia, ranging from the Western Cape, South Africa, to southern Morocco extending through Arabia, Iran and western Asia to Turkmenistan, Nepal, and the Indian peninsula (Do Linh San et al. 2016). In India, this species is widely spread from the Himalayan foothills to southern India, excluding the northeast region of the country (Menon and Daniel 2003).

Honey Badgers are used as bushmeat and in traditional medicine, and are directly persecuted by apiculturists and small livestock farmers throughout their range (Begg and Begg 2002, Do Linh San et al. 2016).

SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Honey badger has a distinct broad streak of silver-grey to bright white, running from the head to the base of the tail, while the sides, snout and underparts are deep brown or black. The upper parts are more buff or rust-brown in juveniles. Honey badger has a distinctive broad, cylindrical body, with stumpy legs, small snout and flattened short earflaps. It has a thick and loose skin. The fur is short and glossy. The forefeet are strong and wide, adapted for a fossorial lifestyle. Exhibiting sexual dimorphism, the male is significantly larger than the female (Prater 1971, Menon and Daniel 2003, Sterndale 1884).

Body size:

Head and Body Length: 60-77 cm Tail Length: 15-25 cm (Menon and Daniel 2003)

Body weight:

7-13 kg (Mudappa 2013)

Gestation period:

50-70 days (Begg et al. 2005a)

Litter size:

1-2 (Begg et al. 2005a)

Life span:

7 to 8 years in wild and 24 to 26 years in captivity (Begg et al. 2005a).

ECOLOGY AND BEHAVIOUR

Honey badgers live in a wide variety of habitats from dense rain forests of equatorial Africa (Bahaa-el-din et al. 2013) to the miombo and mopane woodland of Eastern Africa (Bird and Mateke 2013, Fischer et al. 2013), and the arid deserts on the fringes of the Sahara and Namib. It also occurs in sand and clay deserts of Middle Asia (Heptner et al. 1967, Gorbunov 1995). In India, honey badger is found in desert and in dry and moist deciduous zones and avoids regions with heavy rainfall. It is found across elevations up to 4,000m (Do Linh San et al. 2016). It prefers banks of streams or rivers, where burrowing is easy (Prater 1971, Menon and Daniel 2003). Elevation, closeness to water and moderately dense canopied forests were found to predict suitable habitats for honey badger in western India (Gupta et al. 2012). Habitat use in central Indian dry deciduous forest revealed a positive association with forest cover and negative association with elevation (Chatterjee et al. 2020b). A study from southern Iran showed that due to change in land-use patterns, the species was compelled to select poor quality habitats in close proximity to human habitations (Sharifi et al. 2020).

Honey badgers are opportunistic, generalist carnivores, and feed on a range of prey items varying in size from small insect larvae to the young of ungulates (Begg et al. 2003). They can steal food from other carnivores and occasionally scavenge from the kills of large carnivores (Begg et al. 2013). It feeds on small rodents, snakes, birds, amphibians, insects, eggs, occasionally supplemented by a vegetarian diet such as fruits, roots, tubers and especially honey (Prater 1971, Menon 2014).

The species is solitary (Begg et al. 2005b, Menon 2014) with large home ranges (Male 541 km^2, Female 126 km^2; Begg et al. 2005b) in resource poor southern Kalahari. They are primarily nocturnal with activity pattern peaking at midnight (Chatterjee et al. 2020b), but may show diurnal activity patterns within inviolate spaces with less human activity, especially in winter months (Do Linh San et al. 2016).

RESULTS

A total of 3967 independent photo-captures obtained from 1957 camera trap locations were used for modelling, recorded during the field sampling with majority of the locations in dry deciduous forests, moist deciduous forests of the terai region and savannas in tropical India (Figure 23.1). Additionally, we used 19 presence records from secondary sources (Y.V. Jhala unpublished data). Proportion of time spent active in a day was 0.45 (SE 0.01) for the honey badger and it was primarily found to be active at night with maximum activity between 20:00 hrs and 02:00 hrs (Figure 23.2). Data used and parameters of the best model are provided in Table 23.1 and modelled distribution of honey badger is given in Figure 23.4.

Human pressure had the maximum contribution (36.60, SD 2.25%) to the model. Higher human disturbance was negatively correlated with occurrence of honey badgers (Table 23.2, Figure 23.3). Honey badgers habitat was further defined by areas that have open to moderate canopied forests (Summer NDVI, 31.10, SD 1.22 %) and that have maximum temperatures of the warmest months beyond 430C (BIO5, 28.10, SD 2.25%). The response curve for annual precipitation explained that species found in habitats that have 200-2000 mm (low to moderate) rainfall (BIO12, 4.20, SD 0.57%), (Table 23.2, Figure 23.3). The resultant distribution (Figure 4) indicated higher distribution in Protected Areas of semi-arid and deciduous forests (e.g. Sariska, Ranthambhore, Satpura, Melghat, Tadoba, Amrabad, Nagarjunasagar-Srisailam Tiger Reserves), and in drier regions of the Western Ghats, Himalayan foothills and Odisha that have lower rainfall.

Figure 23.1: Presence locations and intensity of photo-captures of honey badger obtained from camera traps in 2018-19 and secondary data.

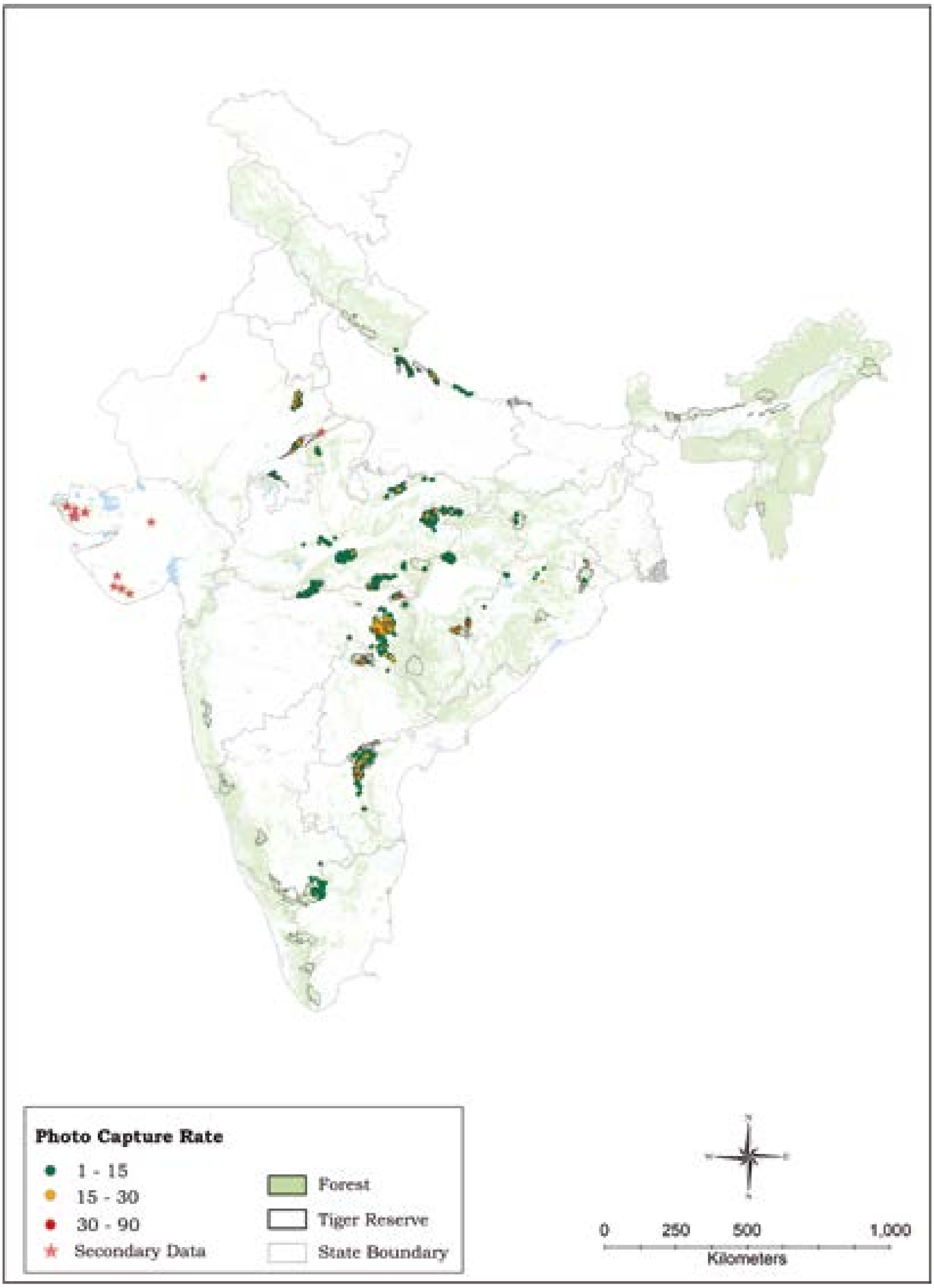


Figure 23.2: Activity pattern of honey badger obtained from camera trap photo-captures (N= 3967) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

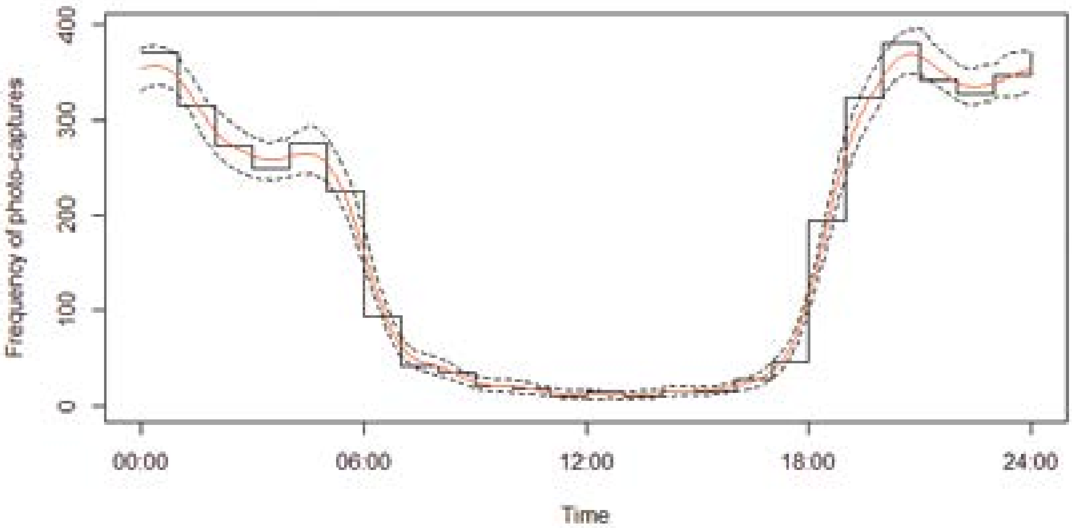


Table 23.1: Parameters used in MaxEnt setting for modelling the distribution/habitat of honey badger in forested landscapes of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'maximum test sensitivity plus specificity'	0.38
Area under the ROC* Curve (AUC)	0.80

**receiver operating characteristic*

Table 23.2: Contribution percentage of every covariate (SD) to the best model explaining distribution of honey badger

Covariates	Percent contribution (SD)	Permutation contribution (SD)
Human pressure	36.60 (2.25)	28.90 (1.78)
NDVI April	31.10 (1.22)	34.70 (1.26)
Maximum temperature of the warmest month (BIO5)	28.10 (2.25)	23.40 (2.07)
Annual precipitation (BIO12)	4.20 (0.57)	12.90 (1.19)

Figure 23.3: Relationship of honey badger with A) Human pressure, B) NDVI April, C) Maximum temperature of the warmest month, and D) Annual precipitation

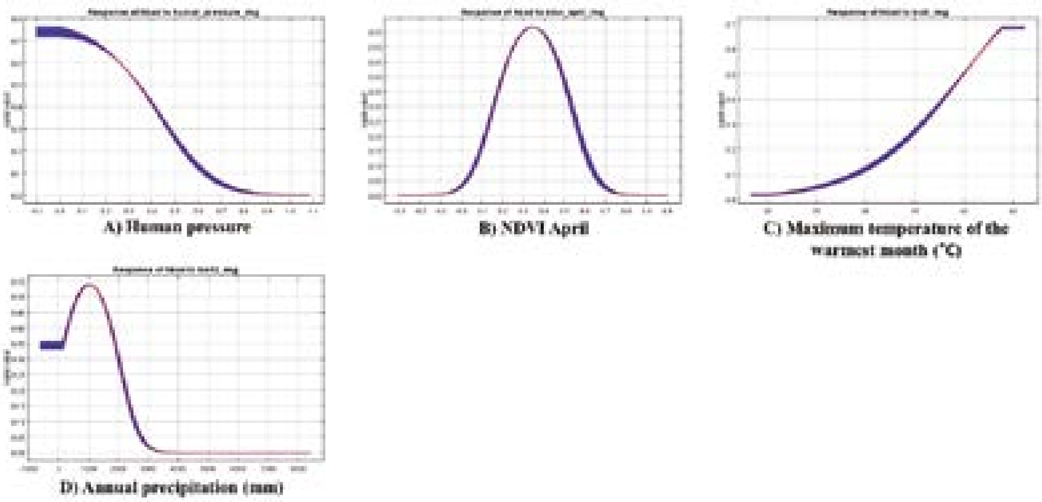
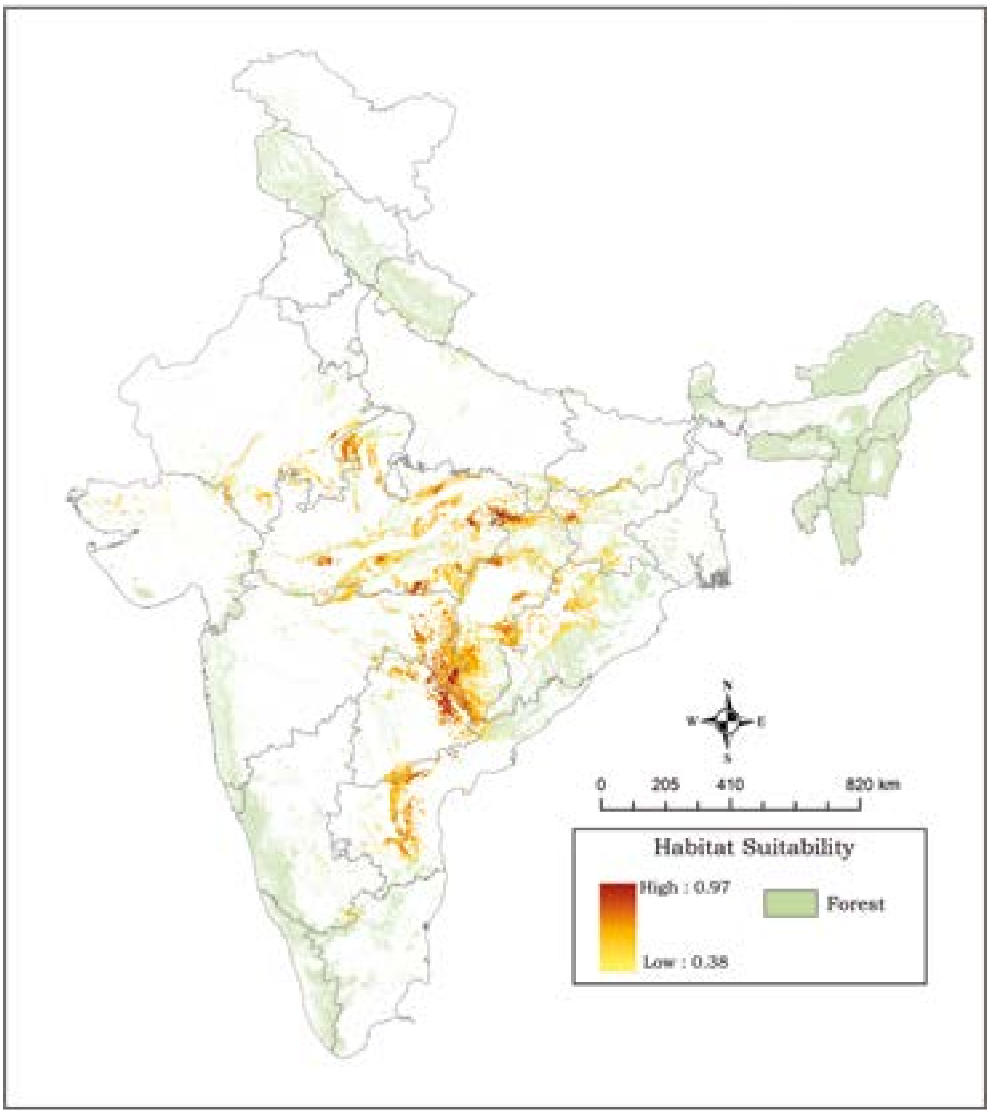


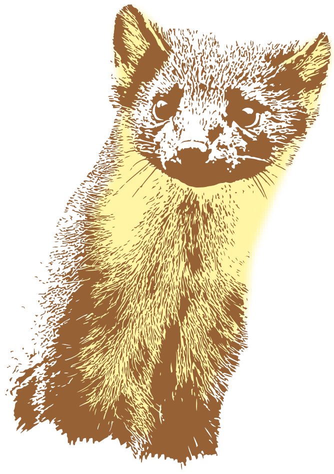
Figure 23.4: Distribution of honey badger across the forested areas of India estimated from presence obtained by camera traps, secondary data and environmental covariates.



Conservation significance

The information presented herein is the first comprehensive baseline for the status of elusive honey badger in India. It was heartening to see that the species still has a wide distribution and occurs in many of the protected areas in semi-arid thorn and deciduous forest regions. However, much of the honey badger's habitat outside of the protected areas ,that was constituted by pasture lands and open scrub, has been lost to agriculture and fragmented by linear infrastructure. The surviving populations are likely isolated small populations which will be left exposed to high extinct risks by stochastic demographic and environmental events. An in-depth study of some target populations using modern technology is required for understanding population density, ranging patterns, habitat use, diet and threats. Information from current distribution and relative abundance along with information on the ecology of the species will help form policy and management strategy for conserving honey badger in India.

CHAPTER 24:
NILGIRI MARTEN
(MARTES GWATKINSII)

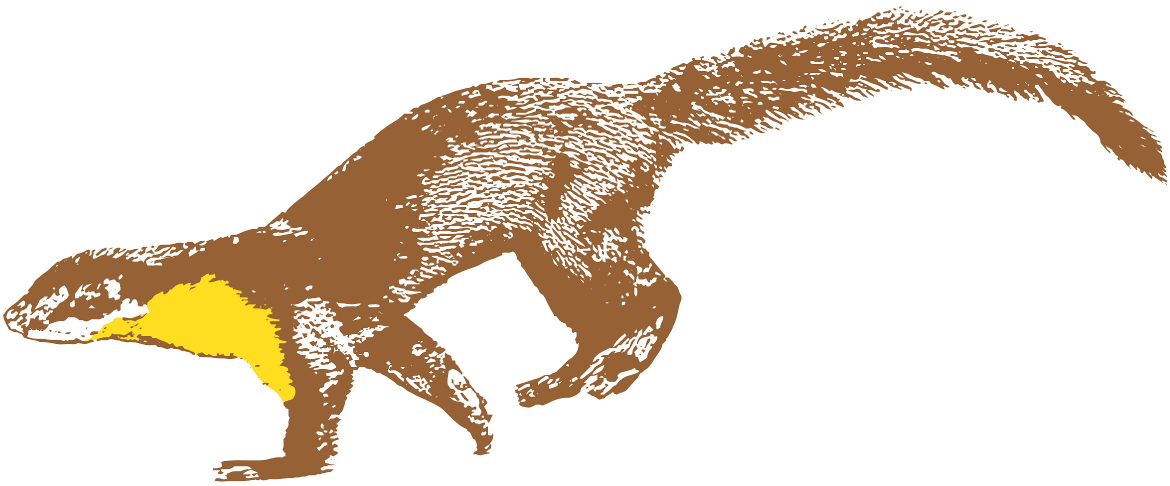


INTRODUCTION

Conservation status
IUCN Red List: Vulnerable (VU)
Wildlife (Protection) Act, 1972: Schedule II (Part I)

Nilgiri marten is one of the most elusive mustelids and is endemic to southern Western Ghats [excluding Sri Lanka] (Wirth and Van Rompaey 1991, Mudappa 2013). This species was earlier considered a subspecies of *Martis flavigula* (Corbet and Hill 1992), but subsequently has been recognised as a different species (Rozhnov 1995, Wozencraft 2005). Prior information on the species comes from a handful of sighting reports by biologists and naturalists. The species is distributed patchily, starting at the southernmost tip of the Western Ghats in Kalakkad-Mundanthurai Tiger Reserve (KMTR) (Mudappa 2001, 2002, Mudappa et al. 2007). The northern limit of its distribution appears to be in the forests of Charmadi-Kanapadi, which borders Kudremukh National Park to the south. Areas known to harbour the species include Eravikulam National Park (Madhusudan 1995, Nikhil and Nameer 2017); Mukurthi National Park (Yoganand and Kumar 1995, 1999); Peppara Wildlife Sanctuary (Christopher and Jayson 1996); Kalakkadu-Mundanthurai Tiger Reserve (Mudappa, 1998), Periyar Tiger Reserve, (Kurup and Joseph 2001), Silent Valley National Park (Sanghamithra and Nameer 2018), Parambikulam Tiger Reserve (Sreehari and Nameer 2013), Mudumalai tiger reserve (Jhala et al. 2020).

Major threats faced by the species include habitat destruction due to large developmental projects, persecution in retaliation for destroying apiaries and hunting for human consumption (Kumara and Singh 2007, Mudappa et al. 2015).



SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Nilgiri marten has a dark brown or black coloured coat along with a distinct yellow or orangish-yellow underside with relatively shorter blackish-brown tail. It has weasel-like stout legs with sharp partial retractile claws and flat pointed head (Mudappa 1999, Larivière 2009). It can be confused with Malabar Giant Squirrel (Ratufa indica) however the tail of the latter is bushier than Nilgiri marten (Mudappa 2001).

Body size:
Head and Body Length- 50 to 70 cm, Tail Length 35 to 50 cm (Menon 2014, Anil et al. 2018)

Body weight:
1-3 kg (Anil et al. 2018)

Gestation period:
Nilgiri martens' reproductive habits have not been studied, gestation typically lasts 30 to 65 days for mustelids. Gestation periods of closely related yellow-throated martens last between 220 and 290 days (Webb 2013).

Litter size:
2 to 6 (Webb 2013)

Life span:
10 to 18.1 years in captivity (Max-Planck-Gesellschaft 2002)

ECOLOGY AND BEHAVIOUR

Nilgiri marten is found mainly in evergreen forests, shola-grasslands and moist deciduous forests adjoining wet evergreen forests (Hutton 1949a, b, Madhusudan 1995, Christopher and Jayson 1996, Gokula and Ramachandran 1996, Kurup and Joseph 2001, Mudappa 2001, 2002, Balakrishnan 2005, Mudappa et al. 2007, Krishna and Karnad 2010). There are a few reports of the species' occurrence in plantations (described as occasional) adjoining evergreen forests, including tea, wattle *Acacia mearnsii, Eucalyptus* spp., and coffee-cardamom (Schreiber et al. 1989, Madhusudan 1995, Gokula and Ramachandran 1996). Mudappa (1999) reported that moist and tropical rainforests within an altitudinal range of 300 – 1,200 m are the preferred habitats of Nilgiri Marten. Recent reports indicate that it survives in forest patches on mountain summits up to an altitude of 2,600 m (Mudappa et al. 2015).

Niligiri marten predates on small bird or mammal (Roberts 1977). There are reports of hunting birds, mouse deer and monitor lizards (Pocock 1941, Hutton 1944, Mudappa 1999, Anil et al. 2018, Larivière and Jennings 2009) by this species. It also feeds on nectar (Balakrishnan 2005) and fruits (Anil et al. 2018).

The number of individuals seen at each sighting ranged from 1-4, with the maximum sightings of solitary individuals followed closely by several sightings of pairs (Jathanna 2014). All sighting reports indicate that the species is diurnal (Balakrishnan 2005).

RESULTS

A total of 87 independent photo-captures were recorded during the field sampling showing higher encounters in shola grasslands, semi evergreen forests, coffee and tea plantations from moist forest areas such as Periyar, Parambikulam Tiger Reserves etc. (Figure 24.1). Proportion of time spent active in a day by the species was 0.39 (SE 0.06) and activity pattern of the species shows maximum photo-captures during dawn and late evening (Figure 24.2), showing diurnal behaviour. Among the sampling areas, it was endemic to the semi evergreen forests and shola grasslands of Western Ghats. Data used and parameter settings of MaxEnt that used photo-capture intensity and eco-geographical covariates to model occurrence of nilgiri marten are provided in Table 24.1.

Maximum contribution to Nilgiri marten's habitat model was by (BIO5) which is maximum temperature of the warmest month (92.9, SD 2.89%) and NDVI difference (deciduousness of forests) (2.5, SD 1.87%) where predicted occurrence of the species appears in areas with predominant semi evergreen moist forests and low human pressure (1.5, SD 1.55%). Nilgiri marten habitat was further defined by distance from grassland (1.3, SD 0.98%), BIO14 (precipitation of driest month) (1.0, SD 1.27 %), evapotranspiration (0.5, 0.42 SD %), and forest height (0.3, 0.33 SD %) (Table 24.2, Figure 24.3).

The response curve for BIO5 (maximum temperature of warmest month) explains the species preferred areas with cooler summer temperatures. The NDVI April curve explains the evergreen forests as the preferred habitat by the species. This model is also supported by the response curve for potential evapotranspiration and precipitation of driest month (BIO14) that explains the preference of moist or wet areas. Distance from grassland covariate shows grasslands as one of the preferred habitat (shola grasslands) by the species. The forest height curve described the species as a semi arboreal species and prefer trees of height around 20-50 ft. Probability of occurrence within the forested habitats of tiger states based on the best MaxEnt model is given in Figure 24.4.

Figure 24.1: Presence locations and intensity of photo-captures of Nilgiri marten obtained from camera traps in 2018-19

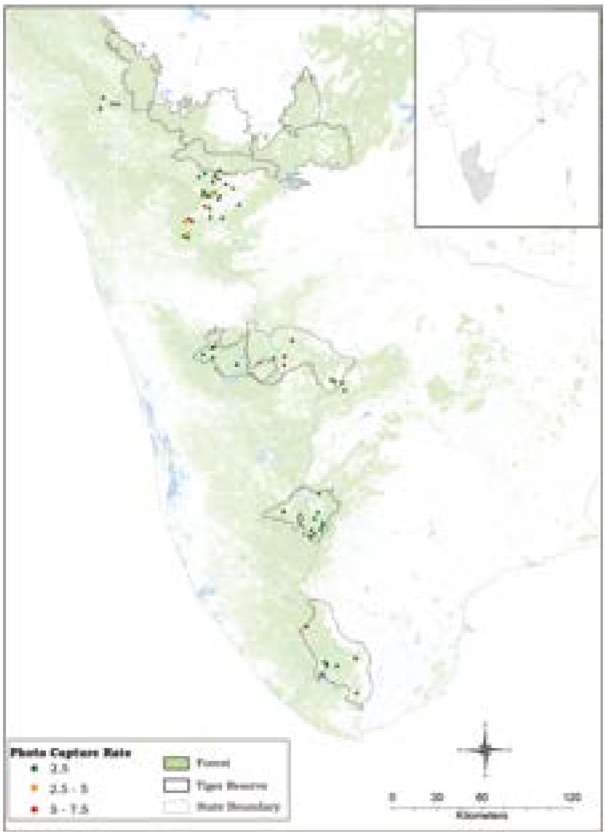


Figure 24.2: Activity pattern of Nilgiri marten obtained from camera trap photo-captures (N= 87) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

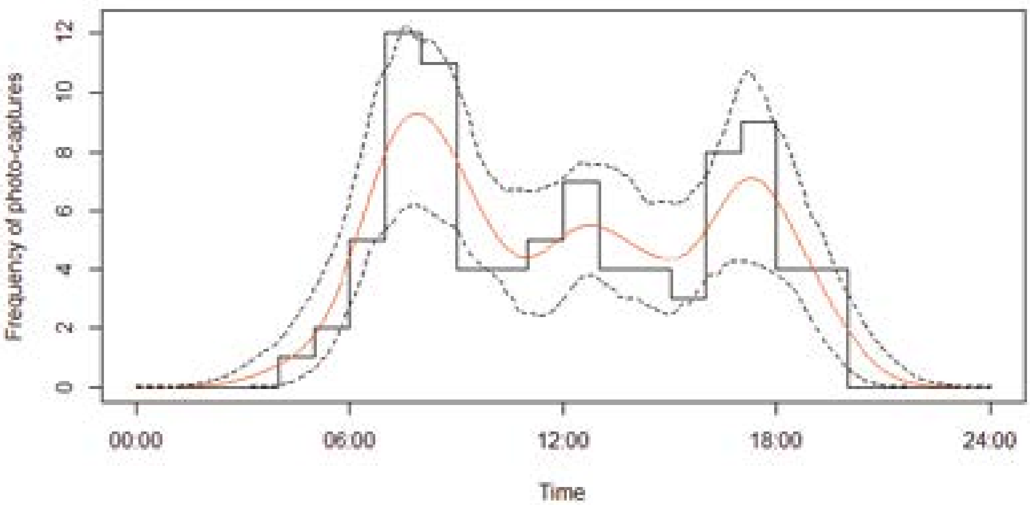


Table 24.1: Parameters used in MaxEnt setting for modeling Nilgiri marten distribution/habitat in the forested landscapes of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.12
Area under the ROC* Curve (AUC)	0.97

**receiver operating characteristic*

Table 24.2: Contribution percentage of every covariate (SD) to the best model explaining Nilgiri marten distribution

Covariates	Percent contribution (SD)	Permutation Importance (SD)
Max Temperature of Warmest Month (BIO5)	92.9 (2.89)	90.9 (7.71)
NDVI difference (deciduousness)	2.5(1.87)	6.0 (7.52)
Human pressure	1.5 (1.55)	1.2 (1.80)
Distance from grassland	1.3 (0.98)	0.8 (1.16)
Precipitation of Driest Month (BIO14)	1.0 (1.27)	0.4 (0.48)
Evapotranspiration	0.5 (0.42)	0.7 (0.55)
Forest height	0.3 (0.33)	0.1 (0.15)

Figure 24.3: Relationship of Nilgiri marten with A) Max Temperature of Warmest Month (°C) B) NDVI difference, C) Human pressure, D) Distance from grassland E) Precipitation of the Driest Month F) Evapotranspiration G) Forest height (ft.)

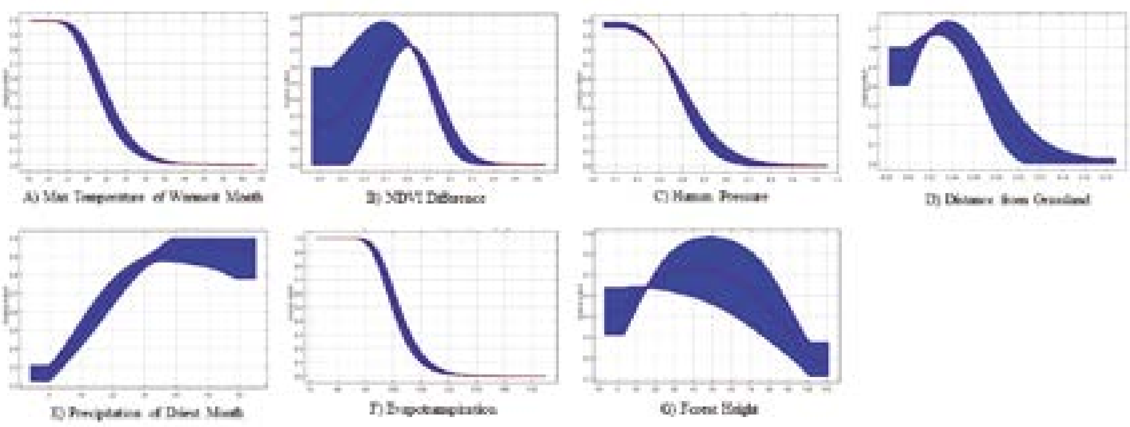
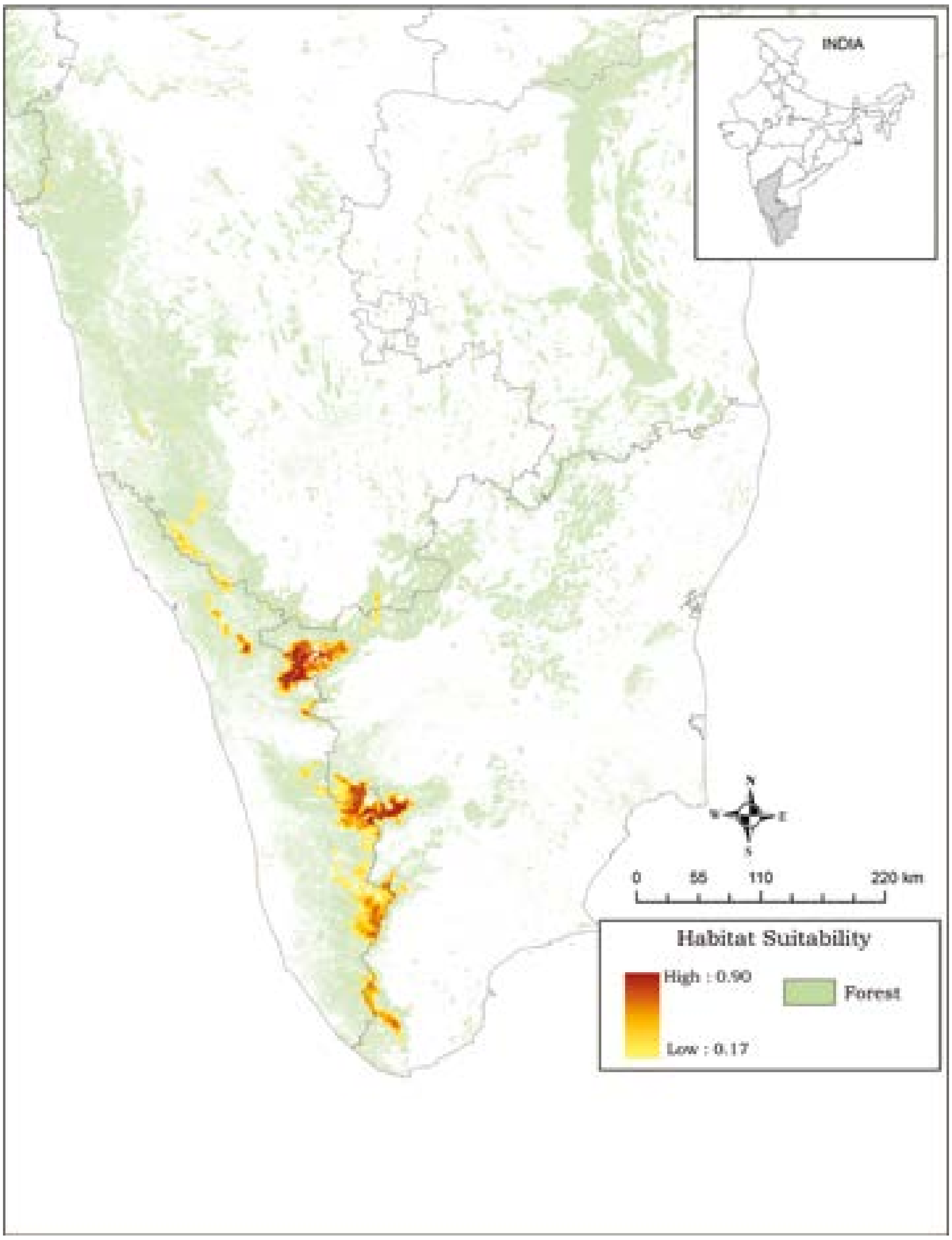


Figure 24.4: Distribution of Nilgiri marten across the forested areas of India estimated from presence obtained by camera traps and environmental covariates.



Conservation significance

The Nilgiri marten is a poorly studied, rare small carnivore. It is endemic to the Western Ghats landscape and merits a proper assessment of its status and an in-depth study of its ecology and genetics (phylogeography) using telemetry and non-invasive sampling. It is an arboreal predator and likely plays a major role in maintaining species diversity and density of arboreal species like civets, giant squirrels, other rodents, hornbills and other birds. A proper documentation of its role and importance is required for planning conservation strategies for the species.

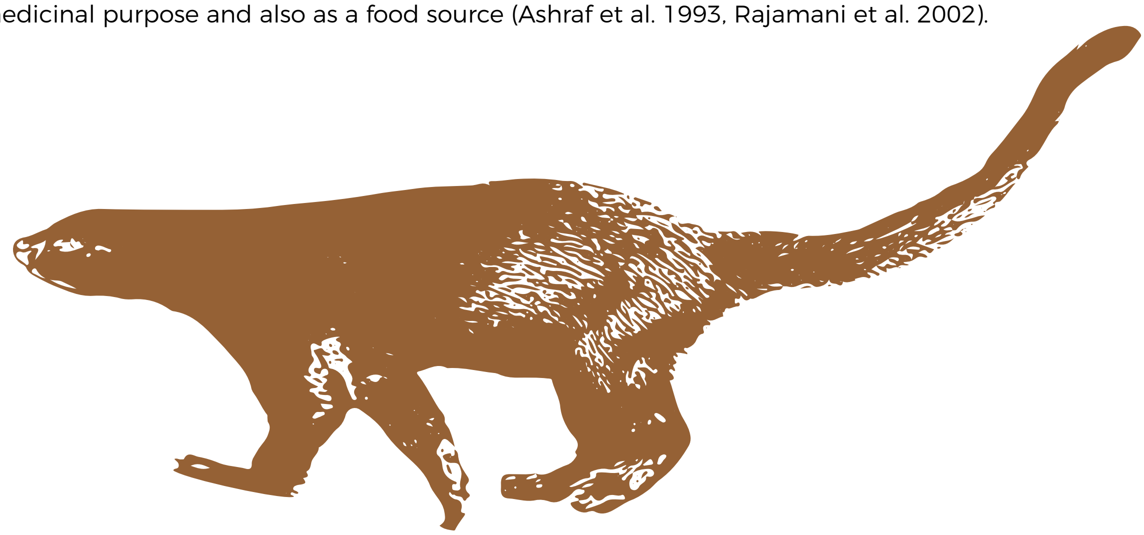
CHAPTER 25:
BROWN PALM CIVET *(PARADOXURUS JERDONI)*

INTRODUCTION

Conservation status:
IUCN Red List: Least Concern (LC)
Wildlife (Protection) Act, 1972: Schedule II

The brown palm civet or Jerdon's palm civet replaces the common palm civet *(Paradoxurus hermaphroditus)* in tropical rainforests of Western Ghats, south from Goa (Mudappa 2013). It is endemic to the rainforest tracts of the Western Ghats. Until 1990s, the species was known only from museum collections, captive animals in two European zoos and one American zoo (Schreiber et al. 1989), and from captivity in a private zoological park (Katrej Snake Park) in Pune (Ashraf 1992). In one early report, Ryley (1913) found them to be abundant in Coorg using the coffee estates. Earlier records indicate occurrence of the species from different sites in Tamil Nadu viz. Kateri in Nilgiri hills (Pocock 1939) and Tirunelveli (Webb-Peploe 1947). Brown palm civet had also been recorded in Trivandrum in Kerala (Pocock 1939) and in Castle Rock in North Kanara district of Karnataka (Kinnear 1913). Later, reports through photographs or direct sighting indicate its presence in Anamalais, Nilgiris, Coorg (Schreiber et al. 1989), Silent Valley (Ramachandran 1990), and Kalakad-Mundanthurai Tiger Reserve (Ganesh 1997, Mudappa 1998). Rajamani et al. (2002) identified the entire distributional range of the species to be extending from the southern extremity of Western Ghats in Kalakad-Mundanthurai Tiger Reserve to Dudh Sagar (Mollem National Park) in Goa in the north. Kalle et al. (2013) reported occurrence of the species even from the deciduous forests such as Mudumalai Tiger Reserve in Tamil Nadu. Recent records of the species have been from Sangli, Sindhudurg and Satara districts of Maharashtra (Bhosale et al. 2013, Sayyed et al. 2019).

Rapid conversion of forests and coffee and cardamom plantations (which hold substantial numbers of the species) into non-agroforestry uses (which do not support it) is one of the major threats for brown palm civets (Mudappa et al. 2016). Brown palm civet is hunted for its fat which is used for medicinal purpose and also as a food source (Ashraf et al. 1993, Rajamani et al. 2002).



SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Brown palm civet has a uniformly brown pelage that is darker around the head, neck, shoulder, legs and tail. Two subspecies have been described on the basis of the colour of the pelage but both Pocock (1933) and Hutton (1949c) state that the colour is extremely variable going from pale buff over light brown to dark brown. The tail is long and sleek which sometimes may have a white or pale-yellow tip. This species has a distinctive feature wherein the direction of hair growth on the nape is reversed (Rajamani et al. 2002) – an adaptation to probably deter predators (Menon 2014).

Body size:
Head and body length: 43-62 cm, Tail length: 38-53 cm (Mudappa 2001)

Body weight:
1.2-4.3 kg (Menon 2014)

Gestation period:
60-70 days (Bodle 2013)

Litter size:
2 to 4 (Bodle 2013)

Lifespan:
11 to 15 years (Walker et al. 1964, Rajamani et al. 2002)

ECOLOGY AND BEHAVIOUR

Brown palm civet has been recorded from evergreen forest and in degraded and anthropogenic habitats such as coffee and cardamom plantations (Mudappa et al. 2016). The species is tolerant of fragmented landscapes (Mudappa et al. 2007). The species has been reported from an altitudinal range of 500–1,300 m, being more common in higher altitudes upto 2,000m (Mudappa, 1998, 2001, Mudappa et al. 2016).

Brown palm civets are nocturnal, arboreal, and generally a solitary species (Mudappa et al. 2010). When resting during the day, *P. jerdoni* exhibit a day-bed preference for the nests of Indian giant squirrels *[Ratufa indica]* (Mudappa 2006). It is mainly frugivorous, feeding on at least 50 rainforest tree and liana fruit species, although it does supplement its diet with birds, rodents, and insects (Pocock 1939, Mudappa et al. 2010).

RESULTS

A total number of 1610 independent photo captures were recorded during the field sampling with higher encounters from tropical rainforests of Western Ghats, Nilgiri biosphere reserve, Kalakad-Mundanthurai Tiger Reserve and Silent Valley National Park (Figure 25.1). Proportion of time active in a day was 0.40 (SE 0.02), it had peaks in activity during late evening (19:00hrs) and dawn (05:00 hrs) (Figure 25.2), showing nocturnal activity pattern. Data used and parameter settings of MaxEnt that used photo-capture intensity and eco-geographical covariates to model occurrence of brown palm civet are provided in Table 25.1.

Maximum contribution to the habitat model was by ruggedness (33.63, SD 4.05%) and NDVI April (5.37, SD 2.54%), where the brown palm civets preferred areas which are moderately rugged and have high canopy cover during summer (Table 25.2, Figure 25.3). Brown palm civet habitat was further defined by areas that have human pressure (36.97, SD 3.78%), NDVI difference (deciduousness of forests) (20.15, SD 5.13%) and precipitation of driest quarter (3.87, SD 0.75%) (Table 25.2, Figure 25.3). The response curve of human pressure explains that the species prefers the areas, which have less human pressure (Figure 25.3). Response curve of NDVI difference depicts that the species is occurring in evergreen vegetation (Figure 25.3). This is also supported by the response curve for precipitation of driest quarter (Figure 25.3) which depicts that the species prefers areas that receive high rainfall during the summer. Probability of occurrence within the forested habitats of tiger states based on the best MaxEnt model is given in Figure 25.4.

Figure 25.1: Presence locations and intensity of photo-captures of brown palm civet obtained from camera traps in 2018-19

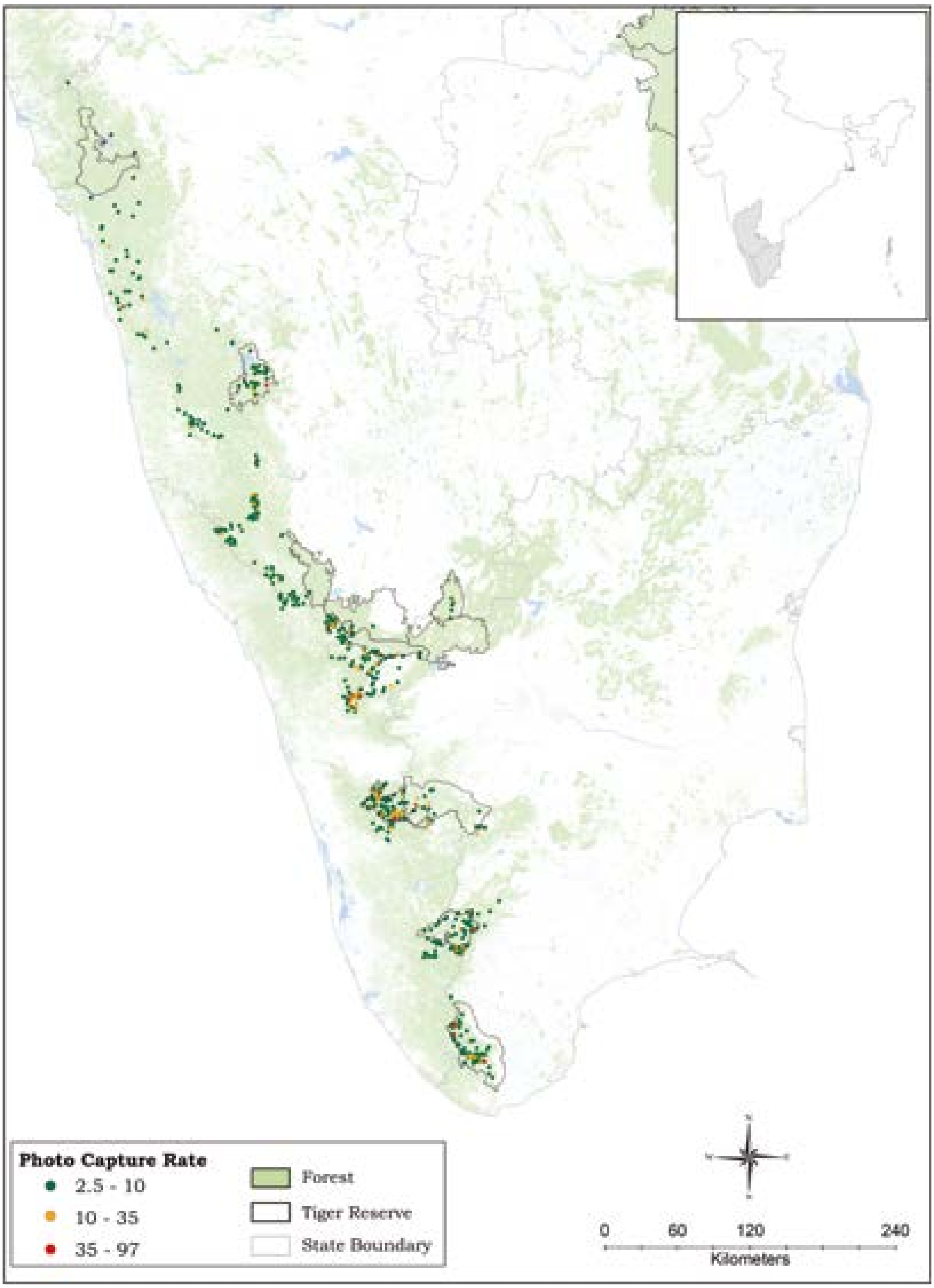


Figure 25.2: Activity pattern of brown palm civet obtained from camera trap photo-captures (N= 1610) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

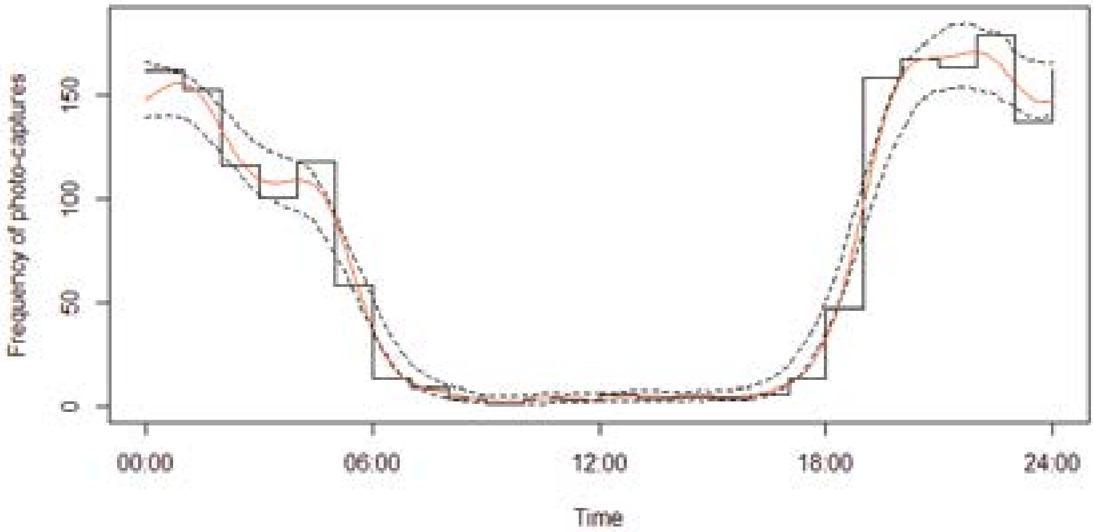


Table 25.1: Parameters used in MaxEnt setting for modelling the distribution/habitat of brown palm civet within forested landscape of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.32
Area under the ROC* Curve (AUC)	0.81

**receiver operating characteristic*

Table 25.2: Contribution percentage of every covariate (SD) to the best model explaining distribution of brown palm civet

Covariates	Percent contribution (SD)	Permutation contribution (SD)
Ruggedness	39.82 (2.09)	33.63 (4.05)
NDVI April	30.13 (3.47)	5.37 (2.54)
Human pressure	15.23 (1.18)	36.97 (3.78)
NDVI difference (deciduousness)	5.93 (2.42)	20.15 (5.13)
Precipitation of driest quarter (BIO17)	2.22 (0.55)	3.87 (0.75)

Figure 25.3: Relationship of brown palm civet with A) Ruggedness, B) Normalized Difference Vegetation Index (NDVI) - April, C) Human pressure, D) Normalized Difference Vegetation Index (NDVI) - difference and E) Precipitation of driest quarter (BIO17)

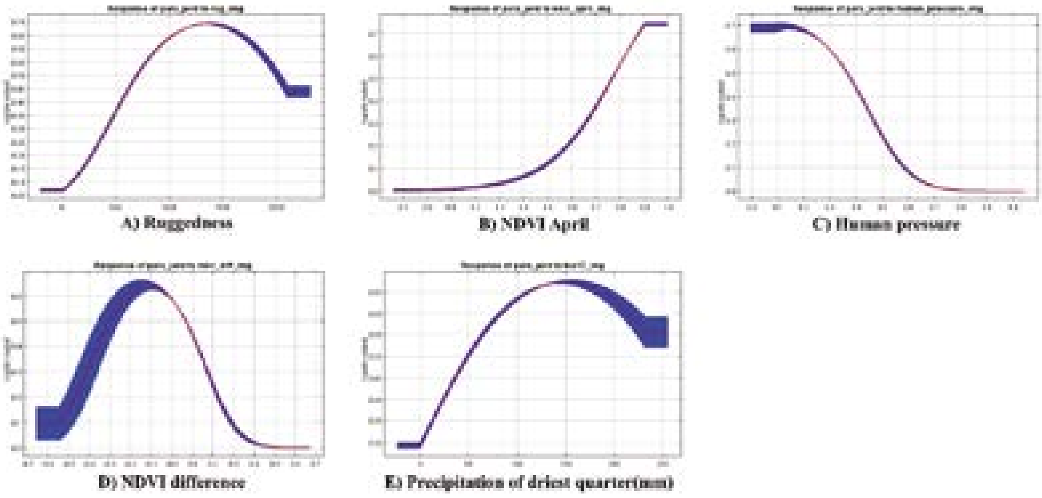
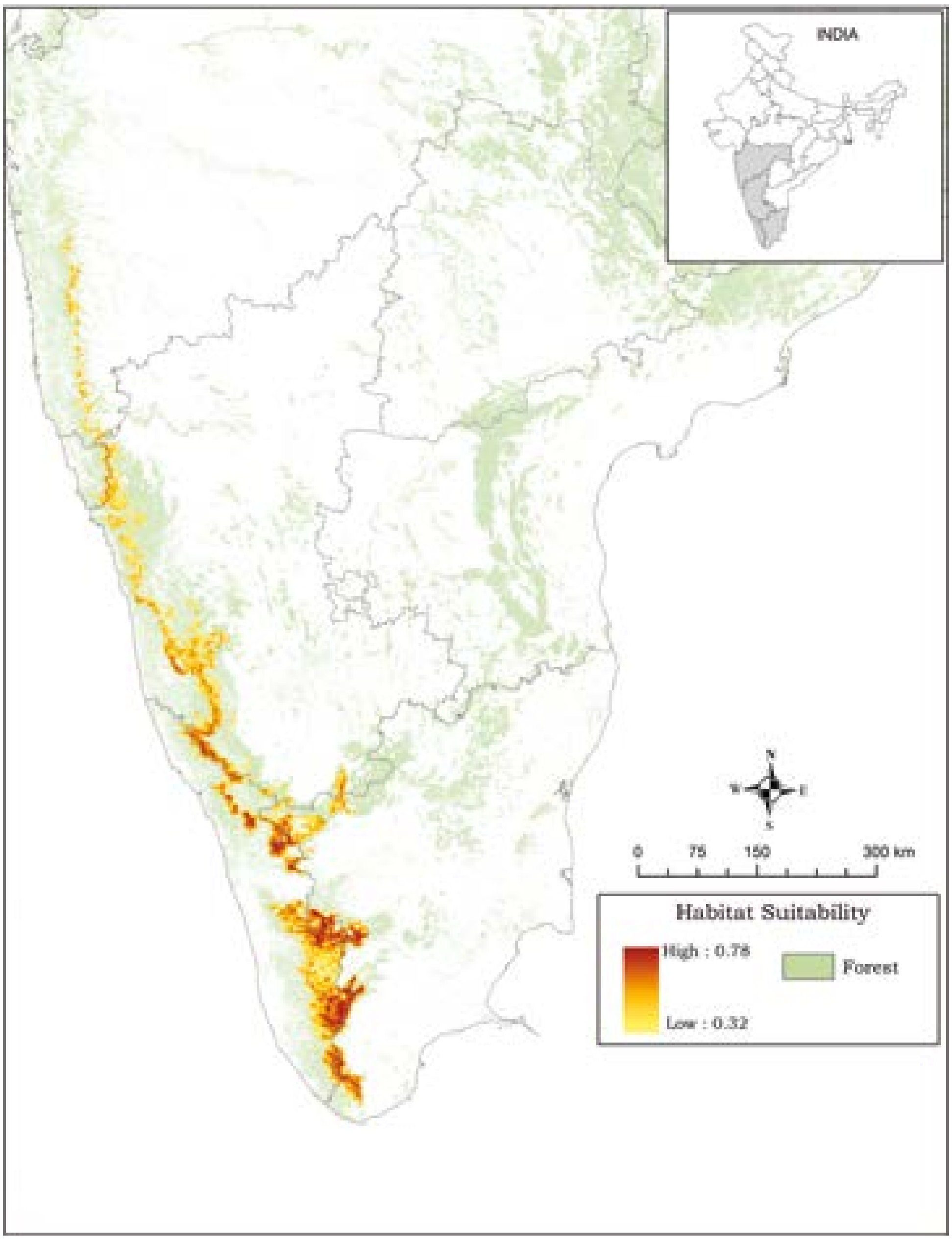


Figure 25.4: Distribution of brown palm civet across the forested areas of India estimated from presence obtained by camera traps and environmental covariates.



Conservation significance

Brown palm civets were encountered across their known geographic range with reasonable encounter rates within tiger reserves. Since the species is adaptable to live in many of the human modified land uses like plantations, the threat to its survival is seemingly minimal. A detailed ecological study using modern techniques of telemetry is required to better understand the role of brown palm civets in the ecosystem especially as seed dispersers.

CHAPTER 26:
COMMON PALM CIVET *(PARADOXURUS HERMAPHRODITUS)*

INTRODUCTION

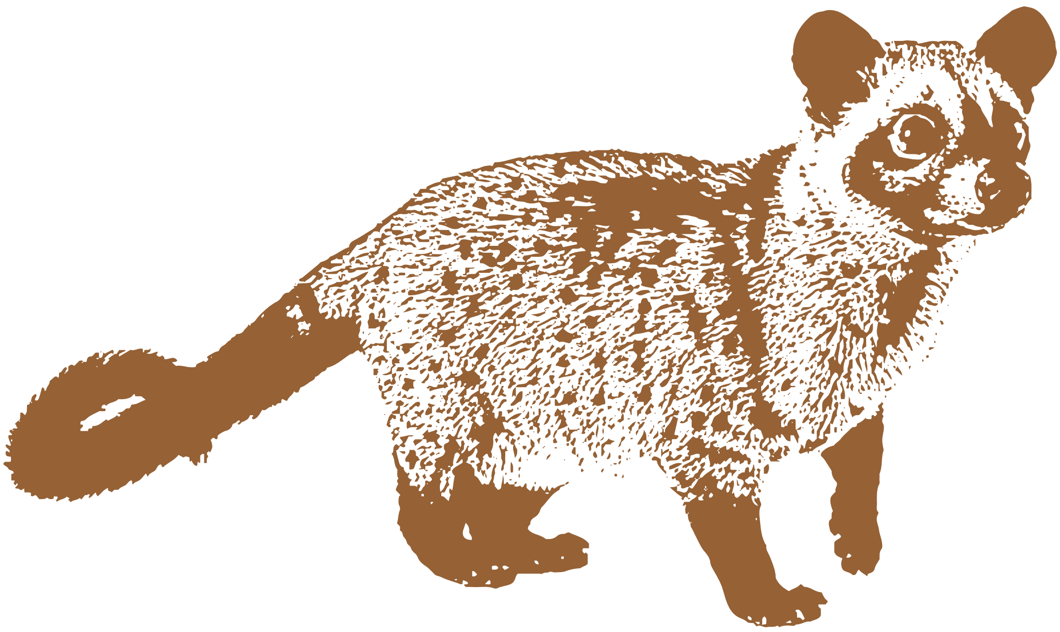
Conservation status

IUCN Red List: Least Concern (LC)

Wildlife (Protection) Act, 1972: Schedule II

Common palm civets are native to Asia, ranging from Hainan and adjacent Chinese coast in the east and Afghanistan in the west with frequent records from Bangladesh, Bhutan, India, Nepal and Sri Lanka (Pocock 1933, Wozencraft 2005, Jennings and Veron 2009, Duckworth et al. 2016). It is distributed all across India, except the arid west and high Himalayas (Kalle et al. 2013a,b, Menon 2014).

Common palm civet is hunted for consumption of meat in some parts of its range (Gupta 2004, Lau et al. 2010, Kalle et al. 2013b). Common palm civets are best known for aiding in the production of an expensive coffee, Kopi luwak, by passing coffee cherries through their digestive tract. To cater the increasing need of this industry, civets are often traded as pet in Indonesia, Java and the Philippines (Shepherd 2012, Nijman et al. 2014).



SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Body coat of common palm civet varies from a rich cream to brownish black to jet-black in colour. It has three longitudinal stripes on its back running up to the tail that clearly distinguishes it from Himalayan Palm Civet *(Paguma larvata)* and Brown Palm Civet *(Paradoxurus jerdoni)*, both of which it shares parts of its range with. It has pale or white patches below the eyes, on the forehead and near the ears (Menon 2014). Both males and females have a perineal scent gland under their tail.

Body size:

Head and body length: 42-71 cm Tail length: 40-66 cm (Mudappa 2013, Menon 2014)

Body weight:

1.5-4.5 kg (Mudappa 2013)

Gestation period:

60 days (Nelson 2013)

Litter size:

2-5 (Nelson 2013)

Lifespan:

Up to 20 years (Nelson 2013)

ECOLOGY AND BEHAVIOUR

Common Palm Civet uses a wide range of habitats including evergreen and deciduous forest (primary and secondary), seasonally flooded *Melaleuca*-dominated peat swamp forest, mangroves (Bangladesh Sundarbans), monoculture plantations (such as oil palm and teak), village and urban environments (Duckworth 1997, Azlan 2003, Su Su 2005, Mudappa et al. 2007, Roberton 2007, Khan 2008, Than Zaw et al. 2008, Low 2011, Chua et al. 2012, Samejima and Semiadi 2012, Choudhury 2013, Kalle et al. 2013a,b, Nakashima et al. 2013, Kakati and Srikant 2014, Chutipong et al. 2014). It occurs widely from the sea-level to the highest records of ~ 2,400 m in North-East India (Choudhury 2013) and in Afghanistan at 2,500 m (Stevens et al. 2011).

Common palm civets are mainly crepuscular or nocturnal (Duckworth 1997), mostly arboreal and frugivorous (Joshi et al. 1995; Grassman 1998, Krishnakumar and Balakrishnan 2003) and are important seed-dispersal agents (Nakashima et al. 2010a, 2010b). In human-modified habitats, this species may be one of the few frugivorous mammalian species that can disperse large seeds (Nakashima and Sukor 2010; Nakashima et al. 2010b). When fruit availability is low, common palm civets also consume small prey, such as insects, earthworms, molluscs, and small vertebrates (Joshi et al. 1995; Nakashima et al. 2010b). Radio-telemetry studies have revealed home-ranges of ~ 17 km^2 for males and 1.6 km^2 for females (Rabinowitz 1991, Joshi et al. 1995, Grassman 1998).

RESULTS

A total of 19,086 independent photo-captures were recorded during the field sampling with higher encounters from tropical forests, scrub forests and human settlements. Common palm civets had high photo-captures from Rajaji Tiger Reserve, Tadoba-Andhari Tiger Reserve, Pench Tiger Reserve and Silent Valley National Park (Figure 26.1). Proportion of time active in a day was 0.44 (SE 0.01), where it had peaks in activity during late evening and dawn (18:00 hrs to 05:00 hrs), showing nocturnal behaviour (Figure 26.2). Data used and parameter settings of MaxEnt that used photo-capture intensity and eco-geographical covariates to model occurrence of common palm civet are provided in Table 26.1.
Maximum contribution to the habitat model was by difference in NDVI between pre and post-monsoon months (23.50; SD 0.49%) and ruggedness (23.31; SD 0.43%), which indicates that the common palm civet prefers canopied forests and less rugged terrain (Table 26.2, Figure 26.3). Common palm civet habitat was further defined by the areas that have aridity (25.36; SD 0.43%), human pressure (13.15; SD 0.45%), NDVI April (9.54; SD 0.31%) and annual mean temperature (5.13; SD 0.31%) (Table 26.2, Figure 26.3). The response curves of aridity and annual mean temperature explains that the species prefers the areas, which are drier and have annual mean temperature above 25˚C (Figure 26.3). Response curve of human pressure depicts that the species is occurring in areas with less human pressure (Figure 26.3). The response curve of summer NDVI explains that the species prefers areas that have low canopy cover during summer (Figure 26.3). Probability of occurrence within the forested habitats of tiger states based on the best MaxEnt model is given in Figure 26.4.

Figure 26.1: Presence locations and intensity of photo-captures of common palm civet obtained from camera traps in 2018-19

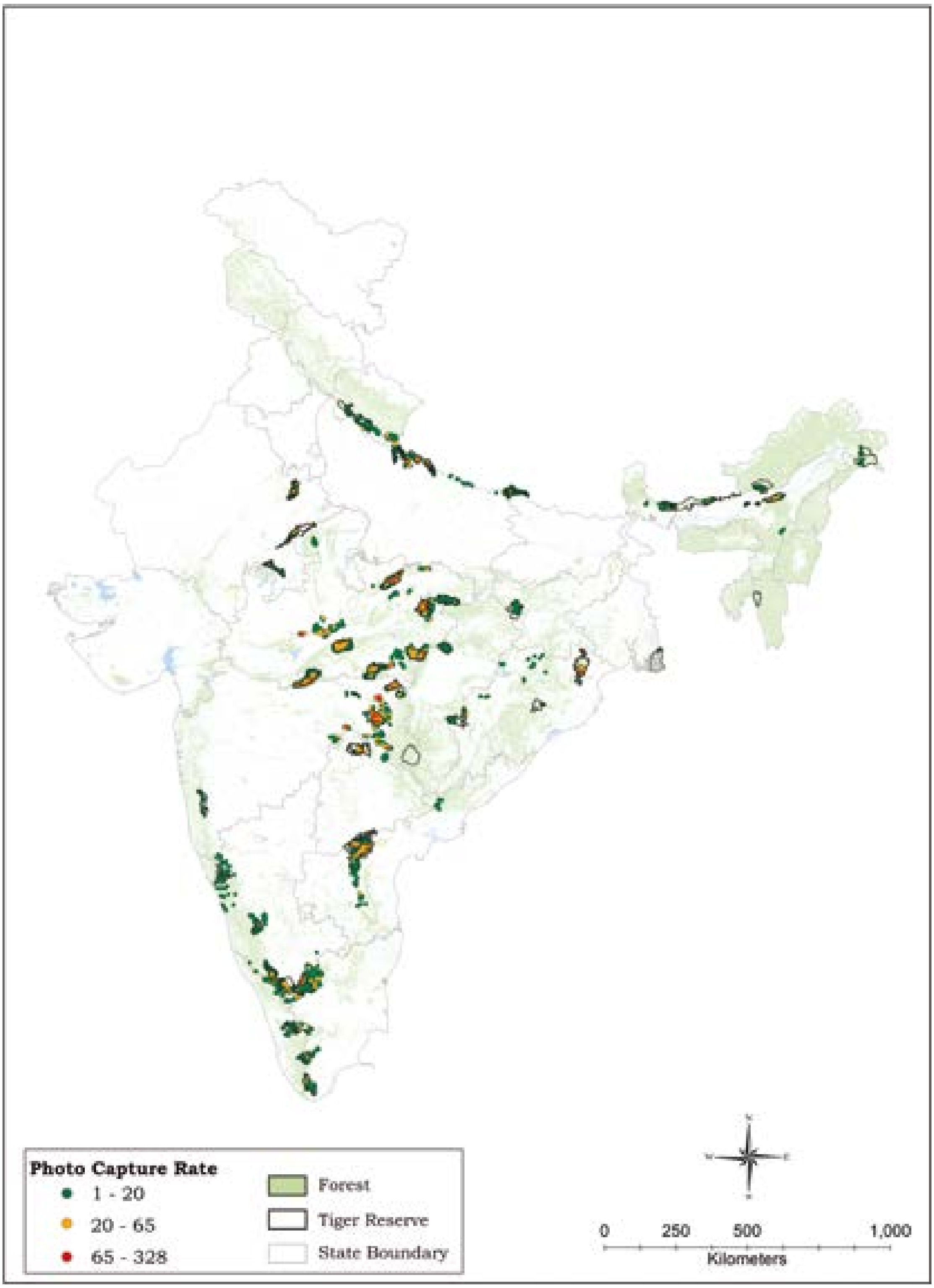


Figure 26.2: Activity pattern of honey badger obtained from camera trap photo-captures (N= 19,086) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

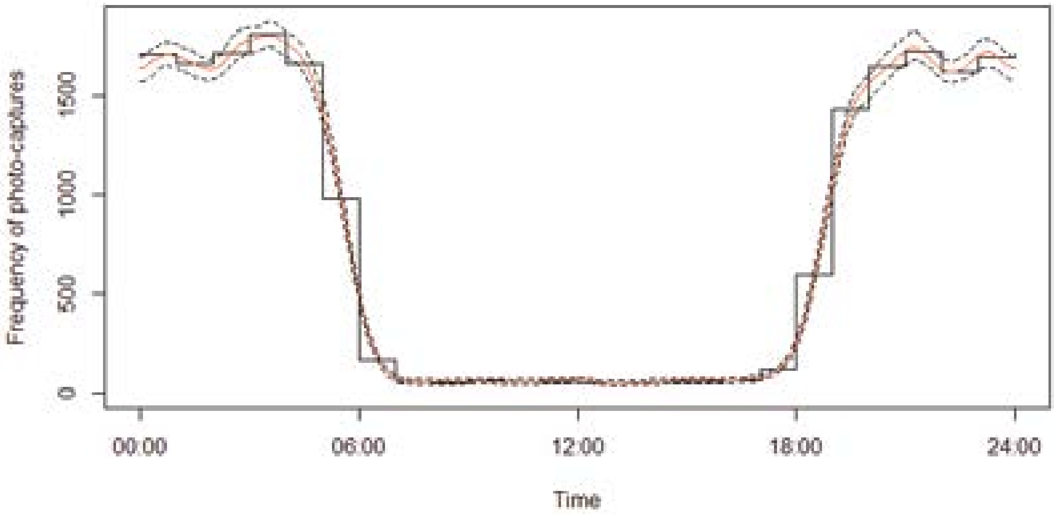


Table 26.1: Parameters used in MaxEnt setting for modelling the distribution/habitat of common palm civet within forested landscape of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.47
Area under the ROC* Curve (AUC)	0.58

**receiver operating characteristic*

Table 26.2: Contribution percentage of every covariate (SD) to the best model explaining distribution of common palm civet

Covariates	Percent contribution (SD)	Permutation contribution (SD)
NDVI difference (deciduousness)	29.78 (1.75)	23.50 (0.49)
Ruggedness	24.76 (0.57)	23.31 (0.43)
Aridity Index	21.63 (1.26)	25.36 (0.43)
Human pressure	19.35 (0.73)	13.15 (0.45)
NDVI April	3.36 (0.55)	9.54 (0.31)
Annual mean temperature (BIO1)	1.10 (0.22)	5.13 (0.31)

Figure 26.3: Relationship of Common Palm Civet with A) Normalized Difference Vegetation Index (NDVI) - difference, B) Ruggedness, C) Aridity, D) Human pressure, E) Normalized Difference Vegetation Index (NDVI) - April and F) Annual mean temperature(˚C)

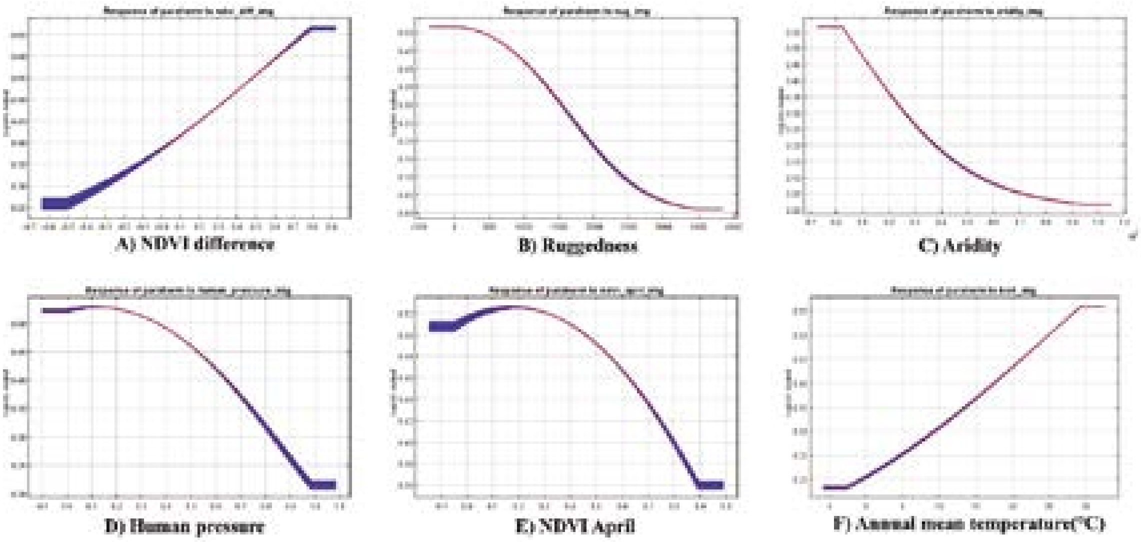
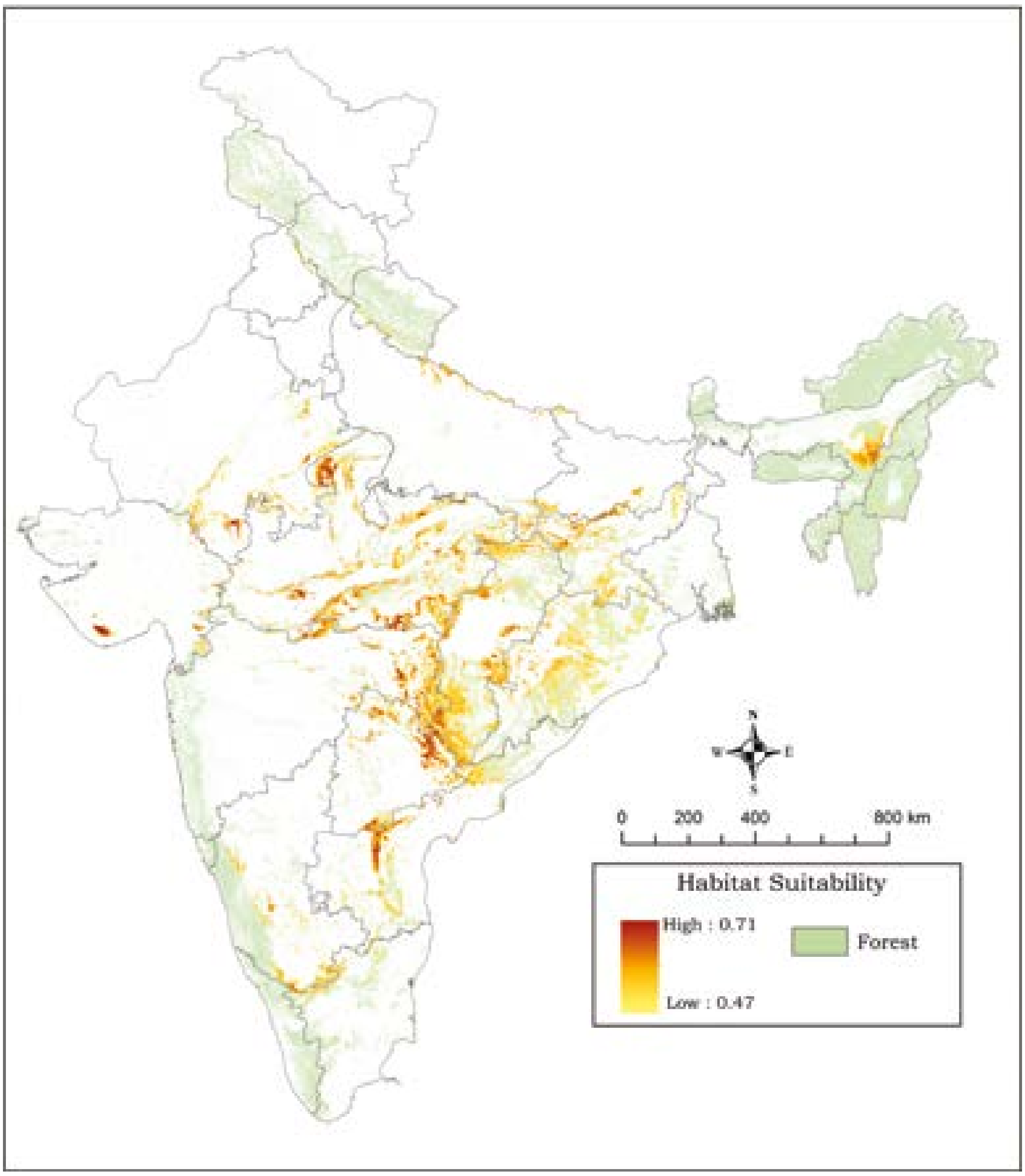


Figure 26.4: Distribution of common palm civet across the forested areas of India estimated from presence obtained by camera traps and environmental covariates.



Conservation significance

Large sampling coverage and predicted distribution shows that the common palm civet is widely distributed across India and its populations are doing well with no imminent conservation investments required. Photo-captures showed wide variations in its pelage pattern across India, making it a potential subject for genetic study to understand its historical dispersal and isolation patterns. An in-depth ecological study using telemetry would provide insights into its role in maintaining ecosystem integrity through seed dispersal and rejuvination of forests.

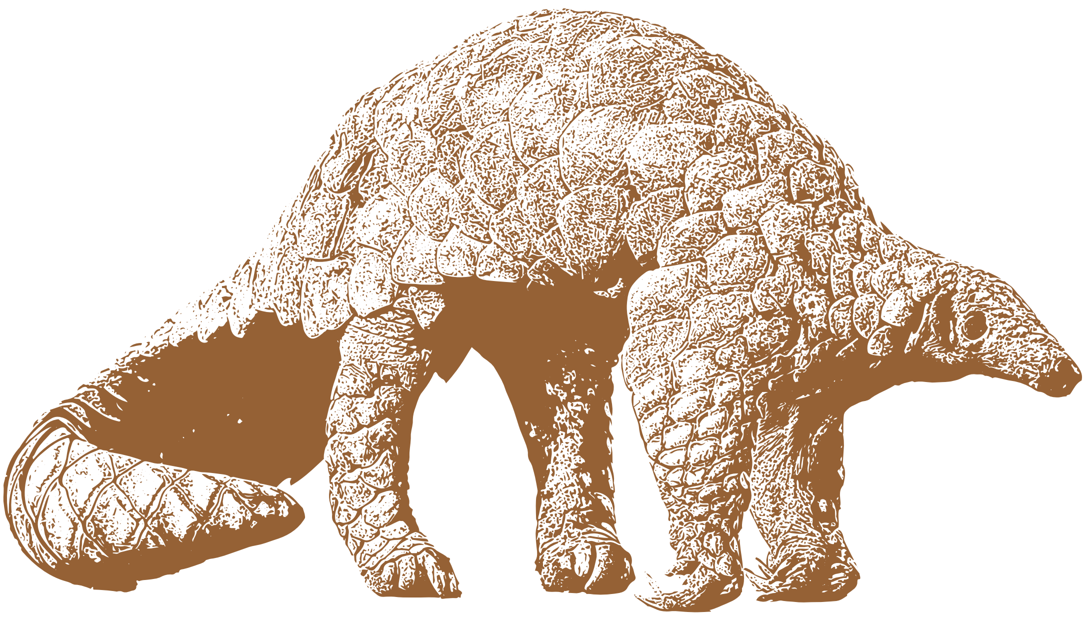
CHAPTER 27:
INDIAN PANGOLIN *(MANIS CRASSICAUDATA)*

INTRODUCTION

Conservation status
IUCN Red List: Endangered (EN)
Wildlife (Protection) Act, 1972: Schedule I

Indian pangolin is distributed in South Asia from northern and south-eastern Pakistan through much of India south of the Himalayas, southern Nepal, and Sri Lanka (Prater 1971, Roberts 1977, Schlitter 2005, Srinivasulu and Srinivasulu 2012). Widely distributed in India from the Himalayan foothills to the far south, except the far northeast (Tikader 1983, Jhala et al. 2020). The eastern most record of the species possibly occurs in Meghalaya (Agrawal et al. 1992). There is a record from Manas National Park (Goswami and Ganesh 2014) where the species appears to be sympatric with the Chinese Pangolin.

Pangolins are considered to be the one of the world's most trafficked wild mammals (Challender and Waterman 2017, Heinrich et al. 2017). With contemporary illegal trade largely involving whole pangolins and their scales (Nijman 2015), pangolins are threatened by overexploitation for both international and local use. Major threats to pangolins in India are hunting and poaching for local consumptive use (e.g. as a protein source and traditional medicine) and international trade, for its meat and scales in East and South East Asian countries, particularly in China and Vietnam (Misra and Hanfee 2000, Irshad et al. 2015, Mohapatra et al. 2015, Kanagavel et al. 2016, Karawita et al. 2018).



SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Indian Pangolin is a medium sized toothless mammal with long protrusible tongue and large overlapping scales on the upper body acting like an armour (Pocock 1924). They are large anteaters with faint pinkish white skin covered dorsally by 11-13 rows of 280 to 305 dirty yellow scales (Heath 1995). A terminal scale is also present on the ventral side of the tail of the Indian Pangolin, which is absent in the Chinese Pangolin. These scales are composed of keratin and make up 1/4 to 1/3 of the body mass of Indian pangolins (Kingdon 1974). The face is small and mouth tubular (Menon 2014). The adult male is about one-third larger than the female (Roberts 1977).

Body size:
Head and Body Length: 60-75 cm, Tail Length: 45 cm (Prater 1971).

Body weight:
3-8 kg (Irshad et al. 2015), 9-11 kg (Menon 2014).

Gestation period:
65-70 days (Hayssen and Van Tienhoven 1993, Zoological Survey of India 2002).

Litter size:
1-2 (Mahmood et al. 2015)

Life span:
>13.5 years in captivity (Jones 1977). The oldest pangolin kept in captivity lived to be over 19 years old. It is believed that they can live for over 20 years in the wild (Hua et al. 2015)

ECOLOGY AND BEHAVIOUR

Indian pangolin occurs in various types of tropical forests as well as open land, grasslands, arid areas and degraded habitat, including in close proximity to human settlements (Prater 1971, Roberts 1977). The species is thought to adapt well to modified habitats, provided its ant and termite prey remains abundant and it is not subject to hunting pressure. The habitat preferences for the species have been found to be closely associated to the presence of plant species like Ziziphus mauritiana, Acacia nilotica, *Ziziphus nummularia, Prosopis cineraria and Lantana camara*, possibly due to the availability of termite mounds and ant's colonies on the soil below and on the trunks of these tree species (Mahmood et al. 2014). Their habitat extends upto 1,850 m above mean sea level (Mahmood et al. 2019).

Pangolins are obligate myrmecophages (Redford 1987) foraging on eggs, young and adults of ants and termites (Prater 1971, Roberts 1977, Yang et al. 2007, Mahmood et al. 2013) with a preference for insect eggs over adults (Prater 1971). The most favoured food sources have been reported to be leaf nests containing eggs and adults of large red ants (Heath 1995, Mahmood et al. 2013). The species uses its olfaction to locate prey (Israel et al. 1987).

Indian pangolin is a solitary, nocturnal species (Mahmood et al. 2013). No information is available on its home range sizes. However, home ranges of 41 ha for males and 7 ha for females has been reported in case of Sunda Pangolin (Lim 2007, Lim and Ng 2008).

RESULTS

A total of 260 independent photo-captures were recorded during the field sampling with higher captures from tropical evergreen, moist and dry deciduous forests, scrub forests and grasslands (Figure 27.1). Pangolins spent 0.38 (SE 0.02) proportion of time active daily and their frequency of photo-captures during late evening to night and early morning (19:00 to 5:00 hours) shows nocturnal activity pattern (Figure 27.2). Indian pangolins were photo-caputred in protected areas and tiger reserves of western Ghats, central India, Himalayan foothills and semi-arid regions (Figure 27.1). Data used and parameter settings of MaxEnt that used photo-capture intensity and eco-geographical covariates to model occurrence of Indian pangolin are provided in Table 27.1.

Maximum contribution to Indian pangolin habitat model was by human pressure (52.2, SD 6.34%) and NDVI April (43.5, SD 6.46%) where predicted occurrence of the species appears in areas with medium vegetation cover and less human disturbance (Table 27.2, Figure 27.3). Indian pangolin habitat was further defined by areas that had digital elevation model (3.1, SD 1.65%) and aridity (1.2, SD 2.12%) (Table 27.2, Figure 27.3). The response curve for digital elevation model explains that the species' suitable habitats ranged between 500 m to 2,000 m in elevation (Figure 27.3). The response curve for aridity depicts moderately humid areas are more suitable habitats for the species (Figure 27.3). Probability of occurrence within the forested habitats of tiger states based on the best MaxEnt model is given in Figure 27.4.

Figure 27.1: Presence locations and intensity of photo-captures of Indian pangolin obtained from camera traps in 2018-19

Figure 27.2: Activity pattern of Indian pangolin obtained from camera trap photo-captures (N= 260) from across India. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity at different times of the day

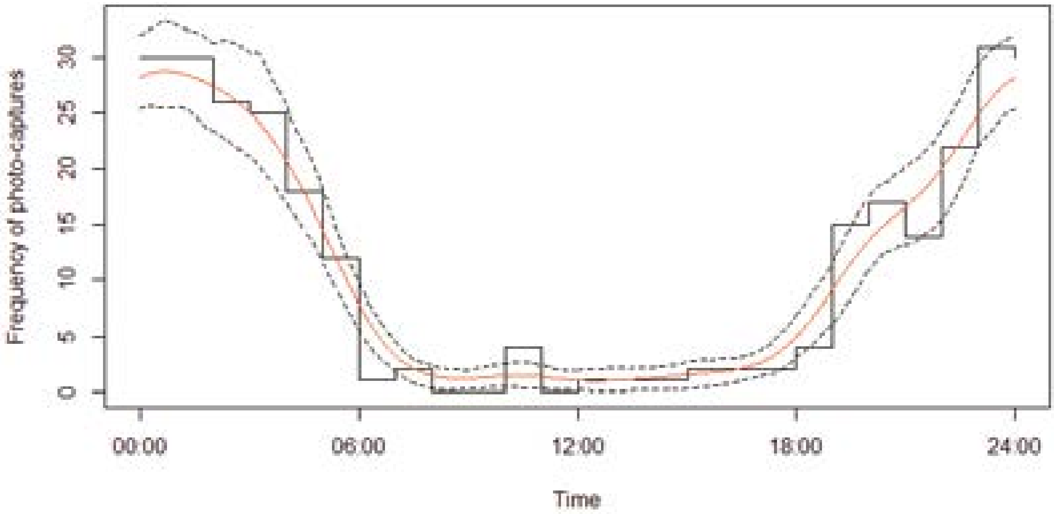


Table 27.1: Parameters used in MaxEnt setting for modelling distribution/habitat of Indian pangolin in the forested landscapes of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.35
Area under the ROC* Curve (AUC)	0.75

**receiver operating characteristic*

Table 27.2: Contribution percentage of every covariate (SD) to the best model explaining distribution of Indian pangolin

Covariates	Percent contribution (SD)	Permutation Importance (SD)
Human pressure	52.2 (6.34)	55.7 (7.46)
NDVI April	43.5 (6.46)	38.5 (6.80)
Digital Elevation Model (DEM)	3.1 (1.65)	4.6 (2.81)
Aridity index	1.2 (2.12)	1.2 (1.62)

Figure 27.3: Relationship of Indian pangolin with A) Human pressure, B) NDVI April, C) Digital elevation model (meter), and D) Aridity

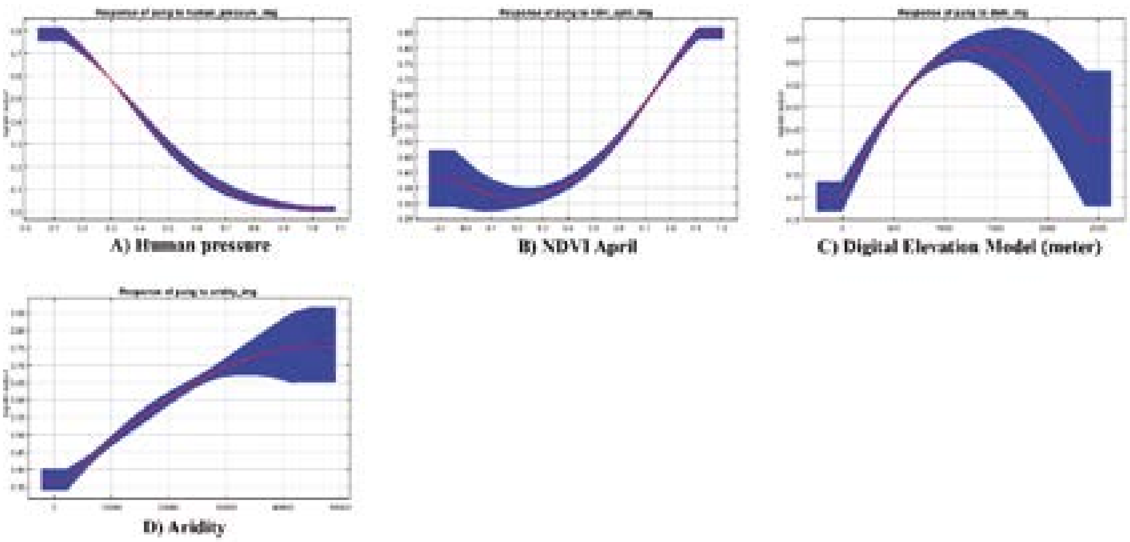
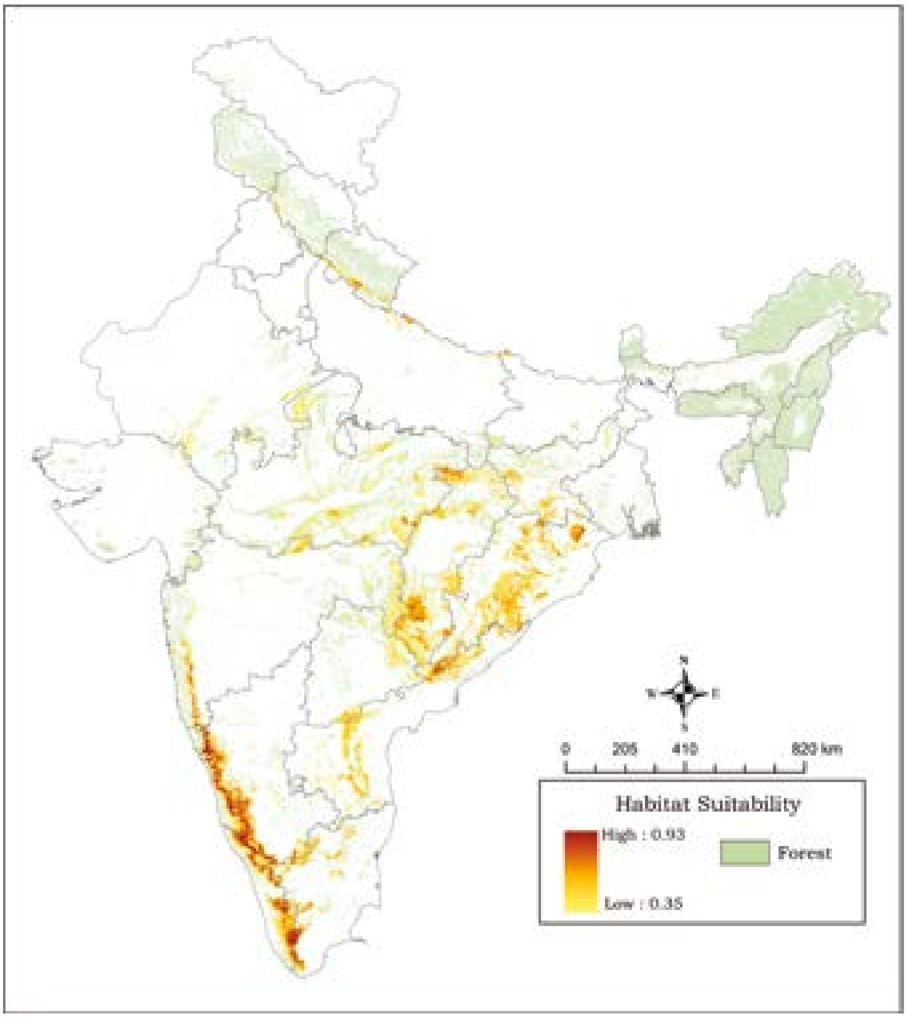


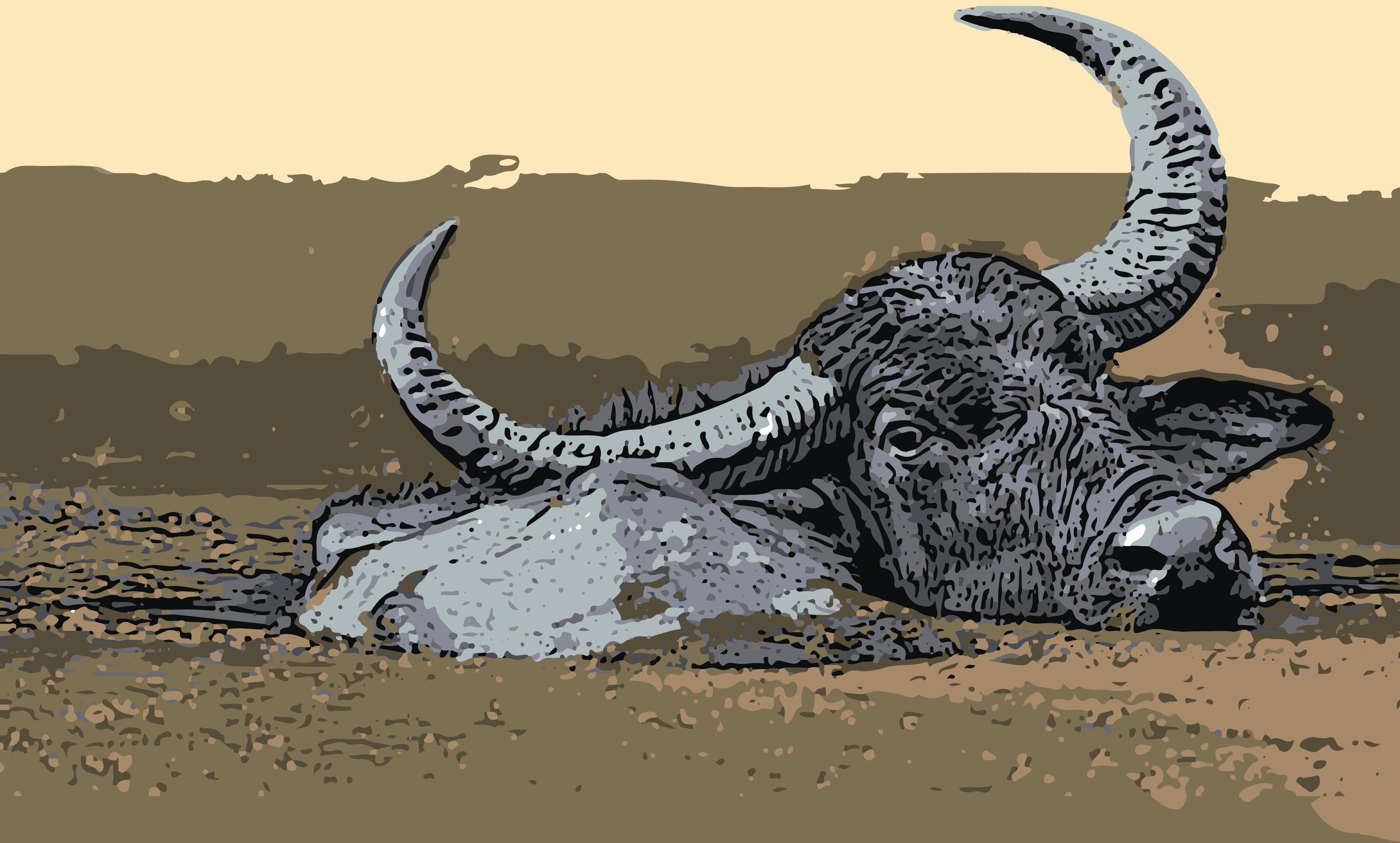
Figure 27.4: Distribution of Indian pangolin across the forested areas of India estimated from presence obtained by camera traps and environmental covariates.



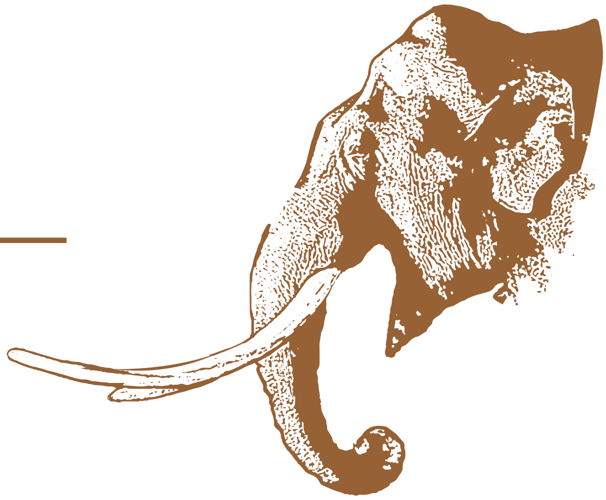
Conservation Significance

Despite its widespread distribution and being legally protected, pangolins are one of the most common species involved in illegal poaching and wildlife trade. Inadequate information on population and distribution further accentuates the threats arising from hunting and poaching. The information presented herein is the first comprehensive baseline for the status of elusive Indian pangolin in the country. There is an urgent need to ensure that legislation providing the species with protection are adequately enforced by enhancing the capacity building of various law enforcement agencies dealing with this. It is essential to map pangolin trade hubs, conduits, transportation, high poaching areas and drivers in relation to poaching and illegal trafficking. Multipronged efforts in terms of more campaigns are required aiming at creating public awareness regarding ecological role of the species and curbing illegal trade in pangolins. In-depth studies of some target populations using modern technology is required for understanding population density, ranging patterns, habitat use, diet and threats. Information from current distribution and relative abundance along with information on the ecology of the species will help form policy and management strategy for conserving pangolins in India.

MEGAHERBIVORES



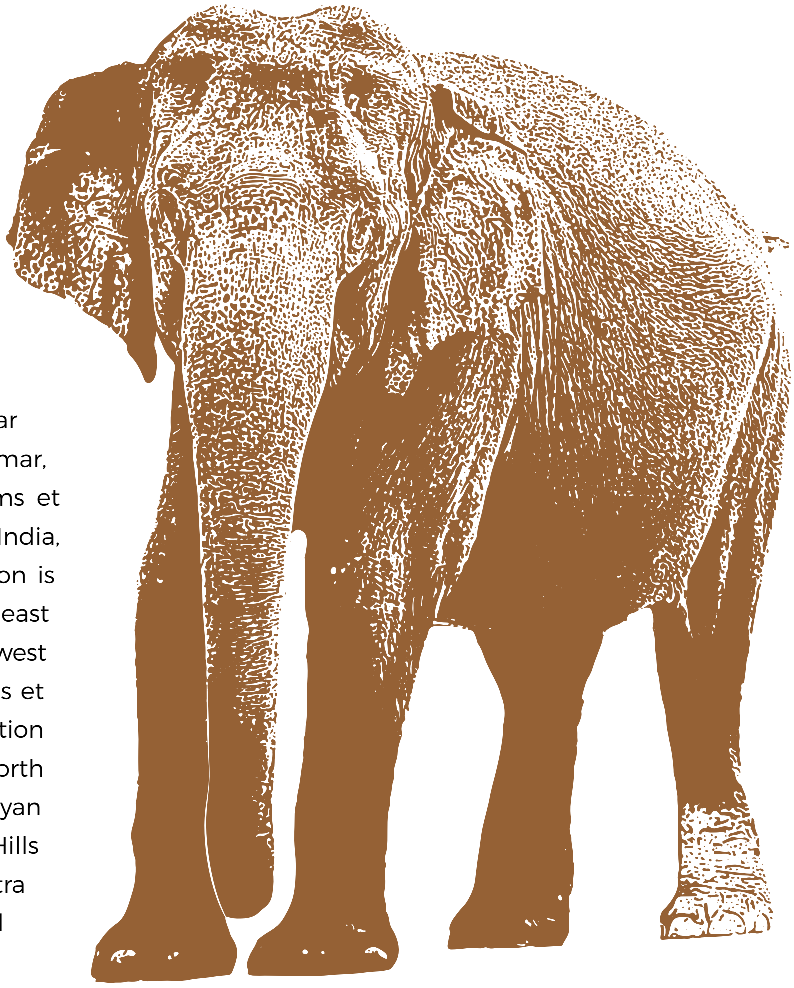
CHAPTER 28:
ASIAN ELEPHANT *(ELEPHAS MAXIMUS)*



INTRODUCTION

Conservation status
IUCN Red list: Endangered (EN)
Wildlife (Protection) Act, 1972: Schedule I

The Asian elephant *(Elephas maximus)* is the only survivor of the genus *Elephas* and belongs to the family Elephantidae. It is one of the three elephant species extant in the world today. Asian elephants range once stretched from West Asia along the Iranian coast into the Indian subcontinent and eastwards into South East Asia, including the islands of Sumatra, Java and Borneo, and extended as far north as the Yangtze River in China (Olivier 1978) and covered over 9 million km² (Sukumar 2003).



Currently the Asian elephant has become extinct from 95% of its historical range (Sukumar, 2006), and is extinct in West Asia, Java and most of China. Elephants occur in South Asia, in Bangladesh, Bhutan, India, Nepal and Sri Lanka, and in Southeast Asia, in Cambodia, China, Indonesia (Kalimantan and Sumatra), Lao PDR, Malaysia (Peninsular Malaysia and Sabah), Myanmar, Thailand and Vietnam (Williams et al. 2020). Once widespread in India, the current elephant population is restricted to four clusters: Northeast India, Central India, Northwest India and South India (Williams et al. 2020). The Northeast population extends from near western north Bengal along the Himalayan foothills up to the Mishmi Hills and the eastern Brahmaputra plains of Assam and Arunachal Pradesh and covers plains of upper Assam, foot of Naga Hills, Garo and Khasi Hills of Meghalaya and parts of Brahmaputra plains and Karbi plateau in Assam (Choudhury 1999). In Central India, fragmented elephant populations exist in the states of Odisha, Jharkhand, Chhattisgarh and southern West Bengal with recent dispersal in Madhya Pradesh. The fragmented north western population occurs along the Himalayan foothills extending from Katarniaghat Wildlife Sanctuary (Uttar Pradesh) in the east to Yamuna river (Uttarakhand) in the west. The southern population ranges along the forested hilly tracts of the Western Ghats and Eastern Ghats in the states of Karnataka, Kerala and Tamil Nadu with recent colonization in some parts of Goa, Andhra Pradesh and Maharashtra. A small feral population also persists in the islands of Andaman. Menon and Tiwari 2019 reported a global Asian elephant population of 48,323–51,680 individuals in the wild with the Indian population at 29,964 supporting about 60% of the global population.

Major conservation challenges confronting the Asian elephant in most range states are habitat loss and fragmentation, human–elephant conflict, and poaching to meet illegal trade demands (Sukumar 1990, Desai 1991, Sukumar et al. 1998, Williams et al. 2001, Leimgruber et al. 2003, Miliken 2005, Hedges et al. 2006, Goswami et al. 2015, Menon et al. 2017). As per a study in the early 2000s, about 51% of the elephants' range spanning 873,000 km² across 13 countries in the continent was forested land of which only 16% were under legal protection (Leimgruber et al. 2003); anthropogenic activities and developmental projects affected the remaining range areas. Linear intrusions such as railway lines, power transmission lines, and highways cutting through elephant habitats also affect the species by fragmenting the habitat and causing direct mortality (Shankar Raman 2011).

SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Asian elephants are smaller than the African bush elephant. Their back is usually convex, ears are small with dorsal borders folded laterally. The forehead has two hemispherical bulges, unlike the flat front of the African elephant and the trunk length varies from 1.5 to 2 m depending on the age of the individual (Shoshani 1982, Sukumar et al. 1988).

Body size:

Adult males stand at a height of 2.75 m at the shoulder while adult females at about 2.4 m (Sukumar et al. 1988)

Body weight:

3,300-5,400 kg (Menon 2014)

Litter size & gestation period:

Both males and females reach sexual maturity at around 17 years. The gestation period is 18–22 months, and the female gives birth to one calf, only occasionally twins (Mar 2002). Generally, from 14 to 17 years the young male begins to achieve adult stature and exhibit the condition of musth [copious secretion from the temporal glands located on either sides of the face between eye and ear] (Eisenberg 1980, Lahiri-Choudhury 1992).

Life span:

60 years in the wild while around 80 years in captivity.

ECOLOGY AND BEHAVIOUR

Asian elephants are hindgut fermenters, having a poor digestive efficiency compared to ruminants (Dumonceaux 2006), thus, they must consume large amounts of forage to meet their energy requirements (Williams et al. 2020). Considered to be generalist, they feed on a variety of plants, which change with seasons (Williams et al. 2020). It has been recorded that elephants' diet shifts to 70% browse in the dry season as compared to only 45% in wetter months (Sukumar 1992). *Elephas maximus* inhabits a variety of habitats ranging from grassland, tropical evergreen forest, semi-evergreen forest, moist deciduous forest, and dry deciduous forested. They are also known to utilize dry thorn forests, cultivated lands and scrublands (Williams et al. 2020). A study in northern Sumatra found that elephant presence was positively related to forest cover and vegetation productivity, and elephants were largely confined to valleys and utilized forest edges (Rood et al. 2010). Elephant presence has been recorded from 3000 m elevation (Choudhury 1999), although habitats at such elevations clearly do not represent optimal suitability for elephants (Williams et al. 2020).

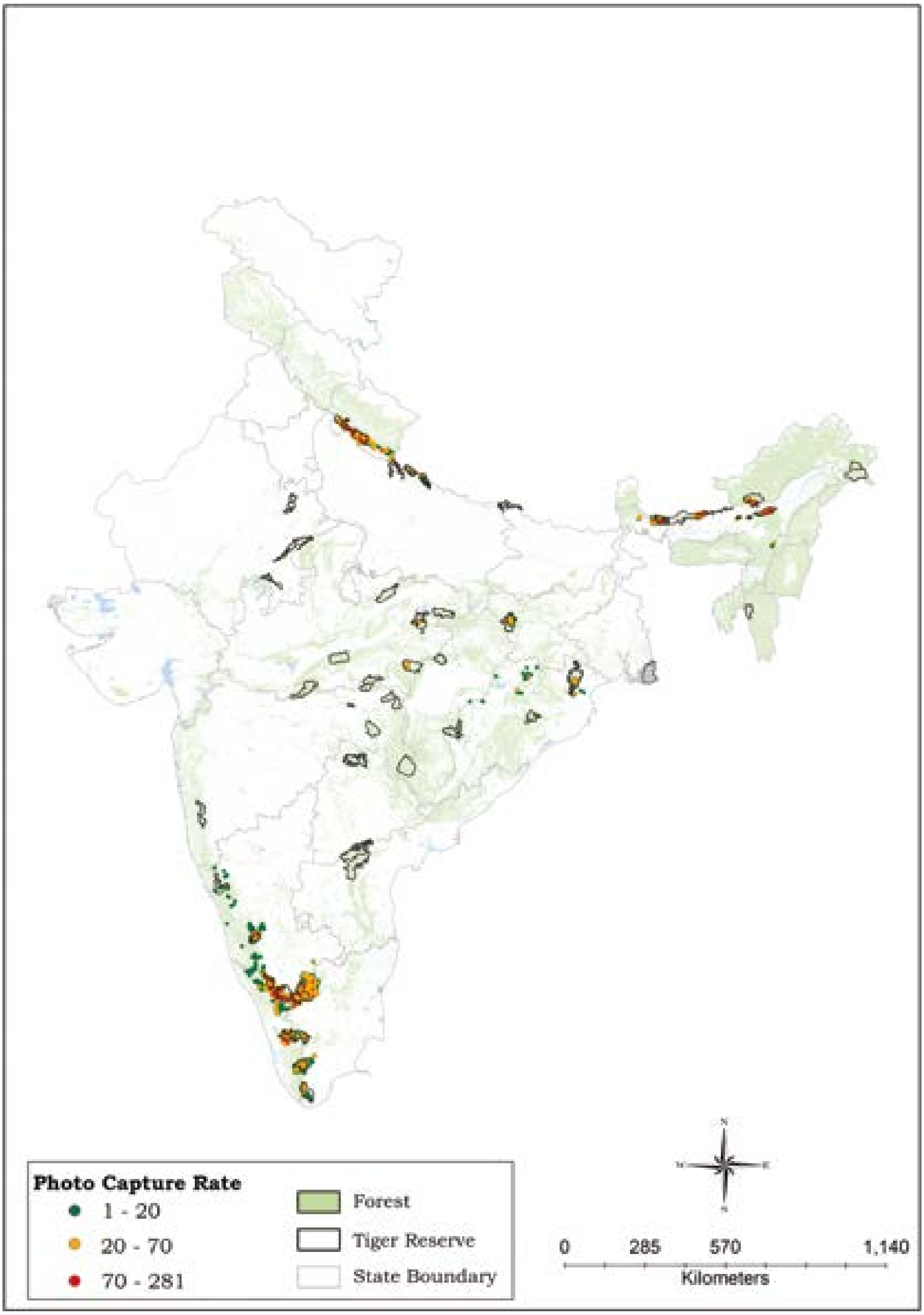
Asian Elephant society is organized into well-defined, matrilineal groups comprising of adult females and their dependent offspring (McKay 1973, Sukumar 1992, Vidya and Sukumar 2005). It is a society with fission fusion dynamics where groups of elephants sometimes seen together usually being a part of a larger community or clan (de Silva et al. 2011, Nandini et al. 2018). Sub-adult males disperse out from these clans while adult males are mostly solitary temporarily associated with the female groups (Desai and Johnsingh 1995, Vidya and Sukumar 2005). Elephant home range sizes depended on availability of forage and water (for drinking and thermoregulation) (Dunkin et al. 2013, Williams et al. 2020). Home range sizes in India have been estimated to be between 550 and 700 km^2 for female clans in tropical deciduous forests of south India (Baskaran et al. 1995) and between 188 and 407 km^2 for different males and female clans in north India (Williams et al. 2008). A study in fragmented rainforest and plantations in the Anamalai hills revealed elephant herd home ranges varying in between 114 to 122 km^2 with elephants using tea and coffee plantations at night as movement corridors (Kumar et al. 2010). Home range studies have revealed that these megaherbivores are greatly influenced by the level of disturbance and other development activities (Desai and Baskaran 1996).

RESULTS

A total of 44875 independent photo-captures were recorded during the field sampling with high number of captures from tropical forests of the southern Western Ghats, dry deciduous forests of southern India and the forests from the *Terai*. Captures were also recorded from central India (Chhattisgarh) and North-eastern India (Figure 28.1). Elephants use a variety of habitats ranging from grassland, tropical evergreen forest, semi-evergreen forest, moist deciduous forest, and dry deciduous forest. The proportion of time spent active in a day was 0.61 (SE 0.01) and photo-captures show that elephants were more active during the night and early morning and their activity was the least during mid-day hours (Figure 28.2).

The MaxEnt model best explaining occurrence of elephants (Figure 28.3) had covariates such as Pre- Monsoon NDVI, aridity, human pressure, precipitation of the driest quarter, NDVI difference, ruggedness, Evapotranspiration Index (Table 28.2). The model had an average AUC of 0.7 (Table 28.1). Pre-monsoon NDVI had the highest contribution to the model (47.2%), where elephants occurred in areas with some green cover in the dry season (Figure 28.3a). Aridity contributed 22.9% to the model. The response curve suggests that elephants prefer less arid habitats (Figure 28.3b). Elephant occurrence peaked at low human pressures and declined with increase in human pressures (Figure 28.3c). This covariate had a contribution of 13.1%. Precipitation of the driest quarter contributed 7.1%, here elephants preferred areas having high precipitation in the driest quarter (peaked at 225 mm precipitation) (Figure 28.3d). Difference in NDVI of Pre and Post Monsoon contributed 6.3% to the model variance. The response curve of the same suggests that elephants avoid dense evergreen forests and open scrublands (Figure 28.3e). Elephants are known to inhabit more rugged habitats than other megaherbivores, the response curve of ruggedness thus had a more gradual slope (Figure 28.3f) and contributed 1.9% to the model. Evapotranspiration Index contributed 1.3% to the model, wherein elephant occurrence peaked at an optimal index of 100-110 and they avoided areas with extremes (Figure 28.3g). The modelled distribution of elephant across India, developed by the presence points and environmental covariates is given in Figure 28.4.

Figure 28.1: Presence locations and intensity of photo-captures of Asian elephants obtained from camera traps in 2018-19



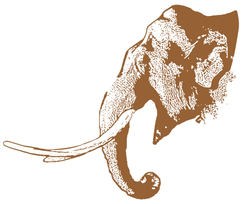


Figure 28.2: Activity pattern of Asian elephant obtained from camera trap photo-captures (N = 44875) during the All India Tiger Estimation exercise, 2018-19. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity

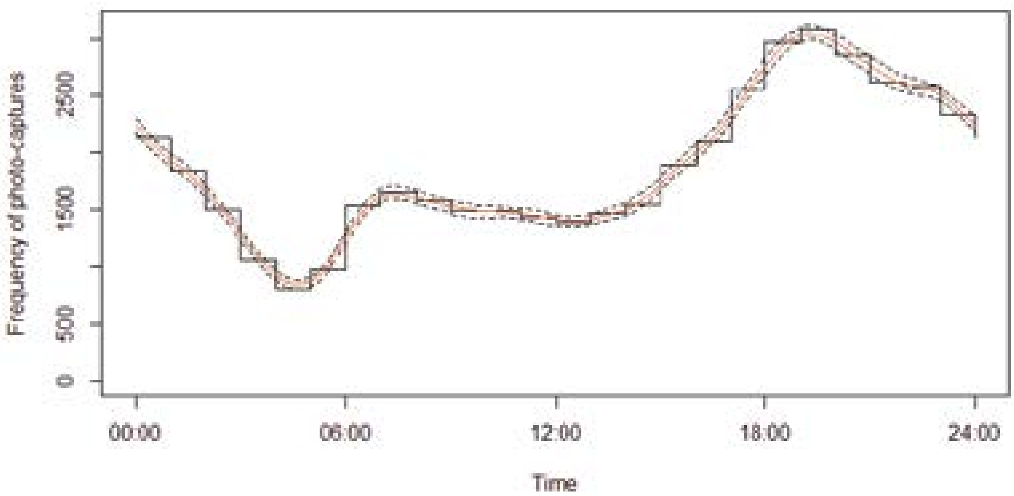


Table 28.1: Parameters used in MaxEnt setting for modelling elephant distribution/habitat in forested landscapes of India

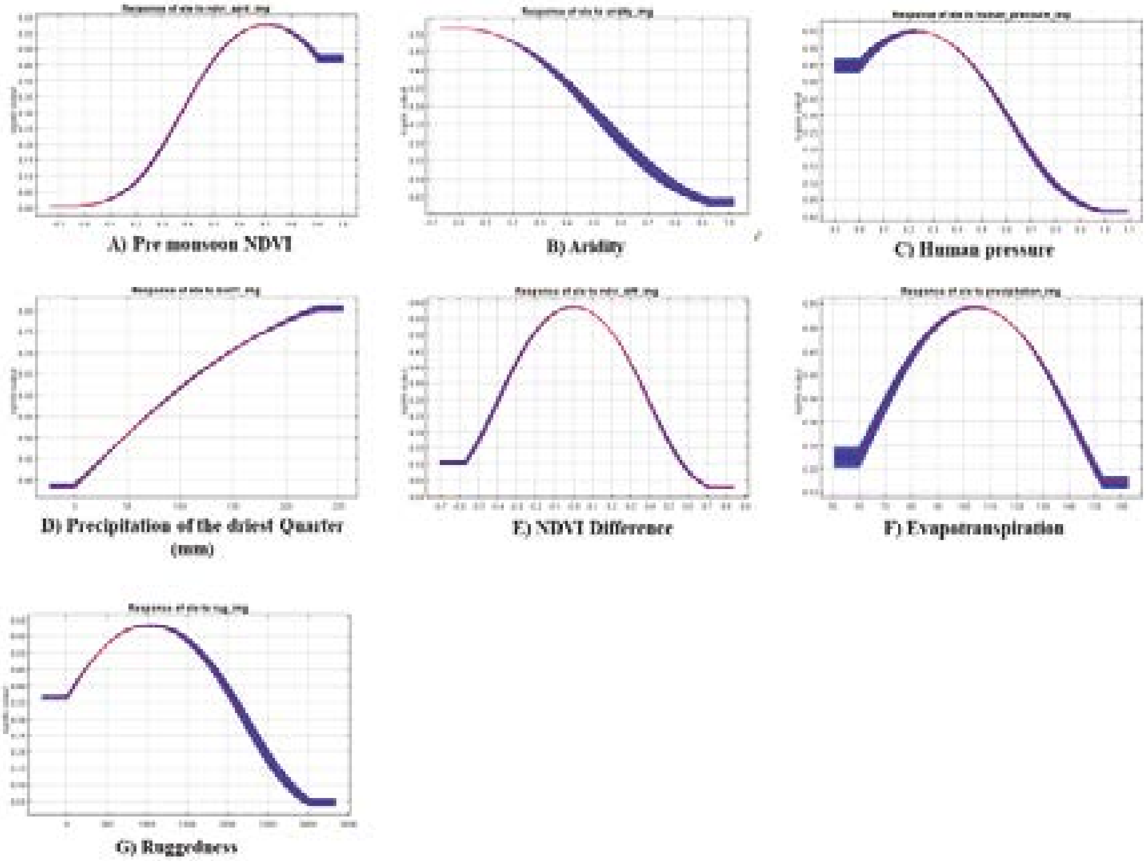
Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.41
Area under the ROC* Curve (AUC)	0.79

**receiver operating characteristic*

Table 28.2: Contribution percentage of every covariate (SD) to the best model explaining elephant distribution

Covariates	Percent contribution (SD)	Permutation contribution (SD)
Pre monsoon NDVI	47.2 (1.60)	46.1 (1.49)
Aridity Index	22.8 (1.03)	17 (0.88)
Human pressure	13 (0.98)	15 (0.87)
Precipitation of the driest quarter (BIO17)	7.1 (1.38)	7.1 (0.65)
NDVI difference (deciduousness)	6.48 (0.95)	6.9 (1.06)
Ruggedness	1.9 (0.35)	0.6 (0.17)
Evapotranspiration	1.3 (0.38)	7.1 (0.65)

Figure 28.3: Relationship of elephant with A) Pre monsoon NDVI difference, B) Aridity, C) Human pressure, D) Precipitation of driest quarter E) NDVI difference, F) Evapotranspiration and G) Ruggedness



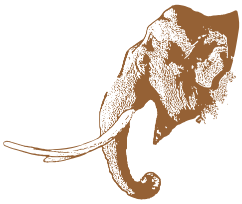
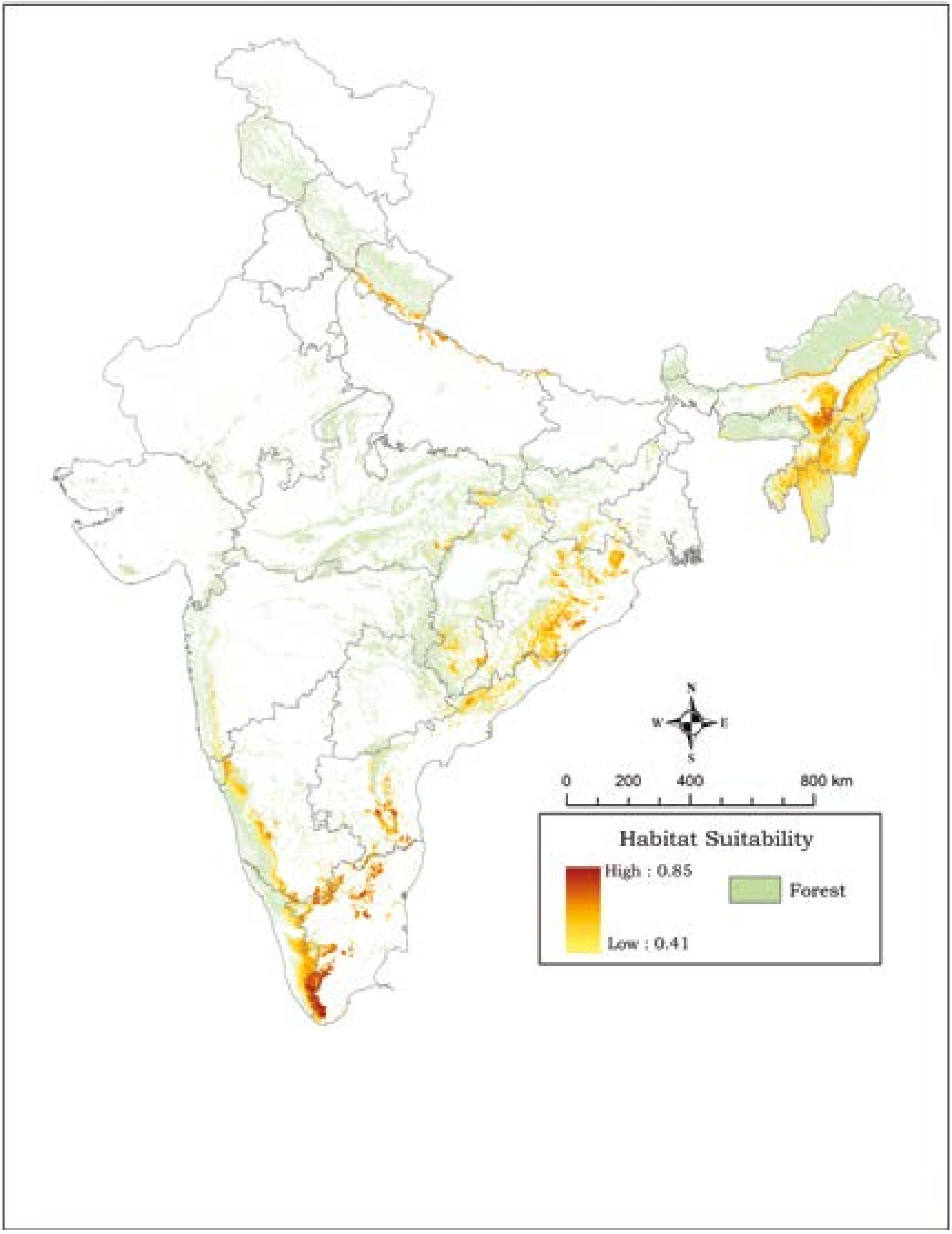


Figure 28.4: Distribution of elephant across the forested areas of India estimated from presence obtained by camera traps and environmental covariates.



Conservation significance

Like tigers, India is the major strong-hold for the Asiatic elephant. Elephant habitats were all within the range of the tiger and therefore investments made for tiger have been beneficial for elephant conservation as well. Conservation problems that plague tigers also affect elephants, especially demand for illegal wildlife trade, but in the case of elephants this is limited to the males with tusks. Rampant poaching in the past two decades has skewed the sex ratio significantly in the Western Ghats population reducing the effective population size. However, poaching has been under control in recent years. Human-elephant conflict is on the increase due to loss of forest extent and quality as well as changes in cropping patterns and degradation/loss of connecting corridors. More lethal retaliations by people and deaths due to infrastructure are reported in recent years. Conservation measures need to address elephant passage ways across all linear infrastructures in elephant habitats, such as under and over passes (Wildlife Institute of India, 2016). These elephant passage ways will ensure habitat connectivity for all biota of the region including that for tigers. In areas of high conflict with humans, mitigation measures need to include pulsating electric fencing on hard boundaries with good maintenance of these fences, timely and fair compensation for crop, property and human-life losses. Creation of large inviolate space by incentivized human resettlement from core areas of PA's will not only help tiger conservation but elephant populations as well and help prevent degradation of forest quality by livestock overgrazing and thereby reduce elephant-human conflict. Like being done for tigers, problem elephants (declared man killers) need to be identified and removed from the wild to prevent backlash from local communities against the entire elephant population. Elephants are now colonizing parts of central India, here awareness campaigns for local communities on how to live with elephants in their neighbourhood, need to be conducted as these people have no living memory of elephants.

CHAPTER 29:
GAUR
(BOS GAURUS)

INTRODUCTION

Conservation status
IUCN Red List: Vulnerable (VU)
Wildlife (Protection) Act, 1972: Schedule I

The Gaur, also known as Indian Bison, is the largest living member of family Bovidae confined to the Oriental biogeographic region of the world. three subspecies of Gaur have been recognized: *Bos gaurus gaurus* (India and Nepal), *B. g. readei* (Myanmar and Indo-China) and B. g. *hubbacki* (Thailand, south of Isthmus of Kra and west Malaysia (Lydekker 1903, 1907, Srikosamatara and Suteethorn 1994) and B. g. *gaurus* is genetically closer to B. g. *readei* compared to B. g. *hubbacki* (Kamalakkannan et al. 2020). The domesticated form of Gaur, considered by IUCN as a separate species (*Bos frontalis*; Mythun, Mithan or Gayal), occurs in parts of India, China, and Myanmar as feral, semi-feral, and domestic animal.

Global distribution is patchy with gaur distributed in India, Nepal, Bhutan, Myanmar, Thailand, China, Laos, Cambodia, Vietnam and Malaysia (Ellerman and Morrison-Scott 1951, Corbet and Hill 1992). The species is locally extinct in Sri Lanka and possibly extinct in Bangladesh (Grubb 2005,

Duckworth et al. 2016). The estimated global population is in between 13,000 to 30,000 individuals with approximately 85% of the population being present in India (Ashokkumar et al. 2011). In India, distribution of gaur is discontinuous and highly fragmented with four major (Western Ghats, Eastern Ghats, Central India and North-East) and two minor (Bihar and West Bengal) priority 'Gaur conservation areas' have been identified, reflecting the remaining distribution (Sankar et al. 2000, Choudhury 2002, Pasha et al. 2004). Gaur is found in 124 protected areas in India which cover 26% of actual distribution area of gaur (Ashokkumar et al. 2011). The major populations are found in the protected areas of Kerala, Tamil Nadu and Karnataka upto Bhagwan Mahaveer National Park in Goa and Radhanagari Wildlife Sanctuary in Maharashtra (Karanth and Kumar 2005, 2015, Karanth 2013, Ahrestani and Karanth 2014). The area has tropical wet evergreen forest to scrub forest habitat and supports the largest population of gaur in Asia (Choudhary 2002). In central India, gaurs range from Satpura range to Chhotanagpur plateau and upto Similipal in Odisha. Major gaur areas are Melghat in Maharashtra, Kanha and Pench in Madhya Pradesh, Indravati in Chhattisgarh, Palamau in Jharkhand and Similipal in Odisha. Following a local extirpation, gaurs have been translocated to Bandhavgarh Tiger Reserve from Kanha Tiger Reserve during 2011-2012 (Sankar et al. 2013). In the northern region, gaurs are extended from Himalayan foot hills through north Bengal to the Meghalaya Plateau and Mishmi Hills. The habitat in the north-east is contiguous with that in Bhutan, Bangladesh, Myanmar and Nepal.

Major threats to guar population in India are due to habitat loss, poaching, illegal hunting and diseases. Expanding fragmentation of the forest patches and habitat loss has been responsible majorly for the declining population of gaur and it remains as a major threat to their conservation in Asia (Choudhury 2002, Duckworth et al. 2008). Due to shrinking habitats, gaurs often move out of the Protected Areas for raiding crops, especially in cardamom plantations and this gives rise to serious conflict with humans. Gaurs are poached for their meat and horns; thus it is a serious threat for its conservation even within the Protected Areas (Areendran 2000). Gaurs are vulnerable to epidemics of foot and mouth disease, rinderpest (Ali 1953) and anthrax (Baker 1890, Stewart 1928, Peacock 1933, Davidar 1997, Ranjitsinh 1997) and heavy mortality have been reported from Mudumalai, Bandipur, Periyar and Kanha.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SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

The gaur is the largest wild bovid having strong and massively built. It has a head and body length of 250 to 330 cm with 70-105 cm long tail. The animal has high convex ridge on the forehead between the horns, protruding anteriorly causing deep hollow in the upper part of the head. They have a shoulder hump, it is 142 to 220 cm high at the shoulder with an average of 168 cm in females and 188 cm in males. This hump is pronounced in males. They have a huge head and a deep body having reddish/brown to black in color. The animal has strong limbs of pale in color, a dewlap under chin hangs between their front legs. The presence of a distinct muscular crest between shoulders and a large dewlap hanging between the forelegs and smaller one under the chin distinguishes adult bulls from cows (Krishnan 1972). They weigh between 650 -1000 kg where males are 25 % larger than females. Both male and females have horns of 1.1 m in length, these horns grow from side of their heads curving upwards. The color at the base is yellow and changes to black at the tip of the horns. The white-to-black colour ratio on gaurs' horns characterizes the age of the individuals. Males above 8 years have horns that are over 85% white, worn at the ends, and heavily corrugated closer to the head. Similarly, females with more than 80% of white on the horns are older than 10 years (Ahrestani et al. 2011).

Body Size:
Head and body length: 250-330 cm, height at shoulder: 165-225 cm (Menon 2014)

Body Weight:
600-1000 kg in males and 500-800 kg in females (Pasha et al. 2004)

Gestation Period:
275 days (Pasha et al. 2004)

Litter Size:
1 (Pasha et al. 2004)

Life Span:
24 years (Crandall 1964, Ahrestani et al. 2011)

ECOLOGY AND BEHAVIOUR

Gaur inhabits undisturbed forest tracts in hilly terrains with abundant sources of forage and water (Schaller 1967); from sea level up to at least 2,800 m msl (Wood 1937, Wharton 1968, Choudhury 2002). In India, the species is largely confined to the evergreen, semi-evergreen, and moist deciduous forest but it is also likely to be occurred in dry deciduous forest and thorn forest (Schaller 1967, Pasha et al. 2004, Goswami 2007). The preference for hilly terrain is attributed to the conversion of plains and other low-lying areas to croplands and pastures, forcing the species towards areas with low human densities (Schaller 1967, Wharton 1968). They prefer burnt areas due to the availability of regenerating green grass (Paliwal and Mathur 2012).

Gaurs are grazers mainly feeding on grasses and can feed on variety of plants indicating a polyphagous feeding habit (Brander 1923, Krishnan 1972, Ashokkumar 2004). They mainly feed upon bamboo shoots, foliage of trees, shrubs, herbs and grasses. A total of 151 species of food plants were identified to be consumed by gaurs in the Parambikulam Wildlife Sanctuary that supports a vegetation type ranging from evergreen to moist deciduous (Easa 1998). Major food species are from the plant families of Poaceae, Fabaceae, Asteraceae and Malvaceae (Nayak and Patra 2015). Grass comprises a major proportion (66%) of their diet followed by browse, herbs and others (Chetri 2006). The grass species which are preferred for feeding are *Themeda triandra, Oplismenus undulatifolius, Setaria intermedia, Themeda cymbaria and Heteropogon contortus* (Vairavel 1998, Arrendran 2000). Salt licks are periodically visited and they are obligatory drinkers visiting water bodies twice a day during summer (Schaller 1967).

Gaurs are gregarious in nature with matrilineal societies (Ashokkumar et al. 2010) adult females usually lead the herds (Krasinski 1978). The group structure is fluid and dynamic and the observed social associations are solitary males, bull groups and mixed herds (Areendran 2000, Ashokkumar et al. 2010). The group size of mixed herds ranges from 1 to 16 animals (Brander 1923, Karanth and Sunquist 1992, Sankar et al. 2000, Kumaraguru 2006) and occasionally ranges up to 47 individuals (Ashokkumar et al. 2004).

The daily distance covered by gaur has been reported as 3.2 – 4.8 km/day in Kanha by Schaller (1967) while the home range size has been varyingly reported to range from 78 km² in Kanha (Schaller 1967) to 13 km² in Taman Negara National Park, Malaysia (Weigum 1972) and is influenced by habitat conditions. The overall individual home ranges for both sexes were however, reported to be much larger in relocated gaur in the Bandhavgarh Tiger Reserve (135 to 142 km² for males and 32 to 169 km² for females) (Sankar et al. 2013).

Gaurs are predominantly diurnal but have been reported to be nocturnal in areas of high human disturbance (Ashokkumar et al. 2011). They exhibit bimodal diurnal, feeding and movement peaks during morning and evening hours. The noon time heat is avoided by animals moving towards vegetation cover and resting and ruminating (Ashokkumar et al. 2011).

RESULTS

A total 37,397 photos of gaur were captured across the range during the sampling. Most of the photos were captured in tropical dry and moist deciduous and in tropical wet and semi evergreen forest patches (Figure 29.1). Gaur are found in three regions, southwestern India, Central India and in North-Eastern India.

Proportion of time spent active by gaur was 0.46 (SE 0.01), it showed diurnal activity pattern with a bimodal activity peaks in the morning till noon and then in late evenings (Figure 29.2)

Data used and parameter settings of MaxEnt that used photo-capture intensity and eco-geographical covariates to model occurrence of gaur are provided in Table 29.1.

Figure 29.1: Presence locations and intensity of photo-captures of gaur obtained from camera traps in 2018-19.

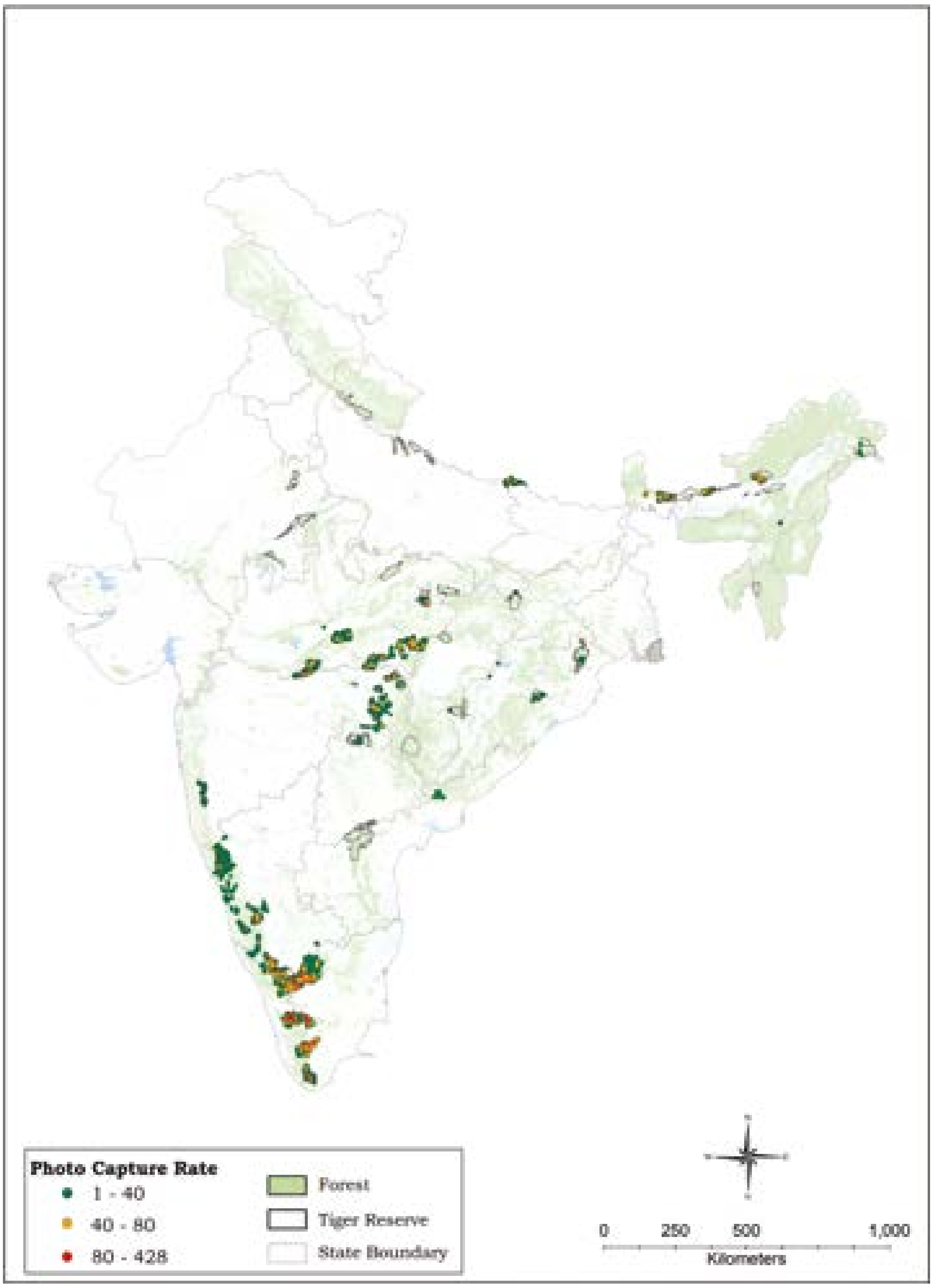
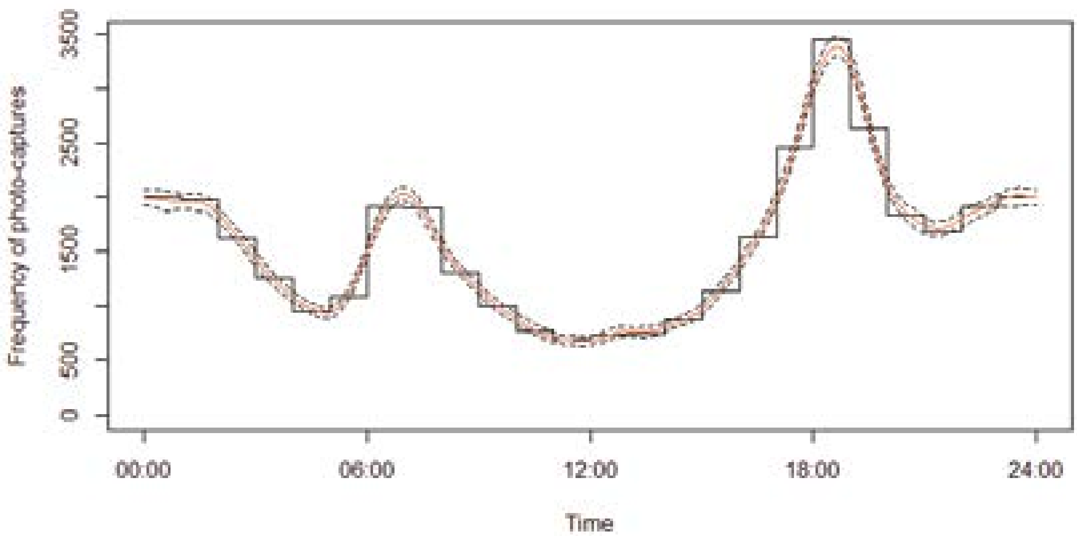


Figure 29.2: Activity pattern of gaur obtained from camera trap photo-captures (N = 37397) during the All India Tiger Estimation exercise, 2018-19. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity



Seven habitat predictors were used in MaxEnt for modelling the suitability for gaurs. The variables used are elevation, ruggedness, human pressure index, minimum temperature, vegetation index, and deciduousness of forest from the difference in NDVI of post monsoon and premonsoon months and aridity index. The result of jackknife test indicated that minimum temperature (30.50 % SD 1.60) had the strongest influence on habitat suitability of gaurs, followed by human pressure (29.30 % SD 1.85), terrain (13.80 % SD 1.01), vegetation condition of premonsoon month (April) was 7.50 % SD 0.79). Ruggedness (7.20 % SD 0.78), NDVI difference (6.70 % SD 0.57) and aridity (5 % SD 0.76) contributed less to the model. Minimum temperature, human pressure and elevation index were the main variables that explained patterns of gaur distribution (Table 29.2).

The response curves for gaurs showed that species' suitable habitats are in central Indian highlands and in western ghats preferring to reside in moist and dry tropical forests and parts of semi and evergreen forest patches. Response curve of NDVI difference shows that species prefers areas of predominantly having deciduous forest and are away from human pressure. Response curve for elevation (DEM) and ruggedness shows that they can inhibit areas having elevation of 300 meters to 3000 meters and with moderate ruggedness. Species do not prefer areas having low temperature (not below 5 degrees, Figure 29.3).

Probability of occurrence of gaur within the forested habitats of tiger states based on the best MaxEnt model is given in Figure 29.4.

Table 29.1: Parameters used in MaxEnt setting for modelling the distribution/habitat of gaur in the forested landscapes of India.

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.35
Area under the ROC* Curve (AUC)	0.757

**receiver operating characteristic*

Table 29.2: Contribution percentage of every covariate (SD) to the best model explaining gaur distribution

Covariates	Percent contribution (SD)	Permutation contribution (SD)
Minimum temperature of coldest month (BIO6)	31.00 (1.73)	32.60 (0.62)
Human Pressure	24.20 (1.39)	8.70 (0.26)
NDVI April	20.90 (1.49)	34.30 (0.46)
DEM	7.70 (0.69)	12.00 (0.53)
NDVI Difference (deciduousness)	7.60 (0.61)	10.60 (0.47)
Ruggedness	4.90 (0.61)	0(0)
Aridity Index	3.70 (0.55)	1.80 (0.11)

Figure 29.3: Relationship of gaurs with A) Minimum temperature of the coldest month (°C), B) Human pressure, C) DEM, D) NDVI April, E) Ruggedness, F) NDVI difference (Deciduousness of forests) G) Aridity

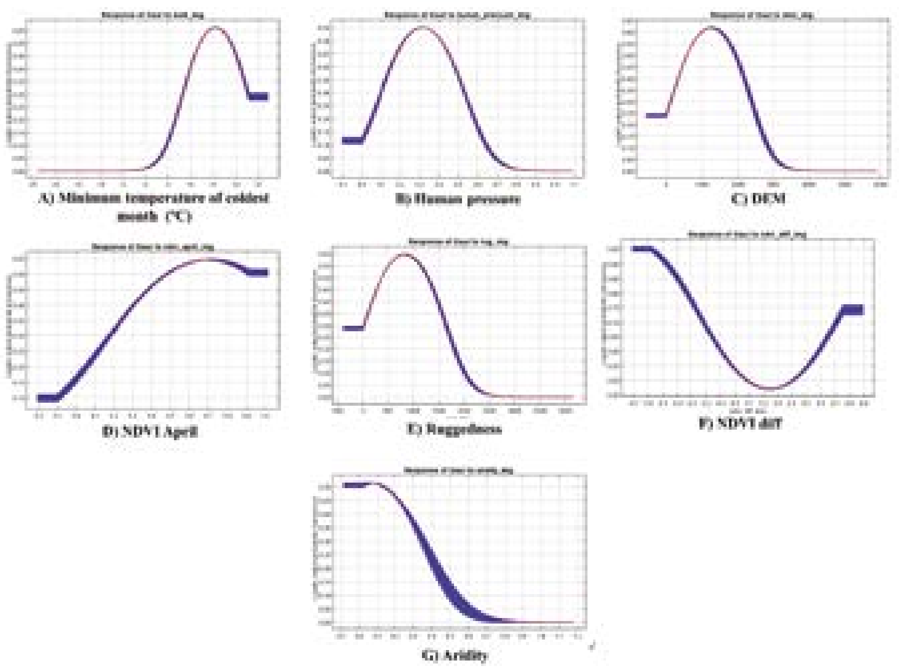
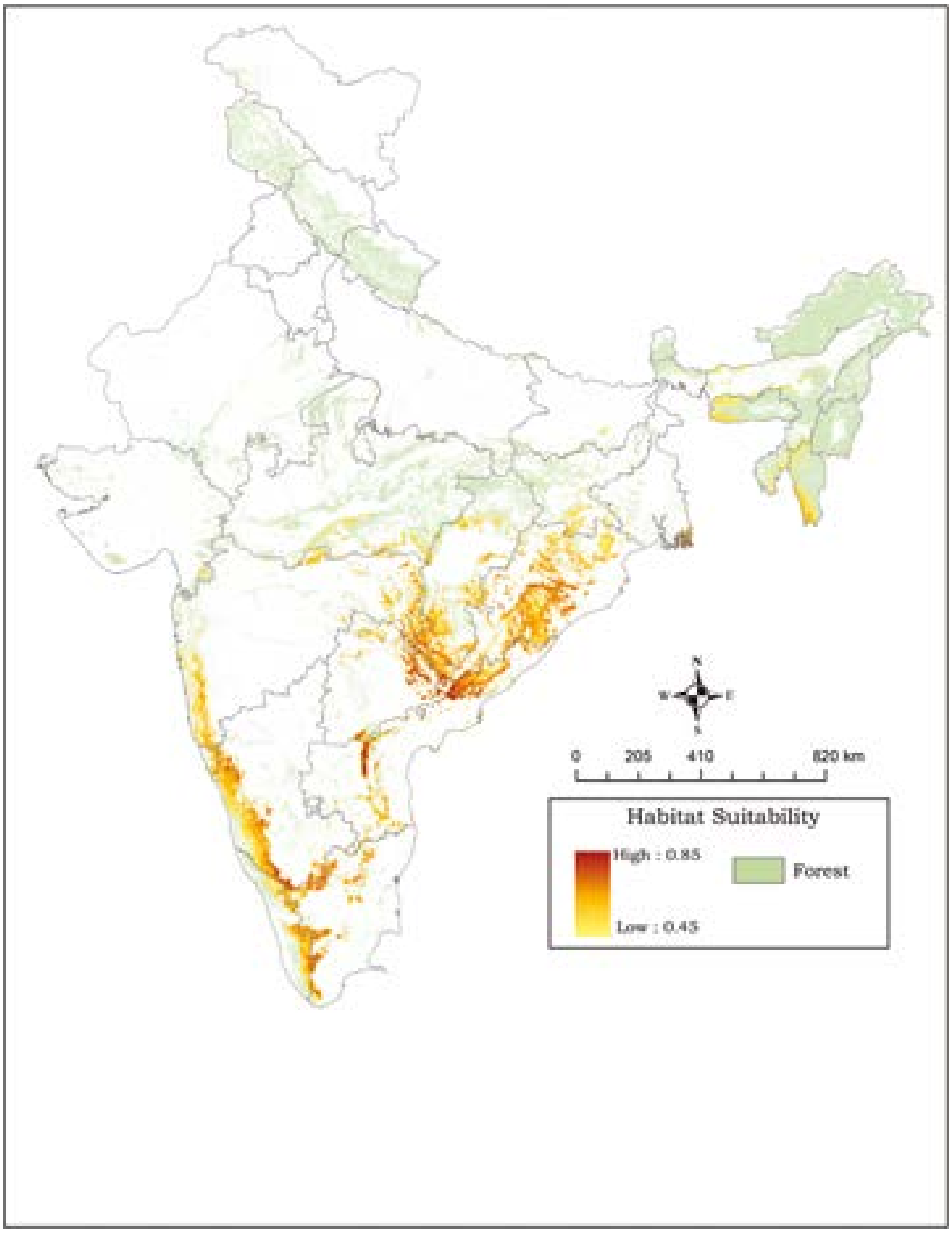


Figure 29.4: Distribution of gaur across the forested areas of India estimated from presence obtained by camera traps and environmental covariates.



Conservation significance

For long-term conservation of gaurs, it is crucial to protect their habitat and to maintain the connectivity between the potential habitat patches. The species are doing well inside the protected areas but it is essential to maintain and safeguard their dispersal routes to ensure their existence in metapopulation framework. This can also help in protecting these species from poaching pressures and from diseases. Relevant management strategies to protect suitable habitat and improving landscape connectivity can ensure long-term population of gaurs.

CHAPTER 30:
GREATER ONE-HORNED RHINOCEROS *(RHINOCEROS UNICORNIS)*

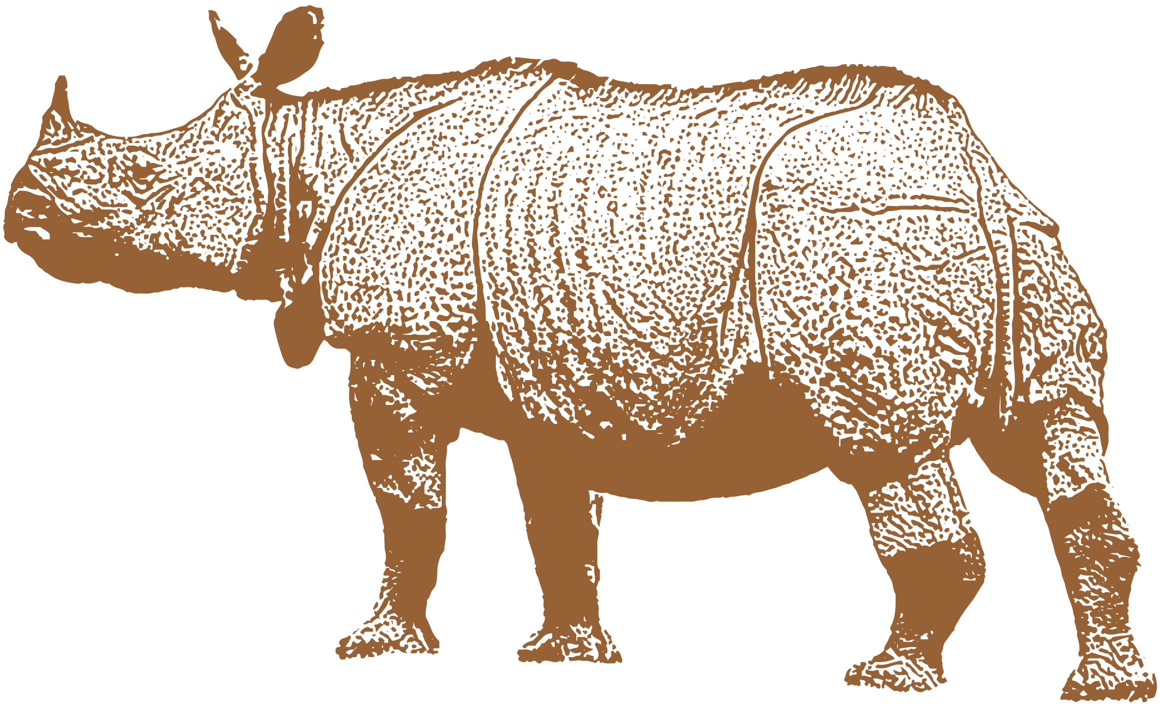
INTRODUCTION

Conservation status

IUCN Red list: Vulnerable (VU)

Wildlife (Protection) Act, 1972: Schedule I

Historically all three species of Asian rhinoceros inhabited the Indian subcontinent. With the extinction of the Javan *(Rhinoceros sondaicus)* and Sumatran *(Diceros sumatrensis)* rhinoceros in the early part of 20th century, Greater one-horned rhinoceros *(Rhinoceros unicornis)* is the only among the five remaining species of the Rhinocerotidae family occurring in the subcontinent (Sinha 2004). The distribution and population of rhino was once continuous and abundant across the floodplains of the Indus, Ganges and the Brahmaputra, a range that stretched from Sindh to the Indo-Burmese border (Roommaker 1984, Foose and van Strien 1997, Sinha 2004). Currently, the species is restricted in eight protected areas of India (Kaziranga, Pabitora, Manas, Orang, Jaldapara, Gorumara, Dudhwa, Katerniaghat) and in four protected areas of Nepal (Chitwan, Bardia, Suklaphanta, Parsa) (Foose and van Strien 1997, Ellis et al. 2015, Emslie et al. 2016). Occasional records have been reported from Valmiki Tiger Reserve of Bihar, Laokhowa and Burhachapori Wildlife Sanctuaries of Assam and



Rautahat district of Nepal (Rimal et al. 2018, Ellis and Talukdar 2019). The current population of rhinos is estimated at approximately 3,600 with Kaziranga National Park in Assam, India (N~2,400) and Chitwan National Park in Nepal (N~600) being the major population strongholds (DNPWC 2017, Talukdar 2020).

The rhino, with slow life history traits, typifies all major conservation problems faced by mega-herbivores. It declined to near extinction in the early 1900s, primarily due to rapid conversion of alluvial plains grasslands to agricultural development. Sport hunting was common until early 1900s. A reversal of government policies shortly thereafter protected many of the remaining populations. However, poaching, mainly for the use of its horn in Traditional Asian Medicine as an anti-pyretic, has remained a constant threat (Leader-Williams 2013). In international markets of the East, one kilogram of powdered horn costs about 35,000 – 40,000 US$ which is one of the strongest incentives for poaching (Vigne and Martin 2016). Other threats include habitat loss, since the floodplain habitat they inhabit is often also prime agricultural land. Furthermore, the grassland habitats are under pressures from overgrazing by livestock, thatch collection, burning of grasslands for fodder (Amin et al. 2006), and by invasion of exotic plant species like *Mikania miracantha, Leea crispa and Mimosa spps (diplotricha, invesa and pigra)* (Lahkar et al. 2011, Murphy et al. 2013, Subedi et al. 2013). The tall grasslands of *Terai* are a dynamic successional stage created by the changing courses of the Himalayan rivers, this very process is now controlled by training rivers by dykes and dams to control floods (Subedi et al. 2013, 2017). Rhinoceros is also vulnerable to the impacts of climate change due to likelihood of proliferation of invasive plant species, flood severity and regimes in its prime habitat, habitat fragmentation, droughts and forest fires (Pant et al. 2020).

SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

Indian rhinos have a thick grey-brown skin with pinkish skin folds and one horn on their snout. Both sexes have a single horn that ranges between 15 to 45 cm (Laurie 1982) with an average weight of 750 g (Menon 1996). They possess a prehensile upper lip for selective grazing. Their skin has loose folds, especially distinct around the neck region in males, behind the forelimbs and before the hindlegs giving an appearance of a suit of armor. The skin is covered with large tubercles especially on the rump (Laurie 1982).

Body size :

Males usually stand up at about 185 cm at the shoulder, while females at 160 cm (Laurie 1982)

Body weight:

1500- 2000 kg (Menon 2014)

Gestation period and litter size:

Females reach sexual maturity at 4-5 years and the age of first calving is observed between 7-9 years (Dinerstein and Price 1991, Subedi et al. 2017), while for males, sexual maturity is reached at 9-10 years. Females have a gestation period of 479 days (almost 16 months), and give birth to only one calf. The inter calving interval is about 41.28 months (Subedi et al. 2017).

Life span:

Rhinos are known to live for 35-40 years in the wild. However, their lifespan is known to increase in captivity.

ECOLOGY AND BEHAVIOUR

The Greater one-horned rhinoceros is known to occupy floodplain habitats of the Ganges and Brahmauputra river systems. Their occurrence is limited to alluvial grassland- forest habitat mosaics interspersed with surface water in forms of wallow pools and oxbow lakes (Dinerstein 2003). They are restricted to low-lying, less rugged habitats. However, it is believed that they occupied much drier and more rugged terrain historically (Prater 1948).

Although considered a mega-grazer, the greater one-horned rhinoceros is known to browse as well. The dietary preferences of the rhinos change seasonally. Rhinos feed on 183 plant species belonging to 57 families but grass (50 species) constitutes about 70-90% of their diet (Laurie 1982). *Saccharum and Cynodon* constitutes majority of their diet, however, browsing on trees and shrubs is more prevalent in the winter (Laurie 1982, Subedi 2012). In addition, their diet also consists of aquatic vegetation, seges and herbs (Sinha 2004).

The greater one-horned rhino is usually a solitary species, with the exception of adult females that are accompanied by their calves (Laurie 1982). Home range size of dominant breeding males have been recorded to be around 4.3 km^2, while those of adult breeding females were around 3.5 km^2 in Chitwan National Park, Nepal (Dinerstein 2003).

RESULTS

A total of 11662 independent photo-captures were recorded during the field sampling with highest captures in grasslands of the Brahmaputra plains. Location samples were also recorded from extant populations of Nepal : Chitwan National Park, Bardia National Park and Shuklaphanta National Park (Figure 30.1), with activity peak observed during early mornings (06:00 hrs to 0:800 hrs) and evening to late night (Figure 30.2). Proportion of time spent active by them was 0.60 (SE 0.01).

Figure 30.1: Presence locations and intensity of photo-captures of one horned rhinoceros obtained from camera traps in 2018-19 and secondary data from Nepal.

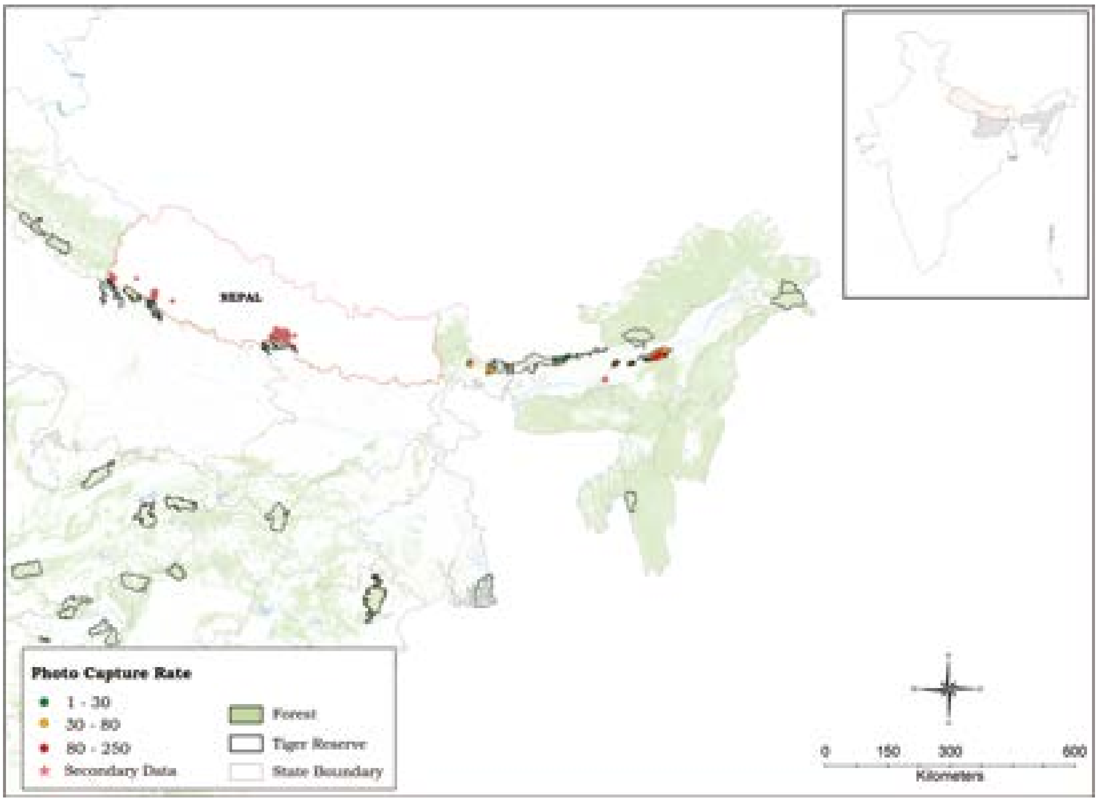
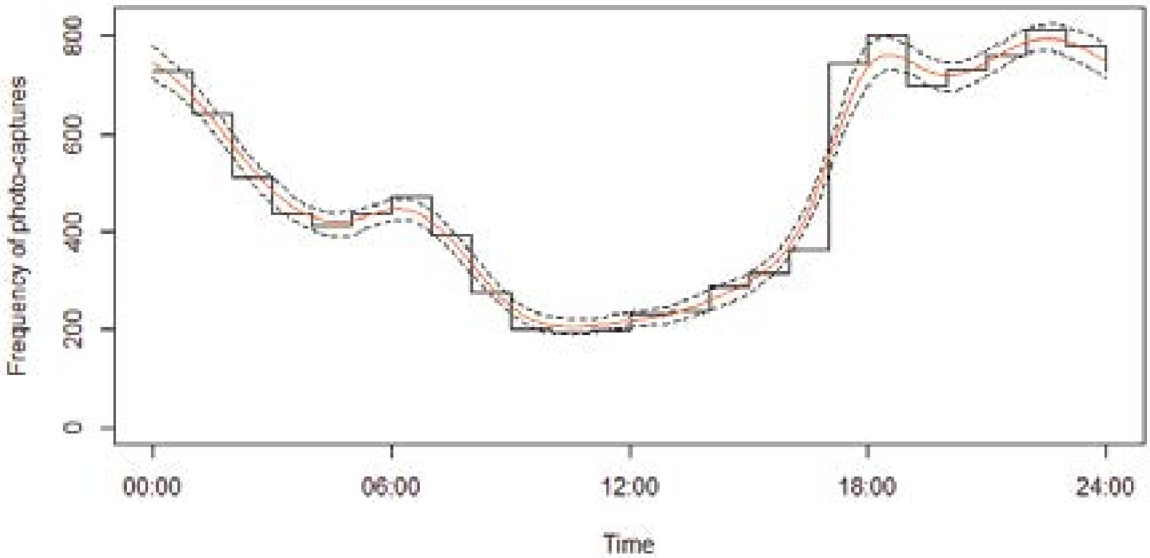


Figure 30. 2: Activity pattern of Greater one-horned rhinoceros obtained from camera trap photo-captures (N = 11662) during the All India Tiger Estimation exercise, 2018-19. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity.



Rhino occurrence data were best explained in MaxEnt by covariates of distance from grasslands, human pressure, ruggedness, distance from forests and maximum temperature of the warmest month (Figure 30.3). The model had an average AUC of 0.79 (Table 30.1). Human pressure had the highest percentage contribution to the model variance (56.5%), the response curve suggest that rhinos occur in areas with low levels of human pressures and occurrence rapidly declines as human pressure increases (Figure 30.3a). Rhino occurrence was found to be high in grasslands and rapidly declined as distance from grasslands increased. This covariate has a contribution of 24.2% (Figure 30.3b). Rhinos occurred in areas with lower ruggedness (Figure 30.3c). Ruggedness contributed 13.5% to the model variance. Similar to Grasslands, Rhino occurrence was high in areas closer to forests and decrease as distance from forests increased (Figure 30.3d). Distance from Forest contributed 4.4% to the model. Rhino occurrence was limited to areas having maximum temperature between 26 to 38°C in the warmest months (Figure 30.3e). Maximum temperature of the warmest month contributed 1.4% to model variance. The modelled distribution of Greater one-horned rhinoceros across India, developed by the presence points and environmental covariates is given in Figure 30.4.

Table 30.1: Parameters used in MaxEnt setting for modelling distribution/habitat of Greater one-horned rhinoceros in forested landscapes of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.26
Area under the ROC* Curve (AUC)	0.79

**receiver operating characteristic*

Table 30.2: Contribution percentage of every covariate (SD) to the best model explaining distribution of Greater one-horned rhinoceros

Covariates	Percent contribution (SD)	Permutation contribution (SD)
Human pressure	56.5 (0.43)	30.2 (0.74)
Distance from Grasslands	24.2 (0.3)	16.5 (0.61)
Ruggedness	13.5 (0.14)	30.3 (0.45)
Distance from Forest	4.4 (0.15)	20.1 (0.55)
Maximum Temperature of Warmest month (BIO5)	1.4 (0.06)	2.9 (0.17)

Figure 30.3: Relationship of Greater one-horned rhinoceros with A)Human pressure, B) Distance from Grasslands, C) Ruggedness, D)Distance form Forest, and E) Maximum temperature of warmest month

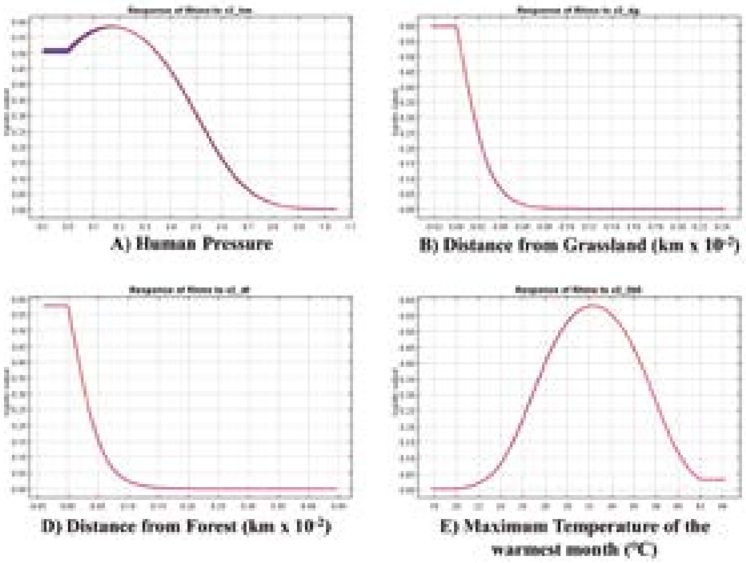
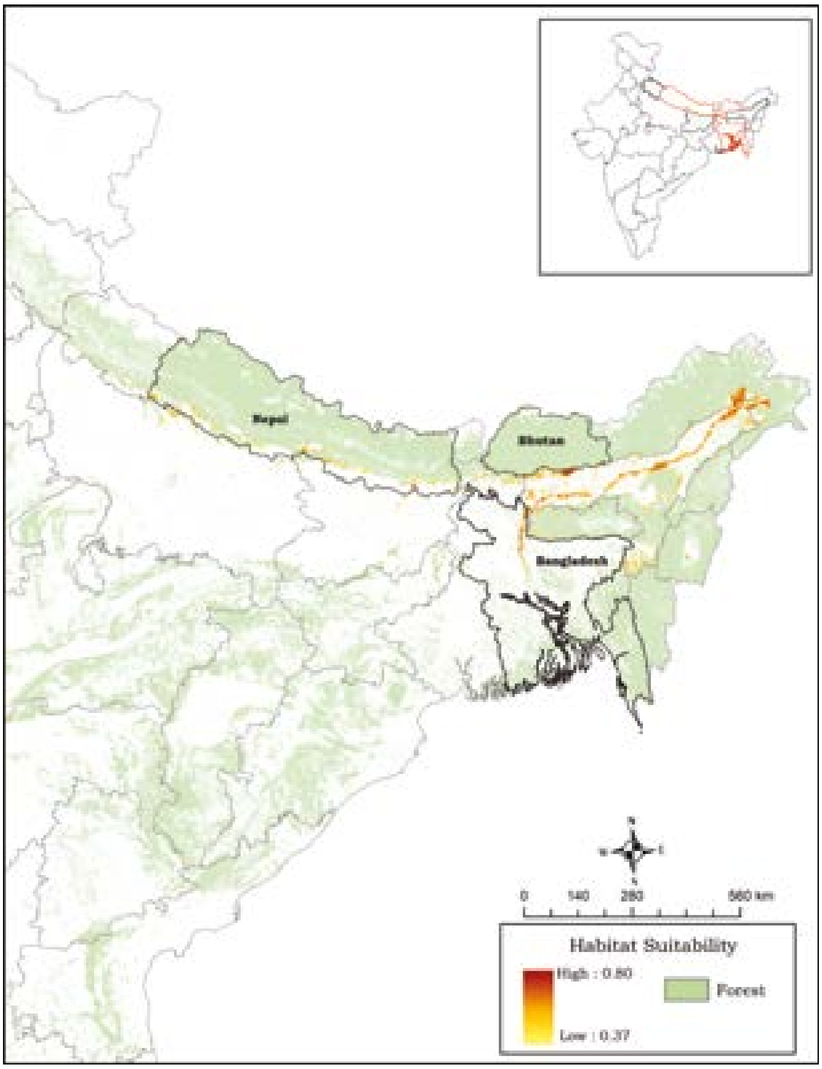


Figure 30.4: Distribution of greater one-horned rhinoceros across India, Nepal and Bhutan estimated from presence obtained by camera traps, secondary data and environmental covariates.



Conservation significance

Rhinoceros are conservation dependent species that are threatened by a high demand in illegal trade. Rhinoceros like other mega-herbivores are habitat architects that facilitate the use of grassland habitats by other grassland specialists like hog deer, pigmy hog, Bengal florican and hispid hare. Now, since the major threat of poaching has been controlled in Tiger Reserves, rhinoceros should be reintroduced in all potential habitats to create safety net populations and harness their benevolent effect on the habitat as well as conspecifics (Jhala et al. 2021) as is being done in Nepal. The reintroduced rhinoceros population in Dudhwa Tiger Reserve is in dire need of supplementation to meet the targets of the reintroduction done two decades ago. Reintroduction in Corbett Tiger Reserve and Valmiki Tiger Reserve is a feasible proposition and requires initiative on the part of policy makers and wildlife managers (Jhala et al. 2021).

CHAPTER 31:
WILD WATER BUFFALO *(BUBALUS ARNEE)*

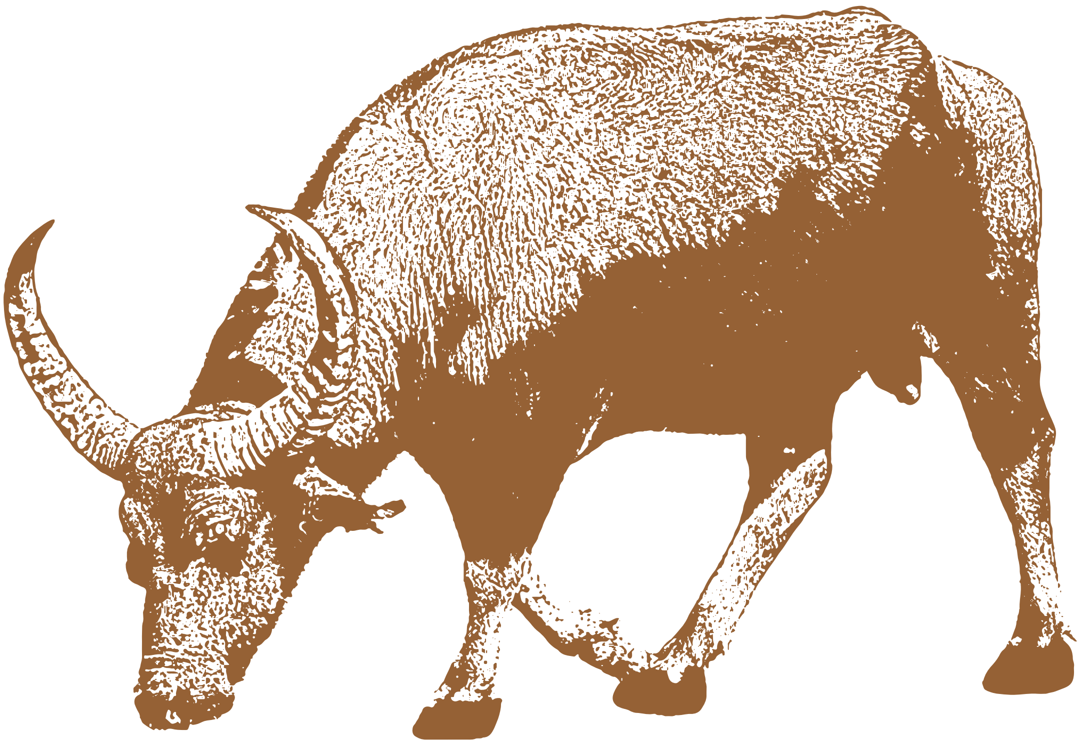
INTRODUCTION

Conservation status

IUCN Red list: Endangered (EN)

Wildlife (Protection) Act, 1972: Schedule I

The wild swamp buffalo or the wild water buffalo *(Bubalus arnee)* is the ancestor of the domestic water buffalo. It is one of the four wild bovine species found in India; others being gaur *(Bos gaurus)*, banteng *(Bos banteng)* and yak *(Bos grunniens)*. The genus *Bubalus* was widely distributed in Europe and southern Asia during the Pleistocene, but was later restricted to the Indian subcontinent and Southeast Asia (Mason 1974). Once abundant across the northern plains of the subcontinent from the Indus basin to Brahmaputra floodplains and into south China, it is now restricted to small pockets in central and north eastern parts of India, southern Bhutan, Nepal, western Thailand and Cambodia (Hedges et al. 2008, Kaul et al. 2019). Their presence is unconfirmed from Myanmar, while the buffalo has been extirpated from Laos, Bangladesh and Vietnam (Choudhury 2010). Their



population is estimated anywhere between 3,000-4,000 with fewer than about 2500 adults and about 91% of the population is confined to India (Choudhury 1994, 2010, Scherf 2000, Hedges et al. 2008). In India, the current population is restricted to few Protected Areas in two states. Kaziranga National Park, Manas National Park, Dibru-Saikhowa Wildlife Sanctuary and adjoining forests of Lakhimpur district in Assam represent the major population stronghold (Mathur et al. 2004, Kaul et al. 2019) while a small remnant population of around 50 animals still exists in Central India (Indravati Tiger Reserve, Udanti-Sitanadi Tiger Reserve, Pamed Wildlife Sanctuary of Chhattisgarh) and might be the only remaining pure wild population in the world (Mathur et al. 1995, 2004). A recent study based on variation in mitochondrial DNA and Cytochrome B sequences revealed that wild buffalo from Central India and North East share a common genetic ancestor (Mishra and Gaur 2019; Pacha et al. 2020).

Major threats to declining wild buffalo populations include habitat loss, hunting for bushmeat. hybridization with domestic buffalo breeds and disease from domestic livestock (Kaul et al. 2019). Flooding has been identified as one of the major threats for buffaloes in Koshi Tappu Wildlife Reserve of Nepal (Shrestha et al. 2018). Conservation efforts in the form of reintroductions have been carried out in recent years (Jhala et al. 2020 in press).

SPECIES DESCRIPTION AND LIFE HISTORY TRAITS

The buffalo has ash-gray to black skin with coarse sparsely distributed hair with a long and narrow head. Body coat color is brownish and the under parts are reddish. Both sexes have a pair of semi-lunar horns that range between 60 to 100 cm, which can be 2 m apart. Distance ce from tip to tip of the horn in case of Central Indian buffaloes (965 mm) is more than compared to North Eastern buffaloes (869 mm) (Mathur et al. 1995).

Body size:

Head and Body Length : 240-300 cm, Tail Length: 60-100 cm, they stand at a height of 2 m from the ground (Massicot 2004).

Body weight:

800-1200 kg (Massicot 2004).

Litter size and gestation period:

Both males and females reach sexual maturity at 3-4 years. Females have a gestation period of 11 months, and give birth to only one calf. The inter calving interval is about 1 year (Nowak 1999, Heinen and Kandel 2006, Jhala et al. 2020 in press).

Life span:

25 years in wild, 29 years in captivity (Nowak 1999, Mathur et al. 2004).

ECOLOGY AND BEHAVIOUR

The buffalo are known to utilize low-lying alluvial grasslands with riparian forests and woodlands (Lydekker 1924, Choudhury 1994). Historically wild buffaloes were known to make long-distance seasonal migrations across the subcontinent, however with a decline in their numbers, their population has been fragmented and restricted majorly to the *Terai* and Brahmaputra flood plains (Hasan 1980, Arun Singh 1980). Although the buffalo is known to use low-lying habitats, they have been recorded upto an elevation of 1,000m (Hedges et al. 2008).

Little is known about the diet of water buffaloes. They are considered grazers by mainly feeding on grasses when available, but they are also known to consume herbs, fruits, bark as well as observed browsing on trees and shrubs. Daniel and Grubh (1966) listed *Cynodon dactylon, Themeda quadrivalvis*, and *Coix* sp., as grasses known to be eaten by wild buffaloes in India. In Koshi Tappu Wildlife Reserve of Nepal, wild buffalo diets had carbohydrate content of 40.41 (± 1.82)% and crude protein content of 10.52 (± 0.93)% and lipid content of 1.68(± 0.23)% (Shrestha et al. 2020). Wild buffalo also raid crops and often feed on rice, sugar cane, and jute crops (Lekagul and McNeely 1977, Kushwaha 1986).

Wild buffaloes are primarily diurnal (Mathur et al. 2004). They form loosely structured herds of maternal groups consisting of 10–20, and at times upto 100, individuals (Hedges et al. 2008). Adult males from bachelor herds of up to 10 individuals, with older males are often solitary. The species exhibits a polygynous mating system, with breeding season in October to January, however, some populations breed year round (Mathur et al. 2004). Home range sizes vary from 1.7 to 10 km^2 (Nowak 1999).

RESULTS

A total of 5906 independent photo-captures were recorded during the field sampling with maximum photographs obtained from the floodplains grassland of the Brahmaputra river. Sighting locations were also obtained from Koshi Tappu Wildlife Sanctuary of Nepal, Royal Manas National Park in Bhutan, and from the reintroduced population in Chitwan National Park, Nepal (Naresh Subedi Pers. Comm.). Locations of dung samples from central India (Udanti- Sitanadi and Indravati) were also used as presence locations for modelling (Figure 31.1). Proportion of time they were active in a day was 0.54 (SE 0.02), they are diurnal species with activity peak in the early morning hours and around sunset (Figure 31.2).

Figure 31.1: Presence locations and intensity of photo-captures of wild buffalo obtained from camera traps in 2018-19 and secondary data from Nepal.

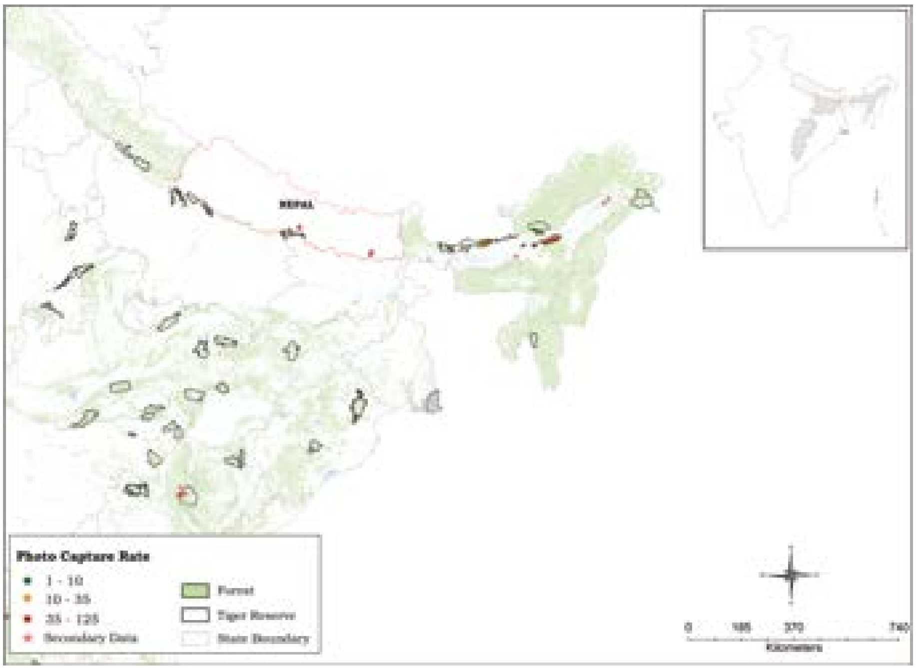
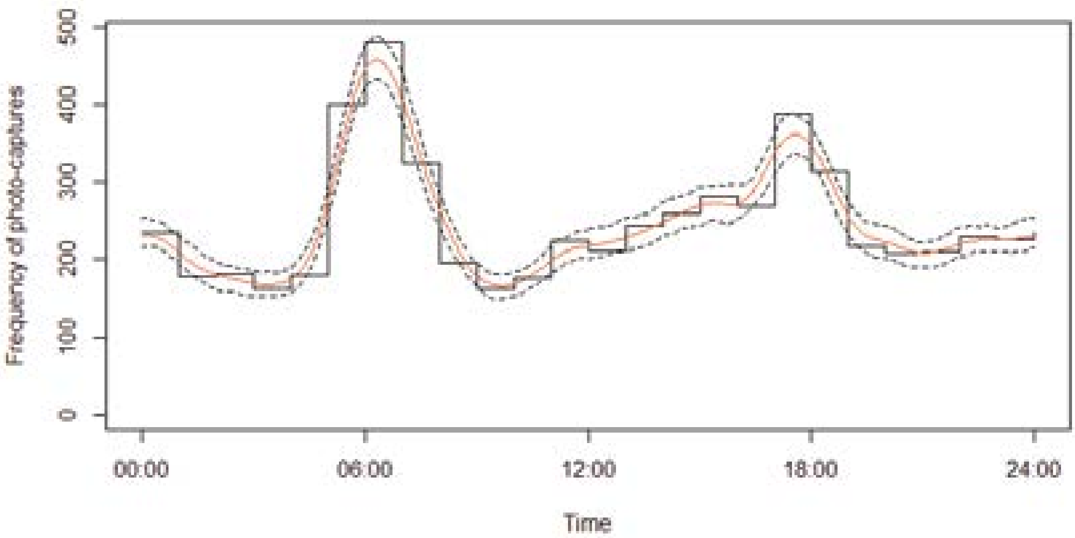


Figure 31.2: Activity pattern of wild buffalo obtained from camera trap photo-captures (N = 5906) during the All India Tiger Estimation exercise, 2018-19. The histograms (black bars) and the kernel density (red line) are depicting the intensity of activity



The MaxEnt model that best explained buffalo abundance/occurrence had covariates of human pressure, ruggedness, distance from grasslands, distance from forests, aridity, and precipitation of the driest quarter (b17) and had an average AUC of 0.83 (Table 31.1, Figure 31.3). Human pressure had the highest percentage contribution of 5% to the model, wherein buffalos occurred in habitats with low human pressures (Figure 31.3a). Ruggedness had a percentage contribution of 23%. Buffalo occurrence sharply declined with increase in ruggedness (Figure 31.3b). Buffalo occurrence was high within grasslands and declined as distance from grasslands increased (Figure 31.3c). This covariate has a contribution of 16.6%. Similarly, buffalo occurrence was also high within forests and declined sharply as distance from grasslands increased (Figure 31.3d). The covariate had a percentage contribution of 3.9%. Buffaloes avoided more arid areas, their occurrence peaked moderate levels of aridity, suggesting they avoid very arid as well as very wet habitats (Figure 31.3e). Aridity has a percentage contribution of 1%. Buffaloes occurred in areas having some precipitation (50-150mm) in the driest quarter (Figure 31.3f). This covariate contributed 0.2% to the model. The modelled distribution of wild buffalo across India, developed by the presence points and environmental covariates is given in Figure 31.4.

Table 31.1: Parameters used in MaxEnt setting for modelling wild buffalo distribution/habitat in forested landscapes of India

Model setting	Values
Model features	Linear, quadratic
Output formats	Logistic
Threshold of 'Maximum test sensitivity plus specificity'	0.29
Area under the ROC* Curve (AUC)	0.83

**receiver operating characteristic*

Table 31.2: Contribution percentage of every covariate (SD) to the best model explaining wild buffalo distribution

Covariates	Percent contribution (SD)	Permutation contribution (SD)
Human pressure	55 (6.02)	37.6 (1.19)
Ruggedness	23.4 (0.31)	34.7 (0.60)
Distance from grasslands	16.6 (0.57)	11.9 (0.62)
Distance from Forest	3.9 (0.11)	14.1 (0.65)
Aridity Index	1(0.96)	1.3 (0.10)
Precipitation of the driest quarter (BIO17)	0.2 (0.57)	0.1 (0.30)

Figure 31.3: Relationship of wild buffalo with A) Human pressure B) Ruggedness, C) Distance form Grassland, D) Distance from Forest, E) Aridity and F) Precipitation of the direst quarter

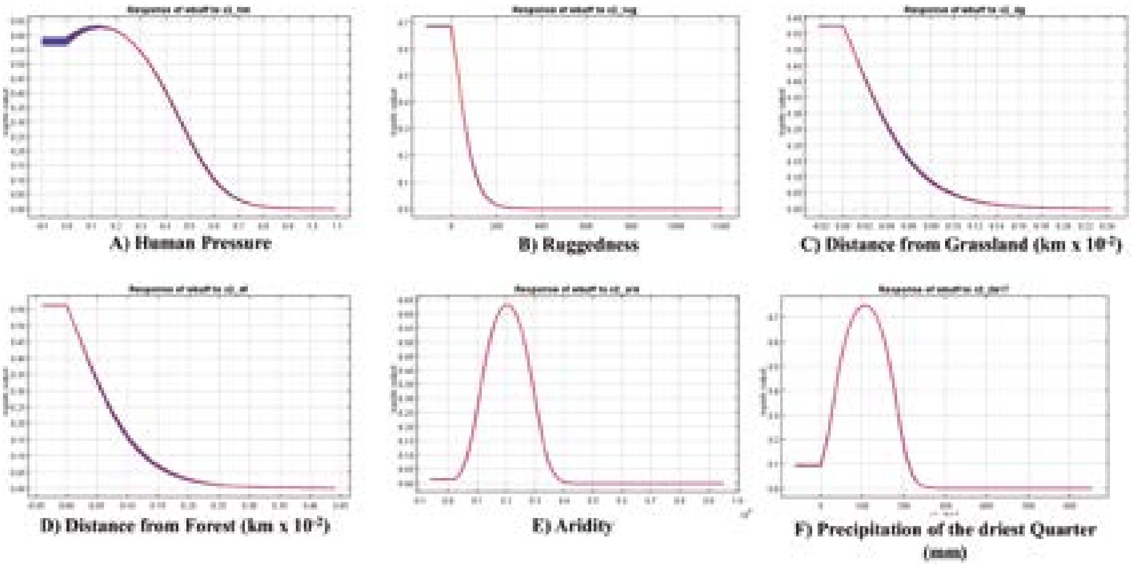
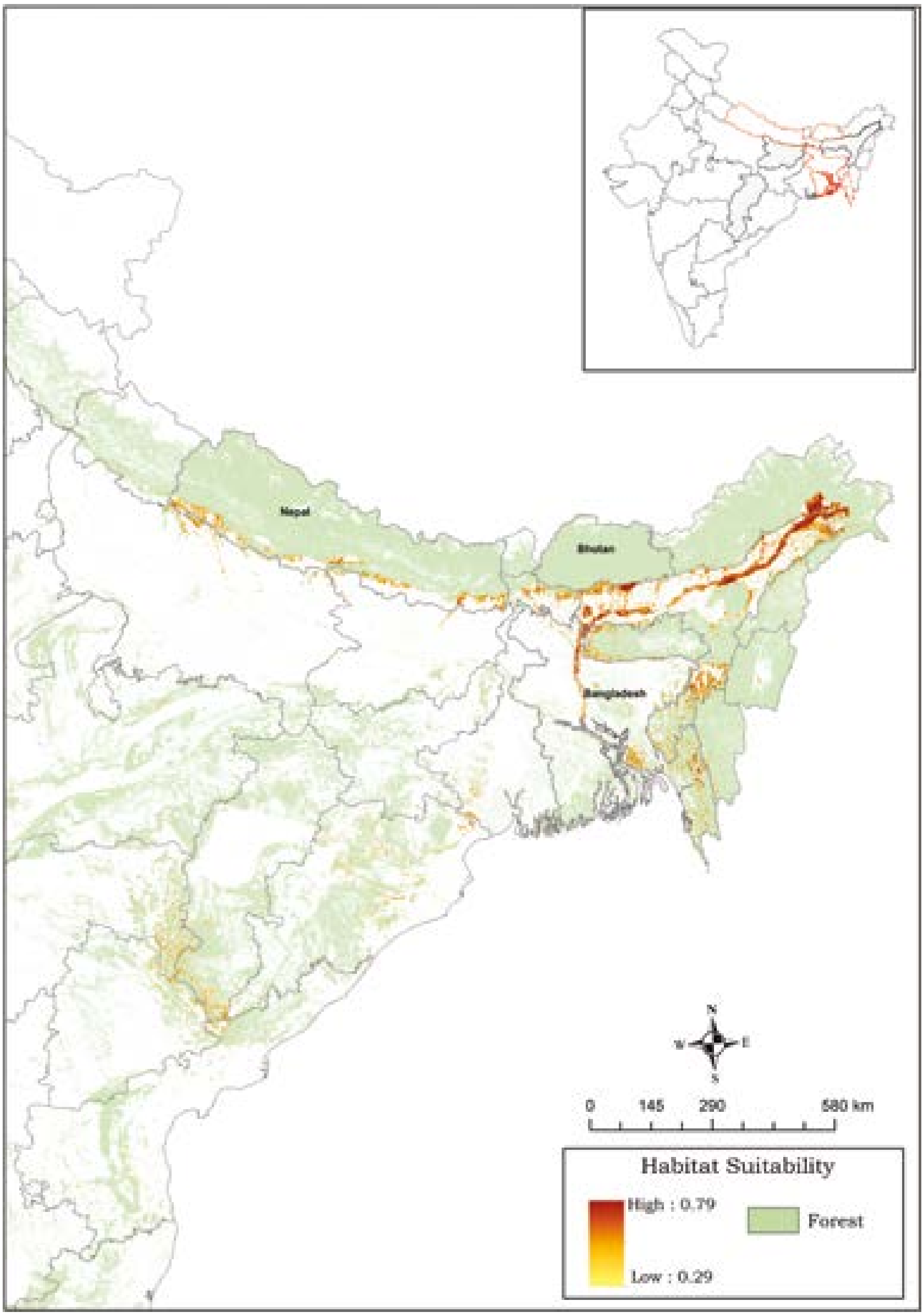


Figure 31.4: Modeled distribution of wild buffalo across the Indian sub-continent estimated from presence obtained by camera traps, secondary data and environmental covariates.



Conservation significance

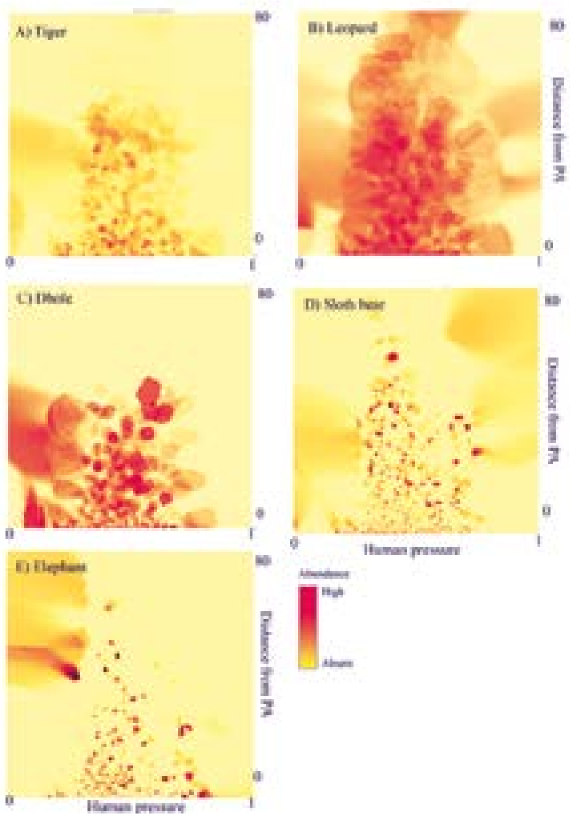
Wild water buffalo populations require priority conservation strategy and investments. Though they are not as prone to poaching as rhinoceros, their populations are dwindling rapidly. This is likely due to their slow demographic life history parameters and the need of some optimal herd size for maintaining anti-predator defences and sociality. Serious efforts need to be made to reintroduce wild water buffalo within tiger reserves in their historic range (Jhala et al. in press). Ideal sites for reintroductions would be Dudhwa Tiger Reserve, Valmiki Tiger Reserve, Corbett Tiger Reserve. Kanha Tiger Resrve has already initiated a project for assessment of its habitat for reintroduction and development of an action plan for wild buffalo reintroduction. The most endangered population of wild water buffalo is the central Indian population found in the state of Chhattisgarh which seasonally uses parts of south eastern Maharashtra. Since this region is severely affected by Naxal extremists, conservation efforts are difficult. Conservation breeding is being attempted near Sitanadi Udanti Tiger Reserve by Chhattisgarh Forest Department by using males from the central Indian wild buffalo lineage and females from Assam. While this effort is commendable, more needs to be done for trying to procure wild buffalo individuals from Central India for conservation breeding and for establishing safety net populations in central India. Recent mitochondrial research has indicated that the North East and Central Indian buffalos are genetically similar (Pacha et al. 2020). Such an inference needs to be validated by nuclear markers, and if indeed the two populations do not differ substantially then the North Eastern buffalos could be used for reintroductions in Central India. The wild water buffalo is poorly studied, research on its demography, food habits, ranging patterns, habitat use and behaviour using modern research tools of radio-telemetry are urgently needed.

CONSERVATION IMPLICATIONS

Models of species occurrence and abundance, provide spatial information of where animals occur and in what numbers. This information is the first step required for formulation of policy and conservation management. With a wide camera trap coverage, the raw data themselves are informative in inferring population extents, relative abundances (RAI's) and thereby species strongholds. When this information is combined with model-based inference using ecologically relevant covariates, we understand the underlying factors responsible for the observed patterns, predict suitable habitats, and identify thresholds of tolerance by various species. The large-scale data also provides an opportunity to better understand within guild and between guild interactions and patterns.

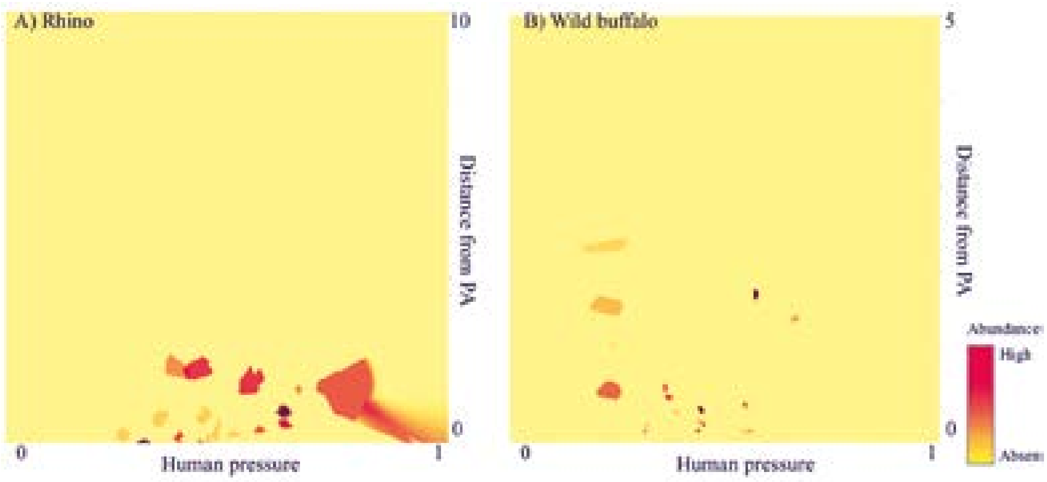
For most species human pressure featured as a covariate in the best model that explained their occurrence. Human impacts were a major negative factor in determining species occurrence as well as abundances. This was more prominent amongst wilderness specialists (tigers, dhole, clouded leopard, wild buffalo, etc) but even seen in human tolerant species like jungle cat and golden jackal. In such supposedly tolerant species the response to human pressure (or its index in the form of distance to roads, night lights, etc.) was parabolic i.e. tolerant at low-medium levels but detrimental beyond a threshold. In a country like India, where human pressures are tremendous and, on the increase, even within forested habitats, the role of Protected Areas (Tiger Reserves) becomes paramount for conservation (Fig. 1). Species like tigers and dhole occur only in forests that are in close proximity to Protected Areas, while species like sloth bear and elephants do occur in forests away from PA's provided these habitats have very low levels of human pressure. Leopards were found to be more tolerant of human disturbances (Fig. 1).

Figure 1. Response of large carnivores and elephants to protectedness of habitats and human pressures.



On the other hand, there are species that are totally dependent on the Protected Areas for their survival such as the greater one horned rhinoceros and wild water buffalo (Fig. 2). Abundance of these two mega herbivores was limited to PA's and their close proximity. The wild water buffalo seems to be very sensitive to human disturbances and even within PA's was limited to areas with low human impacts. Though several species occur in forests outside of PA's, human disturbance free forests were important to hold viable populations for most. PA's serve as habitats for source populations from where animals disperse to occupy landscapes. Human free space for wildlife is the most difficult resource to procure in India, yet it is the most important. The NTCA's conservation initiative of incentivised voluntary relocation of human settlements from within tiger reserves is extremely important for the future survival of not only tigers but of several other species as well. The recent enhancement of this incentive from 1,000,000 to 1,500,000 INR will go a long way in procuring inviolate space for wildlife while simultaneously providing better living standards and livelihood alternatives to impoverished forest dwelling communities. The charismatic tiger that garners public support and resources serves as an umbrella for the conservation of a large assemblage of species that live within forested habitats of the tiger states.

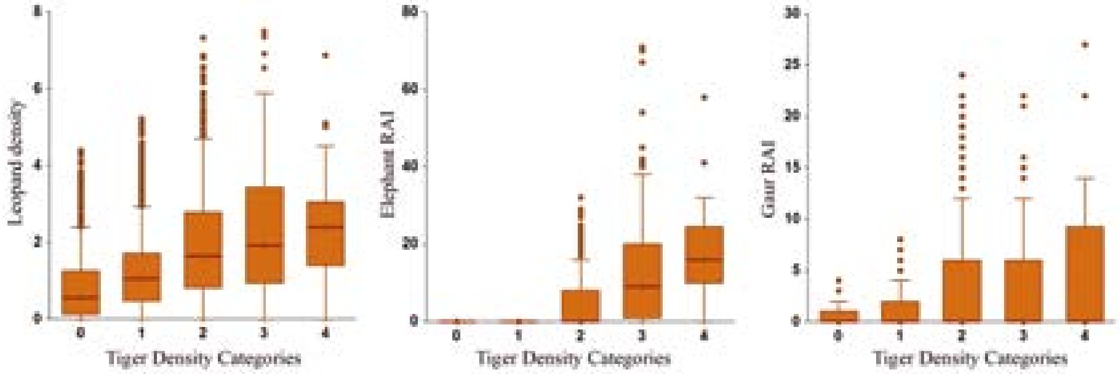
Figure 2. Relative abundance index of rhinoceros and wild water buffalo inferred from camera trap data across their range in relation to human pressure and distance from Protected Areas (km).



Intra and inter guild interactions

The philosophy of Project Tiger is to use the charismatic tiger, the apex predator, to protect entire ecosystems. A measure of success towards this goal has been to increase tiger numbers. For the first time we now have information to better understand how different species (components of the ecosystem) respond to tiger occupancy and density. Many endangered species like leopards, elephants, gaur, etc. show an increase in abundance as tiger density increases (Fig. 3.). However, the pattern is not always this definitive with some species. Tigers directly compete and kill leopards and density response of leopards to increasing tiger density is more of an asymptote or parabolic response i.e. increasing with moderate increase in tiger densities (due to protection and prey availability of these habitats) but declining at very high tiger densities (due to direct interference competition; Kumar et al 2019).

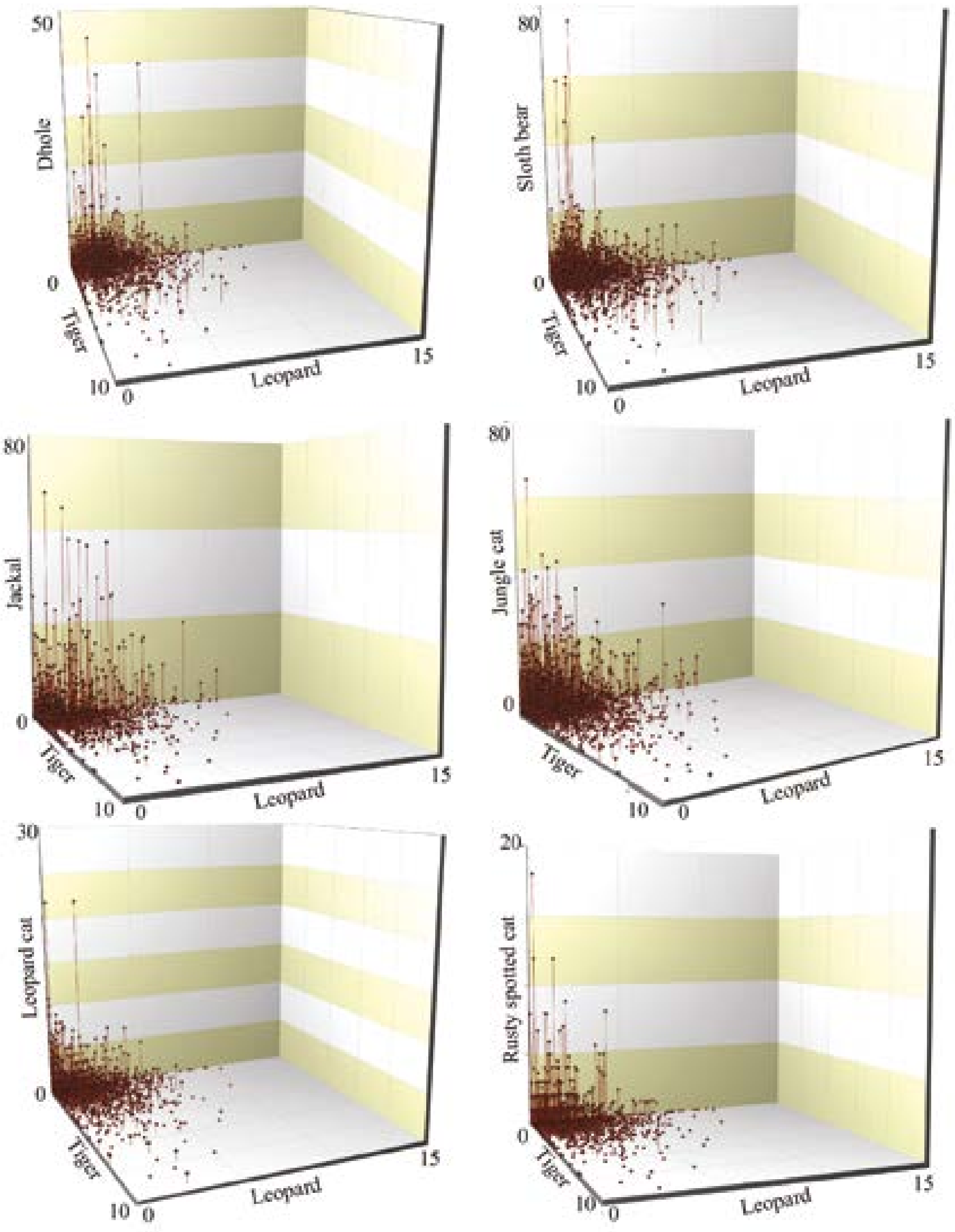
Figure 4. Abundance of leopards, elephant and gaur in 25 km² grids with no tigers (0 category) and with tigers (1-4 categories) at different densities <1, <5, <7, and >7 tigers per 100 km².



All second order carnivores (dhole and sloth bear) that share tiger and leopard habitats across their range occurred at higher abundance in forests occupied by tigers and leopards. However, their abundance declined with increase in tiger and leopard densities (Figure 5). Sloth bear were more tolerant of high density leopard populations compared to high density of tigers. Mesocarnivores found across the range of tigers and leopards too showed similar pattern of occurrence and abundance (Figure 5). Golden jackal abundance was found to be maximum in areas of low to medium tiger densities and they were more tolerant of high leopard abundance compared to that of tigers. Jungle cat and rusty spotted cat too replicated the pattern observed for jackal, being more tolerant of high leopard abundance compared to that of tigers. After restricting the analysis to grids within the range of the leopard cat, we see that this small cat too thrives in habitats occupied by tigers and leopards at low densities. However, leopard cat was abundance was not limited by high tiger densities but restricted by high leopard density (Figure 5).

An in-depth analysis after controlling for climatic and habitat features that offer escape cover and differential food resources to these second order and mesocarnivores a better understanding of these patterns will emerge. Meanwhile, it is safe to conclude that habitats occupied at low to medium density of top carnivores were optimal for other species from carnivorous guilds. In light of this information, we need to give tiger occupancy the same or more importance as given to tiger numbers to measure conservation success. Tigers like most territorial carnivores have demographic mechanisms that regulate their population in equilibrium to the food based carrying capacity. Removal of anthropogenic pressures of poaching and competition of livestock with native ungulates are sufficient managements strategies to achieve optimal tiger numbers in most tiger reserves. Often management interventions to increase tiger numbers beyond the natural capacity may not be a good strategy for conserving other biota of the system and should be done only after proper considered scientific opinion. However, besides the tiger, other species of carnivores often occur at reasonable population sizes in the buffer of tiger reserves and territorial forests. As seen from the data (Figure 5) the tiger and leopard serve as a good indicator of the quality of these forests to support a diversity of other carnivores. Conservation efforts should therefore now be invested in increasing low density occupancy by tigers of forest habitats in buffer and territorial forests. Tiger and leopard occupancy are good indicators of the habitat health to support diverse species communities.

Figure 5. Response in the abundance of dhole, sloth bear, golden jackal, jungle cat, rusty spotted cat and leopard cat to tiger and leopard density from across India.

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REFERENCES

- Abdukadir, A., Khan, B., Masuda, R. and Ohdachi, S. 2010. Asiatic wild cat (Felis silvestris ornata) is no more a 'Least Concern' species in Xinjiang, China. *Pakistan Journal of Wildlife*, 1 (2), 57–63.

- Abdulali, H. 1945. Northern limits of the rusty-spotted cat (Prinalurus r. rubiginosa Geoff.). *Journal of the Bombay Natural History Society*, 45, 600–601.

- AbiSaid, M. and Dloniak, S.M.D. 2015. Hyaena hyaena. *The IUCN Red List of Threatened Species 2015*, e.T10274A45195080.

- Acharya, B.B. 2008. *The ecology of the dhole or Asiatic wild dog (Cuon alpinus) in Pench Tiger Reserve, Madhya Pradesh.* Ph.D. thesis, Saurashtra University, India, 115p.

- Adhya, T. 2015. *Habitat use and diet of two sympatric felids - the Fishing cat (Prionailurus viverrinus) and the Jungle cat (Felis chaus) - in a human-dominated landscape in suburban Kolkata.* M.Sc. thesis, National Centre for Biological Sciences Tata Institute of Fundamental Research.

- Adhya, T., Dey, P., Das, U. and Hazra, P. 2011. *Status survey of Fishing Cat (Prionailurus viverrinus) in Howrah and Hooghly, West Bengal.* Intermediate report submitted to the small grants programme, WWF, India.

- Aditya, A. and Ganesh, T. 2016. Camera trap records of rusty-spotted cat *Prionailurus rubiginosus* and leopard cat *Prionailurus bengalensis* (Mammalia: Carnivora: Felidae) from Papikonda National Park, northern Eastern Ghats, India. *Journal of Threatened Taxa*, 8(5), 8818–8819.

- Aggarwal, R.K., Kivisild, T., Ramadevi, J. and Singh, L. 2007. Mitochondrial DNA coding regionsequences support the phylogenetic distinction of two Indian wolf species. *Journal of Zoological Systematics and Evolutionary Research*, 45, 163–172.

- Aggarwal, R.K., Ramadevi, J. and Singh, L. 2003. Ancient origin and evolution of the Indian wolf: evidence from mitochondrial DNA typing of wolves from Trans-Himalayan region and Pennisular India. *Genome Biology*, 4(6), 1.

- Agrawal, V.C., Das, P.K., Chakraborty, S., Ghose, R.K., Mandal, A.K., Chakraborty, T.K., Poddar, A.K., Lal, J.P., Bhattacharyya, T.P. and Ghosh, M.K. 1992. Mammalia. In Zoological Survey of India (Ed.). *State Fauna Series 3: Fauna of West Bengal, Part 1.* (pp. 27-169). Zoological Survey of India, Calcutta, India.

- Ahrestani, F. and Karanth, K. U. 2014. Gaur Bos gaurus. In Melletti, M. and Burton, J. (Eds.). *Ecology, Evolution and Behavior of Wild Cattle: Implications for Conservation*, (pp. 174-193). Cambridge University Press.

- Ahrestani, F.S., Iyer, S., Heitkonig, I. and Prins, H.H.T. 2011. Life-history traits of gaur Bos gaurus: a first analysis. *Mammal Review*, 41 (1), 75–84.

- Aiyadurai, A. 2001. *Home range, ranging patterns and abundance estimation of golden jackals in the Bhal region of Gujarat.* M.Sc. thesis, Saurashtra University, India, 51 p.

- Aiyadurai, A. and Jhala, Y.V. 2006. Foraging and habitat use by golden jackals (Canis aureus) in the Bhal Region, Gujarat, India. Journal of the Bombay Natural History Society, 103(1), 5-12.

- Aiyadurai, A., Singh, N.J. and Milner-Gulland, E.J. 2010. Wildlife hunting by indigenous tribes: a case study from Arunachal Pradesh, north-east India. *Oryx*, 44, 564-572.

- Akaike, H. 2011. Akaike's Information Criterion. In Lovric M. (Ed.). *International encyclopaedia of statistical science*, (pp. 25). Springer, Berlin, Heidelberg.

- Akash, M., Chowdhury, U.F., Khaleque, F., Reza, R.N., Howlader, D.C., Islam, M.R. and Khan, H. 2020. On the reappearance of the Indian grey wolf in Bangladesh after 70 years: what do we know? *Mammalian Biology*, https://doi.org/10.1007/s42991-020-00064-4.

- Akhtar, N., Bargali, H.S. and Chauhan, N.P.S. 2004. Sloth bear habitat use in disturbed and unprotected areas of Madhya Pradesh, India. *Ursus*, 15, 203-211.

- Alam, M.S. 2011. *Status, ecology and conservation of striped hyena (Hyaena hyaena) in Gir National Park and Sanctuary, Gujarat.* PhD Thesis, Aligarh Muslim University, India, 193 p.

- Ali, S. 1953. Hyderabad State. In Burton, R. (Ed.). *Preservation of wildlife in India: a compilation*, (pp. 82-89). Bangalore.

- Ambarli, H. and Bilgin, C.C. 2013. First record of a melanistic golden jackal (Canis aureus, Canidae) from Turkey. *Mammalia*, 77(2), 219-222.
- Amin, R., Thomas, K., Emslie, R.H., Foose, T.J. and van Strien, N.V. 2006. An overview of the conservation status of and threats to rhinoceros species in the wild. *International Zoo Yearbook*, 40(1), 96–117
- Anderson, K. 1954. *Nine maneaters and one rogue.* Allen and Unwin, London, UK.
- Anil, G., Kishor, N., Gafoor, N., Ommer, N. and Nameer, P.O. 2018. Observations on the Nilgiri marten Martes gwatkinsii (Mammalia: Carnivora: Mustelidae) from Pampadum Shola National Park, southern Western Ghats, India. *Journal of Threatened Taxa*, 10(1), 11226-11230.
- Anile, S., Bizzarri, L., Lacrimini, M., Sforzi, A., Ragni, B. and Devillard, S. 2017. Home-range size of the European wildcat (Felis silvestris silvestris): a report from two areas in Central Italy. *Mammalia*, 82(1), 1-11.
- Anoop, R.P.N. 2013. A sighting of Nilgiri marten Martes gwatkinsii in Peppara Wildlife Sanctuary, southern Western Ghats, India. *Small Carnivore Conservation*, 49, 51–52.
- Anwar, M., Kumar, H. and Vattakavan, J. 2010. Range extension of rusty-spotted cat to the Indian Terai. Cat News, *53, 25–26.*
- Areendran, G. 2000. *A study on vegetation ecology in Pench Tiger Reserve, Madhya Pradesh with reference to gaur (Bos gaurus) using Remote Sensing and GIS techniques.* Ph.D. thesis, Saurashtra University, Gujarat.
- Arun Singh, T. 1980. Feedback: the enigmatic buffalo. *Hornbill*, 1980, 4.
- Ashokkumar, M., Nagarajan, R. and Desai, A.A. 2010. Group size and age-sex composition of Asian elephant and gaur in Mudumalai Tiger Reserve, Southern India. *Gajah*, 32, 27-34.
- Ashokkumar, M., Swaminathan, S., Desai, A.A. and Daniel, J.C. 2004. *A study on ecology and conservation of gaur (Bos frontalis) in Mudumalai Wildlife Sanctuary and National Park.* Nilgiri Wildlife and Environmental Association Report, Ottacamund.
- Ashokkumar, M., Swaminathan, S., Nagarajan, R. and Desai, A.A. 2011. Distribution, ecology and conservation of the gaur (Bos gaurus, H. Smith, 1824). In Gupta, V.K. and Verma, A.K. (Eds.). *Animal Diversity, Natural History and Conservation*, (pp. 77-94). Daya Publishing House, New Delhi, India.
- Ashraf, N.V.K. 1992. Viverrine rarities in little known Indian zoos. *Zoo's Print*, 7(12), 26-27.
- Ashraf, N.V.K., Kumar, A. and Johnsingh, A.J.T. 1993. Two endemic viverrids of the Western Ghats, India. *Oryx*, 27, 109–114.
- Athreya, V. 2010. Rusty-spotted cat more common than we think? *Cat News*, 53, 27.
- Athreya, V. 2012. *Conflict resolution and leopard conservation in a human dominated landscape.* Ph.D. thesis, Manipal University, India, 146 p.
- Athreya, V., Odden, M., Linnell, J.D.C. and Karanth, K.U. 2011. Translocation as a tool for mitigating conflict with leopards in human-dominated landscapes of India. *Conservation Biology*, 25, 133–141.
- Athreya, V., Odden, M., Linnell, J.D.C., Krishnaswamy, J. and Karanth, U. 2013. Big cats in our backyards: persistence of large carnivores in a human dominated landscape in India. *PLoS One*, 8, e57872.
- Athreya, V., Odden, M., Linnell, J.D.C., Krisnaswamy, J. and Karanth, K.U. 2014. A cat among the dogs: leopard Panthera pardus diet in a human-dominated landscape in western Maharashtra, India. *Oryx*, 50(1), 156-162.
- Athreya, V., Srivathsa, A., Puri, M., Karanth, K.K., Kumar, N.S. and Karanth, K.U. 2015. Spotted in the news: using media reports to examine leopard distribution, depredation, and management practices outside Protected Areas in Southern India. *PLoS One*, 10(11), e0142647.
- Austin, S.C., Tewes, M.E., Grassman Jr., L.I. and Silvy, N.J. 2007. Ecology and conservation of the leopard cat Prionailurus bengalensis and clouded leopard Neofelis nebulosa in Khao Yai National Park, Thailand. *Acta Zoologica Sinica*, 53, 1-14.
- Avenant, N.L. and Nel, J.A.J. 1998. Home-range use, activity, and density of caracal in relation to prey density. *African Journal of Ecology*, 36, 347-359.
- Avgan, B., Henschel, P. and Ghoddousi, A. 2016. Caracal caracal. *The IUCN Red List of Threatened Species 2016*,

e.T3847A102424310.

- Azlan, J. 2003. The diversity and conservation of mustelids, viverrids, and herpestids in a disturbed forest in Peninsular Malaysia. *Small Carnivore Conservation*, 29, 8–9.

- Azlan, J.M. and Sharma, D.S.K. 2006. The diversity and activity patterns of wild felids in a secondary forest in peninsular Malaysia. *Oryx*, 40, 1-6.

- Bahaa-el-din, L., Henschel, P., Aba'a, R., Abernethy, K., Bohm, T., Bout, N., Coad, L., Head, J., Inoue, E., Lahm, S., Lee, M. E., Maisels, F., Rabanal, L., Starkey, M., Taylor, G., Vanthomme, A., Nakashima, Y. and Hunter, L. 2013. Notes on the distribution and status of small carnivores in Gabon. *Small Carnivore Conservation*, 48, 19-29.

- Bailey, T.N. 1993. *The African leopard: ecology and behavior of a solitary felid.* Columbia University Press, New York, 429 p.

- Baker, M., Nassar, K., Rifai, L., Qarqaz, M., Al-Melhim, W. and Amr, Z. 2003. On the current status and distribution of the Jungle Cat, Felis chaus, in Jordan (Mammalia: Carnivora). *Zoology in the Middle East*, 30, 5-10.

- Baker, S. 1890. *Wild beasts and their way.* London.

- Balakrishnan, P. 2005. Recent sightings and habitat characteristics of the endemic Nilgiri Marten *Martes gwatkinsii* in Western Ghats, India. *Small Carnivore Conservation*, 33, 14–16.

- Bali, A., Kumar, A. and Krishnaswamy, J. 2007. The mammalian communities in coffee plantations around a protected area in the Western Ghats, India. *Biological Conservation*, 139, 93-102.

- Bargali, H.S. and Ahmed, T. 2018. Patterns of livestock depredation by tiger (Panthera tigris) and leopard (Panthera pardus) in and around Corbett Tiger Reserve, Uttarakhand, India. *PLoS One*, 13(5), e0195612.

- Bargali, H.S., Akhtar, N. and Chauhan, N.P.S. 2005. Characteristics of sloth bear attacks and human casualties in North Bilaspur forest division, Chhattisgarh, India. *Ursus*, 16, 263-267.

- Bargali, H.S., Akhtar, N. and Chauhan, N.P.S. 2012. The sloth bear activity and movement in highly fragmented and disturbed habitat in Central India. *World Journal of Zoology*, 7(4), 312-319.

- Bashir, T., Bhattacharya, T., Poudyal, K. and Sathyakumar, S. 2011. Notable observations on the melanistic Asiatic Golden cat (Pardofelis temminckii) of Sikkim, India. *NeBIO*, *2*(1), 2-4.

- Bashir, T., Bhattacharya, T., Poudyal, K., Roy, M. and Sathyakumar, S. 2013. Precarious status of the Endangered dhole *Cuon alpinus* in the high elevation Eastern Himalayan habitats of Khangchendzonga Biosphere Reserve, Sikkim, India. *Oryx*, 48(1), 125-132.

- Baskaran, N. 1990. *An ecological investigation on the dietary composition and habitat utilization of sloth bear at Mudumalai Wildlife Sanctuary, Tamil Nadu (South India)*. M.Sc. Thesis. A.V.C college, Bharathidasan University, India, 57 p.

- Baskaran, N., Balasubramaniam, M., Swaminathan, S. and Desai, A.A. 1995. Home range of elephants in the Nilgiri Biosphere Reserve, South India. In Daniel, J.C. and Datye, H.S. (Eds.). *A Week with Elephants*, (pp. 296–313). Bombay Natural History Society and Oxford University Press, Bombay and New Delhi.

- Begg, C.M., Begg, K.S., du Toit, J.T. and Mills, M.G.L. 2003. Sexual and seasonal variation in the diet and foraging behaviour of a sexually dimorphic carnivore, the honey badger *(Mellivora capensis)*. *Journal of Zoology*, 260, 301-316.

- Begg, C.M., Begg, K.S., Du Toit, J.T. and Mills, M.G.L. 2005a. Life-history variables of an atypical mustelid, the honey badger Mellivora capensis. *Journal of Zoology*, 265(1), 17-22.

- Begg, C.M., Begg, K.S., Du Toit, J.T. and Mills, M.G.L. 2005b. Spatial organization of the honey badger Mellivora capensis in the southern Kalahari: home-range size and movement patterns. *Journal of Zoology*, 265(1), 23-35.

- Begg, K.S. and Begg, C.M. 2002. The conflict between beekeepers and honey badgers in South Africa: a western Cape perspective. *The Open Country*, 4, 25-37.

- Begg. C., Begg, K. and Kingdon, J. 2013. Mellivora capensis Ratel (Honey Badger). In: Kingdon, J. and Hoffmann, M. (Eds). *The Mammals of Africa, vol. V: carnivores, pangolins, equids and rhinoceroses*, (pp. 119-125). Bloomsbury Publishing, London, UK.

- Behura, B.K. and Guru, G.B. 1969. Wildlife of Orissa. Prakruti. Utkal University. Journal Science, *6(2), 95–96.*

- Bernard, R. and Stuart, C. 1987. Reproduction of the caracal Felis caracal from the Cape Province of South Africa. *South African Journal of Zoology*, 22(3), 177-182.

- Bertola, L.D., Jongbloed, H., Van Der Gaag, K.J., De Knijff, P., Yamaguchi, N., Hooghiemstra, H., and De Iongh, H.H. 2016. Phylogeographic patterns in Africa and high resolution delineation of genetic clades in the lion (Panthera leo). *Scientific Reports*, 6(1), 30807.

- Bertram, B.C.R. 1982. Leopard ecology as studied by radio tracking. *Symposium of Zoological Society of London*, 49, 341-352.

- Bhatt, S., Biswas, S., Karanth, K., Pandav, B. and Mondol, S. 2020. Genetic analyses reveal population structure and recent decline in leopards (Panthera pardus fusca) across the Indian subcontinent. *Peer J*, 8, e8482.

- Bhosale, H.S., Punjabi, G.A. and Bardapurkar, R. 2013. Photographic documentation of brown palm civet Paradoxurus jerdoni in Maharashtra, India, north of its known range. *Small Carnivore Conservation*, 49, 37–39.

- Bird, T.L.F. and Mateke, C.W. 2013. A preliminary survey of the presence and distribution of small carnivores in the Lower Zambezi Protected Area Complex, Zambia. *Small Carnivore Conservation*, 48, 47- 59.

- Biswas, S., Bhatt, S., Sarkar, D., Talukdar, G., Pandav, B. and Mondol, S. 2020. Assessing tiger corridor functionality with landscape genetics and modelling across Terai-Arc Landscape, India. *bioRxiv.*

- Blanford, W.T. 1891. *Fauna of British India.* Taylor and Francis, London.

- Bodle, J. 2013. Paradoxurus jerdoni (On-line), Animal Diversity Web. Available at https://animaldiversity.org/accounts/Paradoxurus_jerdoni/.

- Boitani, L., Phillips, M. and Jhala, Y. 2018. Canis lupus (errata version published in 2020). *The IUCN Red List of Threatened Species 2018*, e. T3746A163508960.

- Bopanna, I.P. 2013. *Habitat use, ranging pattern and food habits of striped hyena (Hyaena hyaena) in Kutch, Gujarat.* Ph.D. Thesis, Saurashtra University, India, 297 p.

- Bora, J.K., Awasthi, N., Kumar, U., Goswami, S., Pradhan, A., Prasad, A., Laha, D. R., Shukla, R., Shukla, S.K., Qureshi, Q. and Jhala, Y.V. 2020. Assessing the habitat use, suitability and activity pattern of the rusty-spotted cat Prionailurus rubiginosus in Kanha Tiger Reserve, India. *Mammalia*, 84, 459-468.

- Borah, J, Wangchuk D., Swargowari, A., Wangchuk T., Sharma, T., Das D., Rabha, N., Basumatari, A., Kakati, N., Ahmed, M.F., Sharma, A., Sarmah A., Dutta D.K., Lahkar, B., Dorji, T., Brahma, P.K., Ramchiary, L., Tempa, T., Wangdi, Y., Nedup, T., Wangdi, T., Tharchen, L., Dhendup, P., Bhobora, C., Pandav, B. and Vattakaven, J. 2013. Tigers in the Transboundary Manas Conservation Complex: conservation implications across borders. *Parks*, 19, 52-62.

- Borah, J., Sharma, T., Das, D., Rabha, N., Kakati, N., Basumatary, A., Ahmed, M. F. and Vattakaven, J. 2014. Abundance and density estimates for common leopard Panthera pardus and clouded leopard Neofelis nebulosa in Manas National Park, Assam, India. *Oryx*, 48 (1), 149–155.

- Borah, J., Sharma, T., Lyngdoh, S. and Tapi, T. 2010. First photograph of a clouded leopard at Pakke Tiger Reserve, India. *Cat News*, 52, 24–25.

- Borchers, D.L. and Efford, M.G. 2008. Spatially explicit maximum likelihood methods for capture recapture studies. *Biometrics*, 64 (2), 377-385.

- Borthakur, U., Das, P.K., Deb, M., Maheen, R., Neog, A., Das, A.K., Baruah, B., Singha Roy, R., Kalita, J., Biswas, A. and Kurmi, R.P. 2017. *Leopard (Panthera pardus) ecology in North Bengal including population estimation, population dynamics, distribution, habitat use pattern and human leopard conflicts.* Technical Report, Aaranyak, Guwahati, India.

- Braczkowski, A., Watson, L., Coulson, D., Lucas, J., Pieser, B. and Rossi, M. 2012. The diet of the caracal, Caracal caracal, in two areas of the southern Cape, South Africa as determined by scat analysis. *South African Journal of Wildlife Research*, 42, 111-116.

- Brander, A.A.D. 1923. *Wild animals in Central India.* Edward Arnold and Co, London.

- Brander, A.A.D. 1982. *Wild animals in central India.* Nataraj Publishers, Dehradun, India.

- Buatip, S., Karntanut, W. and Swennen, C. 2013. Nesting period and breeding success of the Little Egret Egretta garzetta in Pattani province, Thailand. *Forktail*, 29, 120–123.

- Buckley-Beason, V.A., Johnson, W.E., Nash, W.G., Stanyon, R., Menninger, J.C., Driscoll, C.A., Howard, J., Bush, M., Page, J.E., Roelke, M.E., Stone, G., Martelli, P.p., Wen, C., Ling, L, Duraisingam, R.K., Lam, P.V. and O'Brien, S.J. 2006. Molecular evidence for species-level distinctions in clouded leopards. *Current Biology*, 16 (23), 2371-2376.

- Buffon, G.L. 1761. Le Caracal, pp. 262–267. In: *Histoire naturelle générale et particulière, avec la description du Cabinet du Roi. Tome 9.* Imprimerie Royale, Paris, 376pp.

- Burton, R.W. 1899. Jungle notes. *Journal of the Bombay Natural History Society*, 12, 587-589.

- Caro, T.M. 2003. Umbrella species: critique and lessons from East Africa. *Animal Conservation*, 6, 171-181.

- Cat Specialist Group, 1996. *"Fishing Cat Prionailurus viverrinus" (On-line).* Available at http://lynx.uio.no/catfolk/viver01.htm.

- Chakraborty, S. 1978. The rusty-spotted cat *Felis rubiginosa* I. Geoffroy in Jammu and Kashmir. Journal of the Bombay Natural History Society, 75, 478–479.

- Chakravarty, S., Suresh, C.P., Puri, A. and Shukla, G. 2012. North-east India, the geographical gateway of India's phytodiversity. *Indian Forester*, 138(8), 702.

- Challender, D. and Waterman, C. 2017. *Implementation of CITES Decision 2 17.239 B) and 17.240 on pangolins (Manis spp.).* CITES SC69 Doc. 57 Annex. Available at: www.cites.org/sites/default/files/eng/com/sc/69/E-SC69-57-A.pdf.

- Champion, F.W. 1927. *With a camera in tiger-land.* Chatto and Windus, London, xviii+228 p.

- Champion, H. and Seth, S.K. 1968. *A revised survey of the forest types of India.* Daya Publishing House, Delhi, 404 p.

- Chapron, G., Miquelle, D.G., Lambert, A., Goodrich, J.M., Legendre, S. and Clobert, J. 2008. The impact on tigers of poaching versus prey depletion. *Journal of Applied Ecology*, 45, 1667–1674.

- Chatterjee, N., Nigam. P. and Habib, B. 2020a. Population density and habitat use of two sympatric small cats in a central Indian reserve. *PLoS One*, 15(6), e0233569.

- Chatterjee, N., Nigam, P. and Habib, B. 2020b. Population estimate, habitat-use and activity patterns of the honey badger in a dry-deciduous forest of Central India. *Frontiers in Ecology and Evolution*, 8, 585256.

- Chatterjee, P., Mondal, K., Chandra, K. and Tripathy, B. 2008. First photographic evidence of Asian Golden Cat Catopuma temminckii (Vigors and Horsfield, 1827) from Neora valley National Park, Central Himalayas, India. *Records of the Zoological Survey of India*, 118(2), 128-132.

- Chatterjee, S. 2008. Biodiversity conservation issues of Northeast India. *The International Forestry Review*, 10(2), 315-324.

- Chaudhary, R., Zehra, N., Musavi, A. and Khan, J.A. 2020. Spatio-temporal partitioning and coexistence between leopard (Panthera pardus fusca) and Asiatic lion (Panthera leo persica) in Gir protected area, Gujarat, India. *PLoS One*, 15(3), e0229045.

- Chauhan, D.S. and Goyal, S.P. 2001. *A study on distribution, relative abundance and food habits of Leopard (Panthera pardus) in Garhwal Himalayas.* Technical Report (December 1999 – July 2000), Wildlife Institute of India, Dehradun.

- Chauhan, D.S., Harihar, A., Goyal, S.P., Qureshi, Q., Lal, P. and Mathur, V.B. 2005. *Estimating leopard population using camera traps in Sariska Tiger Reserve.* Wildlife Institute of India, Dehradun.

- Chauhan, N.S. 2006. The status of sloth bears in India. *Understanding Asian bears to secure their future*, pp. 26-34. Japan Bear Network, Ibaraki, Japan.

- Chavan, S.A., Patel, C.D., Pawar, S.V., Gogate, N.S. and Pandya, N.P. 1991. Sighting of the rusty-spotted cat Felis rubiginosa Geoffroy in Shoolpaneshwar Sancturу, Gujarat. *Journal of the Bombay Natural History Society*, 88, 107–108.

- Cheema, G.S., Anand, S., Qureshi, Q. and Jhala, Y.V. 2018. *CaTRAT: Camera Trap Data Repository and Analysis Tool.* Wildlife Institute of India, Dehradun and Indraprashtha Institute of Information Technology, New Delhi. Available at https://wii.gov.in/tiger_monitoring_software.

- Chellam, R. 1993. *Ecology of the Asiatic lion (Panthera leo persica).* Ph.D. Thesis, Saurashtra University, Rajkot, India, 170 p.

- Chen, M.T., Liang, Y.J., Kuo, C.C. and Pei, K.J.C. 2016. Home ranges, movements and activity patterns of leopard cats (Prionailurus bengalensis) and threats to them in Taiwan. *Mammal Study*, 41(2), 77-86.

- Chetri, M. 2006. Diet analysis of Gaur, Bos gaurus gaurus (Smith, 1827) by microhistological analysis of fecal samples in Parsa Wildlife Reserve, Nepal. *Our Nature*, 4, 20-28.

- Chettri, N., Sharma, E. and Deb, D. C. 2001. Bird community structure along a trekking corridor of Sikkim Himalaya: a conservation perspective. *Biological Conservation*, 102(1), 1-16.

- Cheyne, S.M. and Macdonald, D.W. 2010. Marbled cat in Sabangau peat-swamp forest, Indonesian Borneo. *Cat News*, 52, 11–12.

- Choudhury A. 1994. The decline of the wild water buffalo in north-east India. *Oryx*, 28(1),70–73.

- Choudhury, A. 1996. The marbled cat *Felis marmorata* Martin in Assam-some recent records. *Journal of the Bombay Natural History Society*, 93, 583.

- Choudhury, A. 2002. Distribution and conservation of the Gaur *Bos gaurus* in the Indian Subcontinent. *Mammal Review*, 32, 199-226.

- Choudhury, A. 2007. Sighting of Asiatic golden cat in the grasslands of Assam's Manas National Park. *Cat News*, 47, 29.

- Choudhury, A. 2010. *The vanishing herds: the wild water buffalo.* Gibbon Books and Rhino Foundation for Nature in NE India, 184p.

- Choudhury, A. 2013. *The mammals of North east India.* Gibbon Books and the Rhino Foundation for Nature in NE India, Guwahati, Assam, India, 431 p.

- Choudhury, A. U. 1992. The clouded leopard in Assam. *Oryx*, 27 (1), 51–53.

- Choudhury, A. U. 1996. The clouded leopard. *Cheetah*, 35 (1–2), 13–18.

- Choudhury, A.U. 1997. The clouded leopard in Manipur and Nagaland. *Journal of the Bombay Natural History Society*, 94 (2), 389–391.

- Choudhury, A.U. 1999. Status and Conservation of the Asian elephant *Elephas maximus* in northeastern India. *Mammal Review*, 29, 141-173.

- Choudhury, A.U. 2003. The cats in North East India. *Cat News*, 39, 15–19.

- Choudhury, A.U. 2011. *Records of sloth bear and Malayan sun bear in north east India.* Final report to International Association for Bear Research and Management (IBA). The Rhino Foundation for Nature in NE India, Guwahati, Assam, India.

- Chourasia, P. 2015. *Ecology of golden jackal (Canis aureus) in Sariska Tiger Reserve, Rajasthan.* Ph.D. thesis, Saurashtra University, India, 204 p.

- Christiansen, P. 2006. Sabertooth characters in the clouded leopard (Neofelis nebulosa Griffiths 1821). *Journal of Morphology*, 267(10), 1186-1198.

- Christopher, G. and Jayson, E.A. 1996. Sightings of Nilgiri marten *(Martes gwatkinsii Horsfield)* at Peppara Wildlife Sanctuary and Silent Valley National Park, Kerala, India. *Small Carnivore Conservation*, 15, 3-4.

- Chua, M.A.H., Lim, K.K.P. and Low, C.H.S. 2012. The diversity and status of the civets (Viverridae) of Singapore. *Small Carnivore Conservation*, 47, 1–10.

- Chutipong, W., Tantipisanuh, N., Ngoprasert, D., Lynam, A.J., Steinmetz, R., Jenks, K.E., Grassman Jr., L.I., Tewes, M., Kitamura, S., Baker, M.C., McShea, W., Bhumpakphan, N., Sukmasuang, R., Gale, G.A., Harich, F.K., Treydte, A.C., Cutter, P., Cutter, P.B., Suwanrat, S., Siripattaranukul, K., Hala-Bala Wildlife Research Station, Wildlife Research Division and Duckworth, J.W. 2014. Current distribution and conservation status of small carnivores in Thailand: a baseline review. *Small Carnivore Conservation*, 51, 96–136.

- Ćirović, D., Penezić, A. and Krofel, M. 2016. Jackals as cleaners: ecosystem services provided by a mesocarnivore in human-dominated landscapes. *Biological Conservation*, 199, 51-55.

- Clutton-Brock, J., Corbet, G. B. and Hills, M. 1976. A review of the family Canidae, with a classification by numerical methods. *Bulletin of the British Museum (Natural History)- Zoology*, 29, 119-199.
- Cohen, J.A. 1977. A review of the biology of the dhole or Asiatic wild dog (Cuon alpinus Pallas). *Animal Regulation Studies*, 1: 141-158.
- Cohen, J.A. 1978. Cuon alpinus. *Mammalian Species*, 100, 1-3.
- Corbet, G.B. and Hill, J.E. 1992. *Mammals of the Indo-Malayan Region: a systematic review.* Oxford University Press, Oxford, UK, viii+488 p.
- Coudrat C.N.Z., Nanthavong C., Sayavong S., Johnson A.N., Johnston J. and Robichaud W.G. 2014. Non-Panthera cats in Nakai-Nam Theun National Protected Area, Lao PDR. *Cat News*, Special Issue 8, 45-52.
- Crall, J.P., Stewart, C.V., Berger-Wolf, T.Y., Rubenstein, D. and Sundaresan, S.R. 2013. Hotspotter - patterned species instance recognition. *Proceedings of IEEE Winter Conference on Applications of Computer Vision (WACV)*, 230-237.
- Crandall, L.S. 1964. *The management of wild mammals in captivity.* The University of Chicago Press, Chicago, Illinois, USA, xv+769 p.
- Dahal, S. and Dahal, D. R. 2011. Trapping of fishing cat in Chitwan National Park, Nepal. *Cat News*, 55, 10-11.
- Daniel, J.C. 1996. *The leopard in India- a natural history.* Natraj Publishers. Dehradun, 228 p.
- Daniel, J.C. and Grubh, B.R. 1966. The Indian wild buffalo Bubalus bubalis (Linn), in peninsular India: a preliminary survey. *Journal of the Bombay Natural History Society*, 63, 32-53.
- Daniels, M.J., Golder, M.C., Jarrett, O. and MacDonald, D W. 1999. Feline viruses in wildcats from Scotland. *Journal of Wildlife Diseases*, 35(1), 121-124.
- Datta A., Anand M.O. and Naniwadekar R. 2008. Empty forests: Large carnivore and prey abundance in Namdapha National Park, Northeast India. *Biological Conservation*, 141, 1429-1435.
- Davidar, E.R.C. 1974. Observation at the dens of the dhole or Indian wild dog *(Cuon alpinus). Journal of the Bombay Natural History Society*, 71, 183-187.
- Davidar, E.R.C. 1975. Ecology and behaviour of dhole or Indian wild dog (Canis lupus Pallas). In M.W. Fox (Ed.). *The wild canids*, (pp. 109-119). Van Nostrand Reinhold, New York.
- Davidar, E.R.C. 1985. Den full of hyenas. *Sanctuary Asia*, V(4), 336-341.
- Davidar, E.R.C. 1997. *Cheetal walk: living in the wilderness.* Oxford University Press, Chennai, 224 p.
- Davies, R.G. 1990. Sighting of a clouded leopard (Neofelis nebulosa) in a troop of pigtail macaques (Macaca nemestrina) in Khao Yai National Park, Thailand. *Siam Society Natural History Bulletin*, 38, 95–96.
- de Magalhaes, J., Budovsky, A., Lehmann, G., Costa, J., Li, Y., Fraifeld, V., Church, G. 2009. *An Age entry for Caracal caracal" (On-line). The Human Ageing Genomic Resources: online databases and tools for biogerontologists.* Available at http://genomics.senescence.info/species/entry.php?species=Caracal_caracal.
- de Silva, S., Ranjeewa, A.D.G., and Kryazhimskiy, S. 2011. The dynamics of social networks among female Asian elephants. *BMC Ecology*, 11, 17.
- de Vries H, Lemmens M. 2021. Observation.org, Nature data from around the World. Observation.org. Occurrence dataset https://doi.org/10.15468/5nilie accessed via GBIF.org on 2021-01-28.
- Department of National Parks and Wildlife Conservation. 2017. *The Greater One-Horned Rhinoceros Conservation Action Plan for Nepal 2017-2021*. Kathmandu, Nepal
- Desai, A.A. 1991. The home range of elephants and its implications for management of the Mudumalai Wildlife Sanctuary, Tamil Nadu. *Journal of the Bombay Natural History Society*, 88, 145-156.
- Desai, A.A. and Baskaran, N. 1996. Impact of human activities on the ranging behaviour of elephants in the Nilgiri biosphere reserve, South India. *Journal of the Bombay Natural History Society*, 93, 559-569.
- Desai, A.A. and Johnsingh, A.J.T. 1995. Social organization and reproductive strategy of the male Asian elephant

(Elephas maximus). Abstract in Daniel, J.C. and Datye, H.S. (Eds.). *A week with elephants*. Bombay Natural History Society and Oxford University Press, Bombay, pp 532.

- Dewey, T. 2005. "Felis silvestris" (On-line), *Animal Diversity Web*. https://animaldiversity.org/accounts/Felis_silvestris/

- Dey, S., Sagar, V., Dey, S. and Choudhary, S.K. 2010. Sight record of the Indian wolf Canis lupus pallipes in the river Gandak floodplains. *Journal of the Bombay Natural History Society*, 107(1), 51-53.

- Dhanwatey, H., Crawford, J., Abade, L., Dhanwatey, P., Nielsen, C., and Sillero-Zubiri, C. 2013. Large carnivore attacks on humans in central India: A case study from the Tadoba-Andhari Tiger Reserve. *Oryx*, 47(2), 221-227.

- Dharaiya, N. and Ratnayeke, S. 2009. Escalating human-sloth bear conflicts in north Gujarat: a tough time to encourage support for bear conservation. *International Bear News*, 18(3), 12-14.

- Dharaiya, N., Bargali, H.S. and Sharp, T. 2020. Melursus ursinus (amended version of 2016 assessment). *The IUCN Red List of Threatened Species* 2020, e.T13143A166519315.

- Dhendup, T. 2016. Status of Asiatic Golden Cat Catopuma temminckii Vigors and Horsfield, 1827 (Carnivora: Felidae) in Bhutan. J*ournal of Threatened Taxa*, 8, 8698–8702.

- Didan, K., Munoz, A.B., Solano, R. and Huete, A. 2015. MODIS *Vegetation Index User's Guide (MOD13 Series), version 3.00*. Vegetation Index and Phenology Lab, University of Arizona, USA, 32 p.

- Digveerendrasinh, M.S. 1964. Occurrence of the rusty-spotted cat Felis rubiginosa Geoffroy in South Gujarat. *Journal of the Bombay Natural History Society*, 61, 179.

- Dinerstein, E. 2003. *The return of the unicorns: the natural history and conservation of the greater one-horned rhinoceros*. Columbia University Press, New York, 384 p.

- Dinerstein, E. and Price, L. 1991. Demography and habitat use by greater one-horned rhinoceros in Nepal. *Journal of Wildlife Management*, 55, 401-411.

- Divyabhanusinh 1995. *The end of a trail - The cheetah in India*. Banyan Books, New Delhi, India, 248 p.

- Dmock, R. 1997. Husbandry, Breeding, and Population Development of the Sri Lankan Rusty spotted cat Prionailurus rubiginosus phillipsi. *International Zoo Yearbook*, 35, 115-120.

- Do Linh San, E., Begg, C., Begg, K. and Abramov, A.V. 2016. Mellivora capensis. *The IUCN Red List of Threatened Species 2016*, e.T41629A45210107.

- Dookia, S. 2007. Sighting of Asiatic Wildcat in Gogelao Enclosure, Nagaur in Thar Desert of Rajasthan. *Cat News*, 46, 17–18.

- Driscoll, C.A., Menotti-Raymond, M., Roca, A.L. Hupe, K., Johnson, W.E., Geffen, E., Harley, E.H., Delibes, M., Pontier, D., Kitchener, A.C., Yamaguchi, N., O'Brien, S.J. and Macdonald, D.W. 2007. The near eastern origin of cat domestication. *Science*, 317, 519-523.

- Duckworth, J., Steinmetz, R., Sanderson, J. and Mukherjee, S. 2008. *IUCN Red List of Threatened Species - Felis chaus*. Retrieved at www.iucnredlist.org.

- Duckworth, J.W. 1997. Small carnivores in Laos: a status review with notes on ecology, behaviour and conservation. *Small Carnivore Conservation*, 16, 1–21.

- Duckworth, J.W., Salter, R.E. and Khounbline, K. 1999. *Wildlife in Lao PDR: 1999 Status Report*. IUCN, Vientiane, Laos.

- Duckworth, J.W., Sankar, K., Williams, A.C., Samba Kumar, N. and Timmins, R.J. 2016. Bos gaurus. *The IUCN Red List of Threatened Species 2016*, e.T2891A46363646.

- Duckworth, J.W., Steinmetz, R., Timmins, R.J., Pattanavibool, A., Than Zaw, Do Tuoc and Hedges, S. 2008. Bos gaurus. *The IUCN Red List of Threatened Species. Version 2014.3*.

- Duckworth, J.W., Timmins, R.J., Choudhury, A., Chutipong, W., Willcox, D.H.A., Mudappa, D., Rahman, H., Widmann, P., Wilting, A. and Xu, W. 2016. Paradoxurus hermaphroditus. *The IUCN Red List of Threatened Species 2016*, e.T41693A45217835.

- Dumonceaux, G.A. 2006. Digestive System. In Fowler. M.E. and Mikota, S.K. (Eds.). *Biology, Medicine, and Surgery* *of Elephants*, (pp. 299-307). Blackwell Publishers, Ames, Iowa.

- Dunkin, R. C., Wilson, D., Way, N., Johnson, K., and Williams, T. M. 2013. Climate influences thermal balance and water use in African and Asian elephants: physiology can predict drivers of elephant distribution. *Journal of Experimental Biology*, 216, 2939–2952.

- Durbin, L.S., Venkataraman, A., Hedges, S. and Duckworth, J.W. 2004. Dhole *(Cuon alpinus)*. In Sillero-Zubiri, C., Hoffman, M. and Macdonald, D.W. (Eds.). *Canids, Foxes, Wolves, Jackals, and Dogs: Status Survey and conservation Action Plan* (pp. 210-218). IUCN/SSC Canid Specialist Group. Gland, Switzerland and Cambridge, UK.

- Dutta, T., Sharma, S., Maldonado, J.E., Panwar, H.S. and Seidensticker, J. 2015. Genetic variation, structure, and gene flow in a sloth bear (Melursus ursinus) meta-population in the Satpura-Maikal landscape of Central India. *PLoS One*, 10(5), e0123384.

- Dutta, T., Sharma, S., Maldonado, J.E., Wood, T.C. and Seidensticker, J. 2012. A reliable method for individual identification and gender determination of wild leopards (Panthera pardus fusca) using non-invasive samples. *Conservation Genetics Resources*, 4, 665–667.

- Dutta, T., Sharma, S., Maldonado, J.E., Wood, T.C., Panwar, H.S. and Seidensticker, J. 2013. Fine-scale population genetic structure in a wide-ranging carnivore, the leopard (Panthera pardus fusca) in central India. *Diversity and Distributions*, 19(7), 760-771.

- Dutta, T., Sharma, S., Maldonado, J.E., Wood, T.C., Panwar, H.S. and Seidensticker, J. 2013. Gene flow and demographic history of leopards (Panthera pardus) in the central Indian highlands. *Evolutionary Applications*, 6, 949–959.

- Easa, P.S. 1998. *Habitat utilization of animals in Parambikulam Wildlife Sanctuary with special reference to Gaur.* KFRI Research Report 155, Peechi, Kerala.

- Edgaonkar, A. 2008. *Ecology of the leopard (Panthera pardus) in Bori Wildlife Sanctuary and Satpura National Park, India*. Ph.D. thesis, University of Florida, USA. 135 p.

- Edwards, S., Allison, J. and Cheetham, S. 2012. Recent mammal records from the Oddar Meanchey portion of the Kulen-Promtep Wildlife Sanctuary, Northern Cambodia. *Cambodian Journal of Natural History*, 2012(1), 8-12.

- Efford, M.G. 2011. Estimation of population density by spatially explicit capture–recapture analysis of data from area searches. *Ecology*, 92, 2202–2207.

- Efford, M.G. 2015. *secr: spatially explicit capture-recapture models. - R package version 2.9.4.* http://CRAN.R-pro ject.org/package=secr.

- Eisenberg, J. F. 1980. Ecology and Behavior of the Asian Elephant. *Elephant*, 1(5), 36-56.

- Elith, J., Phillips, S.J., Hastie, T., Dudik, M., Chee, Y.E. and Yates, C.J. 2010. A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions*, 17(1), 43-57.

- Ellerman, J.R. and Morrison-Scott, R.C.S. 1951. *Checklist of Palearctic and Indian Mammals.* British Museum of Natural History, London, 810 p.

- Ellis, S. and Talukdar, B. 2019. Rhinoceros unicornis. *The IUCN Red List of Threatened Species 2019*, e.T19496A18494149.

- Ellis, S., Miller, P.S., Agarwalla, R.P., Yadava, M.K., Ghosh, S., Sivakumar, P., Bhattacharya, U., Singh, V.K., Sharma, A., and Talukdar, B.K. (Eds.). 2015. *Indian Rhino Vision 2020 Population Modeling Workshop Final Report.* Workshop held 4-5 November 2015. Guwahati, Assam, India. International Rhino Foundation: Fort Worth, TX, USA.

- Elvidge, C.D., Baugh, K., Zhizhin, M., Hsu, F.C. and Ghosh, T. 2017. VIIRS night-time lights. *International Journal of Remote Sensing*, 38 (21), 5860-5879.

- Emslie, R.H., Milliken, T., Talukdar, B., Ellis, S., Adcock, K., and Knight, M.H. 2016. *African and Asian Rhinoceroses – status, conservation and trade: a report from the IUCN Species Survival Commission (IUCN/SSC) African and Asian Rhino Specialist Groups and TRAFFIC to the CITES Secretariat pursuant to Resolution Conf. 9.14 (Rev. CoP15).* Available at https://cites.org/sites/default/files/eng/cop/17/WorkingDocs/ECoP17-68-A5.pdf.

- Erdbrink, D.P. 1953. *A review of fossil and recent bears of the world.* University of Utrech, Deventer-Drukkerij jan de Lange, 597 p.

- Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology, Evolution and Systematics*, 34(1), 487-515.

- FAO 2007. *State of the world's forests.* United Nations Food and Agriculture Organization, Rome, Italy.

- Farhadinia, M.S., Akbari, H., Beheshti, M. and Sadeghi, A. 2007. Ecology and status of the Caracal, Caracal caracal, in Abbasabad Naein Reserve, Iran. *Zoology in the Middle East*, 41, 5–9.

- Farhadinia, M.S., Akbari, H., Beheshti, M., Sadeghi, A. and Halvani, M.R. 2008. Felids of Abbasabad Naein Reserve, Iran. *Cat News*, 48, 14–16.

- Farr, T.G., Rosen, P.A., Caro, E., Crippen, R., Duren, R., Hensley, S., Kobrick, M., Paller, M., Rodriguez, E., Roth, L., Seal, D., Shaffer, S., Shimada, J., Umland, J., Werner, M., Oskin, M., Burbank, M. and Alsdorf, D. 2007. The Shuttle Radar Topography Mission. *Review of Geophysics*, 45, RG2004.

- Fauzi, N.F.B.M, Azman, M.S., Munian, K., Ruzman, N.H.B.A. and Zakaria, N.A.B. 2018. *Prionailurus bengalensis (Kerr, 1792).* Malaysia Biodiversity Information System (MyBIS). https://www.mybis.gov.my/art/249

- Feng, L., Lin, L., Zhang, L., Wang, L., Wang, B., Luo, A., Yang, S., Smith, J.L.D., Luo, S. J. and Zhang, L. 2008. Evidence of wild tigers in southwest China – a preliminary survey of the Xishuangbanna National Nature Reserve. *Cat News*, 48, 4–6.

- Fick, S.E. and Hijmans, R.J. 2017. WorldClim 2: new 1km spatial resolution climate surfaces for global land areas. *International Journal of Climatology*, 37 (12), 4302-4315.

- Finn, F. 1929. *Mammalia of India.* Thaker, Spink and Co., Bombay, 347 p.

- Fischer, C., Tagand, R. and Hausser, Y. 2013. Diversity and distribution of small carnivores in a miombo woodland within the Katavi region, Western Tanzania. *Small Carnivore Conservation*, 48, 60-66.

- Foose, T. J. and van Strien, N. (eds). 1997. *Asian rhinos. status survey and conservation action plan.* IUCN/SSC Asian Rhino Specialist Group, Gland, Switzerland.

- Forest Survey of India (FSI) 2017. *State of Forest Report 2017.* Forest Survey of India, Dehradun, India.

- Forest Survey of India (FSI) 2019. *State of Forest Report 2019.* Forest Survey of India, Dehradun, India.

- Fox, M. and Johnsingh, A.J.T. 1975. Hunting and feeding in wild dogs. *Journal of the Bombay Natural History Society*, 72, 321-326.

- Fox, M.W. 1984. *The whistling hunters: field studies of the Asiatic wild dog (Cuon alpinus).* State University of New York Press, Albany. ISBN 978-0-9524390-6-6.

- Frankham, R. 2010. Where we are in conservation genetics and where we need to go? *Conservation Genetics*, 11, 661–663.

- Fuller, T.K. 1989. Population dynamics of wolves in north-central Minnesota. *Wildlife Monographs*, 105: 3-41.

- Gajera, N. and Dharaiya, N. 2011. Status, occurrence, distribution of some mammals of North Gujarat, India. Proceedings of Zoological Society, 64(1), 46–53.

- Ganesh, T. 1997. Occurrence of the brown palm civet in the wet forest of Kalakad Mundanthurai Tiger Reserve, Tamil Nadu. *Journal of the Bombay Natural History Society*, 94, 556.

- Garshelis, D.L., Joshi, A.R. and Smith, J.L.D. 1999b. Estimating density and relative abundance of sloth bears. *Ursus*, 11, 87-98.

- Garshelis, D.L., Joshi, A.R., Smith, J.L.D. and Rice, C.G. 1999a. Sloth bear conservation action plan. In C. Servheen, S. Herrero and B. Peyton (Eds.). *Bears: status survey and conservation action plan*, (pp. 225- 240). IUCN/SSC Bear and Polar Bear Specialist Groups, Gland, Switzerland and Cambridge, U.K.

- Geoffroy-Saint-Hilaire, I. 1831. Mammiferes. In: Belanger C. (ed.). *Voyage aux Indes-Orientales par le nord de l'Europe, les provinces du Caucases, la Georgie, l'Armenie et la Perse, suivi des details topographiques, statis-tiques et autre sur le Pegou, les Iles de Jave, de Maurice et de Bourbon, sur le Cap-de-bonne-Esperance et Sainte-Helene, pendant les annees 1825, 1826, 1827, 1828 et 1829 publie sous les auspices de ll. ee. mm. les Ministres de la Marine et de l'Interieur, 3. Zoologie.* Arthus Bertrand, Paris.

- Ghaskadbi, P., Habib, B., Mir, Z., Ray, R., Talukdar, G., Lyngdoh, S., Pandav, B., Nigam, P. and Kaur, A. 2016. Rusty spotted Cat in Kalesar National Park and Sanctuary, Haryana, India. *Cat news*, 63, 28–29.

- Ghimirey, Y. and Ghimire, B. 2010. Leopard Cat at high altitude in Makalu-Barun National Park, Nepal. *Cat News*, 52, 16-17.

- Ghimirey, Y. and Pal, P. 2009. First camera trap image of Asiatic Golden Cat in Nepal. *Cat News*, 51, 19.

- Ghoddousi, A., Ghadirian, T. and Fahimi, H. 2009. Status of Caracal in Bahram'gur Protected Area, Iran. *Cat News*, 50, 10–13.

- Ghose, D. 2002. First sighting of clouded leopard Neofelis nebulosi from the Blue Mountain National Park, Mizoram, India. *Current Science*, 83, 20–21.

- Ghose, M., Sharma, D. and Murali, N.S. 2019. First photographic evidence of polymorphic Asiatic Golden Cat Catopuma temminckii Vigors and Horsfield, 1827 (Mammalia: Carnivora: Felidae) in Buxa Tiger Reserve, West Bengal, India. *Journal of Threatened Taxa*, 11, 13502–13505.

- Ginsberg, J.R. and Macdonald, D.W. (Eds.) 1990. *Foxes, wolves, jackals and dogs. An action plan for the conservation of canids.* IUCN, Gland, Switzerland.

- Gokula, V. and Ramachandran, N.K. 1996. A record of Nilgiri Marten *(Martes gwatkinsii Horsfield). Journal of the Bombay Natural History Society*, 93, 82.

- Gopal, R., Sinha, P.R., Mathur, V.B., Jhala, Y.V. and Qureshi, Q. 2007. *Guidelines for preparation of tiger conservation plan.* Technical document, National Tiger Conservation Authority, Ministry of Environment and Forests, Government of India, New Delhi, India, NTCA/01/07.

- Gopi, G.V, Lyngdoh, S. and Selvan, K.M. 2010. *Conserving the endangered Asiatic Wild Dog Cuon alpinus in Western Arunachal Pradesh: fostering better coexistence for conservation.* Final Technical Report Submitted to Rufford Small Grant Program, UK. 54 p.

- Gorbunov, A.V. 1995. Honey badger – Mellivora capensis Schreiber, 1776. In V.V. Kucheruk (Ed.). *Mammals of Turkmenistan. Vol. 1. Carnivores, Pinnipeds, and Ungulates*, (pp. 111-121). Ylym, Ashgabat, Turkmenistan.

- Goswami, K.G. 2007. Habitat preference of Indian bison (Bos gaurus) during summer in Billigiri Rangaswamy Temple Wildlife Sanctuary, Karnataka, India. *Nature Environment and Pollution Technology*, 6(1), 117-120.

- Goswami, R. and Ganesh, T. 2014. Carnivore and herbivore densities in the immediate aftermath of ethnopolitical conflict: The case of Manas National Park, India. *Tropical Conservation Science*, 7(3), 475-487.

- Goswami, V.R., Medhi, K., Nichols, J.D. and Oli, M.K. 2015. Mechanistic understanding of human–wildlife conflict through a novel application of dynamic occupancy models. *Conservation Biology*, 29, 1100-1110.

- Gouda, J., Sethy, J. and Chauhan, N.P.S. 2016. First photo capture of Asiatic Golden Cat in Dampa Tiger Reserve, Mizoram, India. *Cat News*, 64, 26–27.

- Government of Manipur 2018. State of Environment Report, Manipur 2018. Environment and Ecology Office, Government of Manipur. Available at http://moef.gov.in/wp-content/uploads/2018/04/manipur-SoE_0.pdf.

- Govind, S.K. 2015. *Studies on human wildlife conflict in central Kerala, India.* Ph.D. thesis, Kerala Forest Research Institute, Peechi, Kerala.

- Goyal, S.M., Mech, L.D., Rademacher, R.A., Khan, M.A. and Seal, S.U. 1986. Antibodies against canine parvovirus in wolves in Minnesota: a serological study from 1975 to 1985. *Journal of the American Veterinary Medical Association*, 189(9), 1092-1094.

- Grassman Jr., L.I. and Tewes, M.E. 2002. Marbled cat pair in in northeastern Thailand. *Cat News*, 36, 19.

- Grassman, Jr. L.I., Tewes, M.E., Silvy, N.J. and Kreetiyutanont, K. 2005. Ecology of three sympatric felids in a mixed evergreen forest in north-central Thailand. *Journal of Mammalogy*, 86, 29–38.

- Grassman, L. 2000. Movements and diet of the leopard cat Prionailurus bengalensis in a seasonal evergreen forest in south-central Thailand. *Acta Theriologica*, 45, 421-426.

- Grassman, L., Lynam, A., Mohamad, S., Duckworth, J.W., Bora, J., Wilcox, D., Ghimirey, Y., Reza, A., and Rahman, H. 2016. Neofelis nebulosa. *The IUCN Red List of Threatened Species 2016*, e.T14519A97215090.

- Grassman, L.I., Jr. 1998. Movements and fruit selection of two Paradoxurinae species in a dry evergreen forest in

Southern Thailand. *Small Carnivore Conservation*, 19, 25-29.

- Grassman, L.I., Tewes, M.E., Silvy, N.J. and Kreetiyutanont, K. 2005. Spatial organization and diet of the leopard cat *(Prionailurus bengalensis)* in north-central Thailand. *Journal of Zoology*, 266, 45–54.

- Gray, T.N.E., Ou R., Huy K., Pin C. and Maxwell, A. L. 2012. The status of large mammals in eastern Cambodia: a review of camera trapping data 1999–2007. *Cambodian Journal of Natural History*, 2012(1), 42-45.

- Gray, T.N.E., Phan, C., Chanrattanak, P. and Sovanna, P. 2014. The status of jungle cat and sympatric small cats in Cambodia's Eastern Plains. *Cat News*, 8, 19–23.

- Gray, T.N.E., Timmins, R.J., Jathana, D., Duckworth, J.W., Baral, H. and Mukherjee, S. 2016. Felis chaus. *The IUCN Red List of Threatened Species 2016*, e.T8540A50651463.

- Green, R. 1991. *Wild cat species of the world.* Basset Publications, Plymouth, UK.

- Grewal, B., Sreenivasan, R. and Haralu, B. 2011. *Nagaland biodiversity and conservation programme: an action document.* Nagaland Biodiversity Conservation Project, Dimapur, India, 55 p.

- Grobler, J.H. 1981. Feeding behavior of the caracal Felis caracal Schreber 1776 in the Mountain Zebra National Park. *South African Journal of Zoology*, 16, 259-262.

- Grubb, P. 2005. Artiodactyla. In Wilson, D.E. and Reeder, D.M. (Eds.). *Mammal Species of the World. A Taxonomic and Geographic Reference (3rd edition)*, (pp. 637-722). Johns Hopkins University Press, Baltimore, USA.

- Gubbi, S., Kolekar, A. and Kumara, V. 2020b. Policy to on-ground action: evaluating a conflict policy guideline for leopards in India. Jo*urnal of International Wildlife Law and Policy*, 23, 127-140.

- Gubbi, S., Nagashettihalli, H., Bhat, R., Poornesha, H.C., Anoop, A. and Madhusudan, M.D. 2017. *Ecology and conservation of leopards in protected and multiple use forests in Karnataka.* Nature Conservation Foundation, Mysore, India.

- Gubbi, S., Nagashettihalli, H., Suthar, S. and Menon, A.M. 2019. *Report on monitoring of leopards at Biligiri Rangaswamy Temple Tiger Reserve in Karnataka.* Nature Conservation Foundation, Mysore, India.

- Gubbi, S., Poornesha, H.C., Daithota, A. and Nagashettihalli, H. 2014. Roads emerging as a critical threat to leopards in India. *Cat News*, 60, 30–31.

- Gubbi, S., Ramesh, S., Menon, A.M., Girish, M.N. and Poornesha, H.C. 2020. The lone wolf: new distribution update of the Indian grey wolf *(Canis lupuspallipes)* in southern India. *Canid Biology and Conservation*,22(6), 21-24.

- Gubbi, S., Sharma, K. and Kumara, V. 2020a. Every hill has its leopard: patterns of space use by leopards (Panthera pardus) in a mixed use landscape in India. *Peer J*, 8, e10072.

- Gubiani, R., Zaabi, R.A., Chuven, J. and Soorae, P. 2020. Rediscovery of Caracal Caracal caracal (Schreber, 1776) (Mammalia: Carnivora: Felidae) in Abu Dhabi Emirate, UAE. *Journal of Threatened Taxa*, 12(16), 17194–17202.

- Gupta, B.K. 2004. Killing civets for meat and scent in India. *Small Carnivore Conservation*, 31, 21.

- Gupta, S., Mondal, K., Sankar, K. and Qureshi, Q. 2012. Abundance and habitat suitability model for ratel (Mellivora capensis) in Sariska Tiger Reserve, western India. *Wildlife Biology in Practice*, 8(1), 13-22.

- Gupta, S., Sanyal, A., Saha, G.K. and Ghosh, A.K. 2016. Diurnal activity pattern of Golden Jackal (Canis aureus Linn.) in an urban landscape of Kolkata, India. *Proceedings of the Zoological Society*, 69(1), 75-80.

- Guptha, M.B. and Ramanujam, M.E. 2017. A photographic record of the Rusty-spotted Cat *Prionailurus rubiginosus* (Mammalia: Carnivora: Felidae) in a forest plantation on the east coast of Tamil Nadu, India. Journal of Threatened Taxa, 9, 10242–10245.

- Habib, B. and Kumar, S. 2007. Den shifting by wolves in semi-wild landscapes in the Deccan Plateau, Maharashtra, India. *Journal of Zoology*, 272, 259-265.

- Habib, B., 2007. *Ecology of Indian wolf, Canis lupus pallipes Sykes, 1831, and modeling its potential habitat in the great Indian bustard sanctuary, Maharashtra, India.* Ph.D. thesis, Aligarh Muslim University, India, 264 p.

- Hamilton, P.H. 1976. *The movements of leopards in Tsavo National Park, Kenya, as determined by radio-tracking.* M.Sc. thesis, University of Nairobi, 512 p.

- Hamlin, M. 2004. *"Prionailurus viverrinus" (On-line).* Animal Diversity Web. Available at https://animaldiversity.org/accounts/Prionailurus_viverrinus/.

- Hanski, I., Moilanen, A. and Gyllenberg, M. 1996. Minimum viable metapopulation size. *The American Naturalist*, 147(4):527-541.

- Happold, D.C.D. 1987. *The mammals of Nigeria.* Oxford: Clarendon Press.

- Haque, N. 1988. Scavenging habit of fishing cat (Felis viverrina) in Keoladeo National Park, Bharatpur. *Journal of the Bombay Natural History*, 85(1), 183-184.

- Haque, N. M. and Vijayan, V. 1993. Food habits of the fishing cat *Felis viverrina* in Keoladeo National Park, Bharatpur, Rajasthan. *Journal of the Bombay Natural History Society*, 90, 498-500.

- Harihar, A., Pandav, B. and Goyal, S.P. 2009. Density of leopards (Panthera pardus) in the Chilla Range of Rajaji National Park, Uttarakhand, India. *Mammalia*, 73, 68–71.

- Harihar, A., Pandav, B. and Goyal, S.P. 2011. Responses of leopard Panthera pardus to the recovery of a tiger Panthera tigris population. *Journal of Applied Ecology*, 48(3), 806-814.

- Harting, J. 1883. An Arabic Treatise on Hunting, pp. 362–370. In: *Essays on Sport and Natural History.* Horace Cox, London, 485pp.

- Hasan, S.M. 1980. The enigmatic buffalo. *Hornbill*, 1980, 26-27.

- Hayssen, V.D. and Van Tienhoven, A. 1993. *Asdell's patterns of mammalian reproduction: a compendium of species-specific data.* Cornell University Press, Ithaca, New York.

- Hayward, M., Henschel, P., O'Brien, J., Hofmeyr, M., Balme, G. and Kerley, G. 2006. Prey preferences of the leopard (Panthera pardus). *Journal of Zoology*, 270, 298-313.

- Hayward, M., Lyngdoh, S. and Habib, B. 2014. Diet and prey preferences of dholes (Cuon alpinus): Dietary competition within Asia's apex predator guild. *Journal of Zoology*, 294, 255-266.

- Hearn, A.J., Ross, J., Bernard, H., Bakar, S.A., Hunter, L.T.B. and Macdonald, D.W. 2016. The first estimates of marbled cat Pardofelis marmorata population density from Bornean primary and selectively logged forest. *PLoS One*, 11, e0151046.

- Heath, M.E. 1995. Manis crassicaudata. *Mammalian Species*, 513, 1-4.

- Hedges, S., Sagar Baral, H., Timmins, R.J. and Duckworth, J.W. 2008. Bubalus arnee. *The IUCN Red List of Threatened Species 2008*, T3129A128960945

- Hedges, S., Tyson, M. J., Sitompul, A. F. and Hammatt, H. 2006. Why inter-country loans will not help Sumatra's elephants. *Zoo Biology*, 25, 235–246.

- Heinen, J.T. and Kandel, R. 2006. Threats to a small population: a census and conservation recommendations for wild buffalo Bubalus arnee in Nepal. *Oryx*, 40(3), 324-330.

- Heinrich, S., Wittman, T.A., Ross, J.V., Shepherd, C.R., Challender, D.W.S. and Cassey, P. 2017. *The global trafficking of pangolins: a comprehensive summary of seizures and trafficking routes from 2010-2015.* Petaling Jaya, Malaysia: Traffic. Available at: www.traffic.org/publications/the-global-trafficking-ofpangolins.html.

- Henle, K., Lindenmayer, D.B., Margules, C.R., Saunders, D.A. and Wissel, C. 2004. Species survival in fragmented landscapes: where are we now? *Biodiversity and Conservation*, 13(1), 1-8.

- Heptner, V.G. and Sludskii, A.A. 1992. *Mammals of the Soviet Union. Volume II, Part 2. Carnivora (hyaenas and cats).* Smithsonian Institution Libraries and National Science Foundation. Available from the National Technical Information Service, Springfield, Virginia, xxiv + 784 pp.

- Heptner, V.G., Naumov, N.P., Yurgenson P.B., Sludskii, A.A., Chirkova, A.F. and Bannikov, A.G. 1967. *Mammals of Soviet Union. Vol. 2(1). Sea Cows and Carnivora.* Vyshaya shkola, Moscow, Russia.

- Hiby, L., Lovell, P., Patil, N., Kumar, N.S., Gopalaswamy, A.G. and Karanth, K.U. 2009. A tiger cannot change its stripes: using a three-dimensional model to match images of living tigers and tiger skins. *Biology Letters*, 5 (3), 383 - 386.

- Hoath, R. 2003. *A field guide to the mammals of Egypt.* The American University in Cairo Press, Cairo, Egypt.

- Hoffmann, M. and Atickem, A. 2019. Canis lupaster. *The IUCN Red List of Threatened Species 2019*, e.T118264888A118265889.

- Hoffmann, M., Arnold, J., Duckworth, J.W., Jhala, Y., Kamler, J.F. and Krofel, M. 2018. *Canis aureus. The IUCN Red List of Threatened Species 2018*, e.T118264161A46194820.

- Holden, J. 2001. Small cats in Kerinci Seblat National Park, Sumatra, Indonesia. *Cat News*, 35, 11-14.

- Holmes, K. 2009. Neofelis nebulosa (On-line). *Animal Diversity Web*. Available at https://animaldiversity.org/accounts/Neofelis_nebulosa/.

- Hua, L., Gong, S., Wang, F., Li, W., Ge, Y., Li, X. and Hou, F. 2015. Captive breeding of pangolins: current status, problems and future prospects *ZooKeys*, 507, 99 – 114.

- Huete, A.R., Didan, K., Miura, T., Rodriguez, E.P., Gao, X., and Ferreira, L.G. 2002. Overview of the radiometric and biophysical performance of the MODIS vegetation indices. *Remote Sensing of Environment*, 83, 195-213.

- Hunter. L. 2011. *A field guide to the carnivores of the world*. New Holland Publishers (UK) Ltd., London (UK), 256 p.

- Hunter, L. 2015. *Wild cats of the world*. Bloomsbury Natural History, New York, USA.

- Hutton, A.F. 1944. Feeding habits of the Nilgiri marten. *Journal of the Bombay Natural History Society*, 48, 374-375.

- Hutton, A.F. 1949a. Feeding habits of the Nilgiri marten. *Journal of the Bombay Natural History Society*, 48, 355-356.

- Hutton, A.F. 1949b. Mammals of the High Wavy Mountains, Madurai district, southern India. *Journal of the Bombay Natural History Society*, 48, 681-694.

- Hutton, A.F. 1949c. Notes on the snakes and mammals of the High Wavy Mountains, Madura district, south India. *Journal of the Bombay Natural History Society*, 48, 681-694.

- İlemin, Y. and Gürkan, B. 2010. Status and activity patterns of the Caracal, Caracal caracal (Schreber, 1776), in Datça and Bozburun Peninsulas, Southwestern Turkey. *Zoology in the Middle East*, 50(1), 3-10.

- Irshad, N., Mahmood, T., Hussain, R., and Nadeem, M.S. 2015. Distribution, abundance and diet of the Indian pangolin (Manis crassicaudata). *Animal Biology*, 65, 57-71.

- Islam, S., Nawaz, R. and Moazzam, M. 2015. A survey of smooth-coated otter (Lutrogale perspicillata sindica) and fishing cat (Prionailurus viverrinus) in Chotiari Reservoir, Sanghar, Pakistan using camera traps. *International Journal of Biology and Biotechnology*, 12 (4), 579-584.

- Israel, S., Sinclair, T., Grewal, B. and Hoefer, H.J. 1987. *Indian wildlife*. APA Productions (HK) Ltd., Hong Kong.

- Iyengar, A., Babu, V.N., Hedges, S., Venkataraman, A.B., Maclean, N. and Morin, P.A. 2005. Phylogeography, genetic structure, and diversity in the dhole (Cuon alpinus). *Molecular Ecology*, 14(8), 2281-2297.

- Jackson, P. 1998. Conserving the smaller cats. ENVIS Newsletter, *1(2), 1–4*.

- Jacobson, A.P., Gerngross, P., Lemeris, Jr J.R., Schoonover, R.F., Anco, C., Breitenmoser-Würsten, C., Durant, S.M., Farhadinia, M.S., Henschel, P., Kamler, J.F., Laguardia, A., Rostro-García, S., Stein, A.B. and Dollar, L. 2016. Leopard (Panthera pardus) status, distribution, and the research efforts across its range. *Peer J*, 4, e1974.

- Jaffeson, R.C. 1975. *Melursus ursinus: survival status and conditions*. Unpublished report, Washington DC.

- Jathanna, D. 2014. *Ecology and conservation of small carnivores in the Western Ghats*. Final report submitted to CEPF/ATREE. Centre for Wildlife Studies, Bangalore.

- Jena, J., Dey, S., Borah, J. and Bhargava, D. 2016. Occurrence of Rusty-spotted Cat in Balaghat forest division, Madhya Pradesh, India. *Cat News*, 64, 15–16.

- Jennings, A. P. and Veron, G. 2009. Family Viverridae (civets, genets, and oyans). In D.E. Wilson and R.A. Mittermeier (Eds.). *Handbook of the mammals of the world. Vol. 1. Carnivores*, (pp. 174–232). Lynx Edicions, Barcelona, Spain.

- Jenny, D. 1996. Spatial organization of leopards Panthera pardus in Tai National Park, Ivory Coast: Is rain forest habitat a 'tropical haven'? *Journal of Zoology*, 240, 427-440.

- Jethva, B.D. and Jhala, Y.V. 2004. Foraging ecology, economics and conservation of Indian wolves in the Bhal region of Gujarat, Western India. *Biological Conservation*, 116: 351-357.

- Jhala, H.Y., Qureshi, Q., Jhala, Y.V. and Black, S. A. 2021. Feasibility of reintroducing grassland megaherbivores, the Greater One-horned Rhinoceros, and Swamp Buffalo within their historic global range. Scientific Reports 11(1) : 1-15.

- Jhala, Y.V. 2013. Indian wolf. In A.J.T. Johnsingh and N. Manjrekar (Eds.). *Mammals of South Asia, Vol. I*, (pp. 377-391). University Press, Hyderabad, India.

- Jhala, Y.V. 1991. *The habitat and population dynamics of wolves and blackbuck in Velavadar National Park, Gujarat, India*. Ph.D. thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 236 p.

- Jhala, Y.V. 1993. Predation on blackbuck by wolves in Velavadar National Park. *Conservation Biology*, 7(4), 874-881.

- Jhala, Y.V. 2000. *Human-conflict in India. Abstract in "Beyond 2000: realities of global wolf restoration"*. Symposium, Duluth, MN, USA, February 23–26.

- Jhala, Y.V. 2003. Status, ecology and conservation of the Indian wolf Canis lupus pallipes Sykes. *Journal of the Bombay Natural History Society*, 100 (2 and 3), 293-307.

- Jhala, Y.V. 2008. *Conservation of the Indian wolf.* Final Technical Report, Wildlife Institute of India, Dehradun.

- Jhala, Y.V. 2013. Striped hyena. In A.J.T. Johnsingh and N. Manjerkar (Eds.). *Mammals of South Asia, Vol I*, (pp. 522-530). University Press, Hyderabad, India.

- Jhala, Y.V. and Giles, J.R. 1991. The status and conservation of the wolf in Gujarat and Rajasthan, India. *Conservation Biology*, 5, 476–483.

- Jhala, Y.V. and Moehlman, P.D. 2004. Golden Jackal Canis aureus Linnaeus, 1758. In: S. Sillero-Zubiri, M. Hoffmann and D.W. Macdonald (Eds.). *Canids: Foxes, Wolves, Jackals and Dogs. Status Survey and Conservation Action Plan*, (pp. 156-161). IUCN, Gland, Switzerland.

- Jhala, Y.V. and Moehlman, P.D. 2008. Canis aureus. *IUCN Red List of Threatened Species. Version 2013.2.* www.iucnredlist.org

- Jhala, Y.V. and Moehlman, P.D. 2013. Golden jackal. In A.J.T. Johnsingh and N. Manjrekar (Eds.). *Mammals of South Asia, Vol. I*, (pp. 366-376). University Press, Hyderabad, India.

- Jhala, Y.V. and Sharma, D.K. 1997. Child-lifting by wolves ineastern Uttar Pradesh, India. *Journal of Wildlife Research*, 2, 94–101.

- Jhala, Y.V., Gopal, R., Mathur, V., Ghosh, P., Negi, H.S., Narain, S. Yadav, S.P., Malik, A., Garawad, R, and Qureshi, Q. (in press). Recovery of Tigers in India: Critical Introspection and Potential Lessons. *People and Nature.*

- Jhala, Y.V., Quershi, Q. and Nayak, A.K. (Eds.) 2020. *Status of tigers, copredators and prey in India, 2018.* National Tiger Conservation Authority, Government of India, New Delhi, and Wildlife Institute of India, Dehradun. ISBN No. 81-85496-50-1, 650 p.

- Jhala, Y.V., Qureshi, Q. and Gopal, R. (Eds.) 2015. *The status of tigers in India, 2014.* National Tiger Conservation Authority, New Delhi and Wildlife Institute of India, Dehradun, 456 p.

- Jhala, Y.V., Qureshi, Q. and Gopal, R. 2011. Can the abundance of tigers be assessed from their signs? *Journal of Applied Ecology*, 48, 14-24.

- Jhala, Y.V., Qureshi, Q. and Gopal, R. 2017. *Field Guide: Monitoring tigers, co-predators, prey and their habitats.* Technical Publication of National Tiger Conservation Authority, New Delhi and the Wildlife Institute of India, Dehradun. Technical Report TR-2017/012.

- Jhala, H.Y., Qureshi, Q., Jhala, Y.V. and Black, S.A., 2021. *Feasibility of reintroducing grassland megaherbivores,* the greater one-horned rhinoceros, and swamp buffalo within their historic global range. Scientific reports, 11(1), pp.1-15.

- Jigme, K. 2011. Four colour morphs of and the altitudinal record of Asiatic Golden Cat in Bhutan. *Cat News*, 55, 12-13.

- Jiménez-Valverde, A. 2012. Insights into the area under the receiver operating characteristic curve (AUC) as a discrimination measure in species distribution modelling. *Global Ecological Biogeography*, 21(4), 498-507.
- Jnawali, S.R., Baral, H.S., Lee, S., Acharya, K.P., Upadhyay, G.P., Pandey, M., Shrestha, R., Joshi, D., Lamichhane, B.R., Griffiths, J., Khatiwada, A.P., Subedi, N. and Amin, R. 2011. *The Status of Nepal's Mammals: The National Red List Series.* Department of National Parks and Wildlife Conservation, Kathmandu, Nepal, 276 p.
- Johnsingh, A.J.T. 1983. Large mammalian prey-predators in Bandipur. *Journal of the Bombay Natural History Society*, 80, 1-57.
- Johnsingh, A.J.T. 1985. Distribution and status of dhole *Cuon alpinus* Pallas, 1811 in South Asia. *Mammalia*, 49, 203-208.
- Johnsingh, A.J.T. 2003. Bear conservation in India. *The Journal of the Bombay Natural History Society*, 100, 190-201.
- Johnsingh, A.J.T. and Acharya, B. 2013. Asiatic wild dog. In A.J.T. Johnsingh and N. Manjrekar (Eds.). *Mammals of South Asia, Vol. I*, (pp. 392-415). University Press, Hyderabad, India.
- Johnsingh, A.J.T., Ramesh, K., Qureshi, Q., David, A., Goyal, S.P., Rawat, G.S., Rajapandian, K. and Prasad, S. 2004. *Conservation status of tiger and associated species in the Terai Arc Landscape, India. Wildlife Institute of India*, Dehradun, viii+ 110 p.
- Johnson, A., Vongkhamheng, C. and Saithongdam, T. 2009. The diversity, status and conservation of small carnivores in a montane tropical forest in northern Laos. *Oryx*, 43, 626–633.
- Jombart, T. 2008. adegenet: a R package for the multivariate analysis of genetic markers. *Bioinformatics*, 24(11), 1403-1405.
- Jones, F.W.C. 1907. Some notes on wild dogs and panthers. *Journal of the Bombay Natural History Society*, 18, 194-195.
- Jones, M.L. 1977. Longevity of mammals in captivity. *International Zoo Yearbook*, 19, 16-19.
- Joshi, A.R., Garshelis, D.L. and Smith, J.L.D. 1995. Home ranges of sloth bears in Nepal: implications for conservation. *Journal of Wildlife Management*, 59(2), 204-214.
- Joshi, A.R., Smith, J.L.D. and Cuthbert, F.J. 1995. Influence of food distribution and predation pressure on spacing behavior in palm civets. *Journal of Mammalogy*, 76, 1205–1212.
- Joshi, A.R., Smith, J.L.D. and Garshelis, D.L. 1999. Sociobiology of the myrmecophagus sloth bear in Nepal. *Canadian Journal of Zoology*, 77(11), 1690-1704.
- Joshi, B., Syiem, B.L.N., Kuotsu, R., Menon, A., Gogoi, J., Goswami, V.R. and Vasudev, D. 2019. Records of the Marbled Cat Pardofelis marmorata and the Asiatic Golden Cat Catopuma temminckii (Mammalia: Carnivora: Felidae) from the community forests surrounding the Dzükou Valley in Nagaland, India. *Journal of Threatened Taxa*, 11, 14363–14367.
- Joshi, N., Srivastava, A. and Joshi, R. 2018. Impact of transportation on mammalian fauna in Rajaji Tiger Reserve, India. *Asian Journal of Conservation Biology*, 7 (1), 73-77.
- Kakati, K. and Srikant, S. 2014. First camera-trap record of Small-toothed Palm Civet Arctogalida trivirgata from India. *Small Carnivore Conservation*, 50, 50–53.
- Kalle, R., Ramesh, T., Qureshi, Q. and Sankar, K. 2011. Density of tiger and leopard in a tropical deciduous forest of Mudumalai Tiger Reserve, southern India, as estimated using photographic capture–recapture sampling. *Acta Theriologica*, 56, 335–342.
- Kalle, R., Ramesh, T., Qureshi, Q. and Sankar, K. 2013a. Predicting the distribution pattern of small carnivores in response to environmental factors in the Western Ghats. *PLoS One*, 8(11), e79295.
- Kalle, R., Ramesh, T., Qureshi, Q. and Sankar, K. 2014. Estimating seasonal abundance and habitat use of small carnivores in the Western Ghats using an occupancy approach. *Journal of Tropical Ecology*, 30, 469-480.
- Kalle, R., Ramesh, T., Sankar, K. and Qureshi, Q. 2013b. Observations of sympatric small carnivores in Mudumalai Tiger Reserve, Western Ghats, India. *Small Carnivore Conservation*, 49, 53–59.
- Kamalakkannan, R., Bhavana, K, Prabhu, V.R., Sureshgopi, D., Singha, H.S. and Nagarajan, M. 2020. The complete

mitochondrial genome of Indian gaur, *Bos gaurus* and its phylogenetic implications. *Scientific Reports*, 10, 11936.

- Kamler, J.F., Johnson, A., Vongkhamheng, C., Bousa, A. 2012. The diet, prey selection, and activity of dholes (Cuon alpinus) in northern Laos. *Journal of Mammalogy*, 93, 627-633.

- Kamler, J.F., Songsasen, N., Jenks, K., Srivathsa, A., Sheng, L. and Kunkel, K. 2015. Cuon alpinus. *The IUCN Red List of Threatened Species 2015*, e.T5953A72477893.

- Kanagavel, A., Parvathy, S., Nameer, P.O. and Raghavan, R. 2016. Conservation implications of wildlife utilization by indigenous communities in the southern Western Ghats of India. *Journal of Asia-Pacific Biodiversity*, 9(3), 271-279.

- Kantimahanti, M. 2016. Community-based Fishing Cat conservation in the Eastern Ghats of South India. In: Appel, A. and Duckworth, J.W. (Eds.). *Proceedings of the First International Fishing Cat Conservation Symposium, 25–29 November 2015, Nepal* (pp. 51-54). Fishing Cat Working Group, Bad Marienberg, Germany and Saltford, Bristol, United Kingdom.

- Karanth, K.U. and Kumar, N.S. 2015. *Population estimation of tigers in Wayanad Wildlife Sanctuary, Kerala*. Annual Report. Centre for Wildlife Studies/ WCS-India, Bangalore, India.

- Karanth, K.K., Nichols, J.D., Karanth, K.U., Hines, J.E. and Christensen, N.L. 2010. The shrinking ark: patterns of large mammal extinctions in India. *Proceedings of the Royal Society B: Biological Sciences*, 277, 1971–1979.

- Karanth, K.U. 1985. Ecological status of the lion tailed macaque and its rainforest habitats in Karnataka. *Primate Conservation*, 6, 73–84.

- Karanth, K.U. 2013. *Meta-population dynamics of tigers in the Malenad-Mysore landscape of Karnataka*. Annual Report. Centre for Wildlife Studies, Bangalore, India.

- Karanth, K.U. and Kumar, N.S. 2005. *Distribution and dynamics of tiger and prey populations in Maharashtra, India*. Final Technical Report. Centre for Wildlife Studies, Bangalore, India.

- Karanth, K.U. and Sunquist, M. 2000. Behavioural correlates of predation by tiger (Panthera tigris) and leopard (Panthera pardus) in Nagarhole, India. *The Zoological Society of London*, 4, 255–265.

- Karanth, K.U. and Sunquist, M.E. 1992. Population structure, density and biomass of large herbivores in the tropical forests of Nagarahole, India. *Journal of Tropical Ecology*, 8, 21-35.

- Karanth, K.U. and Sunquist, M.E. 1995. Prey selection by tiger, leopard and dhole in tropical forests. *Journal of Animal Ecology*, 64, 439-450.

- Karanth, K.U. and Sunquist, M.E. 2000. Behavioral correlates of predation by tiger (Panthera tigris), leopard (Panthera pardus) and dhole (Cuon alpinus) in Nagarahole, India. *Journal of Zoology*, 250, 255-265.

- Karawita, H., Perera, P., Pabasara, G. and Dayawansa, N. 2018. Habitat preference and den characterization of Indian Pangolin (Manis crassicaudata) in a tropical lowland forested landscape of Sri Lanka. *PLoS One*, 13(11), e0206082.

- Katti K.V., Manjrekar N., Mukherjee S. and Sharma A.D. 1990. *A Report on Wildlife Survey in Arunachal Pradesh with Special Reference to Takin*. Wildlife Institute of India, Dehradun, India.

- Kaul, R., Williams, A.C., Rithe, K., Steinmetz, R. and Mishra, R. 2019. Bubalus arnee (wild water buffalo). *The IUCN Red List of Threatened Species 2019*, e.T3129A46364616.

- Kawanishi, K. and Sunquist, M.E. 2008. Food habits and activity patterns of the Asiatic golden cat (Catopuma temminckii) and dhole (Cuon alpinus) in a primary rainforest of Peninsular Malaysia. *Mammal Study*, 33(4), 173–177.

- Kennedy, C.M., Oakleaf, J.R., Theobald, D.M., Baurch-Murdo, S. and Kiesecker, J. 2019. Managing the middle: A shift in conservation priorities based on the global human modification gradient. *Global Change Biology*, 25(3), 811-826.

- Khan, M. 2015. First confirmed record of marbled cat in Bangladesh. *Cat News*, 62, 17.

- Khan, M.M.H. 2008. *Protected areas of Bangladesh- A guide to wildlife*. Nishorgo Program. Bangladesh Forest Department, Dhaka, Bangladesh.

- Khandal, D., Dhar, I. and Reddy, G.V. 2020. Historical and current extent of occurrence of the *Caracal Caracal*

caracal (Schreber, 1776) (Mammalia: Carnivora: Felidae) in India. *Journal of Threatened Taxa*, 12(16), 17173–17193.

- Kingdon, J. 1974. *East African Mammals, Volume 1*. University of Chicago Press, Chicago, Illinois, 446 p.
- Kinnear, N.B. 1913. The brown palm civet in North Kanara. *Journal of the Bombay Natural History Society*, 22, 390.
- Kitahara, E., Isagi, Y., Ishibashi, Y. and Saitoh, T. 2000. Polymorphic microsatellite DNA markers in the Asiatic black bear Ursus thibetanus. *Molecular Ecology*, 9(10), 1661-1662.
- Kitchener A.C., Beaumont M.A. and Richardson D. 2006. Geographical variation in the clouded leopard, Neofelis nebulosa, reveals two species. *Current Biology*, 16, 2377–2383.
- Kitchener, A. 1991. *Natural history of wild cats*. Comstock Publishing Associates, Ithaca, New York, xxi+280 p.
- Kittle, A.M. and Watson, A.C. 2004. Rusty-spotted cat in Sri Lanka: observations of an arid zone population. *Cat News*, 40, 17-19.
- Koju, N.P., Bashyal, B., Pandey, B.P., Thami, S., Dhamala, M.K. and Shah, S.N. 2020. New record on Asiatic Golden Cat Catopuma temminckii Vigors and Horsfield, 1827 (Mammalia: Carnivora: Felidae): photographic evidence of its westernmost distribution in Gaurishankar Conservation Area, Nepal. *Journal of Threatened Taxa*, 12, 15256–15261.
- Kok, O.B. and Nel, J.A.J. 2004. Convergence and divergence in prey of sympatric canids and felids: opportunism or phylogenetic constraint? *Biological Journal of the Linnean Society*, 83, 527-538.
- Kolipaka, S. 2006. Fishing Cat on India's east coast. *Cat News*, 44, 22.
- Kolipaka, S.S. 2011. *Caracals in India. The forgotten cat*. IBD, Dehradun, 84 p.
- Kolipakam, V., Singh, S., Pant, B., Qureshi, Q. and Jhala, Y.V. 2019. Genetic structure of tigers (Panthera tigris tigris) in India and its implications for conservation. *Global Ecology and Conservation*, 20, e00710.
- Krasinski, Z.A. 1978. Dynamics and structure of the European bison population in the Bialowieza Primeval Forest. *Acta Theriologica*, 23, 3-48.
- Krishna, Y.C. and Karnad, D. 2010. New records of the Nilgiri Marten *Martes gwatkinsii* in Western Ghats, India. *Small Carnivore Conservation*, 43, 23–27.
- Krishnakumar, B.M., Nagarajan, R. and Selvan, K.M. 2020. Living with leopard Panthera pardus fusca (Mammalia: Carnivora: Felidae): livestock depredation and community perception in Kalakkad-Mundanthurai Tiger Reserve, southern Western Ghats. *Journal of Threatened Taxa*, 12(10), 16210–16218.
- Krishnakumar, H. and Balakrishnan, M. 2003. Feeding ecology of the Common Palm Civet Paradoxurus hermaphroditus (Pallas) in semi-urban habitats in Trivandrum, India. *Small Carnivore Conservation*, 28, 10-11.
- Krishnan, M. 1972. An ecological survey of the large mammals of peninsular India. *The Journal of the Bombay Natural History Society*, 69, 47-49.
- Krishnan, M. 1972. An ecological survey of the large mammals of Peninsular India. *Journal of the Bombay Natural History Society*, 69, 297-315.
- Krishnan, M. 1972. An ecological survey of the larger mammals of peninsular India. *Journal of the Bombay Natural History Society*, 69, 42-47.
- Krithivasan, R., Athreya V.R., and Odden, M. 2009. *Human-wolf conflict in human dominated landscapes of Ahmednagar District, Maharashtra, India and possible mitigation measures*. Submitted to the Rufford Small Grants Foundation.
- Krofel, M., Giannatos, G., Ćirovič, D., Stoyanov, S. and Newsome, T. 2017. Golden jackal expansion in Europe: a case of mesopredator release triggered by continent-wide wolf persecution? *Hystrix, the Italian Journal of Mammalogy*, 28(1), 9-15.
- Kruuk, H. 1976. Feeding and social behaviour of the striped hyaena (Hyaena vulgaris Desmarest). *African Journal of Ecology*, 14, 91-111.
- Kshettry, A., Vaidyanathan, S. and Athreya, V. 2017. Leopard in a tea-cup: A study of leopard habitat-use and human-leopard interactions in north-eastern India. *PLoS One*, 12(5), e0177013.

- Kshettry, A., Vaidyanathan, S. and Athreya, V. 2018. Diet selection of leopards (Panthera pardus) in a human-use landscape in north-eastern India. *Tropical Conservation Science*, 11, 1-9.

- Kumar S. and Rahmani A. 1997. Status of Indian gray wolf *Canis lupus pallipes* and its conservation in marginal areas of Solapur district, Maharashtra. *Journal of the Bombay Natural History Society*, 94, 466–472.

- Kumar, M. A., Mudappa, D. and Raman, T. R. S. 2010. Asian elephant *Elephas maximus* habitat use and ranging in fragmented rainforest and plantations in the Anamalai Hills, India. *Tropical Conservation Science*, 3 (2), 143-158.

- Kumar, S. 2012. *Fauna of protected areas of Rajasthan and Gujarat.* Zoological Society of India, Kolkata, India 14 p.

- Kumar, S. and Rahmani, A. 2000. Livestock depredation by wolves in the Great Indian Bustard Sanctuary, Nannaj (Maharashtra), India. *Journal of the Bombay Natural History Society*, 97, 340–348.

- Kumar, S., 1998. *Ecology and behavior of Indian grey wolf (Canis lupus pallipes Sykes, 1831) in the Deccan grassland of Solapur, Maharashtra.* Ph.D. thesis, Aligarh Muslim University, India, 215 p.

- Kumar, U., Awasthi, N., Qureshi, Q. and Jhala, Y. 2019. Do conservation strategies that increase tiger populations have consequences for other wild carnivores like leopards? *Scientific Reports*, 9, 14673.

- Kumara, H.N. and Singh, M. 2005. The occurrence of Rusty-spotted Cat *Prinalurus rubiginosa* (Geoffroy) in Nugu Wildlife Sanctuary, Karnataka. Journal of the Bombay Natural History Society, 102(3), 336–337.

- Kumara, H.N. and Singh, M. 2007. Small carnivores of Karnataka: Distribution and sight records. *Journal of the Bombay Natural History Society*, 104, 155– 162.

- Kumara, H.N., Ananda Kumar, M., Sharma, A.K., Sushma, H.S., Singh, M. and Singh, M. 2004. Diversity and management of wild mammals in tea gardens in the rainforest regions of the Western Ghats, India: A case study from a tea estate in the Anaimalai Hills. *Current Science*, 87(9), 1282-1287.

- Kumaraguru, A. 2006. *Studies on the influence of vegetation types and prey composition on the feeding ecology of tiger, leopard and wild dog in Indira Gandhi Wildlife Sanctuary and National Park, Tamil Nadu, India.* Ph.D. thesis, Bharathidasan University, Tiruchirappalli.

- Kurup, D.N. and Joseph, G.K. 2001. Certain observations on the behaviour of the Nilgiri Marten *(Martes gwatkinsii)* in Periyar Tiger Reserve, Kerala, India. *Small Carnivore Conservation*, 25, 1-2.

- Kushwaha, H.P. 1986. *Comparison of census data for wild buffalo and domestic livestocks (buffalo and cow) in Koshi Tappu Wildlife Reserve.* Unpublished project report, Institute of Forestry, Tribhuvan University, Nepal.

- Lahiri-Choudhury, D.K. 1992. Musth in Indian elephant lore. In Shoshani, J. (Ed.). *Elephants: majestic creatures of the wild*, (pp 82-84). Rodale Press, Emmaus.

- Lahkar, B.P., Talukdar, B.K. and Sarma, P. 2011. Invasive species in grassland habitat: an ecological threat to the greater one-horned rhino (Rhinoceros unicornis). *Pachyderm*, 49, 33-39.

- Lalthanpuia, Sarmah, A., Borah, J. and Borthakur, U. 2012. *Brief report on camera trapping exercise in Dampa Tiger Reserve, Mizoram.* Technical report by WWF-India.

- Lama, S.T., Ross, J.G., Bista, D., Sherpa, A.P., Regmi, G.R., Suwal, M.K., Sherpa, P., Weerman, J., Lama, S.S., Thapa, M., Poudyal, L.P. and Paterson, A.M. 2019. First photographic record of marbled cat Pardofelis marmorata Martin, 1837 (Mammalia, Carnivora, Felidae) in Nepal. *Nature Conservation*, 32, 19–34.

- Lariviére, S. and Jennings, A.P. 2009. Family Mustelidae. In D.E. Wilson and R.A. Mittermeier (Eds.). *Handbook of the Mammals of the World. Vol. I – Carnivores*, (pp. 564-658). Lynx Edicions, Barcelona.

- Lau, M.W.N., Fellowes, J.R. and Chan, B.P.L. 2010. Carnivores (Mammalia: Carnivora) in South China: a status review with notes on the commercial trade. *Mammal Review*, 42, 247–292.

- Laurie, A. 1982. Behavioural ecology of the Greater one-horned rhinoceros (Rhinoceros unicornis). *Journal of Zoology*, 196(3), 307-341.

- Laurie, A. and Seidensticker, J. 1977. Behavioural ecology of the sloth bear (Melursus ursinus). *Journal of Zoology*, 182, 187-204.

- Leader-Williams, N. 2013. Fate riding on their horns—and genes? *Oryx*, 47(3), 311-312.

- Leakey, L., Milledge, S., Leakey, S., Edung, J., Haynes, P., Kiptoo, D. and McGeorge, A. 1999. Diet of striped hyaena in northern Kenya. *African Journal of Ecology*, 37, 314-326.
- Leimgruber, P., Gagnon, J. B., Wemmer, C. M., Kelly, D. S., Songer, M. A. and Selig, E. R. 2003. Fragmentation of Asia's remaining wildlands: implications for Asian elephant conservation. *Animal Conservation*, 6, 347–359.
- Lekagul, B. and McNeely, J.A. 1977. *Mammals of Thailand. 1st edition.* Kurusapha Ladprao Press, Bangkok, Thailand.
- Lim, B.L. 2002. Distribution and food-habits of the Asiatic golden cat (Catopuma temminckii) in Peninsular Malaysia. *Journal of Wildlife and Parks*, 20, 43–48.
- Lim, N.T.L. 2007. *Autecology of the Sunda Pangolin (Manis javanica) in Singapore.* M.Sc. Thesis, National University of Singapore, Singapore.
- Lim, N.T.L. and Ng, P.K.L. 2008. Home range, activity cycle and natal den usage of a female Sunda pangolin Manis javanica (Mammalia: Pholidota) in Singapore. *Endangered Species Research, 4, 233–240.*
- Liu, Y.C., Sun, X., Driscoll, C., Miquelle, D.G., Xu, X., Martelli, P. and Luo, S.J. 2018. Genome-wide evolutionary analysis of natural history and adaptation in the world's tigers. *Current Biology*, 28(23), 3840-3849.
- Lokhande, A.S. and Bajaru, S.B. 2013. First record of melanistic Indian wolf Canis lupus pallipes from the Indian subcontinent. *Journal of the Bombay Natural History Society*, 110(3), 220-221.
- Longchar, S. 2013. *Study on the trends of bushmeat consumption and traditional hunting on wild fauna by indigenous community living near protected area in Nagaland.* M.Sc. Thesis, Saurashtra University, India.
- Low, C.H.S. 2011. Observations of civets, linsangs, mongooses and non-lutrine mustelids from Peninsular Malaysia. *Small Carnivore Conservation*, 45, 8–13.
- Lydekker, R. 1903. The Burmese gaur, or pyoung. *Zoologist*, 7, 264-266.
- Lydekker, R. 1907. *The Game Animals of India, Burma, Malaya and Tibet.* Rowland Ward, London, UK.
- Lydekker, R. 1924. *The Game Animals of India, Burma, Malaya and Tibet.* Rowland Ward, London, UK.
- Lynam, A.J., Jenks, K.E., Tantipisanuh, N., Chutipong, W., Ngoprasert, D., Gale, G.A., Steinmetz, R., Sukmasuang, R., Bhumpakphan, N., Grassman, L.I. Jr., Cutter, P., Kitamura, S., Reed, D.H., Baker, M.C., McShea, W., Songsasen, N. and Leimgruber, P. 2013. Terrestrial activity patterns of wild cats from camera-trapping. *The Raffles Bulletin of Zoology*, 61, 407-415.
- Lyngdoh, S., Selvan, K.M., Gopi, G.V. and Habib, B. 2011. First photographic evidences of two rare cats from Pakke Tiger Reserve, western
- MacDonald, D.W. and Loveridge, A.J. (Eds.) 2010. *Biology and conservation of wild felids.* Oxford: Oxford University Press.
- Macdonald, D.W., Daniels, M.J., Driscoll, C.A., Kitchener, A.C. and Yamaguchi, N. 2004. *The Scottish Wildcat: analyses for conservation and an action plan.* The Wildlife Conservation Research Unit, Oxford, UK.
- Madhusudan, M.D. 1995. Sighting of the Nilgiri marten (Martes gwatkinsi) at Eravikulam National Park, Kerala, India. *Small Carnivore Conservation*, 13, 6–7.
- Mahanti, P. and Kumar, S. 2018. Human wildlife conflict: a case study in Kerala, India. *Journal of Biodiversity and Conservation*, 1(2), 42-52.
- Mahmood, T., Challender, D., Khatiwada, A., Andleeb, S., Perera, P., Trageser, S., Ghose, A. and Mohapatra, R. 2019. Manis crassicaudata. *The IUCN Red List of Threatened Species 2019*, e.T12761A123583998.
- Mahmood, T., Irshad, N. and Hussain, R. 2014. Habitat preference and population estimates of Indian Pangolin (Manis crassicaudata) in District Chakwal of Potohar Plateau, Pakistan. *Russian Journal of Ecology*, 45(1), 70–75.
- Mahmood, T., Irshad, N., Hussain, R., Akrim, F., Hussain, I., Anwar, M., Rais, M. and Nadeem, M.S. 2015. Breeding habits of the Indian pangolin *(Manis crassicaudata)* in Potohar Plateau, Pakistan. *Mammalia*, 80(2), 231-234.
- Mahmood, T., Jabeen, K., Hussain, I. and Kayani, A.R. 2013. Plant species association, burrow characteristics and the diet of the Indian pangolin, *Manis crassicaudata*, in the Potohar plateau, Pakistan. *Pakistan Journal of Zoology*,

45(6), 1533-1539.

- Majgaonkar, I., Vaidyanathan, S., Srivatsha, A., Shivakumar, S., Limaye, S. and Athreya, V. 2019. Land-sharing potential of large carnivores in human-modified landscapes of western India. *Conservation Science and Practice*, 2019, 1:e34.

- Majumder, A., Sankar, K., Qureshi, Q. and Basu, S. 2011. Food habits and temporal activity patterns of the golden jackal Canis aureus and the Jungle Cat Felis chaus in Pench Tiger Reserve, Madhya Pradesh, India. *Journal of Threatened Taxa*, 3(11), 2221–2225.

- Malla, G. and Sivakumar, K. 2014. The Coringa mangroves – realm of the fishing cat. *Sanctuary Asia*, XXXIV(6), 60-65.

- Mallon, D. and Budd, K. 2011. *Regional Red List Status of Carnivores in the Arabian Peninsula.* IUCN and Environment and Protected Areas Authority, Cambridge, UK; Gland, Switzerland; and Sharjah, UAE.

- Mandal, D.K. 2018. *Ecology of striped hyena (Hyaena hyaena) in Sariska Tiger Reserve, Rajasthan.* Ph.D. thesis, Saurashtra University, India, 109 p.

- Mani, M.S. (Ed.) 1974. *Ecology and biogeography in India.* Springer, 773 p.

- Mar, K.U. 2002. The studbook of timber elephants of Myanmar with special reference to survivorship analysis. In Baker, I. and Kashio, M. (Eds.). *Giants on our hands: Proceedings of the International Workshop on the domesticated Asian elephant* (pp. 195-211). FAO, Bangkok, Thailand.

- Mardaraj, P.C. 2014. A sloth bear rescued from retaliation killing in eastern India. *International Bear News*, 23(2), 16-17.

- Marker, L.L. and Dickman, A.J. 2005. Notes on the spatial ecology of caracals *(Felis caracal)*, with particular reference to Namibian farmlands. *African Journal of Ecology*, 43, 73-76.

- Maroju, P.A., Yadav, S., Kolipakam, V., Singh, S., Qureshi, Q. and Jhala, Y. 2016. Schrodinger's scat: a critical review of the currently available tiger (Panthera tigris) and leopard (Panthera pardus) specific primers in India, and a novel leopard specific primer. *BMC Genetics*, 17(1), 1-6.

- Mason, I.L. 1974. Species types and breeds. In Cockrill, W.R. (Ed.). *The husbandry and health of the domestic buffalo*, (pp. 1–47). Food and Agriculture Organization of the United Nations, Rome, Italy.

- Massicot, P. 2004. *Animal info – wild water buffalo.* Available at http://www.animalinfo.org/species/artiperi/bubaarne.htm

- Mathai, J., Hon, J., Juat, N., Peter, A. and Gumal, M. 2010. Small carnivores in a logging concession in the Upper Baram, Sarawak, Borneo. *Small Carnivore Conservation*, 42, 1–9.

- Mathur, P.K., Malik, P.K. and Muley, P.D. 1995. *Ecology and population genetics of Asian wild buffalo (Buablus bubalis L.).* Project Report, Wildlife Institute of India, Dehradun, India, 54 p.

- Mathur, P.K., Malik, P.K. and Muley, P.D. 2004. Asian wild buffalo. In Sankar, K. and Goyal, S.P. (Eds.). *Ungulates of India*, (pp. 1-16). Envis Bulletin: Wildlife and Protected Areas, Wildlife Institute of India, Dehradun, India.

- Maurya, K.K., Habib, B. and Kumar, S. 2011. Food Habits of Indian wolf (Canis lupus pallipes) in Deccan Plateau of Maharashtra, India. *World Journal of Zoology*, 6 (3), 318-322.

- Max-Planck-Gesellschaft. 2002. *"Mammals" (On-line). Longevity records: life spans of mammals, birds, amphibians, reptiles, and fish.* Available at http://www.demogr.mpg.de/longevityrecords/0203.htm.

- McCarthy, J., Dahal, S., Dhendup, T., Gray, T.N.E., Mukherjee, S., Rahman, H. and Wilcox, D. 2015. Catopuma temminckii. *The IUCN Red List of Threatened Species 2015*, e. T4038A50651004.

- McCarthy, J.L. 2013. *Conservation and ecology of four sympatric felid species in Bukit Barisan Selatan National Park, Sumatra, Indonesia.* University of Massachusetts, Amherst.

- McKay, G. M. 1973. Behavior and ecology of the Asiatic elephant in Southeastern Ceylon. *Smithsonian Contributions to Zoology*, 125, 1-113.

- McTaggart-Cowan, I. 1972. The status and conservation of bears *(Ursidae)* of the world-1970. *International Conference on Bear Research and Management*, 2, 342-367.

- Mech, L.D. 1970. *The wolf: ecology and behavior of an endangered species.* Minneapolis: University of Minnesota Press.

- Mech, L.D. 1974. Canis lupus. *Mammalian Species*, 37, 1-6.

- Mech, L.D. and Boitani, L. 2010. Canis lupus. *The IUCN Red List of Threatened Species*, e.T3746A10049204.

- Melisch, R., Asmoro, P. B., Lubis, I. R. and Kusumawardhani, L. 1996. Distribution and status of the Fishing Cat (Prionailurus viverrinus rhizophoreus Sody, 1936) in West Java, Indonesia (Mammalia: Carnivora: Felidae). *Faunistische Abhandlungen, Staatliches Museum für Tierkunde*, 20(17), 311-319.

- Mendelssohn H. 1982. Wolves in Israel. In Harrington, F.H. and Paquet, P.C. (Eds.). *Wolves of the world*, (pp. 173-195). Noyes Publications, Park Ridge, New Jersey.

- Menon, V. 1996. *Under siege: poaching and protection of greater one-horned rhinoceros in India.* Traffic India, WWF India, New Delhi.

- Menon, V. 2014. *Indian mammals: a field guide.* Hachette Book Publishing India Pvt. Ltd., Gurgaon, India, 528 p.

- Menon, V. and Daniel, J.C. 2003. *Field guide to Indian mammals.* Dorling Kindersley, India in association with Penguin Book, India.

- Menon, V. and Tiwari, S.K. 2019. Population status of Asian elephants Elephas maximus and key threats. *International Zoo Yearbook*, 53, 1-14.

- Menon, V., Tiwari, S.K., Ramkumar, K., Kyarong, S., Ganguly, U. and Sukumar, R. 2017. *Right of Passage: Elephant corridors of India, 2nd edition.* Wildlife Trust of India, New Delhi.

- Miller, C. 2011. "Prionailurus bengalensis" (On-line). *Animal Diversity Web* at https://animaldiversity.org/accounts/Prionailurus_bengalensis/

- Milliken, T. 2005. *Urgent need for ASEAN to improve elephant ivory trade monitoring performance.* Available at: http://www.traffic.org/news/elephant_ivory.html.

- Mills, M. and Hofer, H. 1998. *Hyaenas, status survey and action plan.* IUCN/SSC Hyaena Specialist Group, Gland, Switzerland.

- Mishra R.P. and Gaur, A. 2019. *Conservation status of Asiatic Wild Buffalo (Bubalus arnee) in Chhattisgarh revealed through genetic study.* Technical Report of WTI and CSIR-CCMB, 17p.

- Mishra, C., Madhusudan, M.D. and Datta, A. 2006. Mammals of the high altitudes of western Arunachal Pradesh, eastern Himalaya: an assessment of threats and conservation needs. *Oryx*, 40, 29-35.

- Mishra, R. 2016. Conservation status of the Fishing Cat in Chitwan National Park, Nepal. In Appel, A. and Duckworth, J.W. (Eds.). P*roceedings of the First International Fishing Cat Conservation Symposium, 25–29 November 2015, Nepal* (pp. 25-26). Fishing Cat Working Group, Bad Marienberg, Germany and Saltford, Bristol, United Kingdom.

- Misra, M. and Hanfee, N. 2000. Pangolin distribution and trade in East and Northeast India. TRAFFIC *Disparches*, 14, 4-5.

- Miththapala, S. 2006. The ecology of the wild cats of Sri Lanka. In Bambaradeniya, C.N.B. (Ed.). *Fauna of Sri Lanka: Status of taxonomy, research and conservation* (pp. 235-256). IUCN and Ministry of Environment, Government of Sri Lanka.

- Mivart, St. G. 1890. *Dogs, jackals, wolves and foxes: a monograph of the Canidae.* R.H. Porter, London.

- Modi, S., Mondol, S., Ghaskadbi, P., Hussain, Z., Nigam, P., and Habib, B. 2018. Noninvasive DNA-based species and sex identification of Asiatic wild dog (Cuon alpinus). *Journal of Genetics*, 97(5), 1457-1461.

- Moehlman, P.D. 1989. Intraspecific variation in canid social systems. In Gittleman, J.L. (Ed.). *Carnivore behaviour, ecology and evolution*, (pp. 143-163). Chapman and Hall, London.

- Moehlman, P.D. and Jhala, Y.V. 2013. Canis aureus golden jackal (Asiatic jackal, common jackal). In J. Kingdom, D. Happold, T. Butynski, M. Hoffman, M. Happold, and J. Kalina (Eds.). *Mammals of Africa, volume 5* (pp. 35-38). Bloomsbury Publishing, London, United Kingdom.

- Mohamed, A., Samejima, H. and Wilting, A. 2009. Records of five Bornean cat species from Deramakot Forest

Reserve in Sabah, Malaysia. *Cat News*, 51, 12-15.

- Mohamed, A., Sollmann, R., Bernard, H., Ambu, L.N., Lagan, P., Mannan, S., Hofer, H. and Wilting, A. 2013. Density and habitat use of the leopard cat (Prionailurus bengalensis) in 3 commercial forest reserves in Sabah, Malaysian Borneo. *Journal of Mammalogy*, 94, 82-89.
- Mohapatra, R.K., Panda, S., Acharjyo, L.N., Nair, M. V. and Challender, D.W.S. 2015. A note on the illegal trade and use of pangolin body parts in India. *TRAFFIC Bulletin*, 27(1), 33-40.
- Mondal, K. 2011. *Ecology of leopard (Panthera pardus) in Sariska Tiger Reserve, Rajasthan.* Ph.D. thesis, Saurashtra University, India, 200 p.
- Mondal, K., Gupta, S., Qureshi, Q. and Sankar, K. 2011. Prey selection and food habits of leopard (Panthera pardus fusca) in Sariska Tiger Reserve, Rajasthan, India. *Mammalia*, 75, 201–205.
- Mondal, K., Sankar, K., Qureshi, Q., Gupta, S. and Chourasia, P. 2012. Estimation of population and survivorship of leopard through photographic capture-recapture sampling in west India. *World Journal of Zoology*, 7, 30–39.
- Moolman, L.C. 1984. 'n vergelyking van die voedingsgewoontes van die rooikat Felis caracal binne en buite die Bergkwagga Nasionale Park. *Koedoe*, 27, 121-129.
- Moolman, L.C. 1986. Aspects of the ecology and behavior of the caracal *Felis caracal* Schreber 1776 in the Mountain Zebra National Park and on the surrounding farms. M.Sc. thesis, University of Pretoria, Pretoria.
- Moqanaki, E.M., Farhadinia, M.S., Tourani, M. and Akbari, H. 2016. The Caracal in Iran – current state of knowledge and priorities for conservation. *Cat News Special Issue, 10, 27–32.*
- Moritz, C. 2002. Strategies to protect biological diversity and the evolutionary processes that sustain it. *Systematic Biology*, 51(2), 238-254.
- Morris, R.C. 1942. Widespread rabies among wild dogs on the Billigiri Rangan Hills (S. India). *Journal of the Bombay Natural History Society*, 43, 100.
- Mousavi, M. 2010. Cause of mortality in large mammals inside Iran network of reserves. In: *Poster presented at: Proceedings of 16th National and 4th International Conference of Biology*, 14.
- Mudappa, D. 1998. Use of camera-traps to survey small carnivores in the tropical rainforest of Kalakad-Mundanthurai Tiger Reserve, India. *Small Carnivore Conservation*, 18, 9-11.
- Mudappa, D. 1999. Lesser-known carnivores of the Western Ghats. In S.A. Hussain (Ed.), ENVIS Bulletin Vol 2(2): *mustelids, viverrids and herpestids of India*, (pp. 65–70). Wildlife Institute of India, Dehradun, India.
- Mudappa, D. 2001. *Ecology of the brown palm civet Paradoxurus jerdoni in the tropical rainforests of the Western Ghats, India.* Ph.D. thesis, Bharathiar University, Coimbatore, India.
- Mudappa, D. 2002. Observations of small carnivores in the Kalakad-Mundanthurai TigerReserve, Western Ghats, India. *Small Carnivore Conservation*, 25, 4–5.
- Mudappa, D. 2006. Day-bed choice by the brown palm civet (Paradoxurus jerdoni) in the Western Ghats, India. *Mammalian Biology*, 71, 238-243.
- Mudappa, D. 2013. Herpestids, viverrids and mustelids. In A.J.T. Johnsingh and N. Manjrekar (eds.). *Mammals of South Asia, Vol. I*, (pp. 471-498). University Press, Hyderabad, India.
- Mudappa, D., Choudhury, A. and Punjabi, G.A. 2016. Paradoxurus jerdoni. *The IUCN Red List of Threatened Species 2016*, e.T16104A45201757.
- Mudappa, D., Jathana, D. and Raman, T.R.S. 2015. Martes gwatkinsii. *The IUCN Red List of Threatened Species 2015*: e.T12847A86161239.
- Mudappa, D., Kumar, A. and Chellam, R. 2010. Diet and fruit choice of the Brown Palm Civet Paradoxurus jerdoni, a viverrid endemic to the Western Ghats rainforest, India. *Tropical Conservation Science*, 3, 282–300.
- Mudappa, D., Noon, B. R., Kumar, A. and Chellam, R. 2007. Responses of small carnivores to rainforest fragmentation in the southern Western Ghats, India. *Small Carnivore Conservation*, 36, 18-26.
- Mukherjee, S. 1989. *Ecological separation of four sympatric carnivores in Keoladeo Ghana National Park, Bharatpur, Rajasthan, India.* M.Sc. thesis, Wildlife Institute of India.

- Mukherjee S. 1998. Cats some large, many small. In S. Mukherjee (Ed.). *Wildlife Institute of India ENVIS (Wildlife and Protected Areas) Bulletin*, (pp 5-13). Wildlife Institute of India, Dehradun.

- Mukherjee, S. 2008. Field Mouser. *Natural History*, 117 (7), 48.

- Mukherjee, S. 2013. Small Cats. In A.J.T. Johnsingh and N. Manjerkar (Eds.). *Mammals of South Asia*, *Vol I*, (pp. 531-540). University Press, Hyderabad, India.

- Mukherjee, S., Adhya, T., Thatte, P. and Ramakrishnan, U. 2012. Survey of the fishing cat Prionailurus viverrinus Bennett, 1833 (Carnivora: Felidae) and some aspects impacting its conservation in India. *Journal of Threatened Taxa*, 4(14), 3355–3361.

- Mukherjee, S., Appel, A., Duckworth, J.W., Sanderson, J., Dahal, S., Willcox, D.H.A., Herranz Muñoz, V., Malla, G., Ratnayaka, A., Kantimahanti, M., Thudugala, A. and Thaung R. and Rahman, H. 2016. Prionailurus viverrinus. *The IUCN Red List of Threatened Species 2016*, e.T18150A50662615.

- Mukherjee, S., Goyal, S., Johnsingh, A.J.T. and Leite Pitman, M. 2004. The importance of rodents in the diet of jungle cat (Felis chaus), caracal (Caracal caracal) and golden jackal (Canis aureus) in Sariska Tiger Reserve, Rajasthan, India. *Journal of Zoology*, 262, 405-411.

- Mukherjee, S., Krishnan, A., Tamma, K., Home, C., Navya, R., Joseph, S., Das, A. and Ramakrishnan, U. 2010. Ecology Driving Genetic Variation: A Comparative Phylogeography of Jungle Cat *(Felis chaus)* and Leopard Cat *(Prionailurus bengalensis)* in India. *PloS One*, 5(10), e13724.

- Mukherjee, S., Singh, P., Silva, A.P., Ri, C., Kakati, K., Borah, B., Tapi, T., Kadur, S., Choudhary, P., Srikant, S., Nadig, S., Navya, R., Björklund, M. and Ramakrishnan, U. 2019. Activity patterns of the small and medium felid (Mammalia: Carnivora: Felidae) guild in northeastern India. *Journal of Threatened Taxa*, 11, 13432–13447.

- Murphy, S.T., Subedi, N., Jnawali, S.R., Lamichhane, B.R.., Upadhyay, G.P., Kock, R., and Amin, R. 2013. Invasive mikania in Chitwan National Park, Nepal: the threat to the greater one-horned rhinoceros, Rhinoceros unicornis, and factors driving the invasion. *Oryx*, 47(3), 361-368.

- Myers, N., Mittermeier, R.A., Mittermeier, C.G., Fonesca, G.A.B. and Kents. J. 2000. Biodiversity hotspots for conservation priorities. *Nature*, 403, 853-858.

- Nadig, S., Navya, R. and Silva, A.P. 2016. Small cats in the Himalayan foothills: the Asian Golden Cat of Nongkhyllem Wildlife Sanctuary, India. *Small Wild Cat Conservation News*, 2, 23.

- Nagendra, H., Mondal, P., Adhikari, S. and Southworth, J. 2013. Peopled Parks: Forest change in India's protected landscapes. In E. Brondizio, and E.F. Moran (Eds.). *Human-Environment Interactions*, (pp. 113-139). Dordrecht, Netherlands: Springer.

- Naha, D., Sathyakumar, S. and Rawat, G.S. 2018. Understanding drivers of human-leopard conflicts in the Indian Himalayan region: spatio-temporal patterns of conflicts and perception of local communities towards conserving large carnivores. *PLoS One*, 13, e0204528.

- Nakashima, Y., and Sukor, J.A. 2010. Importance of common palm civets (Paradoxurus hermaphroditus) as a long-distance disperser for large-seeded plants in degraded forests. *Tropics*, 18, 221–229.

- Nakashima, Y., Inoue, E., Inoue-Murayama, M. and Sukor, J.A. 2010a. Functional uniqueness of a small carnivore as seed dispersal agents: a case study of the common palm civets in the Tabin Wildlife Reserve, Sabah, Malaysia. *Oecologia*, 164, 721–730.

- Nakashima, Y., Inoue, E., Inoue-Murayama, M. and Sukor, J.A. 2010b. High potential of a disturbance-tolerant frugivore, the common palm civet Paradoxurus hermaphroditus (Viverridae), as a seed disperser for large-seeded plants. *Mammal Study*, 35, 209–215.

- Nakashima, Y., Nakabayashi, M. and Jumrafiha, A.S. 2013. Space use, habitat selection, and day-beds of the Common Palm Civet (Paradoxurus hermaphroditus) in human-modified habitats in Sabah, Borneo. *Journal of Mammalogy*, 94, 1169–1178.

- Nandini, S., Keerthipriya, P. and Vidya, T.N.C. 2018. Group size differences may mask underlying similarities in social structure: A comparison of female elephant societies. *Behavioral Ecology*, 29, 145- 159.

- Navya, R., Athreya, V., Mudappa, D. and Shankar Raman, T.R. 2014. Assessing leopard occurrence in the plantation landscape of Valparai, Anamalai Hills. *Current Science*, 107(9), 1381-1385.

- Nayak, B.K. and Patra, A.K. 2015. Food and feeding habits of Indian bison, Bos gaurus (Smith, 1827) in Kuldiha Wildlife Sanctuary, Balasore, Odisha, India and its conservation. *International Research Journal of Biological Sciences*, 4(5), 73-79.

- Nayak, S., Shah, S. and Borah, J. 2017. First record of rusty-spotted cat *Prionailurus rubiginosus* (Mammalia: Carnivora: Felidae) from Ramgarh-Vishdhari Wildlife Sanctuary in semi-arid landscape of Rajasthan, India. Journal of Threatened Taxa, 9(1), 9761–9763.

- Nelson, J. 2013. "Paradoxurus hermaphroditus" (On-line). *Animal Diversity Web*. Available at https://animaldiversity.org/accounts/Paradoxurus_hermaphroditus/.

- Nijhawan, S., Mitapo, I., Pulu, J., Carbone, C. and Rowcliffe, J.M. 2019. Does polymorphism make the Asiatic golden cat the most adaptable predator in the Eastern Himalayas? *Ecology*, 100(10), e02768.

- Nijman, V. 2015. Pangolin seizures data reported in the Indonesian media. *Traffic Bulletin*, 27, 44-46.

- Nijman, V. and Shepherd, C.R. 2015. Trade-in tigers and other wild cats in Mong La and Tachilek, Myanmar – A tale of two border towns. *Biological Conservation*, 182, 1-7.

- Nijman, V., Spaan, D., Rode-Margono, E.J., Roberts, P.D., Wirdateti and Nekaris, K.A.I. 2014. Trade in common palm civet Paradoxurus hermaphroditus in Javan and Balinese markets, Indonesia. *Small Carnivore Conservation*, 51, 11–17.

- Nikhil, S. and Nameer, P.O. 2017. Small carnivores of the montane forests of Eravikulam National Park in the Western Ghats, India. *Journal of Threatened Taxa*, 9(11), 10880–10885.

- Nowak, R. 2005. Leopard Cat. Pp. 249 in *Walker's Carnivores of the World, Vol. 1*, 1st Edition. Baltimore: John Hopkins University Press.

- Nowak, R.M. 1999. *Walker's mammals of the world*. 6th edition. Baltimore, John Hopkin's University, Baltimore, 836 p.

- Nowell, K. and Jackson, P. (Eds.). 1996. *Wild cats: status survey and conservation action plan*. Gland, Switzerland: IUCN, 382 p.

- O'Brien, S.J., Johnson, W.E., Driscoll, C.A., Dobrynin, P. and Marker, L. 2017. Conservation genetics of the cheetah: lessons learned and new opportunities. *Journal of Heredity*, 108(6), 671-677.

- Odden, M., Athreya, V., Rattan, S. and Linnell, J.D. 2014. Adaptable neighbours: movement patterns of GPS-collared leopards in human dominated landscapes in India. *PLoS One*, 9(11), e112044.

- Ognev, S.I. 1931. *Mammals of eastern Europe and northern Asia, Vol II*. Israel Programme for Scientific Translations, Jerusalem, 590 p.

- Ogurlu, I., Gundogdu, E. and Yildirim, I. 2010. Population status of jungle cat (Felis chaus) in Egirdir lake, Turkey. *Journal of Environmental Biology*, 31, 179-183.

- Olivier, R. 1978. Distribution and status of the Asian elephant. *Oryx*, 14, 379–424.

- Oswell, A. 2010. *The big cat trade in Myanmar and Thailand*. TRAFFIC Southeast Asia, Bangkok.

- Pacha, A.S., Nigam, P., Pandav, B. and Mondol, S. 2020. Sequencing and annotation of the endangered wild buffalo (Bubalus arnee) mitogenome for taxonomic and hybridization assessment. *bioRxiv*.

- Paetkau, D., Waits, L. P., Clarkson, P. L., Craighead, L., Vyse, E., Ward, R., and Strobeck, C. (1998). Variation in genetic diversity across the range of North American brown bears. *Conservation Biology*, 12(2), 418-429.

- Pal, R., Thakur, S., Arya, S., Bhattacharya, T. and Sathyakumar, S. 2020. Mammals of the Bhagirathi basin, Western Himalaya: understanding distribution along spatial gradients of habitats and disturbances. *Oryx*, DOI: 10.1017/s0030605319001352.

- Palei, H.S., Debata, S., Mohapatra, P.P. and Sahu, H.K. 2013. Livestock predation by endangered Indian wolf (Canis lupus) in Hadagarh Wildlife Sanctuary, eastern India. *Indian Forester*, 139(10), 895-898.

- Paliwal, A. and Mathur, V.B. 2012. Predicting potential distribution of Gaur (Bos gaurus) in Tadoba-Andhari Tiger Reserve, Central India. *Journal of Life Sciences*, 6: 1041-1049.

- Pande, A., Vasava, A., Solanki, R., Bipin, C.M. and Jhala, Y.V. 2013. Photographic records of the Asiatic Wildcat from two states of India. *Journal of Threatened Taxa*, 5(17), 5283–5287.

- Pandey, P., Kaspal, P. and Acharya, S. 2012. *Status and conservation of Fishing Cat Felis viverrina in and around Koshi Tappu Wildlife Reserve, Nepal.* Report submitted to Chicago Zoological Society, Chicago Board of Trade Endangered Species Fund. Himalayan Nature, Kathmandu, Nepal.

- Pant, G., Maraseni, T., Apan, A. and Allen, B.L. 2020. Climate change vulnerability of Asia's most iconic megaherbivore: greater one-horned rhinoceros (Rhinoceros unicornis). *Global Ecology and Conservation*, 23, e01180.

- Pasha, M.K.S., Sankar, K., Qureshi, Q. and Areendran, G. 2004. Indian bison or gaur. In Sankar, K. and Goyal, S.P. (Eds.). *Ungulates of India*, (pp. 91-102). Envis Bulletin: Wildlife and Protected Areas, Wildlife Institute of India, Dehradun, India.

- Patel, K. 2010. New distribution record data for Rusty-spotted Cat from Central India. *Cat News*, 53, 26–27.

- Patel, K. 2011. Preliminary survey of small cats in Eastern Gujarat, India. *Cat News*, 54, 8–11.

- Patel, K. and Jackson, P. 2005. Rusty-spotted Cat in India: New distribution data. *Cat News*, 42, 27.

- Pathak, B.J. 1990. Rusty-spotted Cat *Felis rubiginosa* Geoffroy: a new record for Gir Wildlife Sanctuary and National Park. *Journal of the Bombay Natural History Society*, 87, 445.

- Pawar, D., Nelson, H.P., Pawar, D.R. and Khanwilkar, S. 2019. Estimating leopard Panthera pardus fusca (Mammalia: Carnivora: Felidae) abundance in Kuno Wildlife Sanctuary, Madhya Pradesh, India. *Journal of Threatened Taxa*, 11, 13531–13544.

- Peacock, E.H. 1933. *A game book for Burma and adjoining territories.* H. F. and G. Witherby, London.

- Pekel, J.-F., Cottam, A., Gorelick, N. and Belward, A.S. 2016. High-resolution mapping of global surface water and its long-term changes. *Nature*, 540 (7633), 418– 422.

- Phelan, P. and Sliwa, A. 2006. Range size and den use of Gordon's wildcats in the Emirate of Sharjah, United Arab Emirates. *Cat News*, 44, 16-17.

- Phillipps, Q. and Phillipps, K. 2016. *Phillipps' Guide to the Mammals of Borneo and their Ecology: Sabah, Sarawak, Brunei, and Kalimantan.* Natural History Publications (Borneo), Kota Kinabalu, Malaysia, 400 p.

- Phillips W. W. A. 1980. *Manual of the mammals of Sri Lanka, 2nd revised edition, Part III.* Wildlife and Nature Protection Society of Sri Lanka, Colombo.

- Phillips, S.J. and Dudík, M. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography*, 31(2), 161-175.

- Phillips, S.J., Anderson, R.P., Dudík, M., Schapire, R.E. and Blair, M.E. 2017. Opening the black box: an open-source release of Maxent. *Ecography*, 40(7), 887-893.

- Phillips, S.J., Dudík, M. and Schapire, R.E. 2004. A maximum entropy approach to species distribution modeling. *Proceedings of the twenty-first international conference on machine learning*, 655-662.

- Phillips, S.J., Dudík, M., Elith, J., Graham, C.H., Lehmann, A., Leathwick, J. and Ferrier, S. 2009. Sample selection bias and presence-only distribution models: implications for background and pseudo-absence data. *Ecological Application*, 19(1), 181-197.

- Phillips, W. 1984. *Manual of the Mammals of Sri Lanka.* Colombo: Wildlife and Nature Protection Society of Sri Lanka.

- Phythian-Adams, E.G. 1949. Jungle Memories Part IV – Wild dogs and Wolves. *Journal of the Bombay Natural History Society*, 48, 645-655.

- Pillay, R., Johnsingh, A.J.T., Raghunath, R. and Madhusudan, M.D. 2011. Patterns of spatiotemporal change in large mammal distribution and abundance in the southern Western Ghats, India. *Biological Conservation*, 144, 1567–1576.

- Poche, R.M., Evans, S.J., Sultana, P., Haque, M.E, Sterner, R. and Siddique, M.A. 1987. Notes on the golden jackal (Canis aureus) in Bangladesh. *Mammalia*, 51, 259-270.

- Pocock R.I. 1932. The marbled cat (Pardofelis marmorata) and some other oriental species, with the definition of a new Genus of the Felidae. *Proceedings of Zoological Society of London*, 102, 741-766.

- Pocock, R. 1934. The races of the striped and brown hyaenas. *Proceedings of the Zoological Society of London*, 104, 799-825.

- Pocock, R.I. 1924. The external characters of the Pangolins (Manidae). *Proceedings of Zoological Society London*, 94, 707-718.

- Pocock, R.I. 1933. The black and brown bears of Europe and Asia. Part II. *Journal of the Bombay Natural History Society*, 36, 101-183.

- Pocock, R.I. 1933. The palm civets or 'Toddy cats' of the genera Paradoxurus and Paguma inhabiting British India. *Journal of the Bombay Natural History Society*, 36, 855-877.

- Pocock, R.I. 1939. *The Fauna of British India, Including Ceylon and Burma, Vol. 1.* Taylor and Francis, London, 463 p.

- Pocock, R.I. 1941. *The fauna of British India, including Ceylon and Burma. Mammalia, Vol II. Taylor* and Francis, London.

- Potapov, P., Li, X., Hernandez-Serna, A., Tyukavina, A., Hansen, M.C., Kommareddy, A., Pickens, A., Turubanova, S., Tang, H., Silva, C.E., Armston, J., Dubayah, R., Blair, J.B. and Hofton, M. 2020. Mapping and monitoring global forest canopy height through integration of GEDI and Landsat data. *Remote Sensing of Environment*, 112165.

- Prater, S.H. 1948. *The book of Indian animals. Bombay* Natural History Society, Oxford University Press, Calcutta.

- Prater, S.H. 1971. *The book of Indian animals* (3rd ed.). Bombay Natural History Society, India.

- Prater, S.H. 1980. *The book of Indian animals* (3rd edition). Bombay Natural History Society, Bombay, xxii+324 p.

- Pritchard, J. K., Stephens, M., and Donnelly, P. (2000). Inference of population structure using multilocus genotype data. *Genetics*, *155*(2), 945-959.

- Prost, S., Machado, A.P., Zumbroich, J., Preier, L., Mahtani-Williams, S., Guschanski, K., Brealey, J.C., Fernandes, C., Vercammen, P., Godsall-Bottriell, L., Bottriell, P., Dalton, D.L., Kotze, A. and Burger, P.A. 2020. Conservation genomic analyses of African and Asiatic cheetahs (Acinonyx jubatus) across their current and historic species range. *BioRxiv*, 2020.02.14.949081.

- Puri, M., Srivathsa, A., Karanth, K. K., Kumar, N. S., and Karanth, K. U. 2015. Multiscale distribution models for conserving widespread species: the case of sloth bear Melursus ursinus in India. *Diversity and Distributions*, 21(9), 1087-1100.

- Pusparini, W., Wibisono, H.T., Reddy, G.V., Tarmizi, T. and Bharata, P. 2014. Small and medium sized cats in Gunung Leuser National Park, Sumatra, Indonesia. *Cat News*, 8, 4 -9.

- Qureshi, Q., Gopal, R., Kyatham, S., Basu, S., Mitra, A. and Jhala, Y.V. 2006. *Evaluating tiger habitat at the tehsil level.* Project Tiger Directorate, Govt. of India, New Delhi and the Wildlife Institute of India, Dehradun. Technical Report TR No. 06/001, 162 p.

- Qureshi, Q., Saini, S., Basu, P., Gopal, R., Raza, R. and Jhala, Y.V. 2014. *Connecting tiger populations for long-term conservation.* Technical Report, National Tiger Conservation Authority and Wildlife Institute of India, Dehradun, TR 2014-02.

- R Development Core Team 2010. R: *A language and environment for statistical computing. Computer programme.* Retrieved from http://www.R-project.org/.

- Rabinowitz, A.R. 1990. Notes on the behaviour and movements of leopard cats, Felis bengalensis, in a dry tropical forest mosaic in Thailand. *Biotropica*, 22, 397–403.

- Rabinowitz, A.R. 1991. Behaviour and movements of sympatric civet species in Huai Kha Khaeng Wildlife Sanctuary, Thailand. *Journal of Zoology*, 223, 281–298.

- Rahalkar, K. 2008. *Attitudes of local people to conflict with leopards (Panthera pardus) in an agricultural landscape in Maharashtra, India.* M.Sc. thesis, Centre for Wildlife Studies and National Centre for Biological Sciences, University of Agricultural Sciences, GKVK Campus, Bangalore, India, vi + 37 p.

- Rajamani, N., Mudappa, D. and Van Rompaey, H. 2002. Distribution and status of the brown palm civet in the Western Ghats, South India. *Small Carnivore Conservation*, 27, 6-11.

- Rajaratnam, R., Sunquist, M., Rajaratnam, L. and Ambu, L. 2007. Diet and habitat selection of the leopard cat (Prionailurus bengalensis borneoensis) in an agricultural landscape in Sabah, Malaysian Borneo. *Journal of Tropical Ecology*, 23, 209–217.

- Rajpurohit, K.S. 1999. Child lifting wolves in Hazaribagh, India. *Ambio*, 28, 162–166.

- Rajpurohit, K.S. and Krausman, P.R. 2000. Human-sloth bear conflicts in Madhya Pradesh, India. *Wildlife Society Bulletin*, 28, 393-399.

- Ramachandran, K.K. 1990. Recent evidence of the Brown Palm Civet, Paradoxurus jerdoni, from Silent Valley National Park, India. *Mustelid and Viverrid Conservation*, 3, 15.

- Ramesh, T., Kalle, R. and Downs, C.T. 2017. Space use in a South African agriculture landscape by the caracal *(Caracal caracal). European Journal of Wildlife Research*, 63, 1–11.

- Ramesh, T., Kalle, R., Sankar, K. and Qureshi, Q. 2012. Spatio-temporal partitioning among large carnivores in relation to major prey species in Western Ghats. *Journal of Zoology*, 287, 269-275.

- Ramesh, T., Snehalatha, V., Sankar, K. and Qureshi, Q. 2009. Food habits and prey selection of tiger and leopard in Mudumalai Tiger Reserve, Tamil Nadu, India. *Journal of Scientific Transactions in Environment and Technovation*, 2, 170-181.

- Ramesh, T., Sridharan, N., Sankar, K., Qureshi, Q., Selvan, K.M., Gokulakannan, N., Francis, P., Narasimmarajan, K., Jhala, Y.V. and Gopal, R. 2012. Status of large carnivores and their prey in tropical rainforests of South-western Ghats, India. *Tropical Ecology*, 53(2), 137-148.

- Ranjitsinh, M.K. 1997. *Beyond the tiger: portraits of Asian wildlife.* Birajbasi Printers, New Delhi.

- Ranjitsinh, M.K., Chauhan, S.K.S., Banubakode, S.B., Sivakumar, K., Akhtar, A., Patil, V. and Verma, S.C. 2000. *Status and conservation of the wild buffalo (Bubalus bubalis) in peninsular India.* Unpublished report, Madhya Pradesh Forest Department, WII, BNHS, BSCN, 33 p.

- Rao, K.T., Sudhakar, D., Vasudevarao, V., Nagulu, V. and Srinivasulu, C. 1999. Rusty spotted cat *Prinalurus rubiginosa*: A new record for Nagarjunsagar Srisailam Tiger Reserve, Andhra Pradesh. Journal of the Bombay Natural History Society, 96, 463–464.

- Ratnayaka, A. 2016. Radio-collaring fishing cats in urban wetlands. In: A. Appel and J. W. Duckworth (Eds.). *Proceedings of the First International Fishing Cat Conservation Symposium, 25–29 November 2015, Nepal* (pp. 34-36). Fishing Cat Working Group, Bad Marienberg, Germany and Saltford, Bristol, United Kingdom.

- Rausch, R.A. 1967. Some aspects of the population ecology of wolves, Alaska. *American Zoology*, 7, 253-265.

- Ray, J.C., Hunter, L. and Zigouris, J. 2005. *Setting conservation and research priorities for larger African carnivores.* Working Paper No. 24, Wildlife Conservation Society, New York, USA.

- Raza, R.H., Chauhan, D.S., Pasha, M.K.S. and Sinha, S. 2012. *Illuminating the blind spot: a study on illegal trade in leopard parts in India (2001–2010).* TRAFFIC India/WWF India, New Delhi.

- Redford, K. H. 1987. Ants and termites as food: patterns of mammalian myrmecophagy. In H.H. Genoways (Ed.). *Current Mammalogy* (pp. 349-399). Plenum Press, New York.

- Rieger, I. 1979. A review of the biology of striped hyaenas, *Hyaena hyaena* (Linne, 1758). *Saugetierkund Mitt*, 27, 81–95.

- Rieger, I. 1981. Hyaena hyaena. *Mammalian Species*, 150, 1-5.

- Rieger, R. and Ruppert, E. 1978. Resin embedments of quantitative meiofauna samples for ecological and structural studies - description and application. *Marine Biology*, 46, 223-235.

- Rimal, S., Adhikari, H. and Tripathi, S. 2018. Habitat suitability and threat analysis of Greater One-horned Rhinoceros *Rhinoceros unicornis* Linnaeus, 1758 (Mammalia: Perissodactyla: Rhinocerotidae) in Rautahat District, Nepal. *Journal of Threatened Taxa*, 10(8), 11999-12007.

- Ripple, W.J., Estes, J.A., Beschta, R.L., Wilmers, C.C., Ritchie, E.G., Hebblewhite, M., Berger, J., Elmhagen, B., Letnic, M., Nelson, M.P., Schmitz, O.J., Smith, D.W., Wallach, A.D. and Wirsing, A.J. 2014. Status and ecological effects of the world's largest carnivores. *Science*, 343(6167), 1241484.

- Roberton, S.I. 2007. *Status and conservation of small carnivores in Vietnam*. Ph.D. thesis, University of East Anglia, Norwich, U.K.
- Roberts, T.J. 1977. *The Mammals of Pakistan*. Ernest Benn, London, UK, 525 p.
- Rodgers, W.A. and Panwar, H.S. 1988. *Planning a wildlife protected area network in India*. II Volume. Project FO: IND/82/003. FAO, Dehradun.
- Rodgers, W.A., Panwar, H.S. and Mathur, V.B. 2002. *Wildlife Protected Areas in India: A Review (Executive Summary)*. Wildlife Institute of India, Dehradun, 44 p.
- Rodriguez, E., Morris, C.S., Belz, J., Chapin, E., Martin, J., Daffer, W. and Hensley, S. 2005. *An assessment of the SRTM topographic products*. Technical Report JPL D-31639, Jet Propulsion Laboratory, Pasadena, California, USA.
- Rood, E., Ganie, A.A. and Nijman, V. 2010. Using presence-only modelling to predict Asian elephant habitat use in a tropical forest landscape: implications for conservation. Diversity and Distributions, 16, 975-984.
- Rookmaker, L.C. 1984. The former distribution of the Indian rhinoceros (Rhinoceros unicornis) in India and Pakistan. *Journal of the Bombay Natural History Society*, 80, 555-563.
- Rosevear, D.R. 1974. *The Carnivores of West Africa*. Trustees of the British Natural History Museum Natural History, London, United Kingdom.
- Rosevear, D.R., Parsons, R., Wolseley, P. and Shaffer, M. 1974. *The carnivores of west Africa*. British Museum (Natural History) London, 594 p.
- Ross, J., Brodie, J., Cheyne, S., Datta, A., Hearn, A., Loken, B., Lynam, A., McCarthy, J., Phan, C., Rasphone, A., Singh, P. and Wilting, A. 2016. Pardofelis marmorata. *The IUCN Red List of Threatened Species 2016*, e.T16218A97164299.
- Ross, J., Brodie, J., Cheyne, S., Hearn, A., Izawa, M., Loken, B., Lynam, A., McCarthy, J., Mukherjee, S., Phan, C., Rasphone, A. and Wilting, A. 2015. Prionailurus bengalensis. *The IUCN Red List of Threatened Species 2015*, e.T18146A50661611.
- Ross, J., Hearn, A.J., Bernard, H., Secoy, K. and Macdonald, D. 2010. *A framework for a Wild Cat Action Plan for Sabah*. Global Canopy Programme, Oxford.
- Rowcliffe, J.M. 2019. *activity: Animal Activity Statistics*. R package version 1.2. https://CRAN.R-project.org/package=activity.
- Rowcliffe, J.M., Kays, R., Kranstauber, B., Carbone, C. and Jansen, P.A. 2014. Quantifying levels of animal activity using camera trap data. *Methods in Ecology and Evolution*, 5(11), 1170-1179.
- Rozhnov, V.V. 1995. Taxonomic notes on the Yellow-throated Marten *Martes flavigula*. *Zoologicheskii Zhurnal*, 74, 131–138.
- Rueness, E.K., Asmyhr, M.G., Sillero-Zubiri, C., Macdonald, D.W., Bekele, A., Atickem, A. and Stenseth, N.C. 2011. The cryptic African Wolf: Canis aureus lupaster is not a Golden Jackal and is not endemic to Egypt. *PLoS One*, 6(1), e16385.
- Ryley, K.V. 1913. Bombay Natural History Society's Mammal Survey of India. Report No. 11. Coorg. *Journal of the Bombay Natural History Society*, 22, 486-513.
- Sadhu, A. and Reddy, G. V. 2013. First evidence of fishing cat in the Ranthambhore Tiger Reserve, Rajasthan, India. *Cat News*, 58, 36-37.
- Sahu, Y.K., Bhattacharjee, S., Kidwai, Z., Sharma, S., Shaktawat, D.S. and Khandal, D. 2017. Report of melanistic jungle cats from Ranthambhore Tiger Reserve, Rajasthan, India. *Cat News*, 65, 33-34.
- Samejima, H. and Semiadi, G. 2012. First record of Hose's Civet *Diplogale hosei* from Indonesia, and records of other carnivores in the Schwaner Mountains, Central Kalimantan, Indonesia. *Small Carnivore Conservation*, 46, 1–7.
- Samrakshan Trust 2007. *Wildlife distribution and hunting – South Garo Hills*. Unpublished report.
- Sanei, A., Mousavi, M., Rabiee, K., Khosravi, M.S., Julaee, L., Gudrazi, F., Jaafari, B. and Chalani, M. 2016. Distribution, characteristics and conservation of the jungle cat in Iran. *Cat News*, Special Issue 10 Autumn 2016, 51-55.

- Sanghamithra, D. and Nameer, P.O. 2018. Small carnivores of Silent Valley National Park, Kerala, India. *Journal of Threatened Taxa*, 10(8), 12091–12097.

- Sankar, K. Pabla, H. S., Patil C. K., Nigam P., Qureshi, Q., Navaneethan B., Manjrekar, M., Virkar, P.S., and Mondal, K. 2013. Home range, habitat use and food habits of re-introduced gaur (Bos gaurus gaurus) in Bandhavgarh Tiger Reserve, Central India. *Tropical Conservation Science*, 6(1), 50-69.

- Sankar, K., Qureshi, Q., Pasha, M.K.S. and Areendran, G. 2000. *Ecology of gaur Bos gaurus in Pench Tiger Reserve, Madhya Pradesh*. Final Report. Wildlife Institute of India, Dehra Dun, 27 p.

- Saren, P.C., Basu, D. and Mukherjee, T. 2019. Status Survey of Indian Grey Wolf (Canis lupus pallipes) in WestBengal and some part of Jharkhand. *Records of the Zoological Survey of India*, 119(2), 103-110.

- Sathyakumar, S., Kaul, R., Ashraf, N.V.K., Mookherjee, A. and Menon, V. 2012. *National Bear Conservation and Welfare Action Plan*. Ministry of Environment and Forests, Wildlife Institute of India, and Wildlife Trust of India, India.

- Sathykumar, S., Bashir, T., Bhattacharya, T. and Poudyal, K. 2011. Assessing mammal distribution and abundance in intricate Eastern Himalayan habitats of Khangchendzonga, Sikkim, India. *Mammalia*, 75 (3), 257–268.

- Saunders, D.A., Hobbs, R.J. and Margules, C. R. 1991. Biological consequences of ecosystem fragmentation: a review. *Conservation Biology*, 5(1), 18-32.

- Saxena, A. and Rajvanshi, A. 2014. Diurnal activity of leopard cat in Rajaji National Park, India. *Cat News*, 61, 21.

- Sayyed, A., Talmale, S.S. and Mahabal, A. 2019. Records of brown palm civet Paradoxurus jerdoni in Satara district, Maharashtra: extension of known range in Western Ghats, India. Small Mammal Mail #423, In: *Zoo's Print*, 34(9), 8–11.

- Schaller, G. 1967. *The deer and the tiger*. University of Chicago Press, Chicago, USA, 370 p.

- Schaller, G.B. 1980. *Stones of Silence: Journeys in the Himalaya*. The University of Chicago Press, Chicago, Illinois, 292 p.

- Scherf, B.D. 2000. *World Watch List for Domestic Animal Diversity – 3rd Edition*. Food and Agriculture Organization of the United Nations, Rome, Italy, 746p.

- Schlitter, D.A. 2005. Order Pholidota. In D.E. Wilson and D.M. Reeder (Eds.). *Mammal Species of the World: A Taxonomic and Geographic Reference* (pp 530-531). Johns Hopkins University Press, Baltimore, MD, USA.

- Schreiber, A., Wirth, R., Riffel, M., and Van Rompaey, H. 1989. *Weasels, civets, mongooses, and their relatives. An action plan for the conservation of mustelids and viverrids*. Gland: IUCN, 99 p.

- Seidensticker, J. and Lumpkin, S. 1991. *Great cats*. Merehurst, London, 240 p.

- Selvan, K.M., Gokulakannan, N. and Sridharan, N. 2013. Food habits of dhole *Cuon alpinus* in Kalakad-Mundanthurai Tiger Reserve in Tamil Nadu, India. *Asian Journal of Conservation Biology*, 2, 69-72.

- Selvan, K.M., Gopi, G.V., Habib, B. and Lyngdoh, S. 2013. Hunting record of endangered marbled cat Pardofelis marmorata in the Ziro valley of Lower Subansiri, Arunachal Pradesh, India. *Journal of Threatened Taxa*, 5, 3583-3584.

- Sethy, J., Gouda, S. and Chauhan, N.P.S. 2017. Photographic evidence of marbled cat from Dampa Tiger Reserve, Mizoram, India. *Cat News*, 65, 26–27.

- Shafi, S., Maurya, K.K. and Gupta, M. 2019. Clouded leopard: The sixth felid of Valmiki Tiger Reserve, Bihar, India. *Cat News*, 69, 19-20.

- Shah, V.B. and McRae, B. 2008. Cicuitscape: a tool for landscape ecology. *Proceedings of the 7th Python in Science Conference (SciPy 2008)*, 62-66.

- Shahi, S.P. 1982. Report of grey wolf (Canis lupus pallipes Sykes) in India- a preliminary survey. *Journal of the Bombay Natural History Society*, 79, 493-502.

- Shankar Raman, T.R. 2011. *Framing ecologically sound policy on linear intrusions affecting wildlife habitats. Background paper for the National Board for Wildlife*. Standing Committee of the National Board for Wildlife during its 21st meeting on 20 January 2011.

- Shankar, A., Salaria, N., Balaji, K. and Shameer, T.T. 2019. Indian grey wolf: first photographicrecord of *Canis lupus pallipes* from Papikonda National Park in northern Eastern Ghats, India. MammalTales #9, In: *Zoo's Print*, 34(4), 22-26.

- Sharifi, H., Malekian, M. and Shahnaseri, G. 2020. Habitat selection of honey badgers: are they at the risk of an ecological trap? *Hystrix, the Italian Journal of Mammalogy*, 31(2), DOI: https://doi.org/10.4404/hystrix-00352-2020.

- Sharma, D.K., Maldonado, J.E., Jhala, Y.V. and Fleischer, R.C. 2004. Ancient wolf lineages inIndia. *Proceedings of the Royal Society of London B: Biological Sciences*, *271* (Suppl 3), S1-S4.

- Sharma, I.K. 1978. The wolf in the Indian desert. *Tigerpaper, 5(3)*, 32-33.

- Sharma, L.K., Mukherjee, T., Saren, P.C. and Chandra, K. 2019. Identifying suitable habitat andcorridors for Indian Grey Wolf (Canis lupus pallipes) in Chotta Nagpur Plateau and LowerGangetic Planes: A species with differentialmanagement needs. *PLoS One*, 14(4), e0215019.

- Sharma, S., Sharma, S.K., and Sharma, S. 2003. Notes on mammalian fauna in Rajasthan. *Zoos' Print,* 18 (4), 1085–1088.

- Sharma, S.K. 2007. Breeding season of Rusty-spotted Cat *Prinalurus rubiginosa* (Geffroy) in Sajjangarh Wildlife Sanctuary, Udaipur District, Rajasthan, India. Zoos' Print, *22(10), 2874.*

- Sharma, V. and Sankhala, K. 1984. Vanishing Cats of Rajasthan. In Jackson, P. (Ed.). *Proceedings from the Cat Specialist Group meeting in Kanha National Park*, (pp 116-135).

- Sheldon, J.W. 1992. *Wild dogs: the natural history of the non-domestic Canidae.* Academic Press, Chicago, IL, USA, 248 p.

- Shepherd, C.R. 2012. Observations of small carnivores in Jakarta wildlife markets, Indonesia, with notes on trade in Javan Ferret Badger Melogale orientalis and on the increasing demand for Common Palm Civet Paradoxurus hermaphroditus for civet coffee production. *Small Carnivore Conservation*, 47, 38–41.

- Shih, C. C., Huang, C. C., Li, S. H., Hwang, M. H., and Lee, L. L. 2009. Ten novel tetranucleotide microsatellite DNA markers from Asiatic black bear, Ursus thibetanus. *Conservation Genetics*, 10(6), 1845-1847.

- Shoshani, J. and Eisenberg, J. F. 1982. Elephas maximus. *Mammalian species*, 182, 1-8.

- Shrestha, B.S., Subedi, N. and Kandel, R.C. 2020. Jungle Cat Felis chaus Schreber, 1777 (Mammalia: Carnivora: Felidae) at high elevations in Annapurna Conservation Area, Nepal. *Journal of Threatened Taxa*, 12(2), 15267-15271.

- Shrestha, T.K., Hecker, L.J., Aryal, A. and Coogan, S.C.P. 2020. Feeding preferences and nutritional niche of wild water buffalo (Bubalus arnee) in Koshi Tappu Wildlife Reserve, Nepal. *Ecology and Evolution*, 10, 6897–6905.

- Shrestha, T.K., Shrestha, S., Koirala, S., Parajuli, A., Paudyal, P., Mishra, B., Sapkota, M. and Ghimire, L.N. 2018. Bubalus Arnee forage under threat: an assessment of Koshi Tappu Wildlife Reserve, Nepal. *International Journal of Research Studies in Zoology*, 4(3), 22-27.

- Sidhu, S., Raghunathan, G., Mudappa, D. and Shankar Raman, T.R. 2017. Conflict to coexistence: human – leopard interactions in a plantation landscape in Anamalai Hills, India. *Conservation and Society*, 15(4), 474-482.

- Sidhu, S., Shankar Raman, T.R. and Mudappa, D. 2015. Prey abundance and leopard diet in a plantation and rainforest landscape, Anamalai Hills, Western Ghats. *Current Science*, 109(2), 323-330.

- Silva, A.P., Björklund, M., Fernandes, C. and Mukherjee, S. 2015. Mapping the occurrence of small cats in India: co-occurrence in Prionailurus spp. In: G. Daniel, C. Beierkuhnlein, S. Holzheu, B. Thies, K. Faller, R. Gillespie and J. Hortal (Eds.). *International Biogeography Society – 7th Biennial Meeting* 6: 167 (pp. 167). Bayreuth, Germany.

- Silva, A.P., Mukherjee, S., Ramakrishnan, U., Fernandes, C. and Björklund, M. 2020. Closely related species show species specific environmental responses and different spatial conservation needs: *Prionailurus* cats in the Indian subcontinent. *Scientific Reports,* 10, 18705.

- Simcharoen S., Umponjan M., Duangchantrasiri S. and Pattanavibol A. 2014. Non-Panthera cat records from big cat monitoring in Huai Kha Khaeng Wildlife Sanctuary. *Cat News,* Special Issue 8, 31-35.

- Singh, H.S. 2005. Status of the leopard Panthera pardus fusca in India. *Cat News*, 42, 15-17.

- Singh, P. and Macdonald, D.W. 2017. Populations and activity patterns of clouded leopards and marbled cats in Dampa Tiger Reserve, India. *Journal of Mammalogy*, 98, 1453-1462.

- Singh, P., Gopalaswamy, A.M. and Karanth, K.U. 2010. Factors influencing densities of striped hyenas (Hyaena hyaena) in arid regions of India. *Journal of Mammalogy*, 91, 1152-1159.

- Singh, R., Qureshi, Q., Sankar, K., Krausman, P.R. and Goyal, S.P. 2014. Population and habitat characteristics of caracal in semi-arid landscape, western India. *Journal of Arid Environments*, 103, 92-95.

- Singh, R., Qureshi, Q., Sankar, K., Krausman, P.R., Goyal, S.P. and Nicholson, K.L. 2014. Population density of striped hyenas in relation to habitat in a semi-arid landscape, western India. *Acta Theriologica*, 59 (4), 521 - 527.

- Singh. M. and Kumara. H.N. 2006. Distribution, status and conservation of Indian gray wolf *(Canis lupus pallipes)* in Karnataka, India. *Journal of Zoology*, 270, 164–169.

- Sinha, S.P. 2004. The great Indian one-horned rhinoceros. In Sankar, K. and Goyal, S.P. (Eds.). *Ungulates of India*, (pp. 193-202). Envis Bulletin: Wildlife and Protected Areas, Wildlife Institute of India, Dehradun, India.

- Skinner, J.D. 1979. Feeding behavior in caracal *Felis caracal*. *Journal of Zoology*, 189, 523-525.

- Smith, J.L.D. 1993. The role of dispersal in structuring the Chitwan tiger population. *Behaviour*, 124(3-4), 165-195.

- Smithers, R.H.N. 1971. *The mammals of Botswana*. Museum Memoir no. 4. Salisbury: The Trustees of the national Museums of Rhodesia.

- Smithers, R.H.N. 1983. *The mammals of the southern African subregion*. Pretoria: University of Pretoria.

- Sody, H.J.V. 1936. Seventeen new generic, specific, and subspecific names for Dutch Indian mammals. *Natuur Kundig Tijidschriff voor Nederlandisch-Indie*, 96, 42-55.

- Sondhi, S., Athreya, V., Sondhi, A., Prasad, A. Verma, A. and Verma, N. 2016. *Human attacks by leopards in Uttarakhand, India: an assessment based on perceptions of affected people and stakeholders*. A technical report submitted to the Uttarakhand Forest Department.

- Sreehari, R. and Nameer, P.O. 2013. The first records of Nilgiri Marten *Martes gwatkinsii* from Parambikulam Tiger Reserve, southern Western Ghats, India. *Small Carnivore Conservation*, 49, 40–42.

- Srikosamatara, S. and Suteethorn, V. 1994. Wildlife conservation along the Thai-Lao border. *Natural History Bulletin of the Siam Society*, 42, 3-21.

- Srinivasulu, C. and Srinivasulu, B. 2012. *South Asian Mammals. Their Diversity, Distribution, and Status*. Springer, New York, XII+468 p.

- Srivastha, A., Majgaonkar, I., Sharma, S., Singh, P., Punjabi, G.A., Chawla, M.M. and Banerjee, A. 2020. Opportunities for prioritizing and expanding conservation enterprise in India using a guild of carnivores as flagships. *Environment Research Letters*, 15, 064009.

- Srivathsa, A., Karanth, K.K., Jathanna, D., Kumar, N.S. and Karanth, K.U. 2014. On a dhole trail: examining ecological and anthropogenic correlates of dhole habitat occupancy in the Western Ghats of India. *PLoS One*, 9(6), e98803.

- Srivathsa, A., Kumar, N. and Karanth, K. 2017. Field report: Home range size of the dhole estimated from camera- trap surveys. *Canid Biology and Conservation*, 20, 1-4.

- Srivathsa, A., Puri, M., Karanth, K.K., Patel, I. and Kumar, N.S. 2019. Examining human–carnivore interactions using a socio-ecologicalframework: sympatric wild canids in India as a case study. *Royal Society Open Science*, 6: 182008.

- Srivatsha, A., Parameshwaran, R., Sharma, S. and Karanth, K.U. 2015. Estimating population sizes of leopard cats in the Western Ghats using camera surveys. *Journal of Mammalogy*, 96(4), 742-750.

- Stein, A., Athreya, V., Balme, G., Henschel, P., Karanth, U., Miquelle, D. 2016. Panthera pardus, Leopard. *The IUCN Red List of Threatened Species 2016*, e.T15954A50659089.

- Sterndale, R.A. 1884. *Natural history of the Mammalia of India and Ceylon*. Thacker, Spink.

- Steven J. Phillips, Miroslav Dudík, Robert E. Schapire. [Internet] Maxent software for modeling species niches and distributions (Version 3.4.1). Available from url: http://biodiversityinformatics.amnh.org/open_source/maxent/. Accessed on 2021-2-6.

- Stevens, K., Dehgan, A., Karlstetter, M., Rawan, F., Tawhid, M.I., Ostrowski, S., Ali, J.M. and Ali, R. 2011. Large mammals surviving conflict in the eastern forests of Afghanistan. *Oryx*, 45, 265–271.

- Stewart, A. 1928. *Tiger and other game: the practical experiences of a soldier shikari in India*. Longmans, Green and Company, London, 290 p.

- Stuart, C. and Stuart, T. 2013. Caracal caracal. In: J. S. Kingdon and M. Hoffmann (Eds.), *The Mammals of Africa*, (pp. 174-179). Academic Press, Amsterdam, The Netherlands.

- Stuart, C.T. 1982. *Aspects of the biology of the caracal (Felis caracal) in the Cape Province, South Africa*. M.S. Thesis, University of Natal, South Africa.

- Stuart, C.T. and Hickman, G.C. 1991. Prey of caracal, *Felis caracal*, in two areas of Cape Province, South Africa. *Bontebok*, 1, 1-58.

- Su Su. 2005. Small carnivores and their threats in Hlawga Wildlife Park, Myanmar. *Small Carnivore Conservation*, 33, 6-13.

- Subedi N. 2012. *Effect of Mikania micrantha on demography, habitat use and nutrition of greater one-horned rhinoceros in Chitwan National Park*. Ph.D. thesis, Forest Research Institute University, Dehradun, India.

- Subedi, N., Jnawali, S., Dhakal, M., Pradhan, N., Lamichhane, B., Malla, S., Amin, R, and Jhala, Y. 2013. Population status, structure and distribution of the greater one-horned rhinoceros Rhinoceros unicornis in Nepal. *Oryx*, 47(3), 352-360.

- Subedi, N., Lamichhane, B.R., Amin, R., Jnawali, S.R. and Jhala, Y.V. 2017. Demography and viability of the largest population of greater one-horned rhinoceros in Nepal. *Global Ecology and Conservation*, 12, 241-252.

- Sukumar, R. 1990. Ecology of the Asian Elephant in Southern India. II. Feeding habits and crop raiding patterns. *Journal of Tropical Ecology*, 6, 33-53.

- Sukumar, R. 1992. *The Asian Elephant: Ecology and Management. Second edition*. Cambridge University Press, Cambridge, UK, 272 p.

- Sukumar, R. 2003. *The Living Elephants: Evolutionary Ecology, Behavior, and Conservation*. Oxford University Press, Oxford, UK, 478 p.

- Sukumar, R. 2006. A brief review of the status, distribution and biology of wild Asian elephants Elephas maximus. *International Zoo Yearbook*, 40, 1-8.

- Sukumar, R., Joshi, N.V. and Krishnamurthy, V. 1988. Growth in the Asian elephant. *Proceedings of Indian Academy of Science (Animal Sciences)*, 97(6), 561-571.

- Sukumar, R., Ramakrishnan, U. and Santosh, J. A. 1998. Impact of poaching on an Asian elephant population in Periyar, southern India: a model of demography and tusk harvest. *Animal Conservation*, 1, 281–291.

- Sunarto, Sollmann, R., Mohamed, A. and Kelly, M.J. 2013. Camera trapping for the study and conservation of tropical carnivores. *The Raffles Bulletin of Zoology*, Supplement No. 28, 21-42.

- Sunquist, M. and Sunquist, F. 2002. *Wild Cats of the World*. University of Chicago Press, Chicago, 452 p.

- Suzuki, A., Kyaw, W.W.H. and Naing, K.M. 2019. The presence of Asiatic Golden Cat in human-modified landscape in Ayeyarwady Region. *Proceedings of the International Joint Symposium 2019*, 235-239.

- Talukdar, B. K. 2020. Asian Rhino Specialist Group report/Rapport du Groupe de Spécialistes du Rhinocéros d'Asie. *Pachyderm*, 61, 43-48.

- Vigne, L. and Martin, E. 2016. High rhino horn prices drive poaching. *Swara*, July-September 2016, 42-46.

- TAWIRI. 2009. *Tanzania carnivore conservation action plan*. TAWIRI, Arusha, Tanzania.

- Tehsin, R. 1994. Rusty-spotted Cat *Prionailurus rubiginosa* Geoffroy Sighted near Udaipur. Journal of the Bombay Natural History Society, 91, 136.

- Tempa, T., Hebblewhite, M., Mills, L.S., Wangchuk, T.R., Norbu, N., Wangchuk, T., Nidup, T., Dendup, P., Wangchuk, D., Wangdi, Y. and Dorji, T. 2013. Royal Manas National Park, Bhutan: a hot spot for wild felids. *Oryx*, 47, 207–210.
- Than Zaw, Saw Htun, Saw Htoo Tha Po, Myint Maung, Lynam, A.J., Kyaw Thinn Latt and Duckworth, J.W. 2008. Status and distribution of small carnivores in Myanmar. *Small Carnivore Conservation*, 38, 2–28.
- Than Zaw, Than Myint, Saw Htun, Saw Htoo Tha Po, Kyaw Thinn Latt, Myint Maung and Lynam, A. J. 2014. Status and distribution of smaller cats in Myanmar. *Cat News Special Issue*, 8, 24-30.
- Thapa, K., Shrestha, R., Karki, J., Thapa, G.J., Subedi, N., Pradhan, N.M.B., Dhakal, M., Khanal, P. and Kelly, M.J. 2014. Leopard panthera pardus fusca density in the seasonally dry, Subtropical Forest in the Bhabhar of Terai Arc, Nepal. *Advances in Ecology*, 2014, 1–12.
- Thatte, P., Joshi, A., Vaidyanathan, S., Landguth, E., and Ramakrishnan, U. 2018. Maintaining tiger connectivity and minimizing extinction into the next century: Insights from landscape genetics and spatially-explicit simulations. *Biological Conservation*, *218*, 181-191.
- Thaung R. and Herranz Muñoz, V. 2016. Identifying priority sites and conservation actions for Fishing Cat in Cambodia. In: A. Appel and J. W. Duckworth (Eds.). *Proceedings of the First International Fishing Cat Conservation Symposium, 25–29 November 2015, Nepal* (pp. 37-40). Fishing Cat Working Group, Bad Marienberg, Germany and Saltford, Bristol, United Kingdom.
- Thorn, M., Green, M., Marnewick, K., Bateman, P.W., Cameron, E.Z. and Scott, D.M. 2011. Large-scale distribution patterns of carnivores in northern South Africa: implications for conservation and monitoring. *Oryx*, 45(4), 579–586.
- Thudugala, A. 2016. Fishing Cat conservation in hill country, Sri Lanka. In: A. Appel and J. W. Duckworth (Eds.). *Proceedings of the First International Fishing Cat Conservation Symposium, 25–29 November 2015, Nepal* (pp. 25-29). Fishing Cat Working Group, Bad Marienberg, Germany and Saltford, Bristol, United Kingdom.
- Tikader, B.K. 1983. *Threatened animals of India.* Zoological Survey of India, Calcutta, India, 307 p.
- Uphyrkina, O., Johnson, W.E., Quigley, H., Miquelle, D., Marker, L., Bush, M. and O'Brien, S.J. 2001. Phylogenetics, genome diversity and origin of modern leopard, Panthera pardus. *Molecular Ecology*, 10, 2617–2633.
- Vairavel, S.M. 1998. *Ecology of gaur (Bos gaurus) with special reference to habitat utilization in Parambikulam Wildlife Sanctuary, Kerala, India.* Ph.D. thesis, Forest Research Institute, Dehra Dun.
- Van Heezik, Y.M. and Seddon, P.J. 1998. Range size and habitat use of an adult male caracal in northern Saudi Arabia. *Journal of Arid Environments*, 40, 109-112.
- Vasava, A., Bipin, C.M., Solanki, R. and Singh, A. 2012. Record of Rusty-spotted Cat from Kuno Wildlife Sanctuary, Madhya Pradesh, India. *Cat News*, 57, 22–23.
- Veals, A.M., Burnett, A.D., Morandini, M., Drouilly, M. and Koprowski, J.L. 2020. Carcal caracal (Carnivora: Felidae). *Mammalian Species*, 52(993), 71-85.
- Velho, N. 2013. Misty mountains. *Sanctuary Asia*, December, 68-70.
- Venkataraman, A.B., Arumugam, R. and Sukumar, R. 1995. The foraging ecology of dhole (Cuon alpinus) in Mudumalai Sanctuary, southern India. *Journal of Zoology*, 237, 543-561.
- Venter, O., Sanderson, E.W., Magrach, A., Allan, J.R., Beher, J., Jones, K.R., Possingham, H.P., Laurance, W.F., Wood, P., Fekete, B.M., Levy, M.A. and Watson, J.E. 2018. *Last of the Wild Project, Version 3 (LWP-3): 2009 Human Footprint, 2018 Release.* NASA Socioeconomic Data and Applications Center (SEDAC), Palisades, NY.
- Vernes K., Sangay T., Rajaratnam R. and Singye R. 2015. Social interaction and co-occurrence of colour morphs of the Asiatic golden cat, Bhutan. *Cat News*, 62, 18-20.
- Vidya, T.N.C. and Sukumar, R. 2005. Social organization of the Asian elephant *(Elephas maximus)* in southern India inferred from microsatellite DNA. *Journal of Ethology*, 23(2), 205-210.
- Vijayan, V.S. 1979. Parambikulam Wildlife Sanctuary and its adjacent areas. *Journal of the Bombay Natural History Society*, 75, 888-901.
- Vyas, P. and Sengupta, K. 2014. Human--leopard conflict in North Bengal, India. *Tigerpaper*, 41(1), 1--6.

- Vyas, R. and Upadhyay, K. 2014. Sighting and distribution of rusty-spotted cat in Gujarat State, India. *Cat News*, 61, 26–29.

- Vyas, R., Shukla, A. and Vaghashiya, P. 2018. Rusty-spotted Cat: Distribution account of Prionailurus rubiginosus (Carnivora: Felidae) with comments on unusual irregularity observed in Gujarat, India. Small Mammal Mail #419. In: *Zoo's Print*, 33(7), 10-18.

- Wagner, A.P. 2006. *Behavioral ecology of the striped hyena (Hyaena hyaena)*. Ph.D. thesis, Montana State University, Bozeman, 182 p.

- Wagner, A.P., Frank, L.G. and Creel, S. 2008. Spatial grouping in behaviourally solitary striped hyaenas, Hyaena hyaena. *Animal Behaviour*, 75, 1131-1142.

- Walker, E., Warnick, F., Hamlet, S., Lange, K., Davis, M., Uible, H. and Wright, P. 1964. Mammals of the world. The Johns Hopkins Press, Baltimore.

- Wang S.W. 2007. A rare morph of the Asiatic golden cat in Bhutan's Jigme Singye Wangchuk National Park. *Cat News*, 47, 27-28.

- Wang, S.W. and Macdonald, D.W. 2009. Livestock predation by carnivores in Jigme Singye Wangchuck National Park, Bhutan. *Biological Conservation*, 129, 558-565.

- Wang, S.W. and Macdonald, D.W. 2009. The use of camera traps for estimating tiger and leopard populations in the high altitude mountains of Bhutan. *Biological Conservation*, 142, 606–613.

- Wang, Z. and Wang, S. 1986. Distribution and recent status of the Felidae in China. In S.D. Miller and D.D. Everett (Eds.). *Cats of the World: Biology, Conservation and Management*, (pp. 201-210). National Wildlife Federation, Washington DC.

- Wangyel, S., Dorji, K., Tobgay, S. and Yangdon, N. 2020. First photographic evidence of the Asiatic Golden Cat Catopuma temminckii Vigors and Horsfield, 1827 (Mammalia: Carnivora: Felidae) in Sakteng Wildlife Sanctuary, Bhutan. *Journal of Threatened Taxa*, 12, 15262–15266.

- Webb, A. 2013. "Martes gwatkinsii" (On-line). *Animal Diversity Web*. Available at https://animaldiversity.org/accounts/Martes_gwatkinsii/.

- Webb-Peploe, C.G. 1947. Field notes on the mammals of south Tinnevely, South India. *Journal of the Bombay Natural History Society*, 46, 629-644.

- Weigl, R. 2005. *Longevity of mammals in captivity: from the living collections of the world*. Stuttgart, Germany: Kleine Senckenberg-Reihe.

- Weisbein, Y. and Mendelssohn, H. 1990. The biology and ecology of the caracal *Felis caracal* in the northern Aravah Valley of Israel. *Cat News*, 12, 20-22.

- Wharton, C. H. 1968. Man, fire and wild cattle in Southeast Asia. *Proceedings of the Annual Tall Timbers Fire Ecology Conference*, 8, 107–167.

- Wibisono, H.T. and McCarthy, J. 2010. Melanistic marbled cat from Bukit Barisan Selatan National Park, Sumatra, Indonesia. *Cat News*, 52, 9–10.

- Wildlife institute of India. 2016. *Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife*. Wildlife Institute of India.

- Willcox D.H.A., Phuong T.Q., Duc H.M. and Truong An T.N. 2014. The decline of non-panthera cat species in Vietnam. *Cat News*, Spec. Issue 8, 53-61.

- Williams, A.C., Johnsingh, A.J.T. and Krausman, P. R. 2001. Elephant-human conflicts in Rajaji National Park, northwestern India. *Wildlife Society Bulletin*, 29, 1097-1104.

- Williams, A.C., Johnsingh, A.J.T. and Krausman, P.R. 2008. Ranging and habitat use by elephants in Rajaji National Park, India. *Journal of the Bombay Natural History Society*, 105, 24-33.

- Williams, C., Tiwari, S.K., Goswami, V.R., de Silva, S., Kumar, A., Baskaran, N., Yoganand, K. and Menon, V. 2020. Elephas maximus. *The IUCN Red List of Threatened Species 2020*, e. T7140A45818198.

- Wilson D.E. and Mittermeier R.A. (eds.) 2009. *Handbook of the mammals of the world. Vol. 1. Carnivores*. Lynx

Edicions, Barcelona, 727 p.

- Wirth, R. and Van Rompaey, H. 1991. The Nilgiri Marten, Martes gwatkinsii, (Horsfield, 1851). *Small Carnivore Conservation*, 5, 6.

- Witt, D.O. 1907. Note on effect of strychnine poison on wild dogs. *Journal of the Bombay Natural History Society*, 18, 211-213.

- Wood, H.S. 1937. Observations on the gaur and its shikar. *Journal of the Bengal (Darjeeling) Natural History Society*, 12(1), 7-17.

- Wozencraft, W.C. 2005. Carnivora. In D.E. Wilson and D.M. Reeder (eds.). *Mammal Species of the World, Third Edition*, (pp 532-628). The Johns Hopkins University Press, Baltimore.

- Wultsch, C., Waits, L.P. and Kelly, M.J. 2016. A comparative analysis of genetic diversity and structure in jaguars (Panthera onca), pumas (Puma concolor), and ocelots (Leopardus pardalis) in fragmented landscapes of a critical Mesoamerican linkage zone. *PLoS One*, 11(3), e0151043.

- WWF-India 2014. *Terai Arc Landscape: securing corridors, curbing poaching and mitigating HWC.* Available online: http://wwf.panda.org/who_we_are/wwf_offices/india/?uProjectID=IN0961.

- Yalden, D., Largen, M., Kock, D. and Hillman, J. 1996. Catalogue of the mammals of Ethiopia and Eritrea. 7. Revised checklist, zoogeography and conservation. *Tropical Zoology*, 9, 73-164.

- Yamaguchi, N., Kitchener, A., Driscoll, C. and Nussberger, B. 2015. *Felis silvestris. The IUCN Red List of Threatened Species 2015*, e.T60354712A50652361.

- Yamaguchi, N., Macdonald, D.W., Passanisi, W.C., Harbour, D.A. and Hopper, C.D. 1996. Parasite prevalence in free-ranging farm cats, *Felis silvestris catus. Epidemiology and Infection*, 116, 217-223.

- Yang, C.W., Chen, S., Chang, C-Y., Lin, M., Block, E., Lorentsen, R., Chin, J.S.C. and Dierenfeld, E.S. 2007. History and dietary husbandry of pangolins in captivity. *Zoo Biology*, 26(3), 223-230.

- Yoganand, K, Rice, C.G., Johnsingh, A.J.T. and Seidensticker, J. 2006. Is the sloth bear in India secure? A preliminary report on distribution, threats and conservation requirements. *Journal of the Bombay Natural History Society*, 103, 57-66.

- Yoganand, K. 2005. *Behavioural ecology of sloth bear (Melursus ursinus) in Panna National Park, Central India.* Ph.D. thesis, Saurashtra University, India.

- Yoganand, K., Johnsingh, A.J.T. and Rice, C.G. 1999. *Annual technical report (October 1998 to September 1999) of the project 'Evaluating Panna National Park with special reference to the ecology of Sloth bear'*. Wildlife Institute of India, Dehradun, India.

- Yoganand, K., Rice, C.G. and Johnsingh, A.J.T. 2013. Sloth bear. In A.J.T. Johnsingh and N. Manjerkar (Eds.). *Mammals of South Asia*, Vol I, (pp. 438-456). University Press, Hyderabad, India.

- Yoganand, T.R.K. and Kumar, A. 1995. The distribution of small carnivores in the Nilgiri Biosphere Reserve, southern India: A preliminary report. *Small Carnivore Conservation*, 13, 1-2.

- Yue, S., Brodie, J.F., Zipkin, E.F. and Bernard, H. 2015. Oil palm plantations fail to support mammal diversity. *Ecological Applications*, 25, 2285-2292.

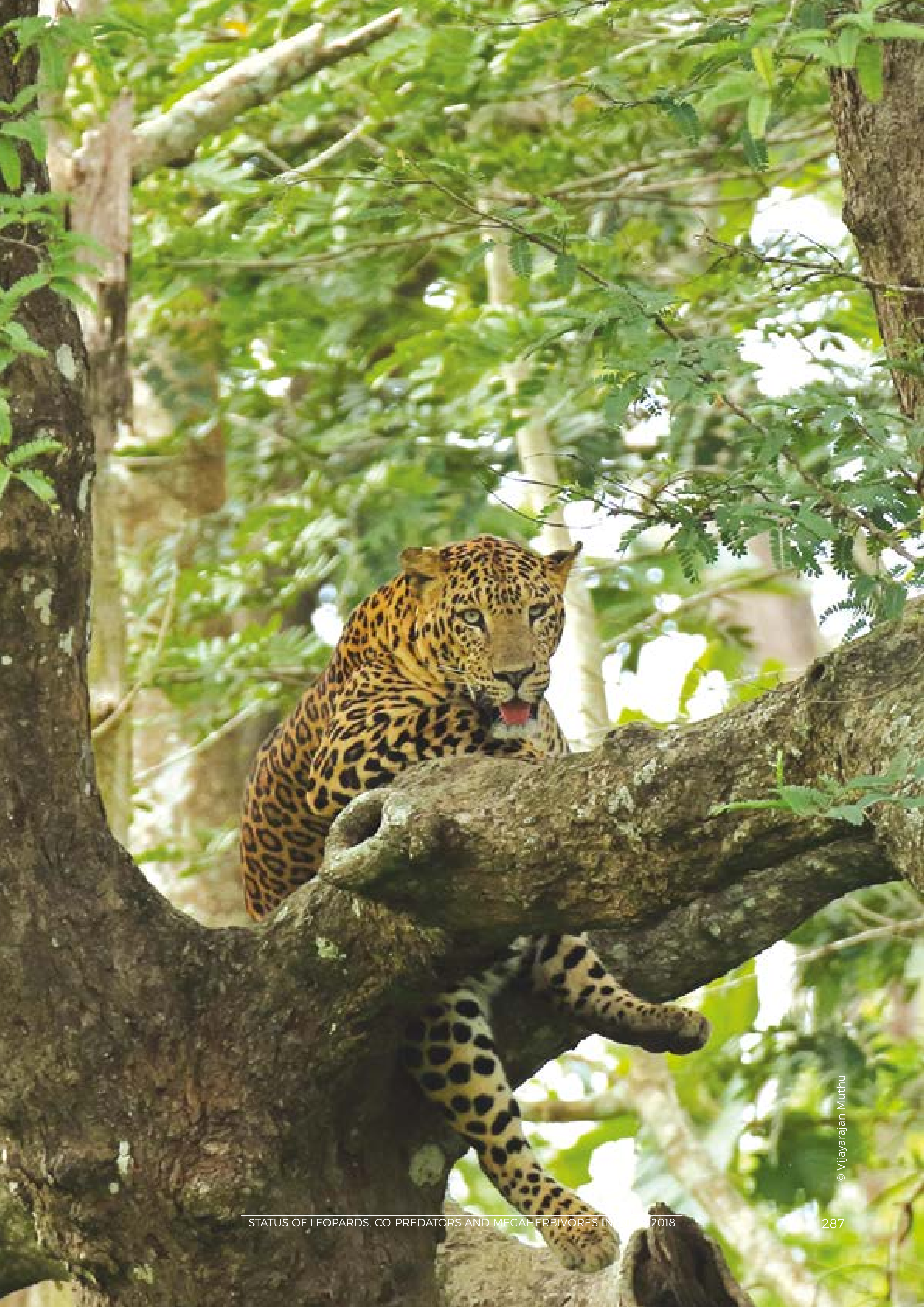
- Yumnam, B., Negi, T., Maldonado, J.E., Fleischer, R.C. and Jhala, Y.V., 2015. Phylogeography of the golden jackal (Canis aureus) in India. *PloS one*, 10(9), p.e0138497. (For secondary data).

- Zaw, T., Myint, T., Htun, S., Po, S.H.T., Latt, K.T., Maung, M. and Lynam, A. 2014. Status and distribution of smaller cats in Myanmar. *Cat News*, 8, 24–30.

- Zomer, R.J., Bossio, D.A., Trabucco, A., Yuanjie, L., Gupta, D.C. and Singh, V.P. 2007. *Trees and water: smallholder agroforestry on irrigated lands in northern India*. International Water Management Institute, Colombo, Sri Lanka, Research Report 122, 45 p.

- Zomer, R.J., Trabucco, A., Bossio, D.A., van Straaten, O. and Verchot, L.V. 2008. Climate change mitigation: a spatial analysis of global land suitability for clean development mechanism afforestation and reforestation. *Agriculture Ecosystems and Environment*, 126, 67-80.

- Zoological Survey of India 2002. Pangolins (Mammalia: Pholidota) of India. *ENVIS Newsletter*, Vol. 9 (No. 1 and 2).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North Eastern Hills & Brahmaputra Flood Plains Landscape

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Genetics Chapter

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Individual species chapters

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Name	Species	Name	Species	Name	Species
Adarsh Kulkarni	Dhole	Manish Singanjude	Golden Jackal	Pooja Chowdhury	Civet
Deb Ranjan Laha	Marbled Cat, Golden Cat	Monika Saraswat	Leopard	Rutu Prajapati	Ratel
Harshini Jhala	Elephant, Rhinoceros, Wild Buffalo	Moulik Sarkar	Nilgiri Martin	Sagarika Das	Sloth Bear
Jayant Bora	Rusty Spotted Cat, Jungle Cat, Clouded Leopard	Neha Awasthi	Desert Cat	Shravana Goswami	Clouded Leopard
		Neha Yadav	Civets	Sourabh Pundir	Caracal
Kainat Latafat	Striped Hyena	Nupur Rautela	Fishing Cat	Swati Saini	Wolf, Gaur
Krishna Mishra	Leopard Cat	Parul Sen	Sloth Bear, Pangolin	Vivekanand Kumar	Mongoose

APPENDIX 2

Remotely sensed spatial and attribute covariates (Phase II data) and habitat variable used for MaxEnt modelling

Raster Data	Time period	Satellite	Resolution	Source	Reference
Water bodies	March 1984 to October 2015	Landsat 4,5,7	30 m	Joint Research Centre's Global Surface Water Dataset (JRC)	Pekel et al. 2016
Normalized Difference Vegetation Index (NDVI)	April and October 2018	Moderate Resolution Imaging Spectroradiometer (MODIS)	250 m	National Aeronautics and Space Administration (NASA)	Didan et al. 2015
Night lights	2016	Visible Infrared Imaging Radiometer Suite (VIIRS)	15 arc sec ~600 m	National Oceanic and Atmospheric Administration (NOAA)	Elvidge et al. 2017
Forest cover map	2016	Linear Imaging Self Scanning Sensor (LISS-III, IV)	23 m	Forest Survey of India	FSI 2017
Protected Area & Tiger Reserves				Wildlife Database cell, Wildlife Institute of India and Project Tiger Directorate	
Prey encounter and dung	2018			All India Tiger Estimation	
Digital elevation model	2000	Shuttle Radar Topography Mission (SRTM)	30 m	National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA)	Rodriguez et al. 2005 & Farr et al. 2007
Road network				Survey of India	
Human foot print	2009		1000 m	Last of the Wild Project, Version 3 (LWP-3)	Venter et al. 2018
Change in forest cover (forest degradation)	2001-2018	MODIS	250 m	Enhanced vegetation index (EVI)	Huete et al. 2002
Bioclimatic variables	1970-2000		1000 m	WorldClim ver 2	Fick and Hijmans. 2017
Evapotranspiration and Aridity			1000 m	WorldClim Global Climate Data (1950-2000) https://cgiarcsi.community/data/global-aridity-and-pet-database/	Zomer et al. 2007, 2008
Forest height	2019	Global Ecosystem Dynamics Investigation (GEDI) lidar forest structure measurements & Landsat time-series data	30 m	https://glad.umd.edu/dataset/gedi	Potapov et al. 2020
Human modification Index			1000 m		Kennedy et al. 2019

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