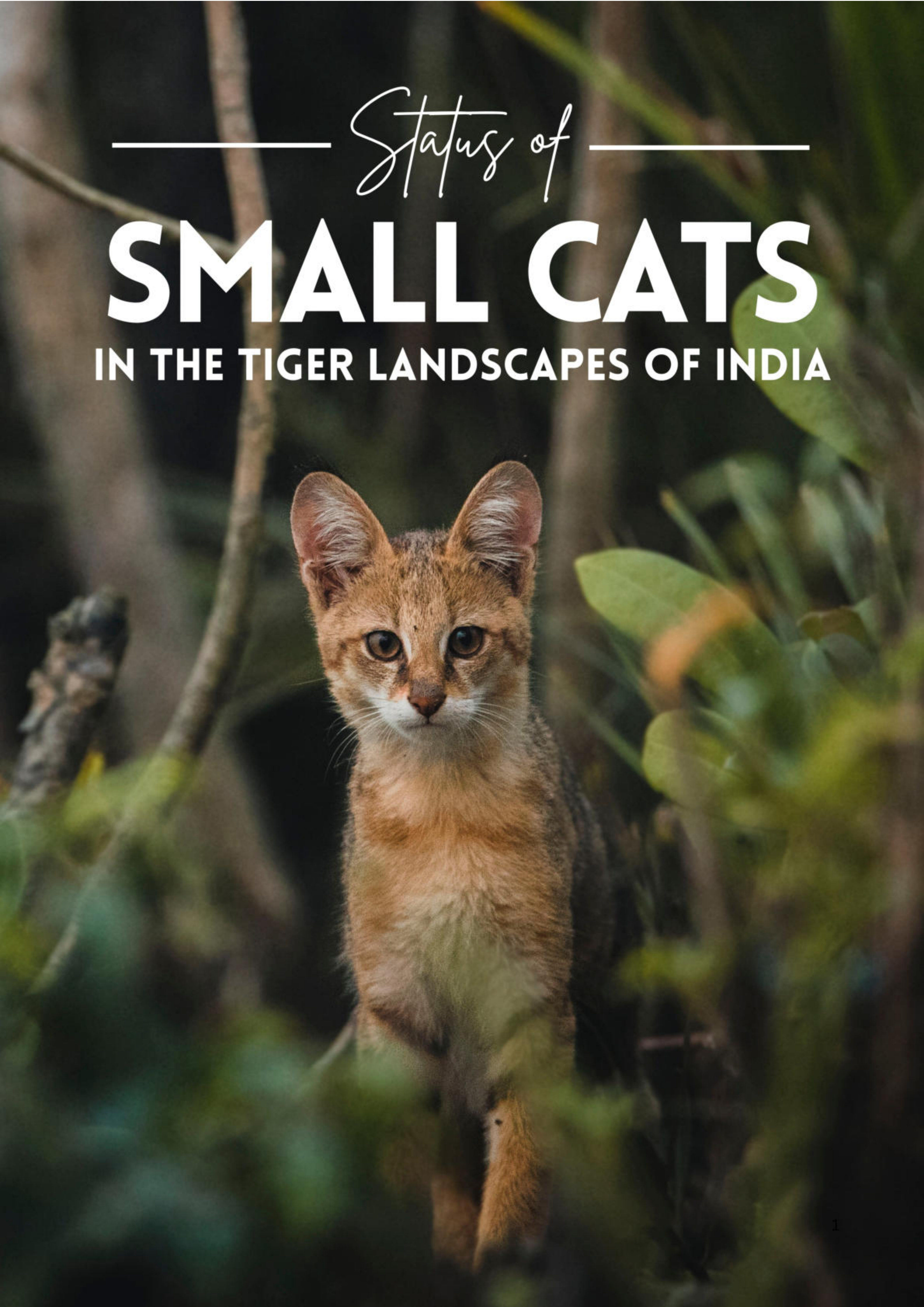
Status of SMALL CATS IN THE TIGER LANDSCAPES OF INDIA



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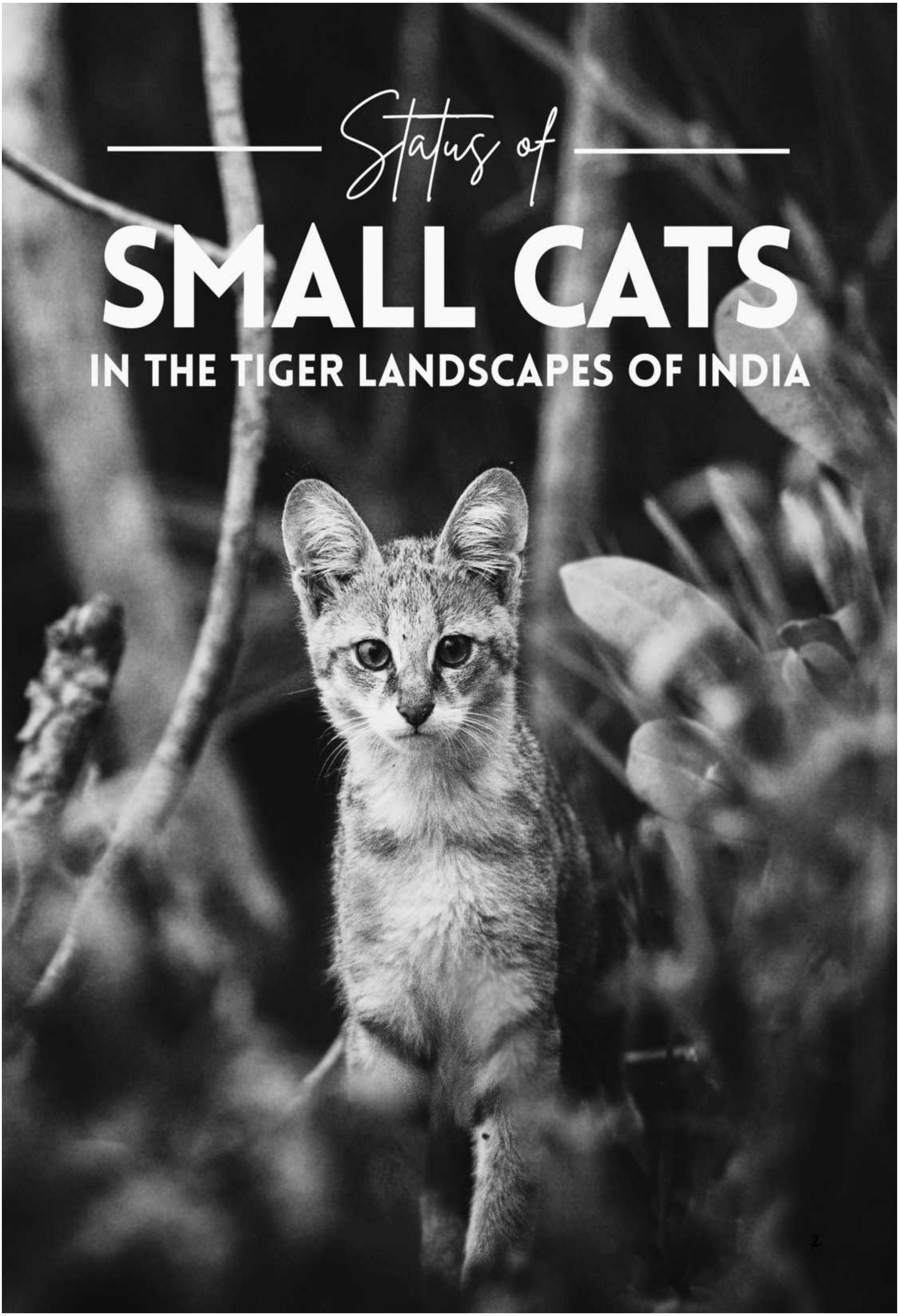


Big Cats vs Small Cats

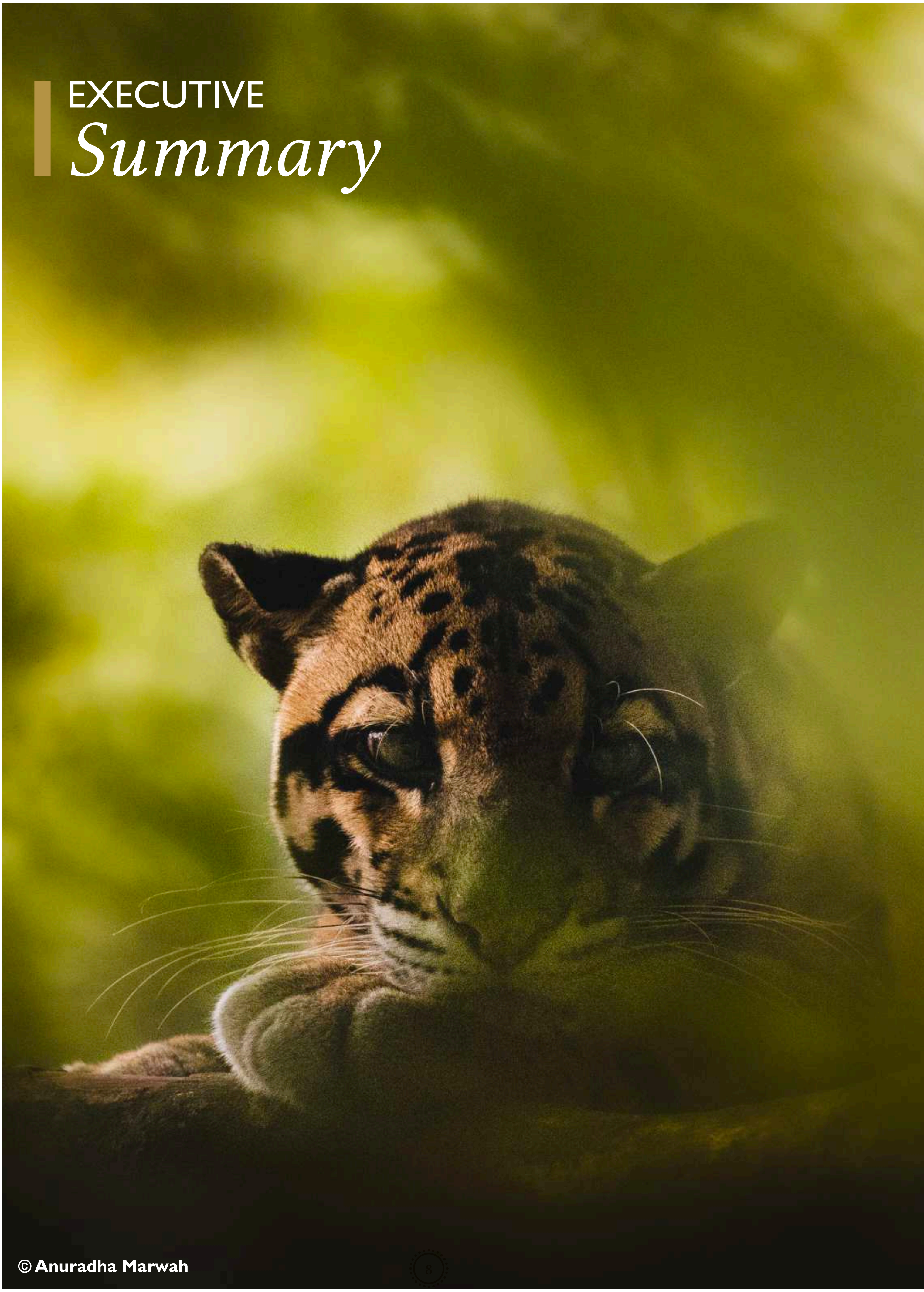
The 'single most fundamental difference' between big cats and small cats is their 'vocal anatomy', specifically the structure of the hyoid bone in their throat.

Big cats have an **'incompletely ossified (flexible) hyoid bone'** anchored by elastic ligaments - can roar.

Small cats have a **'fully ossified (rigid) hyoid bone'** - can purr continuously.

CATS
of Tiger Landscapes of India

EXECUTIVE *Summary*



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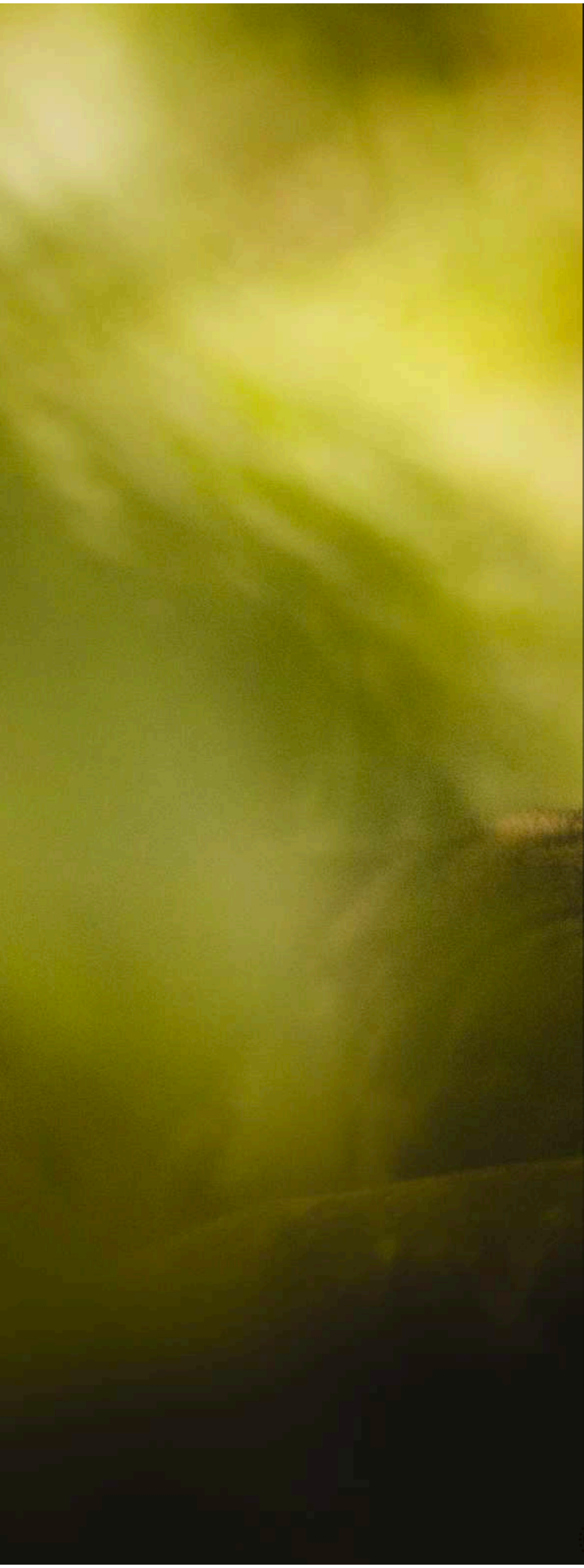
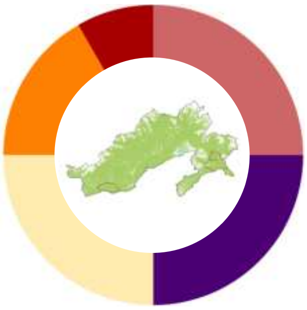
Small felids, despite their ecological importance, remain understudied and underrepresented in conservation planning. This report presents the occupancy status and dynamics of nine small cat species across India's tiger-range forests, using camera trap data from the All-India Tiger Estimation (2018 and 2022). The jungle cat emerged as the most widespread species, occupying an estimated 96275 km^2 (95% CI: 90075 - 98100), across diverse habitats ranging from dry deciduous to moist forests. It was followed by the rusty-spotted cat, occupying 70075 km^2 (66225 - 96075), with high occupancy in mixed deciduous forests. Leopard cats, largely confined to moist forests, occupied 32800 km^2 (27950 - 35900), primarily across the Himalayan foothills, Northeast, Sundarbans, Western Ghats, and Similipal. In contrast, the habitat specialists showed more restricted distributions. The desert cat occupied 12500 km^2 (10675 - 13850) within the semi-arid and dry deciduous forests of Western and Central India. The fishing cat, closely tied to wetlands and riverine systems, was restricted to the Terai, Northeast, and mangrove habitats, occupying 7575 km^2 (6125 - 8150). The three rare and elusive species, clouded leopard (3250 km^2; 2250 - 3725), marbled cat (2325 km^2; 1375 - 3550), and Asiatic golden cat (1850 km^2; 1400 - 3075) were limited to dense forests of Northeast India. Occupancy generally declined with increasing human disturbance, except in habitat generalists such as the jungle cat and rusty-spotted cat. Protected areas supported higher occupancy across most species, highlighting their reliance on secure habitats and underscoring the pivotal role of Project Tiger in safeguarding India's small cat diversity. While occupancy patterns appeared relatively stable between 2018 and 2022, the absence of fine-scale data on prey availability and microhabitat features may mask subtle changes. These findings offer a baseline for targeted research and conservation efforts for India's lesser-known felids.

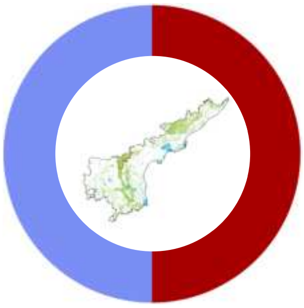


Clouded leopard

ARUNACHAL PRADESH



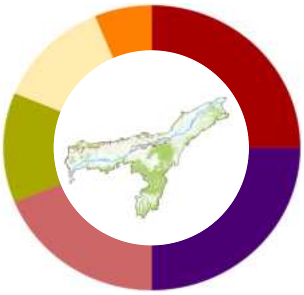
ANDHRA PRADESH



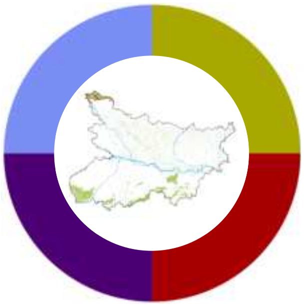
24,852
Total Photo-captures of Small cats

32,588
Total Camera Trap Count

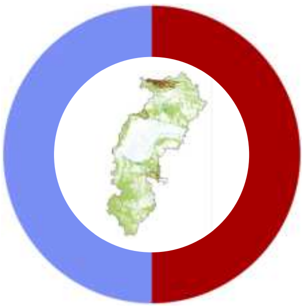
ASSAM



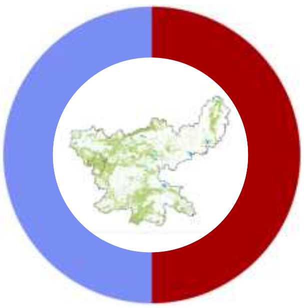
BIHAR



CHHATTISGARH



JHARKHAND



ANDHRA PRADESH
NUMBER OF SPECIES PRESENT-2
TOTAL GRIDS-300
GRIDS OCCUPIED-170

ARUNACHAL PRADESH
NUMBER OF SPECIES PRESENT-5
TOTAL GRIDS-88
GRIDS OCCUPIED-55

ASSAM
NUMBER OF SPECIES PRESENT-6
TOTAL GRIDS-100
GRIDS OCCUPIED-91

BIHAR
NUMBER OF SPECIES PRESENT-4
TOTAL GRIDS-63
GRIDS OCCUPIED-44

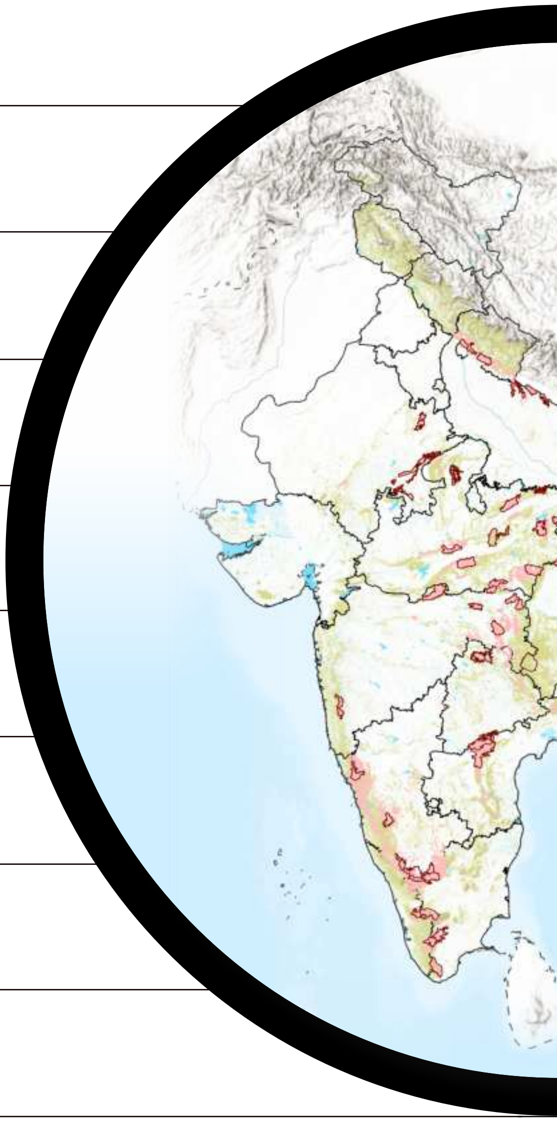
CHHATTISGARH
NUMBER OF SPECIES PRESENT-2
TOTAL GRIDS-129
GRIDS OCCUPIED-94

JHARKHAND
NUMBER OF SPECIES PRESENT-2
TOTAL GRIDS-59
GRIDS OCCUPIED-19

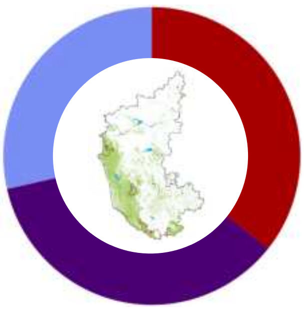
KARNATAKA
NUMBER OF SPECIES PRESENT-3
TOTAL GRIDS-1357
GRIDS OCCUPIED-385

KERALA
NUMBER OF SPECIES PRESENT-3
TOTAL GRIDS-320
GRIDS OCCUPIED-129

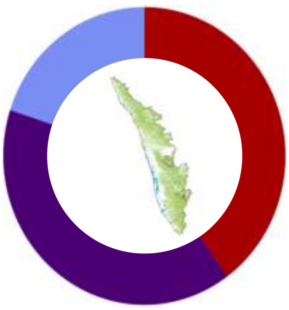
MAHARASHTRA
NUMBER OF SPECIES PRESENT-3
TOTAL GRIDS-762
GRIDS OCCUPIED-573



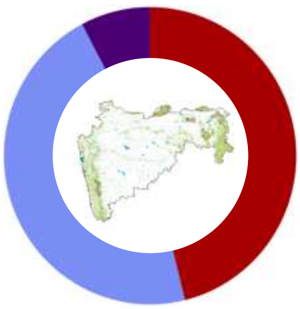
KARNATAKA



KERALA



MAHARASHTRA



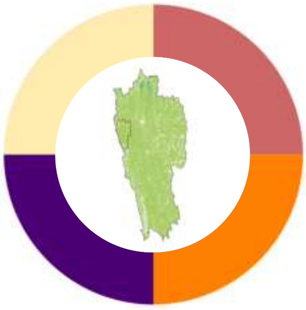
- ASIATIC GOLDEN CAT
- CARACAL
- CLOUDED LEOPARD
- DESERT CAT
- FISHING CAT

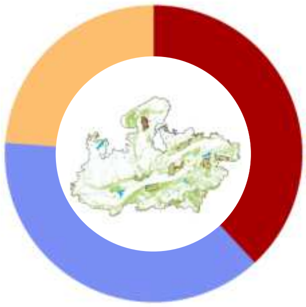
5844

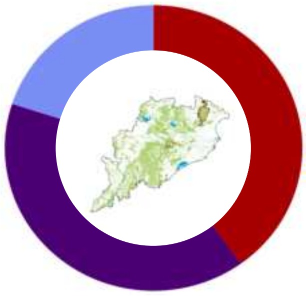
Total Sampled Grids of 25 km²

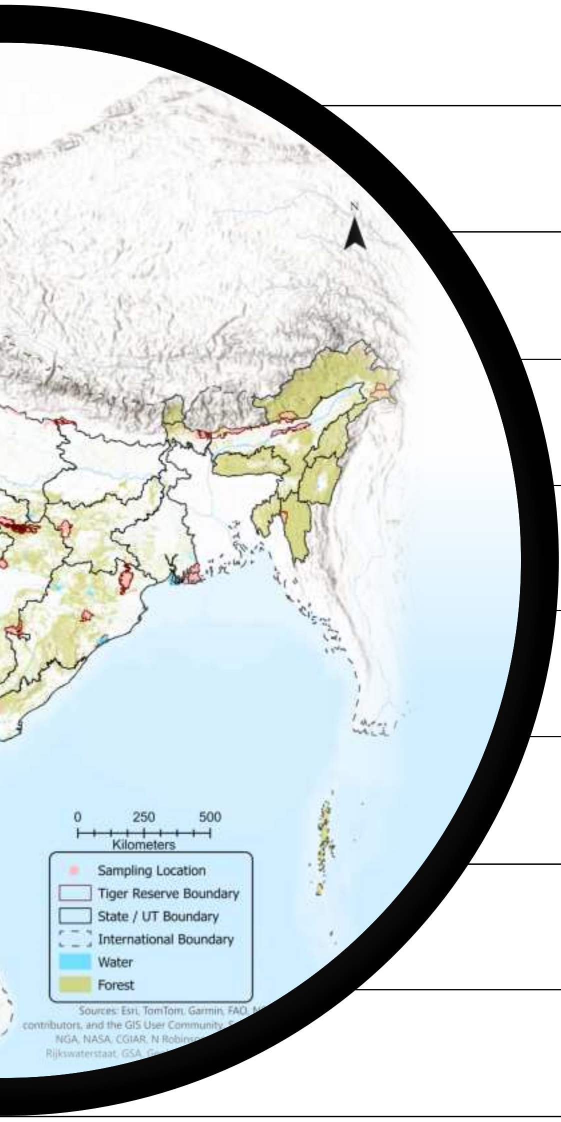
3494

Grids occupied by Small cats









MIZORAM
NUMBER OF SPECIES PRESENT-4
TOTAL GRIDS-10
GRIDS OCCUPIED-6

MADHYA PRADESH
NUMBER OF SPECIES PRESENT-3
TOTAL GRIDS-1051
GRIDS OCCUPIED-887

ODISHA
NUMBER OF SPECIES PRESENT-3
TOTAL GRIDS-129
GRIDS OCCUPIED-84

RAJASTHAN
NUMBER OF SPECIES PRESENT-4
TOTAL GRIDS-164
GRIDS OCCUPIED-119

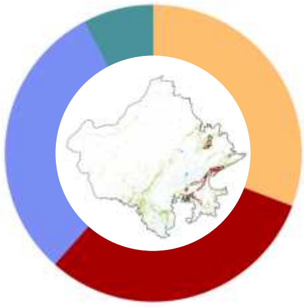
TELANGANA
NUMBER OF SPECIES PRESENT-2
TOTAL GRIDS-389
GRIDS OCCUPIED-296

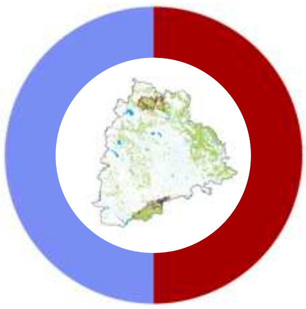
TAMIL NADU
NUMBER OF SPECIES PRESENT-3
TOTAL GRIDS-548
GRIDS OCCUPIED-332

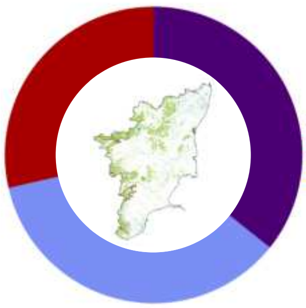
UTTARAKHAND
NUMBER OF SPECIES PRESENT-3
TOTAL GRIDS-327
GRIDS OCCUPIED-299

UTTAR PRADESH
NUMBER OF SPECIES PRESENT-4
TOTAL GRIDS-284
GRIDS OCCUPIED-199

WEST BENGAL
NUMBER OF SPECIES PRESENT-6
TOTAL GRIDS-200
GRIDS OCCUPIED-166





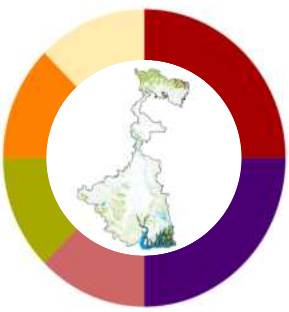


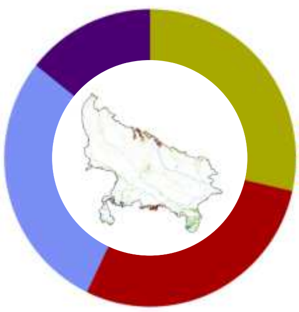
JUNGLE CAT

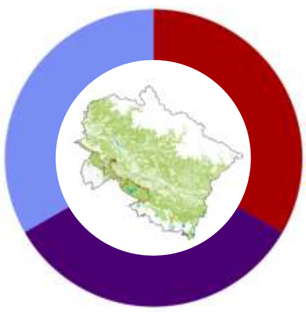
LEOPARD CAT

MARBELED CAT

RUSTY SPOTTED CAT







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Jungle cat

Introduction

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Fishing cat

Small felids are a remarkably diverse group of carnivores, part of the subfamily Felinae that inhabit nearly all terrestrial biomes, from arid deserts to temperate grasslands and tropical rainforests (Hunter, 2015). As obligate carnivores, small cats rely on protein-rich diets, positioning them as vital regulators of food webs (Sunquist & Sunquist, 2009). Typically weighing under twenty kilograms, small cats prey on small to medium-sized mammals, birds, reptiles, and insects, exerting top-down effects that sustain trophic cascades and stabilize diverse ecosystems (Polis *et al.,* 2000). By regulating prey populations, small cats provide critical ecosystem services, such as natural pest control in agroecosystems, reducing crop damage and disease outbreaks while decreasing the need for human interventions (Roemer *et al.,* 2009; Hofmeester *et al.,* 2017; Duckworth *et al.,* 2022). Apart from the regulatory role, small cats may also indirectly influence ecological processes such as seed dispersal, nutrient cycling, and gene flow (Salom Pérez, 2019; Bandyopadhyay *et al.,* 2024). Their role in maintaining ecosystem health and biodiversity makes them important indicators of habitat integrity (Hunter, 2008).

India harbours an exceptional diversity of 10 small cat species, representing nearly one fourth of all felid species worldwide. These range from high-altitude specialists in the Himalayas to lowland forest dwellers including the pallas's cat (*Otocolobus manul*), Eurasian lynx (*Lynx lynx*), jungle cat (*Felis chaus*), fishing cat (*Prionailurus viverrinus*), leopard cat (*Prionailurus bengalensis*), rusty-spotted cat (*Prionailurus rubiginosus*), marbled cat (*Pardofelis marmorata*), Asiatic golden cat (*Catopuma temminckii*), desert cat (*Felis lybica ornata*), and caracal (*Caracal caracal*) (Jhala *et al.,* 2021, Menon 2023). The clouded leopard (*Neofelis nebulosa*) is phylogenetically closer to the big cat lineage (Pantherinae) that includes tiger (*Panthera tigris*), lion (*Panthera leo*), leopard (*Panthera pardus*), jaguar (*Panthera onca*), and snow leopard (*Panthera uncia*) (Kitchener *et al.*, 2017). The *Neofelis* diverged early from the ancestral line leading to *Panthera*, with the split estimated around 6.4 million years ago (Johnson *et al.,* 2006; O'Brien & Johnson, 2007; Kitchener *et al.,* 2017). While morphologically it shares traits with big cats such as a robust cranium and elongated upper canines (Christiansen, 2006) it lacks the ability to roar due to its ossified hyoid bone which aligns it more closely with small felids (Hemmer, 1978; Christiansen, 2006; Weissengruber *et al.,* 2002).

These species occupy diverse habitats, mangroves, grasslands, dry scrublands, dense forests, Himalayan landscapes and even urban peripheries, playing a crucial role in maintaining the ecological integrity of these landscapes (Jhala *et al.,* 2021, Mukherjee, 2013). Conservation efforts directed at small cats inherently contribute to preserving these varied habitats. For instance, the wetland-specialist fishing cat highlights the ecological significance of riverine and mangrove ecosystems, which provide essential services like water filtration, flood control and carbon sequestration. Similarly, the rusty-spotted cat, among the world's smallest wild cats, thrives in mixed deciduous forests, underscoring the importance of habitat heterogeneity in conservation planning. The desert cat and caracal represent the arid and semi-arid ecosystems, while semi-arboreal species like the clouded leopard influence both terrestrial and arboreal prey dynamics in rainforests (Wilting *et al.,* 2006). Some species, like jungle cats, exhibit remarkable adaptability in human-modified landscapes, often utilizing fragmented forests and agricultural fields as secondary habitats, showcasing their ecological plasticity (Manandhar *et al.,* 2025).

The small cats face equally severe and multifaceted threats as larger carnivores, including habitat loss, human-wildlife conflict, poaching, and climate change (Srivathsa *et al.,* 2022). The fishing cat and clouded leopard are particularly vulnerable due to their dependence on specific habitat types (Mukherjee *et al.,* 2012; Wilting *et al.,* 2006; Bashir *et al.,* 2014; Habib *et al.*, 2024). The caracal, once widespread, is now largely restricted to protected areas in Rajasthan, Madhya Pradesh and Gujarat, with its population declining due to habitat fragmentation (Singh *et al.,* 2014). Unlike tigers and lions, small cats often inhabit landscapes interwoven with human settlements, making them particularly susceptible to anthropogenic pressures. This highlights the urgent need for comprehensive studies and targeted habitat conservation efforts to secure their long-term survival and ecological functions (Srivathsa *et al.,* 2022).

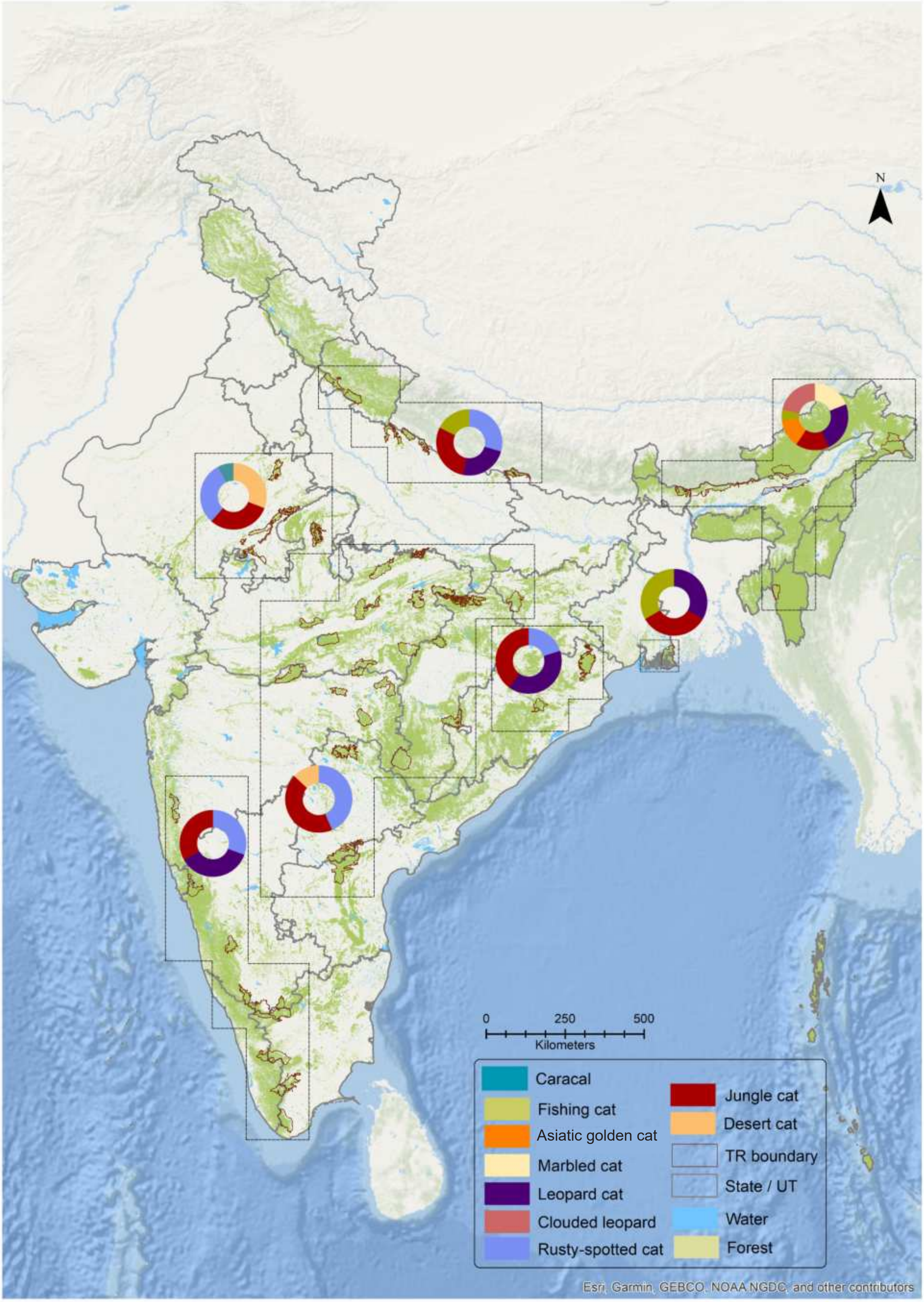

Figure 1.1. The distribution of small cats in the tiger-range forests of India.

Although they are widely distributed across the subcontinent, small felids remain understudied and underrepresented in conservation efforts, with limited data on their population status, habitat use, and ecological roles hindering effective management and conservation strategies (Marneweck *et al.,* 2022; Bandyopadhyay *et al.,* 2024). Elusive behaviour, low population densities, and cryptic nature of the species make field studies challenging, necessitating targeted efforts to assess their status and inform conservation planning. Current understanding primarily stems from studies limited to distribution mapping, habitat suitability, and basic activity patterns from camera trap records (Bora *et al.,* 2020; Jhala *et al.,* 2021, Mukherjee *et al.,* 2019). While relative abundance indices (RAI) from tiger landscapes (Jhala *et al.,* 2020) and scattered density estimates for species like leopard cat (Srivathsa *et al.,* 2015) jungle cat, rusty-spotted cat (Chatterjee *et al.*, 2020) and fishing cat exist (Adhya *et al.,* 2024), comprehensive population assessments across their entire range remain conspicuously absent from the scientific literature.

In the absence of robust population estimates at a landscape scale, occupancy modelling can serve as a valuable tool for assessing the distribution and status of these rare and elusive species (Efford & Dawson, 2012; MacKenzie & Nichols, 2004). Occupancy metrics, which account for imperfect detection, are increasingly used as proxies for population status in large-scale monitoring programs (Efford & Dawson, 2012, Jhala *et al.,* 2025). While occupancy does not directly measure population density or abundance, it provides critical insights into species occurrence, relative abundance and habitat preferences, making it a useful metric for conservation management (Efford & Dawson, 2012). Initially developed for wildlife surveys, occupancy analyses are now widely conducted using camera trap data, which offer the advantage of reliable and verifiable species identification, reducing uncertainties associated with traditional survey methods (Burton *et al.,* 2015; Efford & Dawson, 2012). In this study, we used large-scale camera trap data from the All India Tiger Estimation (AITE) surveys conducted in 2018 and 2022 to assess the occupancy status and dynamics of small cats across India's tiger-range forests (excluding the Pallas's cat and Eurasian lynx). We further identified key environmental drivers influencing their occupancy and offer actionable insights to support their conservation.

Desert cat

Methods

Jungle cat

2.1. Camera trap data

During the AITE exercises, 26, 838 cameras were deployed in 2018-2019, followed by 32, 588 cameras in 2022-2023, across the tiger-range forests in India (Jhala *et al.,* 2020; Qureshi *et al.,* 2023). Camera trap pairs were placed in 2 km² grids, designed to capture tiger, leopard along with other carnivores. Since our focus is on large-scale occupancy rather than fine-scale habitat use, this data-set would not bias our inference to estimate occupancy for the small cats. Grid identities were treated as sites, and spatial camera locations within each grid were arranged as temporal replicates (Srivathsa *et al.,* 2018). For occupancy analysis, we aggregated photo-capture data for each species from camera traps placed within 25 km² grid cells.

2.2. Covariates for detectability and occupancy

We modelled detection probability (p) as a function of sampling effort, hypothesizing that increased camera-trap operational days would improve site-level detection probability. For occupancy (Ψ), we selected environmental covariates based on a priori ecological knowledge of small cat habitat requirements. These included: (I) vegetation indices (*e.g.*, NDVI, forest types), (II) human disturbance metrics (*e.g.*, human footprint index, distance to protected area, habitat integrity), (III) terrain heterogeneity (ruggedness), (IV) bioclimatic variables, and (V) proxy for prey availability (see Table 1 for details). All covariates were resampled to a consistent 25 km² resolution and standardized in R using the scale function to ensure equal weighting in the analysis. Prior to modeling, we assessed multicollinearity among predictors using Pearson's correlation coefficients implemented via the corrplot package, retaining only variables with $|r| < 0.6$ to avoid over parameterization (Dormann *et al.,* 2013, Wei *et al.,* 2024).

2.3. Occupancy modelling

We used photo-captures of small cat species to model their occupancy using maximum likelihood-based occupancy models. These models estimate species occurrence across multiple surveys, accounting for imperfect detection by computing detection probabilities and inferring occupied areas (MacKenzie *et al.,* 2002). Camera trap detections were analyzed using single-season occupancy models to investigate correlates of current distribution and multi-season occupancy models to assess occupancy dynamics, including colonization (transition from unoccupied to occupied) and extinction (transition from occupied to unoccupied) rates between sampling seasons. Here, "season" corresponds to two quadrennial cycles of AITE sampling in 2018 and 2022. Given small cat's home range size is likely below 25 km² (Chen *et al.,* 2016; Katna *et al.,* 2022; Pallemaerts *et al.,* 2019; Ratnayaka *et al.,* 2021), the use of larger grid sizes reduces the risk of movement-related temporal autocorrelation (Efford & Dawson, 2012; Goldstein *et al.,* 2024). We assumed that occupancy state remained constant during the sampling period, as we camera trapped a large area, ensuring geographical closer and the sampling duration ~35 days ensured population closure. The analysis was performed in the unmarked package in R (Fiske & Chandler, 2011).

2.4. Occupancy status

We analyzed small cat occupancy patterns across India using single-season occupancy models (MacKenzie *et al.,* 2002). Detection probability (p) was modeled as a function of sampling effort (*e.g.*, camera-trap days or survey duration), while occupancy (Ψ) was modeled using habitat covariates (*e.g.* vegetation indices, human disturbance) at each sampled site. We identified optimal thresholds for the predicted occupancy probabilities by maximizing sensitivity and specificity via the pROC package, using true presence records against model-estimated occupancy probabilities (Jiménez-Valverde & Lobo, 2007; Robin *et al.,* 2011). Grids with estimated occupancy probabilities exceeding the optimal thresholds and those with confirmed species presence were identified. These grids were then classified into 'very low', 'low', 'moderate', and 'high' occupancy probability categories based on quantile breaks using ArcMap v10.8.

2.5. Occupancy dynamics

To analyze occupancy dynamics, we implemented multi-season occupancy models (MacKenzie *et al.,* 2003) across 3, 900 consistently sampled (25 km²) grids surveyed in both 2018 and 2022. We parameterized initial occupancy (Ψ), colonization (γ), extinction (ϵ), and detection probability (p) as functions of environmental and detection covariates. Occupancy in 2022 was derived from γ and ϵ estimates, allowing us to classify sites into three categories: (I) consistently occupied (occupied in both years), (II) increased occupancy (colonized or newly detected in 2022), and (III) decreased occupancy (extirpated or undetected in 2022) sites. To classify these site-specific trends, we adopted a conservative approach integrating both naïve detections and model predictions. First, we identified optimal probability thresholds for each year (2018 and 2022), by maximizing sensitivity and specificity *via* the pROC package, using true presence records against model-estimated occupancy probabilities (Jiménez-Valverde & Lobo, 2007; Robin *et al.,* 2011). For consistent occupancy classification, we combined sites with naïve detections in both survey periods and model-predicted occupancy probabilities exceeding the optimal thresholds in 2018 and 2022. This approach ensured that known presences were never misclassified as absences while allowing model predictions to identify potentially occupied but undetected habitats. Increased occupancy included sites with new detections in 2022 as well as sites where predicted probabilities exceeded the 2022 threshold (but were not part of the consistent sites). Conversely, decreased occupancy comprised sites with naïve detections in 2018 and sites where predicted probabilities above the 2018 threshold but not occupied in 2022 based on the naïve and estimated occupancy.

2.6. Model selection

We ran several models of occupancy with combinations of the detection and site covariates and selected the best model based on lowest AICc (Burnham & Anderson, 2002).

Table 2.1. Environmental covariates used in occupancy modelling for small cats in India, their ecological relevance & source.

SN	Variable	Ecological relevance	Source and resolution
1.	Carnivore encounter rate (tiger, leopard, striped hyaena, golden jackal, wolf, dhole, sloth bear)	Large carnivores may influence the distribution of meso and small carnivores by either offering high-quality habitats or, conversely, creating a landscape of fear (Jachowski et. al. 2020).	Qureshi *et al.,* 2023; 25 km²
2.	Relative abundance index (RAI) of small mammals and ground birds	Small mammals, ground birds serve as important prey species for the small cats.	Qureshi *et al.,* 2023; 25 km²
3.	Habitat integrity (integ)	Tiger density was included as a proxy for habitat integrity, as these apex carnivores typically occur in ecologically intact, high-quality habitats that may also offer favorable conditions for small cat species.	Qureshi *et al.,* 2023; 100 km²
4.	Normalized difference vegetation Index (NDVI)	NDVI may serve as an indicator of habitat cover for small cats, as well as overall ecosystem productivity (Xu *et al.,* 2012).	Vermote *et al.,* 2016, 30 m
5.	Forest types	Various forest types offer diverse resources and microclimates, which can provide information on the habitat preferences of different species. Additionally, forest type may serve as an indicator of prey abundance, especially for rodents, as some forest types are linked to higher rodent abundance (Gupta *et al.,* 2013; Bashir *et al.,* 2014; Sridhara & Rajendran, 2010; Shimada *et al.,* 2019).	Forest Survey of India (FSI), 2021; 24 m

6.	Distance to open forests (dof)	Open forests, characterized by sparse canopy cover and a mix of grassland or scrub, may offer suitable conditions for species like the jungle cat, which prefer such environments for hunting and movement.	Forest Survey of India (FSI), 2021; 24 m
7.	Distance to open natural ecosystem (done)	Open natural ecosystem such as savannahs, grasslands and scrublands, *etc.* are favored by certain species and hence may directly influence their occupancy.	Madhusudan & Vanak, 2023; 30 m
8.	Forest loss (floss) and tree cover (trcov) in 2018 and 2022	Forest and tree cover directly influence the distribution of certain small cats, particularly those which are arboreal. The loss of forest and low tree cover may negatively impact the occupancy of some species.	Hansen *et al.,* 2013; 30 m
10.	Water sources (water)	Water availability may serve as a limiting factor for certain species and plays a crucial role in determining their abundance and occupancy.	Forest Survey of India (FSI), 2021; 24 m
11.	Perennial (pwater) and seasonal (swater) water sources	The availability of perennial and seasonal water sources can influence the distribution of species like the fishing cat, which relies on aquatic habitats for foraging.	Pekel *et al.,* 2016; 30 m
12.	Terrain ruggedness index index (rug)	Terrain influences resource availability, contributing to the development of microclimates that support diverse species (John *et al.,* 2024).	NASA Shuttle Radar Topography Mission (SRTM), 2013; 30 m
13.	Mean temperature of coldest quarter (bio11)	Extremely low winter temperatures can impact resource availability, potentially driving range shifts and altering the occurrence patterns of small cats. It may serve as a limiting factor for the distribution of species.	Fick & Hijmans, 2017; ~1000 m
14.	Annual mean precipitation (bio12)	Precipitation influences habitat quality, water and prey availability, and vegetation cover.	Fick & Hijmans, 2017; ~1000 m
15.	Distance to protected areas (dpa)	Protection and management directly influence the health of a forest, therefore, protected areas provide safe refuges for wildlife species.	Data archived from Wildlife Database Cell, WII and Project Tiger database
16.	Distance to built-up (dbuilt)	Built-up areas reflect urbanization, and the associated disturbances may influence the distribution of small cats.	Karra *et al.,* 2021, 10 m
17.	Distance to road (droad)	Roads are closely associated with vehicular movement, habitat fragmentation, and disturbances, which can negatively affect the presence and occupancy of small cats.	UN OCHA, 2023
18.	Human footprint (hfp)	Included to quantify the spatial extent and intensity of anthropogenic pressures potentially influencing small cat distribution.	Mu *et al.,* 2022; 1000 m
19.	Distance to croplands (dcrop)	Croplands can alter habitat structure, prey availability, and human disturbance levels, all of which may affect the spatial distribution of these species.	Karra *et al.,* 2021; 10 m

Species Account

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Jungle cat

ASIATIC GOLDEN CAT

(Catopuma temminckii)

3.1. Introduction

Endemic to Indo-Malayan ecorealm, Asiatic golden cat (hereafter "golden cat") is a medium sized oriental felid (Sunquist & Sunquist 2002) and represents one of the earliest felid radiations (Johnson *et al.,* 2006; O' Brien & Johnson 2007). Unlike other sympatric small felids, Asiatic golden cat is largest amongst the Asian small cats and remarkably polymorphic with at least six different morphs have been recorded so far (Nijhawan *et al.,* 2019). Once widely distributed, the species has faced 68% range contractions in last two decades in their habitat strongholds (Peterson *et al.,* 2021). The species is currently assessed as Near Threatened by IUCN (McCarthy *et al.,* 2015), listed in Appendix I of CITES and protected under Schedule I of Indian Wild Life (Protection) Act 1972. Distribution of the species ranges from eastern Nepal, south China, Bangladesh, Bhutan, Northeast India, Myanmar, Vietnam, Thailand, and Indonesia (Dhendhup 2016; Duan *et al.,* 2024; McCarthy *et al.,* 2015; Peterson *et al.,* 2021). In India, golden cat is recorded from Assam (Lahkar *et al.,* 2024); Sikkim (Bashir *et al.,* 2011); Meghalaya (Nadig *et al.,* 2016); Mizoram (Singh & Mcdonald, 2017); Nagaland (Longchar *et al.,* 2017; Joshi *et al.,* 2019); Arunachal Pradesh, and northern West Bengal (Jhala *et al.,* 2020).

The species inhabits a broad variety of habitat types ranging from evergreen broadleaf forests, dry deciduous forests, coniferous forests, and shrub lands (McCarthy *et al.*, 2015; Duan *et al.,* 2024). Altitudinal gradient of their distribution also varies from tropical semi-evergreen forest (~160 m above sea level) to temperate forests (>3000 m above sea level), with individuals recorded from ~4300 m above sea level (Lyngdoh *et al.*, 2011; Dhendhup *et al.,* 2016; Qiao *et al.,* 2022). Diet of the species includes wide range of vertebrates mainly rodents, birds, lizards and occasionally small ungulates like barking deer (Kamler *et al.,* 2020; Xiong *et al.,* 2017). Major threats to the species are hunting for pelt and meat, illegal pet trade and habitat fragmentation (Bal *et al.,* 2023; Kamler *et al.,* 2020; Peterson *et al.,* 2021). This species is mostly solitary; however, occasional pairing is also reported (Vernes *et al.,* 2015, Jhala *et al.,* 2021). Home range size of the species was estimated 11 km² and 16 km² in prey scarce areas of Thailand for male and female respectively (Grassman *et al.,* 2005). Due to its extremely rare occurrence, golden cat remains one of the most understudied feline species in Indian subcontinent. Most of the studies are record of golden cat presence from camera trap data. Jhala *et al.,* 2021 assessed habitat suitability and activity pattern of golden cat in the Northeast Hills and Brahmaputra Floodplains landscape. However, information about population status of the species is majorly lacking, which is essential for conservation planning of the species (Bandyopadhyay *et al.,* 2024).

Based on our ecological understanding and past studies, we explored various environmental factors to model occupancy of the species (Table 2.1). Since the species primarily inhabits evergreen broadleaf, coniferous, and deciduous forests, we used vegetation indices such as the NDVI, tree cover, and canopy height to inform the model about forest types, which may play a key role in its distribution. Given that the species occupies a wide range of elevations, and prefers undisturbed terrain for refuge and cover, we considered terrain ruggedness as an important factor influencing its distribution. To assess the impact of prey availability, we used the RAI of small mammals and ground birds, which are important food resources. We also incorporated bioclimatic variables, to evaluate how climate conditions affect habitat occupancy. Additionally, to account for human influence, we included measure such as the human footprint index.

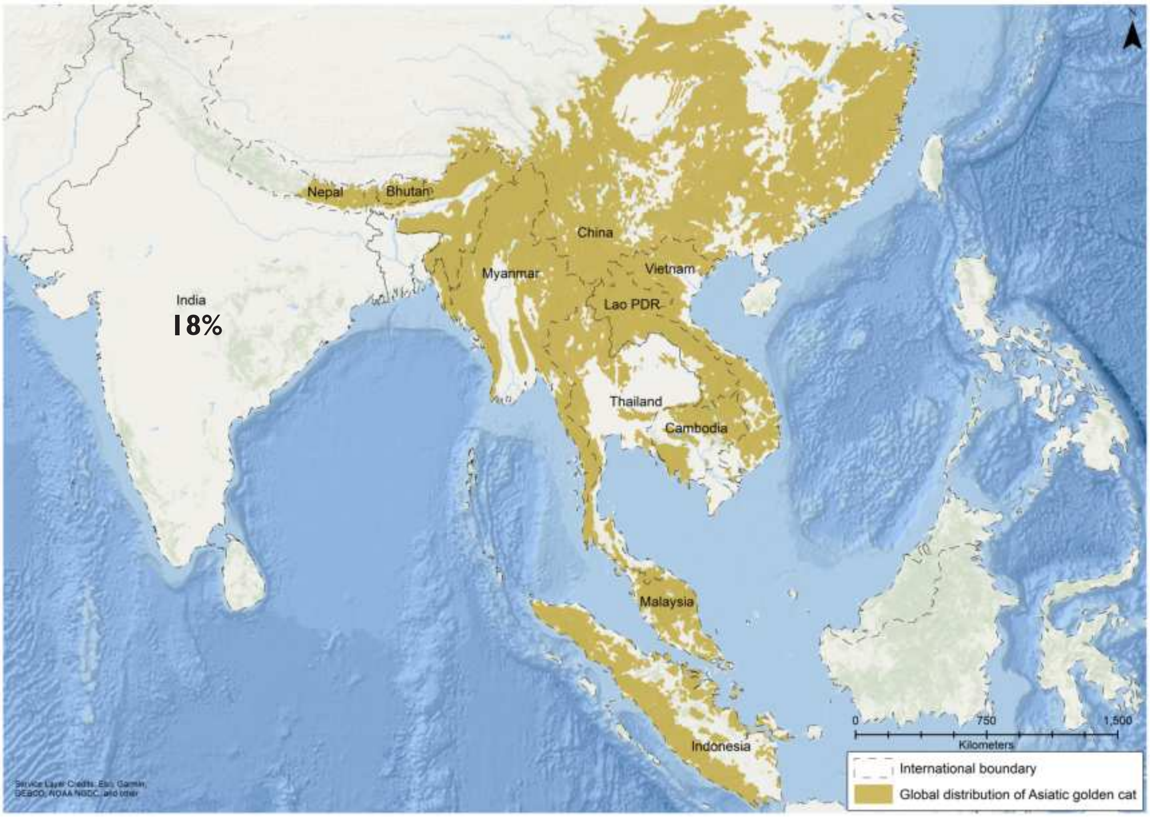

Figure 3.1. Global distribution range of the Asiatic golden cat (*Catopuma temminckii*) based on IUCN Red List data. About 18% of the species' global distribution occurs within India.

3.2 Status of occupancy

During the camera trap surveys, the species occupied 13 out of 143 sampled sites (naïve occupancy, 0.09) based on 26 detections in 2018, and 27 out of 253 sampled sites (naïve occupancy 0.11) based on 43 detections in 2022. Average modelled site occupancy in 2022 was 0.22 (SE 0.06).

Occupancy of the Asiatic golden cat was positively associated with post-monsoon NDVI (β = 2.16, SE = 0.73, P < 0.01) and terrain ruggedness (β = 1.70, SE = 0.45, P < 0.01), indicating a preference for habitats with dense dense vegetation and undualting terrain (Table 3.2). However, the model did not detect a significant relationship of occupancy with prey abundance and sampling effort, likely due to the species' low detection rates across sampled grids

The occupancy dynamics of the Asiatic golden cat were consistent with results from the single-season model, with initial occupancy showing a positive association with rugged terrain (β = 3.10, SE = 0.85, P < 0.001) (Table 3.2). Similarly, the probability of colonization was also significantly higher in rugged areas (β = 2.03, SE = 0.77, P < 0.05). However, no environmental covariates were found to significantly explain variation in extinction probability. Increased sampling effort also did not have a significant influence on detection probability.

Table 3.1. Comparison of occupancy models with different covariate combinations for the Asiatic golden cat across tiger-range forests of India in 2018 and 2022.

Model type	Model	K	AICc	∆AICc	AIC-cWt	Cum. Wt	LL
Occupancy status (single-season)	Ψ(ndvips+rug) p(efffort)	5	311.24	0	0.72	0.72	-150.5
	Ψ(ndvips+smam+gbird) p(efffort)	6	341.31	30.08	0	1	-164.49
	Ψ(.) p(.)	2	347.93	36.69	0	1	-171.94
	Ψ(.) p(efffort)	3	348.56	37.32	0	1	-171.23
Occupancy dynamics (multi-season)	Ψ(rug) γ(rug) ϵ(.) p(.)	6	318.54	0	0.9	0.9	-153
	Ψ(ndvips18+rug+bio11) γ(rug) ϵ(hfp20) p(.)	10	322.99	4.45	0.1	1	-150.75
	Ψ(.) γ(.) ϵ(.) p(.)	4	379.3	60.76	0	1	-185.52
	Ψ(.) γ(.) ϵ(.) p(effort)	5	477.48	158.94	0	1	-233.55

In single-season models: ndvips = NDVI post-monsoon, rug = terrain ruggedness index, smam = small mammal RAI, gbird= ground bird RAI, effort = camera trap days, (.) = constant.

In multi-season models: rug = terrain ruggedness index, nvdips18 = NDVI post-monsoon in 2018, hfp20 = human foot-print in 2020, bio11 = mean temperature of coldest quarter, (.) = constant.

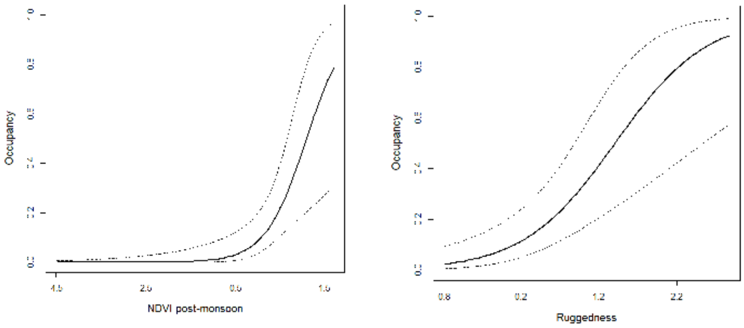

Figure 3.2. Estimated occupancy (Ψ) of the Asiatic golden cat in response to NDVI post-monsoon, ruggedness and sampling effort across tiger-range forests of India, based on camera-trap sampling in 2022.

Table 3.2. Estimated β coefficients for covariates influencing the occupancy of the Asiatic golden cat in India.

Model type	Parameters	Coefficients	β Estimate	SE	P-value
Occupancy status (single-season)	Occupancy	Intercept	-2.39	0.49	0.00
		ndvips	2.16	0.73	0.00
		rug	1.70	0.45	0.00
	Detection	Intercept	-2.48	0.69	0.00
		effort	0.02	0.02	0.23
Occupancy dynamics (multi-season)	Initial occupancy	Intercept	-3.72	0.81	0.00
		rug	3.10	0.85	0.00
	Colonization	Intercept	-2.58	0.50	0.00
		rug	2.03	0.77	0.01
	Extinction	Intercept	-1.40	1.30	0.28
	Detection	Intercept	-1.39	0.20	0.00

In single-season models: ndvips = NDVI post-monsoon, rug = terrain ruggedness index, effort = camera trap days.

In multi-season models: rug =terrain ruggedness index, nvdips18 = NDVI post-monsoon in 2018, hfp20 = human foot-print in 2020, bio11 = mean temperature of coldest quarter.

3.3 Discussion

Highest occupancy of Asiatic golden cats was recorded in the Namdapha–Kamlang cluster, followed by the Dibang Wildlife Sanctuary and Dampa Tiger Reserve. Moderate occupancy levels were observed in Pakke and Neora Valley, while Manas, Buxa, and Nameri Tiger Reserves showed relatively low occupancy. Occupancy of the species was relatively higher in evergreen forests (Figures 3.3 and 12.1) in Northeast India.

Asiatic golden cat occupancy probability remained consistent in Pakke, followed by Namdapha, Buxa, and Dampa Tiger Reserves (Figure 3.4). Higher probabilities of colonization were observed in Nameri, Kamlang, and Buxa. However, a decline in occupancy was noted in parts of Dibang Wildlife Sanctuary Namdapha, Kamlang, and Dampa Tiger Reserves. These patterns highlight the species' association with dense, rugged habitats and underscore the importance of conserving the hill landscapes of Northeast India.

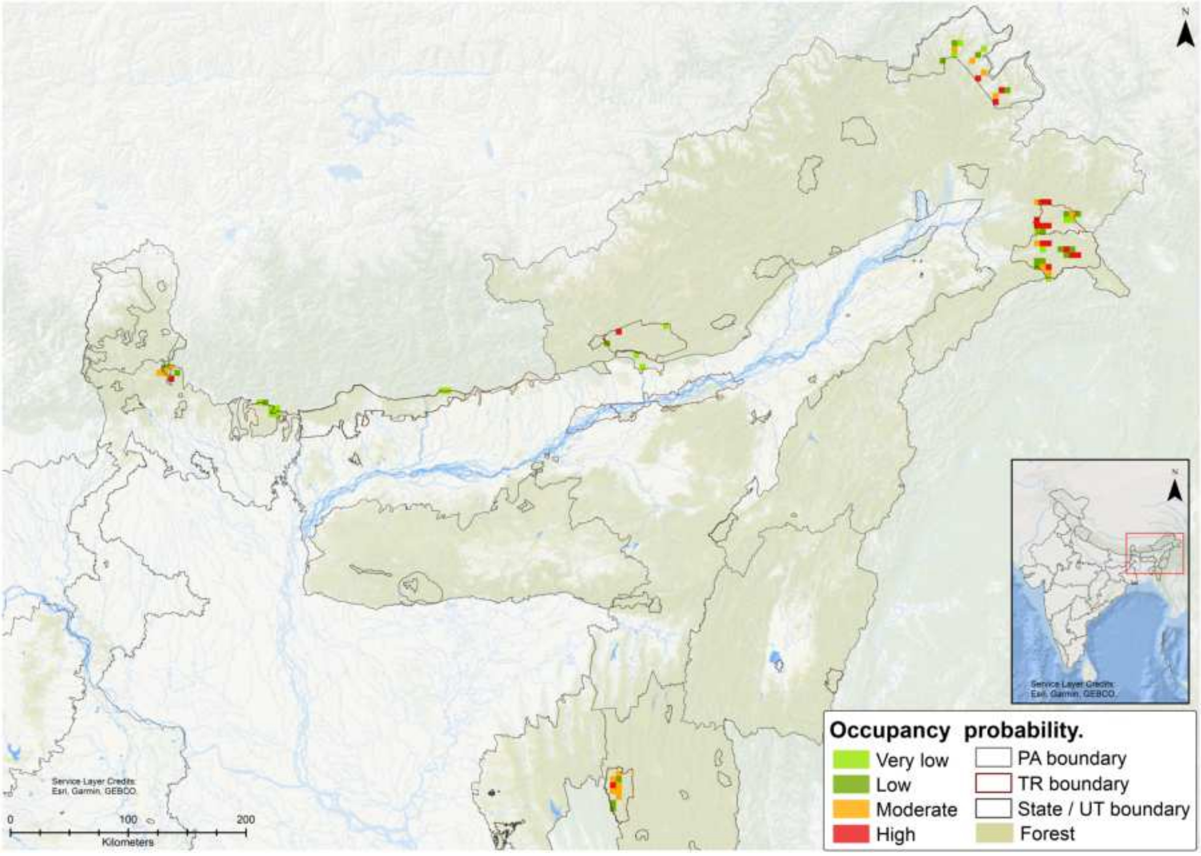

Figure 3.3. Estimated occupancy (Ψ) of the Asiatic golden cat based on camera-trap surveys conducted in tiger-range forests of India in 2022.

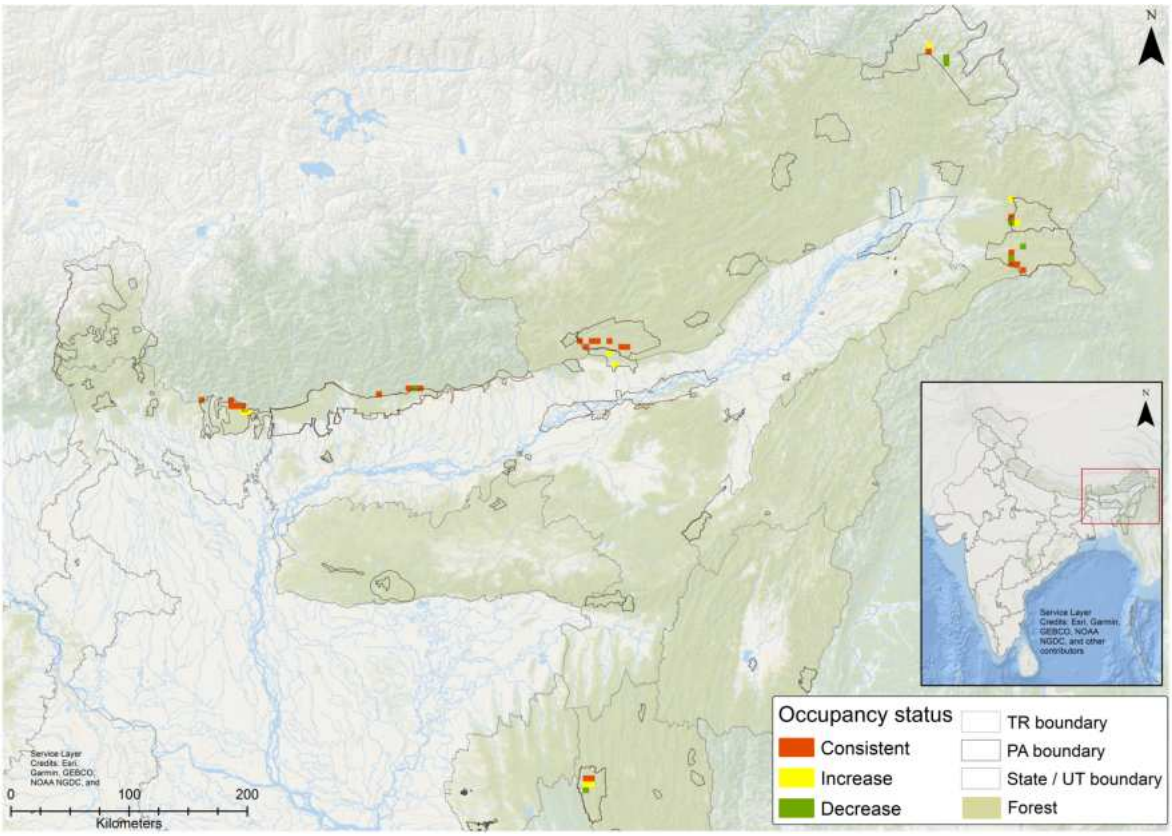

Figure 3.4. Occupancy (Ψ) dynamics of the Asiatic golden cat across consistently sampled camera trap grids in 2018 and 2022 within tiger-range forests of India.

CARACAL
(Caracal caracal)

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4.1. Introduction

The caracal is a medium-sized wild cat distinguished by its striking black-tufted ears (Buffon, 1761; Menon, 2014). It is classified as "Least Concern" on the IUCN Red List (Avgan *et al.,* 2016), included in Appendix I of CITES and considered a Schedule I species under the Wild Life (Protection) Act, 1972. Primarily found in arid and semi-arid regions, caracals inhabit dry grasslands, scrublands, and open forests. They are highly adaptable and capable of surviving in harsh environments, often thriving in areas with sparse vegetation. Caracals are solitary and territorial animals, primarily nocturnal hunters. They are opportunistic meso-predators that feeds on a variety of small to medium sized mammals and birds, and occasionally livestock, which frequently leads to conflicts with humans (Avenant *et al.,* 2002). But in India there is no report of conflict with human.

In India, caracals have been reported in only three states; Rajasthan, Gujarat, and Madhya Pradesh (Singh *et al.,* 2014; Khandal *et al.,* 2020) making them one of the country's rarest and most threatened wild cats. It is estimated that only about 10 to 15 individuals are present in the Kutch region of Gujarat, and less than 50 remain in Rajasthan (Singh *et al.,* 2014). Caracal has a broad but fragmented distribution confined to specific areas in central and western India. The species was recently captured for the first time, in a camera trap in Mukundara Hills Tiger Reserve (Thakar *et al.* 2025). Despite their adaptability, caracals face considerable threats, including habitat loss and fragmentation, human-wildlife conflict, and retaliatory killings. Semi-arid and open landscapes are heavily exploited for conversion into croplands, settlements, and other developmental activities, leading to habitat destruction and further fragmentation of caracal populations (Sunquist & Sunquist, 2002). Additionally, international trade involving caracals represents a serious threat to the long-term survival of the species.

4.2. Status of occupancy

The AITE survey recorded 2 photo captures of the species in 2018, with its presence only in 1 grid. In 2022, the number of photo captures of the species increased to 19, occurring in 7 grids. Moreover, due to lack of spatial captures of caracal, only its naïve occupancy could be obtained (Figure 4.1), which was restricted to Ranthambore Tiger Reserve in Rajasthan.

Figure 4.1. Global distribution range of the caracal (*Caracal caracal*) based on IUCN Red List data. About 2 % of the species' global distribution occurs within India.

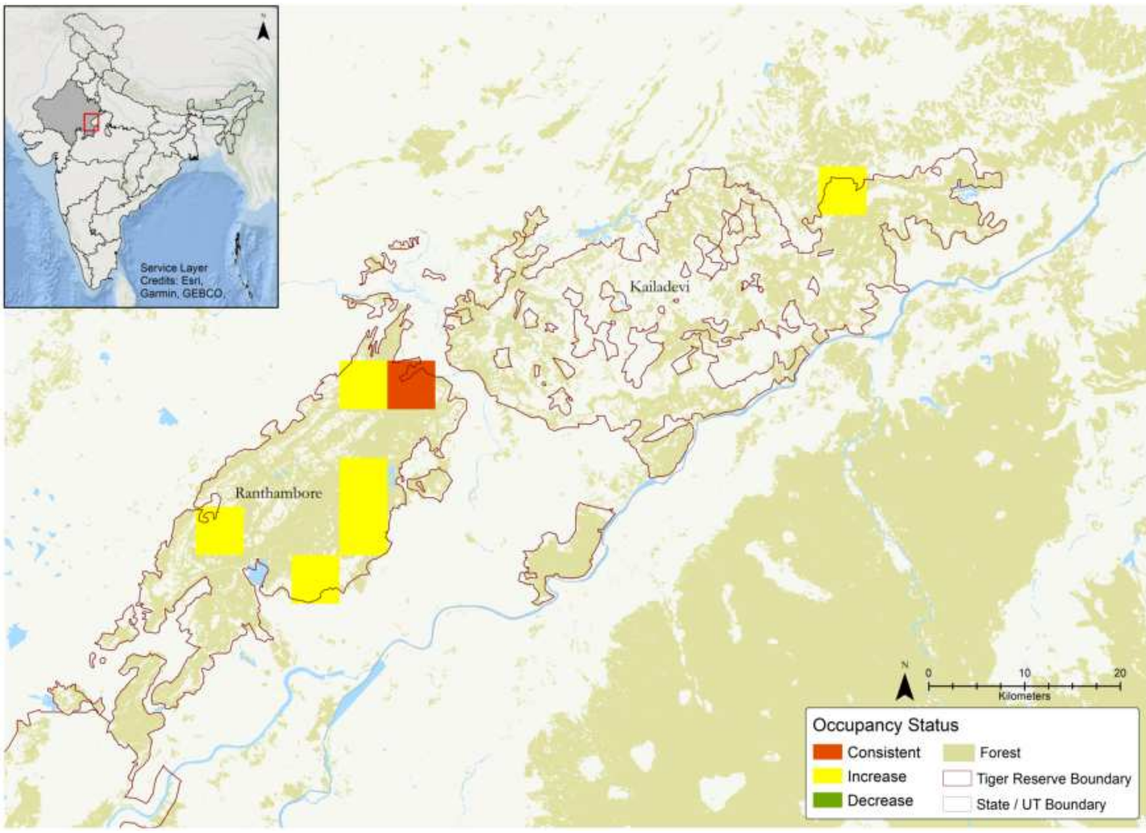
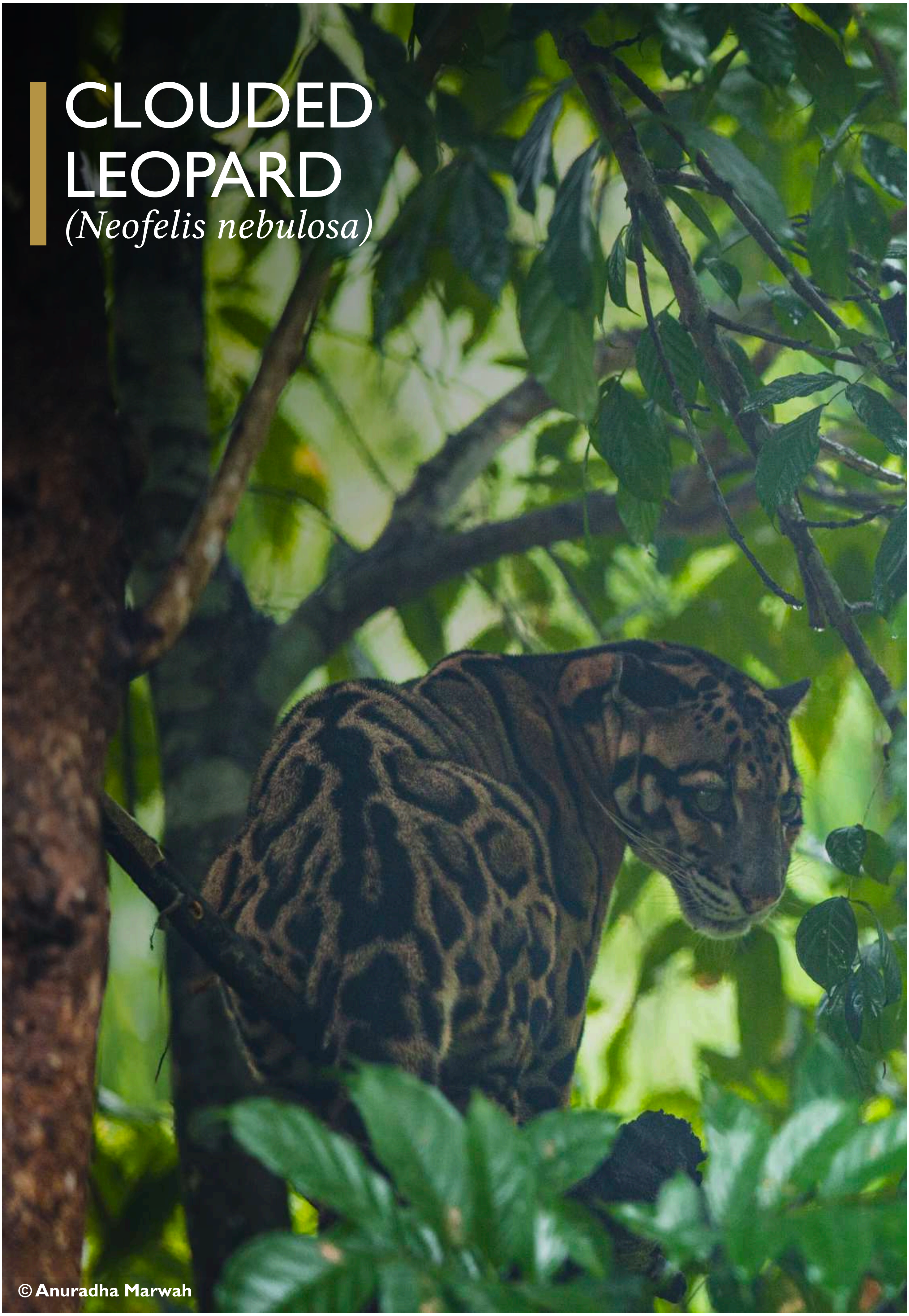


Figure 4.2. Naïve occupancy of caracal obtained during AITE 2018 and 2022. Due to poor detections occupancy could not be modelled.



CLOUDED LEOPARD
(Neofelis nebulosa)

5.1. Introduction

Clouded leopard is a semi-arboreal, medium-sized felid (Gray *et al.,* 2021, Peterson *et al.,* 2020) that inhabits the tropical forests of South and Southeast Asia as a sympatric large feline with tiger and leopard (Giordano, 2022). It is a bitypic genus, and was divided into mainland or Indochinese clouded leopard (*Neofelis nebulosa*) and Sunda clouded leopard (*Neofelis diardi*) based on mtDNA (Wilting *et al.,* 2007). In India, clouded leopard is protected as Schedule I species under Wild Life (Protection) Act 1972, and listed as vulnerable in IUCN and in Appendix I of CITES. Its geographic range spans over south of the Himalayas in Nepal, Bhutan, forested areas of Northeast India and south-eastern Bangladesh, Myanmar, southern China, Taiwan, Vietnam, Laos, Cambodia, Thailand, and Malaysia (Can *et al.,* 2020; Gray *et al.,* 2021). They prefer closed canopy forests (Grassman *et al.,* 2005; Austin *et al.,* 2007). In India, clouded leopard occurs in the states of Sikkim (Sathyakumar *et al.,* 2011), northern West Bengal, Arunachal Pradesh, Assam, Mizoram (Jhala *et al.,* 2020), Meghalaya (Mukherjee *et al.,* 2019), Manipur (Choudhury 1997), Nagaland (Nair *et al.,* 2021), and Bihar (Shafi *et al.,* 2019). While their distribution is recorded till the foothills of central Himalaya (Shafi *et al.,* 2019; Can *et al.*, 2020), much of the population is widely distributed in smaller forested fragments of Northeastern states of India (Bal *et al.,* 2023a; Singh & Macdonald 2017). Population density of clouded leopard is available from only two tiger reserves of India namely Manas and Dampa (Borah *et al.,* 2014; Singh & Mcdonald, 2017; Bhatt & Lyngdoh 2023). However, Bhatt & Lyngdoh (2023) reported a decline in the population density as compared to Borah *et al.,* 2014. Jhala *et al.*, (2021) assessed the habitat suitability and activity patterns of the clouded leopard, while Habib *et al.*, (2024) examined its habitat suitability and connectivity in the Northeast Hills and Brahmaputra Floodplains landscape.

Other than rapid habitat destruction, clouded leopards face multiple threats including prey depletion, demand-driven poaching for pelts, body parts, and live animals for the pet trade (Ball *et al.*, 2023a; Giordano *et al.*, 2023; Peterson *et al.*, 2020; Wolf & Ripple, 2016; D'Cruze & Macdonald, 2015). It is an extremely common species invloved in the illegal wildlife trade. In addition, the mainland clouded leopard has also lost approximately 64% of its global range, underscoring its vulnerability to extinction (Wolf & Ripple, 2017).

Clouded leopards were earlier considered to live only in primary evergreen tropical rainforests. However, recent studies show they can be found in a wider variety of habitats, including tropical dry and moist deciduous forests, secondary and logged forests, mangroves, and scrub areas (Mukherjee 1998; Menon 2023; Grassman *et al.,* 2016). They usually live at elevations up to 3, 000 meters but have been spotted as high as 3, 720 meters in Sikkim (Sathyakumar *et al.,* 2011). The diet of clouded leopards includes various mammals that live in trees and on the ground. This includes slow lorises, other primates, Asiatic brush-tailed porcupines, ground squirrels, hog deer, barking deer, and more (Gray *et al.,* 2021). They are mainly active at night and during twilight hours (Grassman *et al.,* 2005; Austin *et al.,* 2007; Jhala *et al.,* 2021). Although, there are no available estimates of home range size of clouded leopard from India, it ranged between 20-40 km^2 in prey scarce areas of Thailand (Grassman *et al.,* 2005).

Based on our ecological understanding and past studies, we explored various environmental covariates to model the species' occupancy (Table 5.1). Since the species primarily inhabits tropical closed canopy forests, we considered vegetation indices such as the NDVI, tree cover. We assumed that less rugged, lowland tropical rainforests may be more suitable for clouded leopards, as they likely offer higher prey availability, easier movement compared to highly rugged terrain. Clouded leopard is an extremely elusive species and likely to occur in less disturbed habitats, therefore we used tiger density as proxy for habitat integrity since tiger occupy less disturbed habitats (Jhala *et al.,* 2020, 2021; Qureshi *et al.,* 2023). Additionally, to account for human disturbances, we incorporated human footprint index.

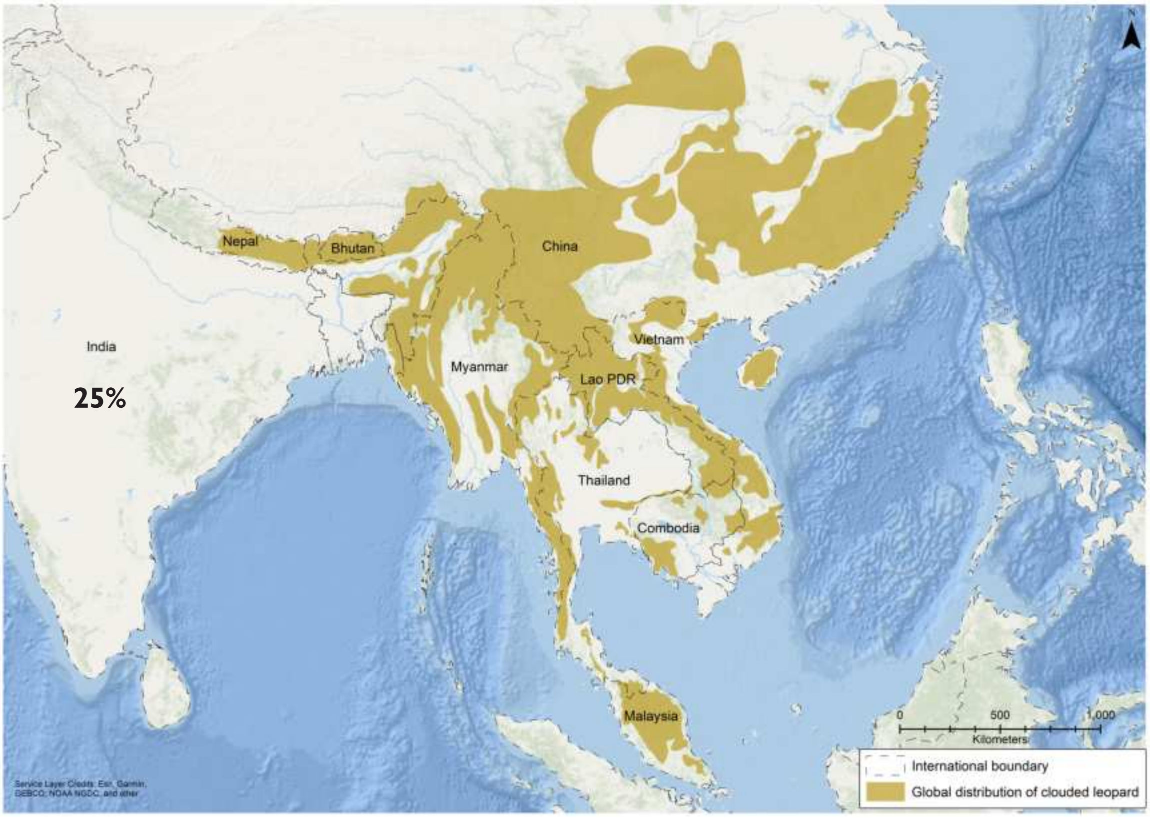


Figure 5.1. Global distribution range of the clouded leopard (*Neofelis nebulosa*) based on IUCN Red List data. About 25% of the species' global distribution occurs within India.

5.2 Status of occupancy

During the sampling period of 2018, clouded leopard occupied 37 out of 180 sampled sites (naïve occupancy, 0.21) based on 55 detections, and during the sampling period of 2022, the species occupied 58 out of 253 sampled sites (naïve occupancy 0.23) based on 79 detections. Averaged modelled site occupancy in 2022 was 0.48 (SE 0.08).

Clouded leopard occupancy was positively associated with tree cover ($\beta = 2.93$, SE = 0.64; $P < 0.01$) and negatively associated with terrain ruggedness ($\beta = -1.32$, SE = 0.63; $P < 0.05$) (Table 5.1), indicating a preference for closed-canopy forests in less rugged, valley habitats, consistent with the species' semi-arboreal nature. Occupancy also increased with habitat integrity ($\beta = 0.77$, SE = 0.34; $P < 0.05$), underscoring the species' reliance on undisturbed habitats. Detection probability was not significantly influenced by sampling effort, and no covariates were found to significantly explain occupancy dynamics across years.

Table 5.1. Comparison of occupancy models with different covariate combinations for the clouded leopard across tiger-range forests of India in 2018 and 2022.

Model Type	Model	K	AICc	∆ AICc	AIC-cWt	Cum. Wt	LL
Occupancy status (single-season)	Ψ(trcov+integ+rug) p(efffort)	6	567.92	0	0.92	0.92	-277.79
	Ψ(ndvips+integ+hfp) p(efffort)	6	572.8	4.89	0.08	0.99	-280.23
	Ψ(trcov+hfp+rug) p(efffort)	6	578.15	10.24	0.01	1.0	-282.91
	Ψ(.) p(.)	2	608.73	40.82	0.00	1.0	-302.34
	Ψ(.) p(efffort)	3	610.65	42.74	0.00	1.0	-302.28

In single-season: trcov = tree cover, integ = habitat integrity, rug = terrain ruggedness index, ndvips = NDVI post-monsoon,
hfp = human footprint, effort = camera trap days, (.) = constant.

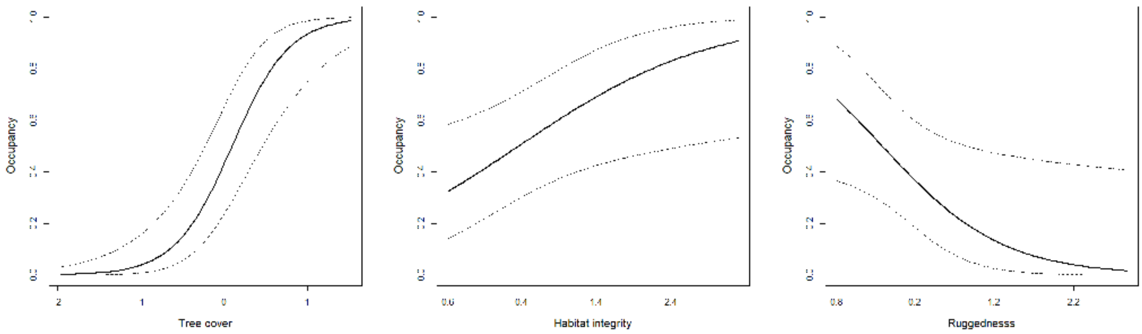


Figure 5.2. Estimated occupancy (Ψ) of the clouded leopard in response to tree cover, habitat integrity, and ruggedness across tiger-range forests of India, based on camera-trap sampling in 2022.

Table 5.2. Estimated β coefficients for covariates influencing the occupancy of the clouded leopard in India.

Model type	Parameters	Coefficients	β Estimate	SE	P-value
Occupancy status (single-season)	Occupancy	Intercept	-0.28	0.46	0.55
		trcov	2.93	0.64	0.00
		integ	0.77	0.34	0.02
		rug	-1.32	0.63	0.04
	Detection	Intercept	-2.52	0.34	0.00
		effort	0.01	0.01	0.24

In single-season: trcov = tree cover, integ = habitat integrity, rug = terrain ruggedness index, effort = camera trap days.

5.3 Discussion

The clouded leopard is one of the most heavily sought-after species in illegal wildlife trading; therefore, it may be found in areas with dense forests and less human disturbance. Highest occupancy of clouded leopard was found in Pakke-Nameri cluster, Dampa, Kamlang- Namdapha cluster and Manas followed by Buxa Tiger Reserves (Figure 5.3). Moderate occupancy of the species was found in Kaziranga Tiger Reserve, Gorumara and Neora Valley National Parks and south-eastern part of Manas and north-western part of Buxa Tiger Reserves. Clouded leopard occupancy was found to be low in Jaldapara National Nark, Dibang, and Mahananda Wildlife Sanctuaries, and Orang Tiger Reserve. The presence of clouded leopards was also recorded during annual Phase-IV monitoring in 2016 at Valmiki Tiger Reserve in Bihar. Occupancy of the species is relatively higher in the evergreen forests, bamboo-mixed and swamp forests.

We did not find any covariates that significantly explained the occupancy dynamics of the clouded leopard between 2018 and 2022. Based on naïve occupancy, the species was consistently detected in Buxa, Dampa, Kaziranga, Kamlang, Namdapha, Nameri, and Pakke Tiger Reserves during both years (Figure 5.4). The number of occupied grids increased in these areas, as well as in Neora Valley National Park. However, some previously occupied grids in Dibang Wildlife Sanctuary Dampa, Kaziranga, Manas, Nameri, Pakke Tiger Reserves showed declines.

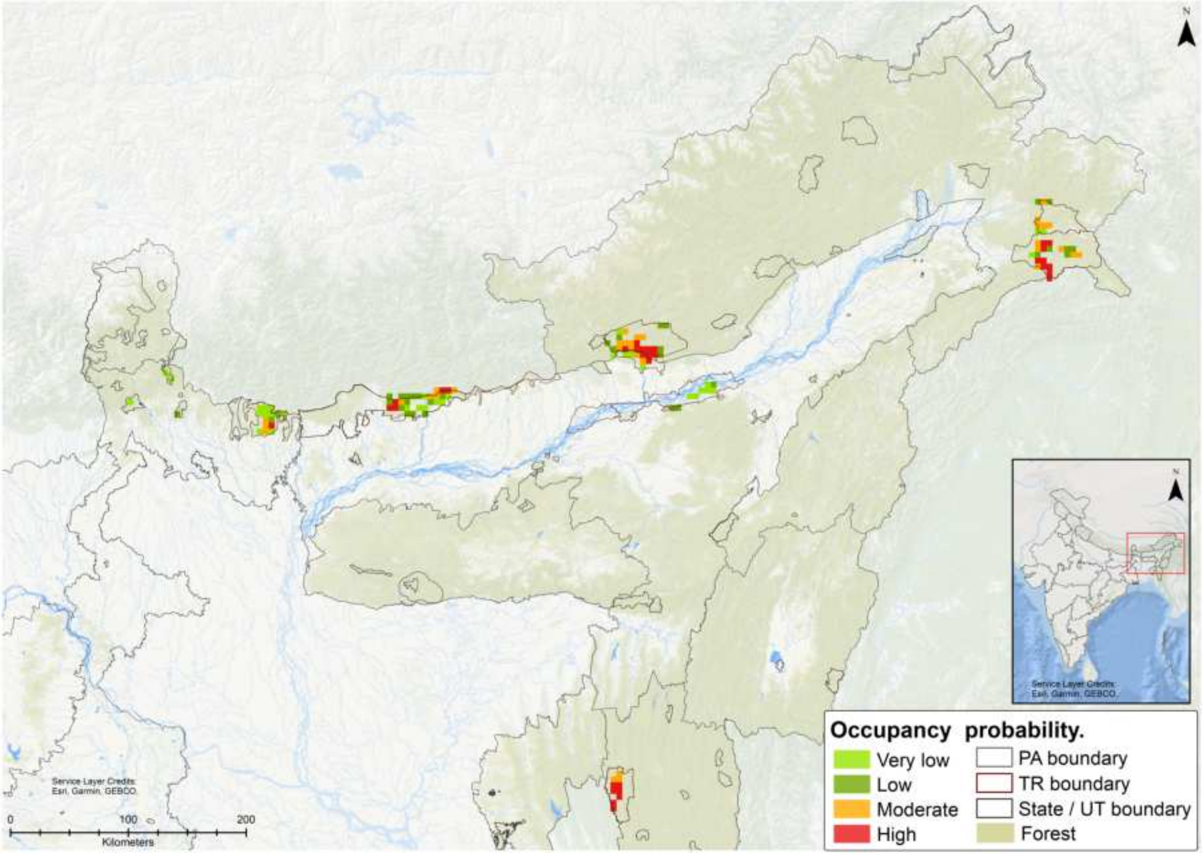


Figure 5.3. Estimated occupancy (Ψ) of the clouded leopard based on camera-trap surveys conducted in tiger-range forests of India in 2022.

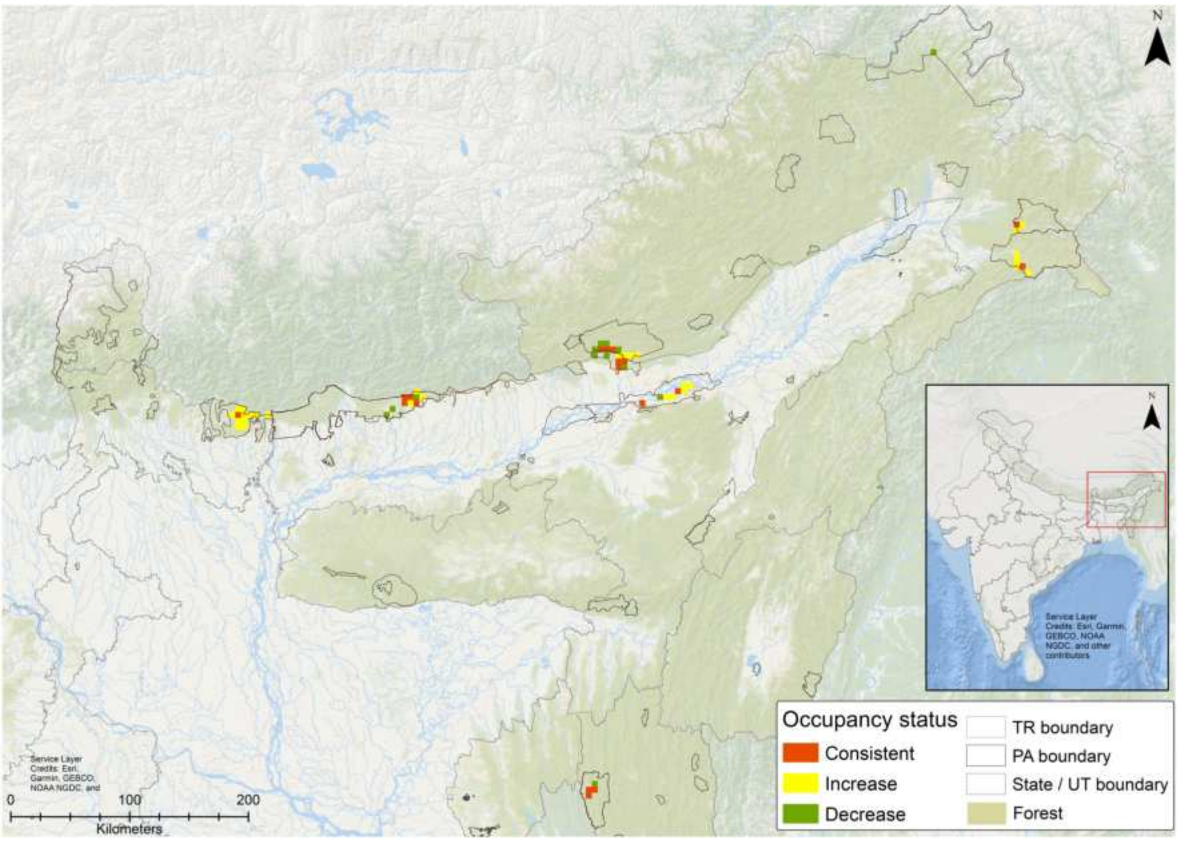
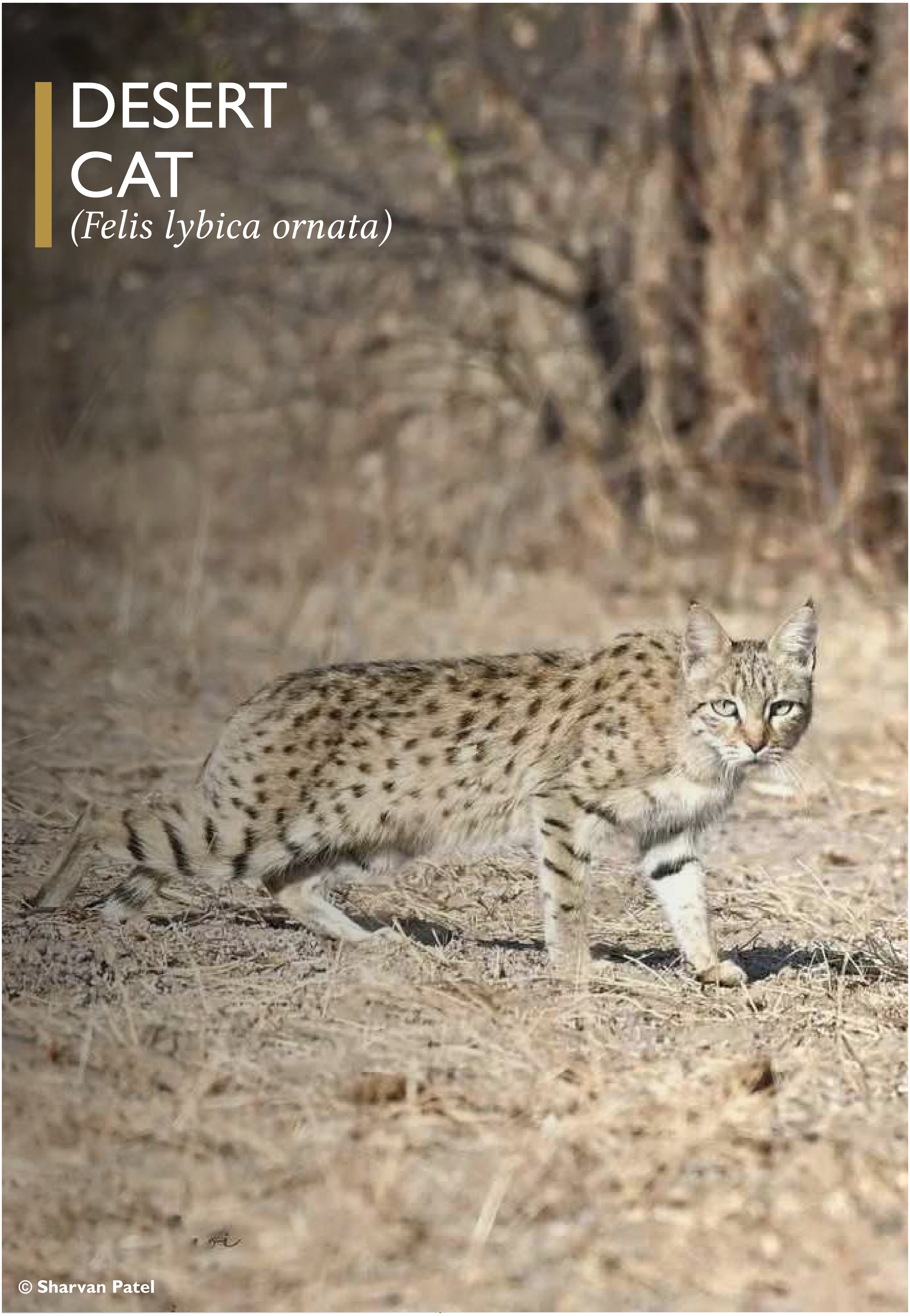


Figure 5.4. Trends in the occupancy (Ψ) dynamics of clouded leopard in tiger-occupied forests of India, derived from consistent camera trap sampling grids in 2018 and 2022

DESERT CAT

(Felis lybica ornata)



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6.1. Introduction

Asiatic wildcat, also known as the desert cat, is a small felid native to the arid and semi-arid landscapes of the Indian subcontinent. In India, it has been documented in the Thar desert and surrounding scrublands, Great Rann of Kutch and Little Rann of Kutch, Banni grasslands, dry riverbeds and scrublands of western India (Ghoddousi *et al.,* 2022; Jhala *et al.,* 2021; Jhala *et al.,* 2020). Desert National Park in Rajasthan serves as a crucial refuge for the species. Recent photographic records have also documented the desert cat in regions like Madhya Pradesh and parts of Maharashtra (Nalavade *et al.,* 2001; Pande *et al.,* 2013; Jhala *et al.,* 2020, 2021), indicating a broader distribution than previously understood. desert cat is highly adapted to survive in a hot climate, low water availability and thrives in arid habitats (Sunquist & Sunquist, 2002). The species primarily inhabits open grasslands, desert scrub, rocky outcrops, and dry woodlands, where it can find adequate cover and prey. Their nocturnal and crepuscular activity patterns help them avoid the extreme daytime heat of desert environments (Nowell & Jackson, 1996). It displays solitary and territorial behaviour (Menon, 2023). Diet of the desert cat primarily consists of small mammals, birds, and reptiles (Dewey, 2005; Abdukadir *et al.,* 2010). Studies have shown that rodents, hares, ground-nesting birds, lizards, and even insects form a crucial part of their prey base (Mukherjee, 2013). There are currently no records available regarding the population assessment of this species. Although listed as 'Least Concern' on IUCN Red List and Schedule-I species in the Wild Life (Protection) Act, 1972, in India, the desert cat faces several localized threats that impact its population. Habitat loss due to agricultural expansion, mining activities, human settlements and desertification has led to significant fragmentation of its natural range (Gajera & Dharaiya, 2011). Additionally, hybridization with domestic cats is a growing concern, as interbreeding dilutes the genetic purity of its wild traits and could impact its ecological role (Driscoll *et al.,* 2011). The species is subjected to growing threats from retaliatory killing and accidental mortality from roadkill.

To model occupancy of the desert cat, NDVI, tree cover and distance to open natural ecosystem were incorporated as indicators of habitat preference, due to the species' affinity to scrublands, deserts and arid landscapes. Moreover, tiger and leopard densities were incorporated as indicators of habitat integrity, as these apex predators are typically associated with well-protected and less disturbed habitats (Jhala *et al.,* 2020, 2021; Qureshi *et al.,* 2023, 2024). These covariates were used to construct ecologically meaningful models to best describe the occupancy of desert cats in the tiger-range forests of India.

6.2. Status of occupancy

Desert cat was detected at 142 out of 748 sites in 2018, based on 265 detections, yielding a naïve occupancy of 0.18. In 2022, the species was recorded at 205 out of 1057 sites, with 390 detections, resulting in a naïve occupancy estimate of 0.19. The average estimated site occupancy was 0.31 (SE 0.03).

Desert cat occupancy was negatively associated with tree cover (β = –1.10, SE = 0.21, P < 0.001), distance to open natural ecosystem (β = –2.81, SE = 0.75, P < 0.001), and annual precipitation (β = –0.83, SE = 0.22, P < 0.001), indicating a strong preference for dry, open, and semi-arid landscapes while avoiding densely vegetated and wetter areas. In contrast, occupancy increased with habitat integrity (β = 0.98, SE = 0.15, P < 0.001), suggesting that well-protected, high-quality habitats support the species.

In the dynamic occupancy model, initial occupancy of the desert cat showed a significant negative relationship with tree cover (β = –0.87, SE = 0.22, P < 0.001), distance to open natural ecosystem (β = –1.17, SE = 0.35, P < 0.001), and annual precipitation (β = –1.05, SE = 0.28, P < 0.001), indicating the species' preference for dry, open forests and grasslands over densely vegetated areas. A positive association with habitat integrity (β = 0.34, SE = 0.16, P = 0.01) highlights the importance of well-preserved habitats for desert cat persistence. The best-fit model further suggests that colonization is more likely in open forests (β= -0.78, SE=0.37, P=0.03), less disturbed areas (β= 0.59, SE=0.18, P<0.001), while extinction probability increases with higher human footprint (β = 1.51, SE = 0.39, P = 0.01). However the impact of human footprint was not statistically significant. Detection probability was unaffected by increasing sampling effort.

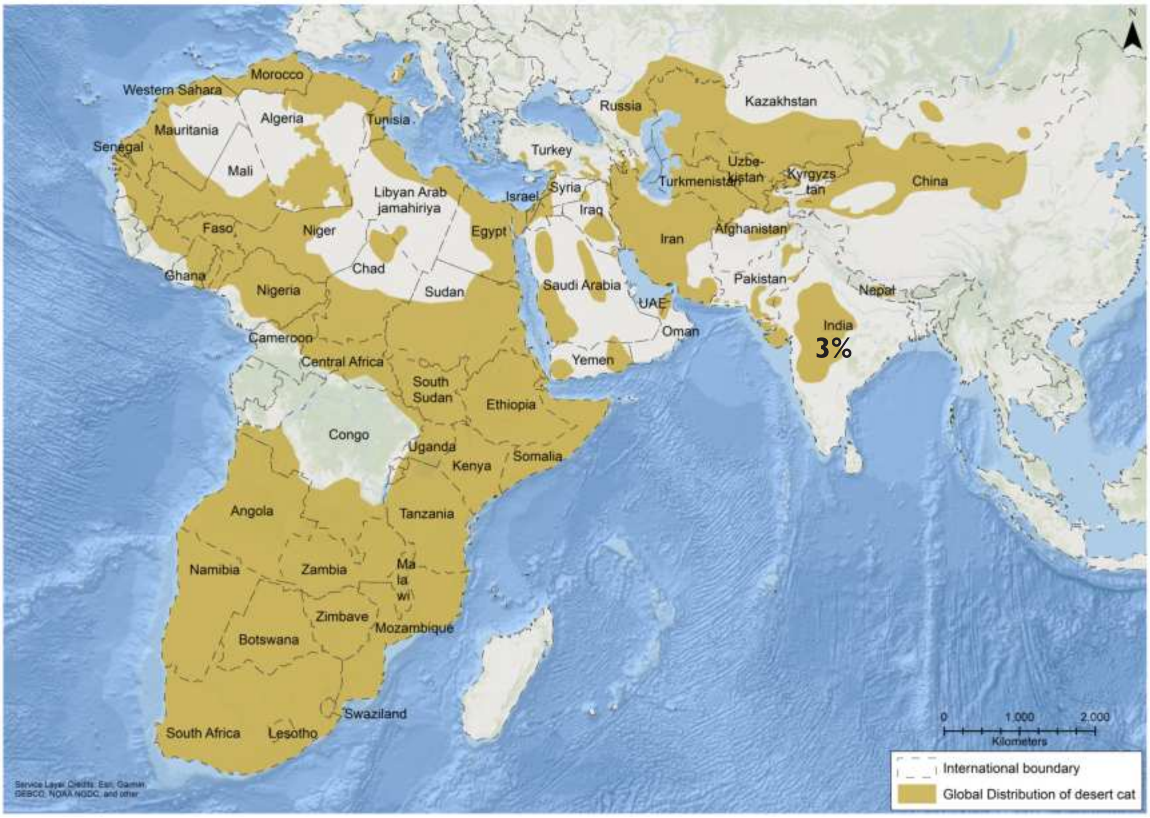


Figure 6.1. Global distribution range of the desert cat (*Felis lybica ornata*) based on IUCN Red List data. About 3% of the species' global distribution occurs within India.

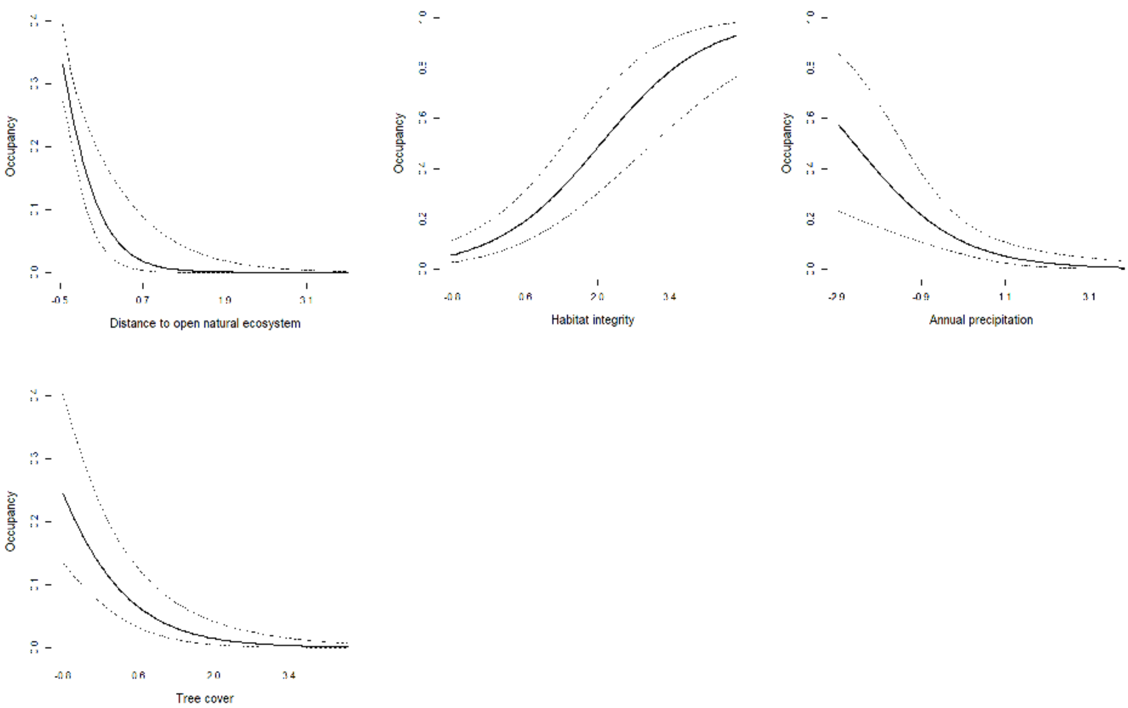


Figure 6.2. Estimated occupancy (Ψ) of the desert cat in response to tree cover, distance to open natural ecosystem, habitat integrity, and annual precipitation across tiger-range forests of India, based on camera-trap sampling in 2022.

Table 6.1. Comparison of occupancy models with different covariate combinations for the desert cat across tiger-range forests of India in 2018 and 2022.

Model type	Model	K	AICc	∆AICc	AICcWt	Cum. Wt	LL
Occupancy status (single-season)	Ψ(trcov+done+bio12+integ) p(.)	6	2389.22	0	1	1	-1188.57
	Ψ(done+integ+bio12+ndvid+droad) p(.)	7	2430.85	41.64	0	1	-1208.37
	Ψ(ndvipr+done+integ+dcrop) p(.)	6	2450.36	61.14	0	1	-1219.14
	Ψ(.) p(effort)	3	2634.5	249.57	0	1	-1314.24
	Ψ(.) p(.)	2	2638.09	248.88	0	1	-1317.04
Occupancy dynamics (multi-season)	Ψ(trcov18+bio12+integ18+done) γ(trcov+integ) ϵ(hfp) p(effort)	12	3848.891	0	1	1	-1912.19
	Ψ(.) γ(.) ϵ(.) p(effort)	5	4235.74	386.1	0	1	-2112.83
	Ψ(ndvipr18+bio12+done) γ(bio12+ndvipr) ϵ(hfp+floss) p(.)	11	4439.09	590.27	0	1	-2208.36
	Ψ(ndvipr18+bio12+integ18) γ(done+integ) ϵ(hfp) p(.)	10	4490.41	641.59	0	1	-2235.05
	Ψ(.) γ(.) ϵ(.) p(.)	4	4643.34	794.52	0	1	-2317.64

In single-season: trcov = tree cover, done = distance to open natural ecosystem, integ = habitat integrity, bio12 = annual precipitation, dcrop = distance to cropland, droad = distance to road, ndvid = NDVI difference, ndvipr = NDVI pre-monsoon, effort = camera trap days, (.) = constant.

In multi-season: trcov18 = tree cover in 2018, bio12 = annual precipitation, done = distance to open natural ecosystem, integ18 = habitat integrity in 2018, integ = habitat integrity in 2018 and 2022, trcov = tree cover in 2018 and 2022, hfp = human footprint in 2018 and 2022, floss = forest loss in 2018 and 2022, ndvipr = NDVI pre-monsoon in 2018 and 2022.

Table 6.2. Estimated β coefficients for covariates influencing the occupancy of the desert cat in India.

Model type	Parameters	Coefficients	β Estimate	SE	P-value
Occupancy status (single-season)	Occupancy	Intercept	-2.02	0.34	0.00
		trcov	-1.10	0.21	0.00
		done	-2.81	0.75	0.00
		bio12	-0.83	0.22	0.00
		integ	0.98	0.15	0.00
	Detection	Intercept	-1.43	0.07	0.00
Occupancy dynamics (multi-season)	Initial Occupancy	Intercept	-1.46	0.19	0.00
		trcov18	-0.87	0.22	0.00
		done	-1.17	0.35	0.00
		bio12	-1.05	0.28	0.00
		integ18	0.34	0.16	0.03
	Colonization	Intercept	-2.51	0.31	0.00
		trcov	-0.78	0.37	0.03
		integ	0.59	0.18	0.00
	Extinction	Intercept	-1.53	0.30	0.00
		hfp	1.51	0.39	0.70
	Detection	Intercept	-5.00	0.20	0.00
		effort	0.11	0.00	0.00

In single-season: trcov = tree cover, done = distance to open natural ecosystem, integ = habitat integrity, bio12 = annual precipitation.

In multi-season: trcov = tree cover in 2018, bio12 = annual precipitation, done = distance to open natural ecosystem, integ18 = habitat integrity in 2018, integ = habitat integrity in 2018 and 2022, trcov = tree cover in 2018 and 2022, hfp = human footprint in 2018 and 2022.

6.3. Discussion

The occupancy analysis of the desert cat offers important insights into its ecology and distribution in India, emphasizing key environmental and anthropogenic factors that shape its occurrence. Our results suggest that dry and semi-arid open forests with minimal human disturbance represent the most suitable habitats for the species. Moderate to high occupancy probabilities were predicted in Sariska, Ranthambore, Panna, Mukundara Hills, Bandhavgarh Tiger Reserves, and, Kumbhalgarh Wildlife Sanctuary, likely due to the dominance of dry deciduous and open forests in these landscapes. Although desert cats have been previously recorded in Kuno National Park (Pawar *et al.,* 2019), our study did not detect the species there, indicating possible variations in detectability or local movement patterns. Lower occupancy was observed in Satpura, Sanjay-dubri, Veerangana Durgawati and Ranipur Tiger Reserves (Figure 6.3).

Our findings indicate that desert cat occupancy is relatively consistent across its known range, particularly in the semi-arid and dry deciduous forests of Sariska, Ranthambore, Satpura, Ratapani, Panna, Bandhavgarh, and Sanjay-dubri Tiger Reserves.

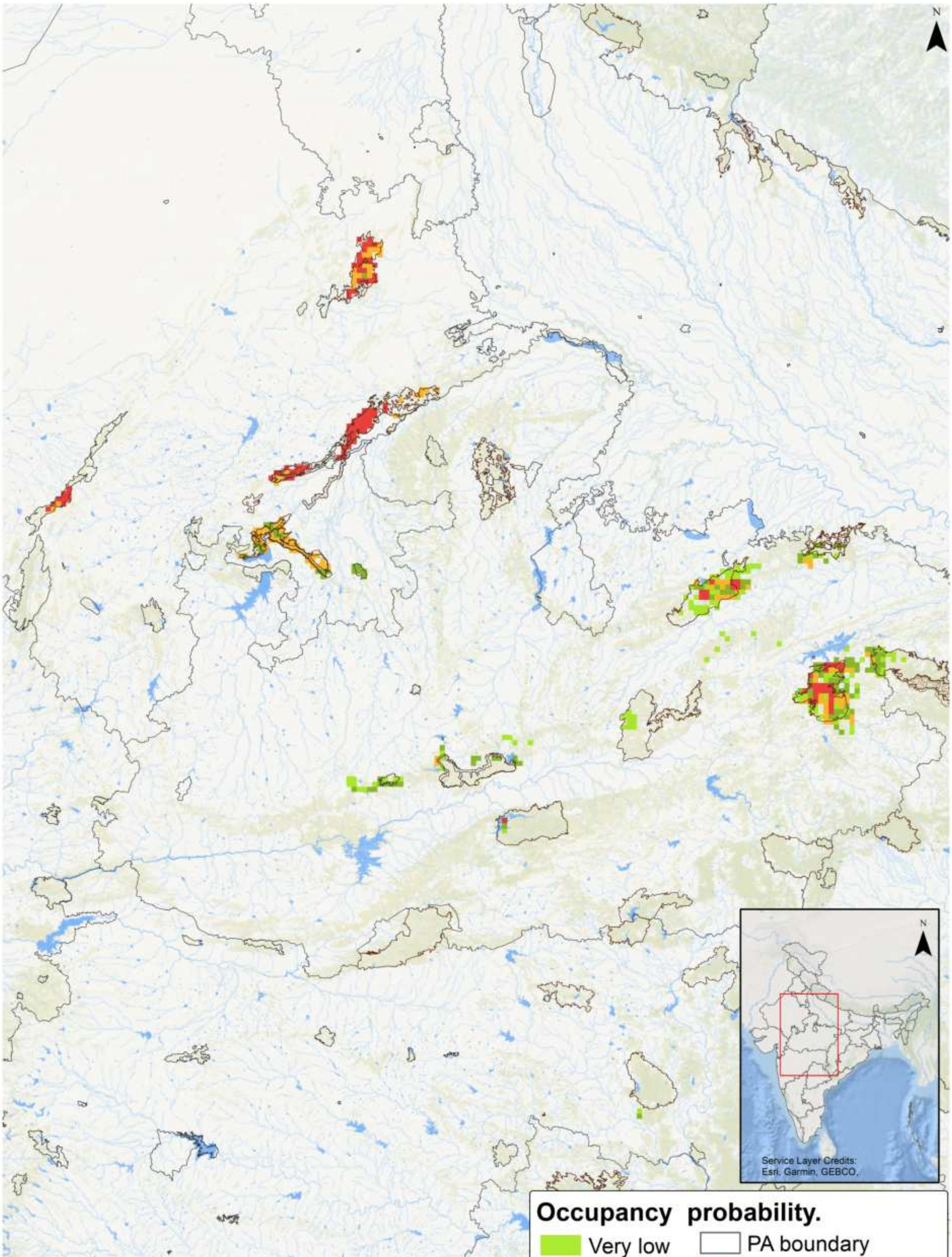


Figure 6.3. Estimated occupancy (Ψ) of the desert cat based on camera-trap surveys conducted in tiger-range forests of India in 2022.

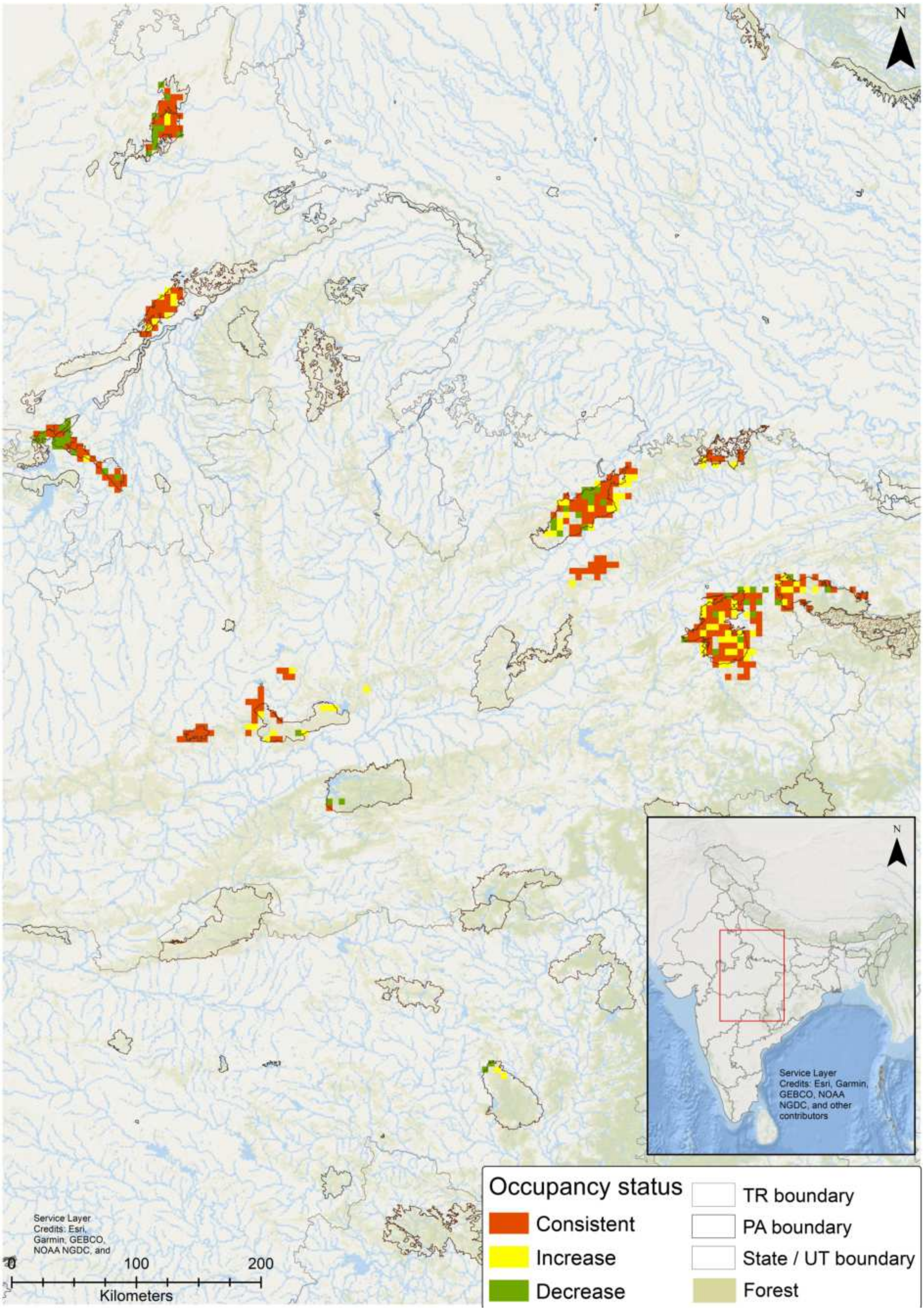


Figure 6.4. Occupancy (Ψ) dynamics of the Desert cat across consistently sampled camera trap grids in 2018 and 2022 within tiger-range forests of India.

FISHING CAT

(Prionailurus viverrinus)

© Soumyajit Nandy

7.1. Introduction

Fishing cat is a medium-sized wild cat closely associated with wetland environments, including mangroves, marshes, riverbanks, and forested areas near water bodies (Mukherjee et al 2012). In India, its habitat extends across the Sundarbans, the Himalayan foothills, and parts of Northeast India, primarily occupying the east coast, floodplains, and mangrove regions. As a globally threatened habitat specialist, fishing cats display variable home range sizes, which can vary from 4 to 22 km², depending on habitat conditions and food availability (Mishra *et al.,* 2025). It is a nocturnal and crepuscular species with a generalist diet, consuming a variety of prey including murid rodents, birds, and fish (Mukherjee *et al.,* 2016). Fishing cat typically hunts in shallow waters, utilizing its webbed hind feet to propel itself while keeping its front limbs free to capture prey. Although fish, amphibians, and crustaceans form the core of its diet, it also preys on birds, insects, rodents, and reptiles. Fishing cats are solitary animals and are predominantly active during the night (Mukherjee, 1998; Sunquist & Sunquist, 2002; Lynam *et al.,* 2013). Recent records indicate that its distribution is primarily in Southeast Asia, where it is widespread in human-dominated landscapes that are currently under significant threat from urbanization. India supports ~30% of its known range and is a stronghold for the species (Figure 7.1). Limited information is available regarding the population status of fishing cats. However, they have been reported to occur in relatively high densities in certain areas. In the Sundarbans Biosphere Reserve, a small sampled area of 25 km² recorded a density of 44 individuals per 100 km² (Das *et al.,* 2017). In Chilika, Odisha, estimates range between 67 (SE 33) and 69 (SE 1) individuals per 100 km² (Adhya *et al.,* 2024). In a protected landscape and its outskirts in Thailand, the species has been recorded at a density of 18 individuals per 100 km². The Wild Life (Protection) Act of 1972 classifies them as a Schedule I species (Kolipaka *et al.,* 2019), while the IUCN Red List categorizes as Vulnerable (Mukherjee *et al.,* 2016) and is listed under CITES Appendix II (Chakraborty *et al.,* 2020).The primary threats to the species include habitat loss, degradation, and fragmentation resulting from human activities such as urbanization, industrialization, agriculture, and aquaculture. The destruction of wetland habitats, driven by urban development, aquaculture, and pollution, poses significant challenges. Additionally, fishing cats are also threatened by hunting, retaliatory killings and road kills (Mishra *et al.,* 2021) and accidental captures further exacerbate the decline in population numbers.

Based on existing ecological knowledge, we selected the relevant covariates to model the occupancy of fishing cats. As habitat specialists, fishing cats are strongly associated with wetlands and swamp habitats (Mishra *et al.,* 2022), making the availability of water sources a crucial covariate in our models. Ruggedness was also included, considering that the species predominantly occurs in lowland environments. Given its vulnerable status, human footprint, distance from protected area and distance from built-up was incorporated to account for anthropogenic impacts on its distribution. Additionally, tiger densities were used as a proxy for habitat quality, as these species typically inhabit areas with minimal human disturbance (Jhala *et al.,* 2020, 2021; Qureshi *et al.,* 2023, 2024). Apart from these we have also examined bioclimatic variables and forest types to assess their influence on fishing cat occupancy. Sampling effort was used to model detection probability.

7.2. Status of occupancy

Fishing cat was recorded in 197 out of 489 sites in 2018 (naïve occupancy, 0.40) based on 670 detections while 199 out of 579 sites (naïve occupancy, 0.34) based on 553 detections in 2022. Average modelled site occupancy in 2022 was 0.41 (SE 0.04).

The single-season occupancy model highlights the influence of habitat covariates on fishing cat distribution. The best-supported model indicates that fishing cat occupancy (Ψ) increases significantly with the availability of water resources ($\beta = 0.46$, SE = 0.18, $P = 0.01$), underscoring the species' dependence on aquatic habitats. Conversely, occupancy declines in areas with higher terrain ruggedness ($\beta = -2.60$, SE = 0.52, $P < 0.01$) and increased human footprint ($\beta = -0.99$, SE = 0.18, $P < 0.01$), reflecting the species' preference for low-disturbance, valley landscapes. Detection probability was positively associated with sampling effort ($\beta = 0.03$, SE = 0.01, $P = 0.01$), indicating improved detectability with increased survey intensity.

The best-fit dynamic occupancy model revealed that initial occupancy of the fishing cat increased with the availability of perennial water sources (β = 2.10, SE = 1.07, P = 0.05), and declined with greater terrain ruggedness (β = –3.45, SE = 0.57, P < 0.01) and distance from protected areas (β = –0.58, SE = 0.27, P = 0.03) (Table 7.2). Colonization probability was positively influenced by seasonal water availability (β = 0.63, SE = 0.17, P < 0.01), highlighting the importance of aquatic habitats. Although extinction probability increased with higher human footprint (β = 0.36, SE = 0.20, P = 0.07), the effect was not statistically significant at the 5% level. Detection probability improved significantly with greater sampling effort (β = 0.05, SE = 0.01, P < 0.01)

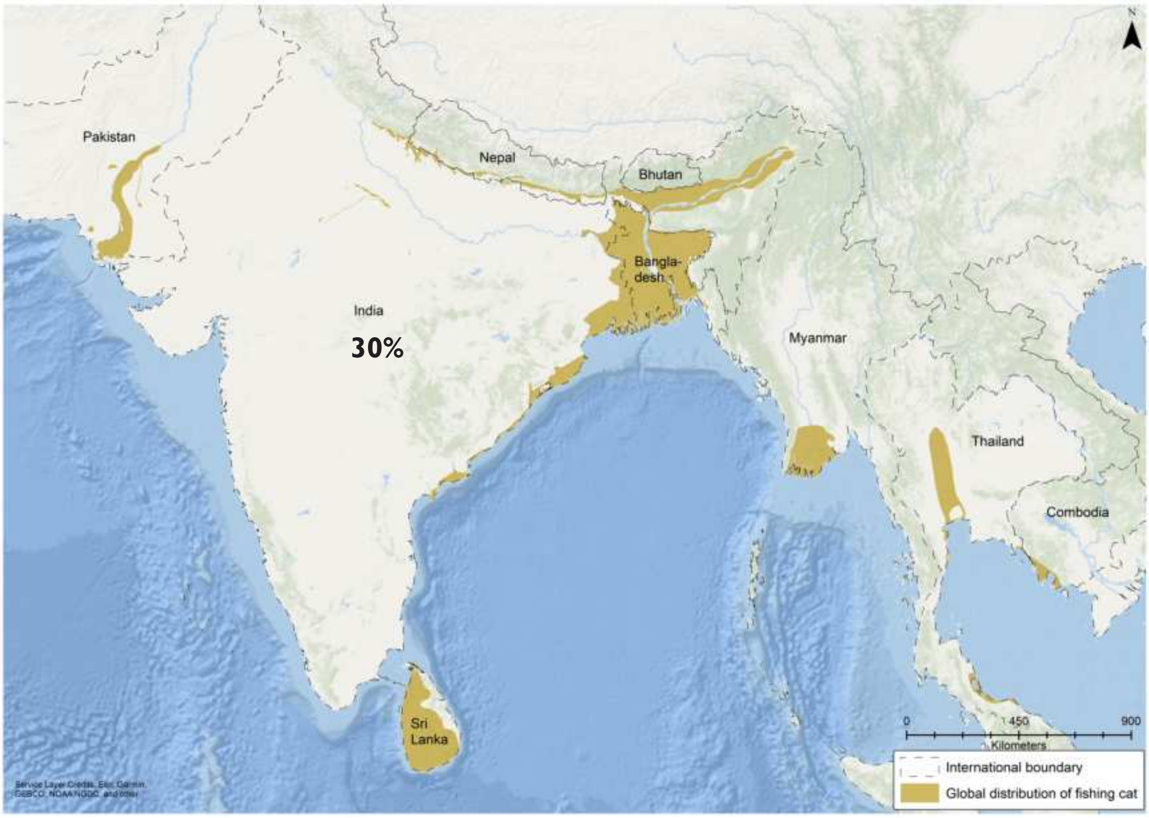
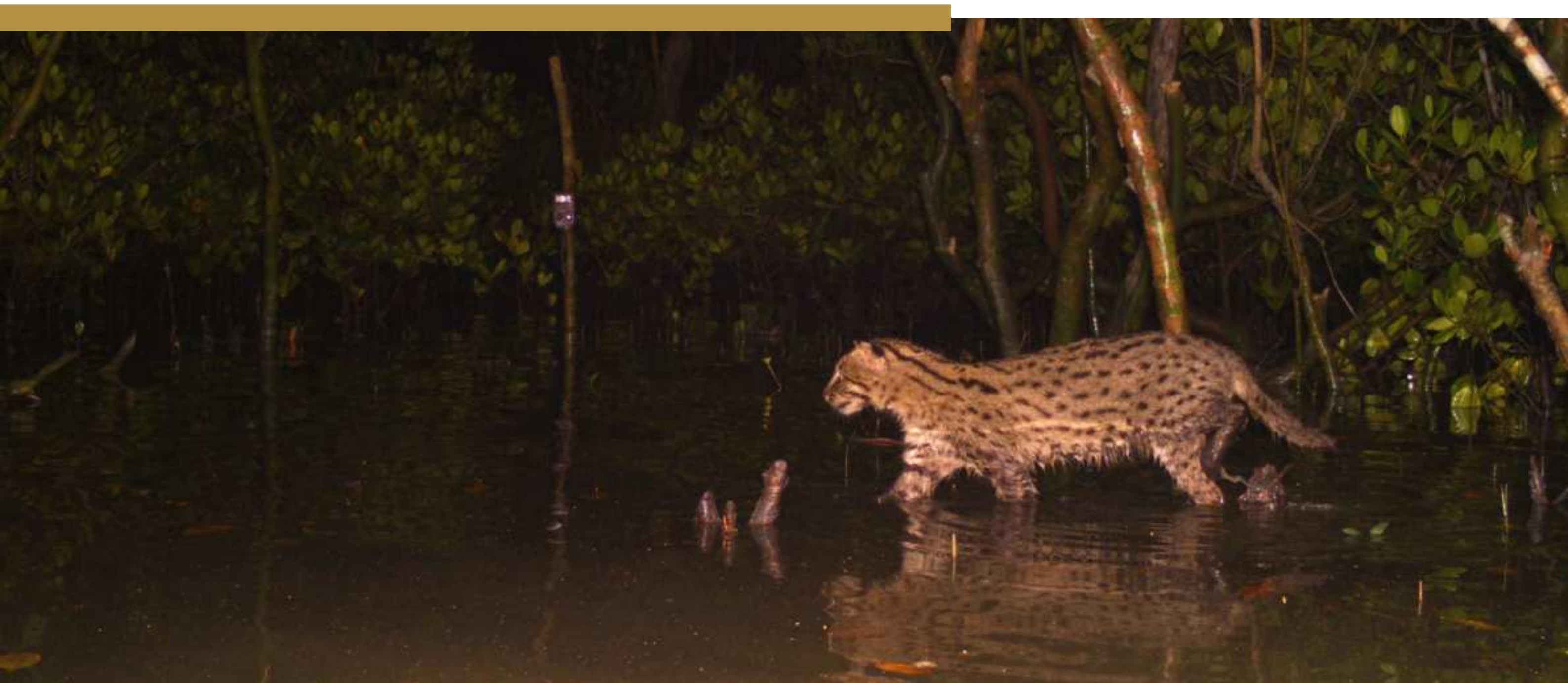


Figure 7.1. Global distribution range of the Fishing cat (*Prionailurus viverrinus*) based on IUCN Red List data.
About 30% of the species' global distribution occurs within India.



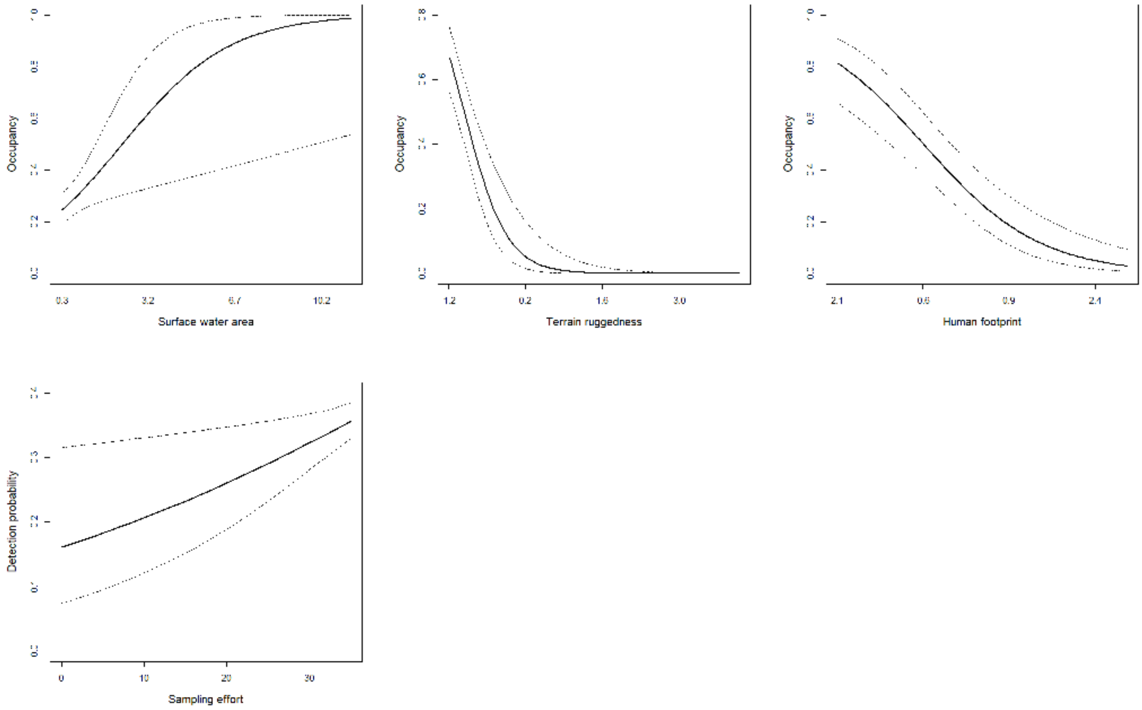


Figure 7.2. Estimated occupancy (Ψ) of the fishing cat in response to water availability, ruggedness and human footprint along with detection probability (p) in relation to sampling effort, across tiger-range forests of India based on 2022 camera-trap data.

Table 7.1. Comparison of occupancy models with different covariate combinations for the fishing cat across tiger-range forests of India in 2018 and 2022.

Model Type	Model	K	AICc	Δ AICc	AIC-cWt	Cum. Wt	LL
Occupancy status (single-season)	Ψ(rug+hfp+water) p(efffort)	6	2322.45	0	1	1	-1155.15
	Ψ(rug+hfp) p(efffort)	5	2334.46	12.01	0	1	-1162.18
	Ψ(rug+water+dbuilt) p(efffort)	6	2338.33	15.88	0	1	-1163.09
	Ψ(.) p(efffort)	3	2527.07	204.62	0	1	-1260.51
	Ψ(.) p(.)	2	2534.68	212.23	0	1	-1265.33
Occupancy dynamics (multi season)	Ψ(pwater+rug+dpa+integ18) γ(swater) ϵ(hfp) p(effort)	11	4452.72	0	1	1	-2215.14
	Ψ(pwater+rug+dpa) γ(swater) ϵ(hfp) p(ef-fort)	10	4466.8	14.08	0	1	-2223.22
	Ψ(swamp+rug+dpa) γ(swater) ϵ(hfp) p(ef-fort)	10	4487.65	34.93	0	1	-2233.64
	Ψ(.) γ(.) ϵ(.) p(.)	4	4813.52	360.8	0	1	-2402.73
	Ψ(.) γ(.) ϵ(.) p(effort)	5	4992.79	540.06	0	1	-2491.34

In single-season: rug = terrain ruggedness index, hfp = human footprint, water = surface water area, dbuilt = distance to built up area, effort = camera trap days, (.) = constant.

In multi-season: pwater = permanent surface water area, rug = terrain ruggedness index, integ18 = habitat integrity in 2018, dpa = distance to protected area, swamp = swamp forest area, swater = seasonal surface water area in 2018 and 2022, hfp = human footprint in 2018 and 2022, effort = camera trap days, (.) = constant.

Table 7.2. Estimated β coefficients for covariates influencing the occupancy of the fishing cat in India.

Model type	Parameters	Coefficients	β Estimate	SE	P-value
Occupancy status (single-season)	Occupancy	Intercept	-2.87	0.47	0.00
		water	0.46	0.18	0.01
		rug	-2.60	0.52	0.00
		hfp	-0.99	0.18	0.00
	Detection	Intercept	-1.65	0.44	0.00
		efffort	0.03	0.01	0.01
Occupancy dynamics (multi-season)	Initial occupancy	Intercept	-0.93	0.50	0.06
		pwater	2.10	1.07	0.05
		rug	-3.45	0.57	0.00
		dpa	-0.58	0.27	0.03
		integ18	0.07	0.14	0.64
	Colonization	Intercept	-2.59	0.25	0.00
		swater	0.63	0.17	0.00
	Extinction	Intercept	-1.10	0.19	0.00
		hfp	0.36	0.20	0.07
	Detection	Intercept	-2.28	0.36	0.00
		effort	0.05	0.01	0.00

In single-season: water = surface water area, rug = terrain ruggedness index, hfp = human footprint, effort = camera trap days.

In multi-season: pwater = permanent surface water area, rug = terrain ruggedness index, dpa = distance to protected area, integ18 = habitat integrity in 2018, swater = seasonal surface water area in 2018 and 2022, hfp = human footprint in 2018 and 2022, effort = camera trap days.

7.3. Discussion

Our results underscore the fishing cat's strong association with undisturbed wetland and swamp habitats. Based on the single-season occupancy model (Figure 7.3), moderate to high occupancy was recorded in the Sundarbans, followed by Kaziranga and Orang Tiger Reserves. Lower occupancy probabilities were found in parts of the Terai landscape, indicating patchy distribution possibly linked to habitat fragmentation or degradation.

The dynamic occupancy model of the fishing cat (Figure 7.4) suggests that the species' presence remained largely stable across the sampled regions between 2018 and 2022. In the Terai, consistent occupancy was observed in Dudhwa, Katerniaghat, Suhelwa, and Valmiki Tiger Reserves. Also in Northeast India and the Sundarbans, fishing cat occupancy remained largely unchanged, although a few peripheral grids outside protected areas exhibited declines. These localized fluctuations may reflect natural variations in occupancy.

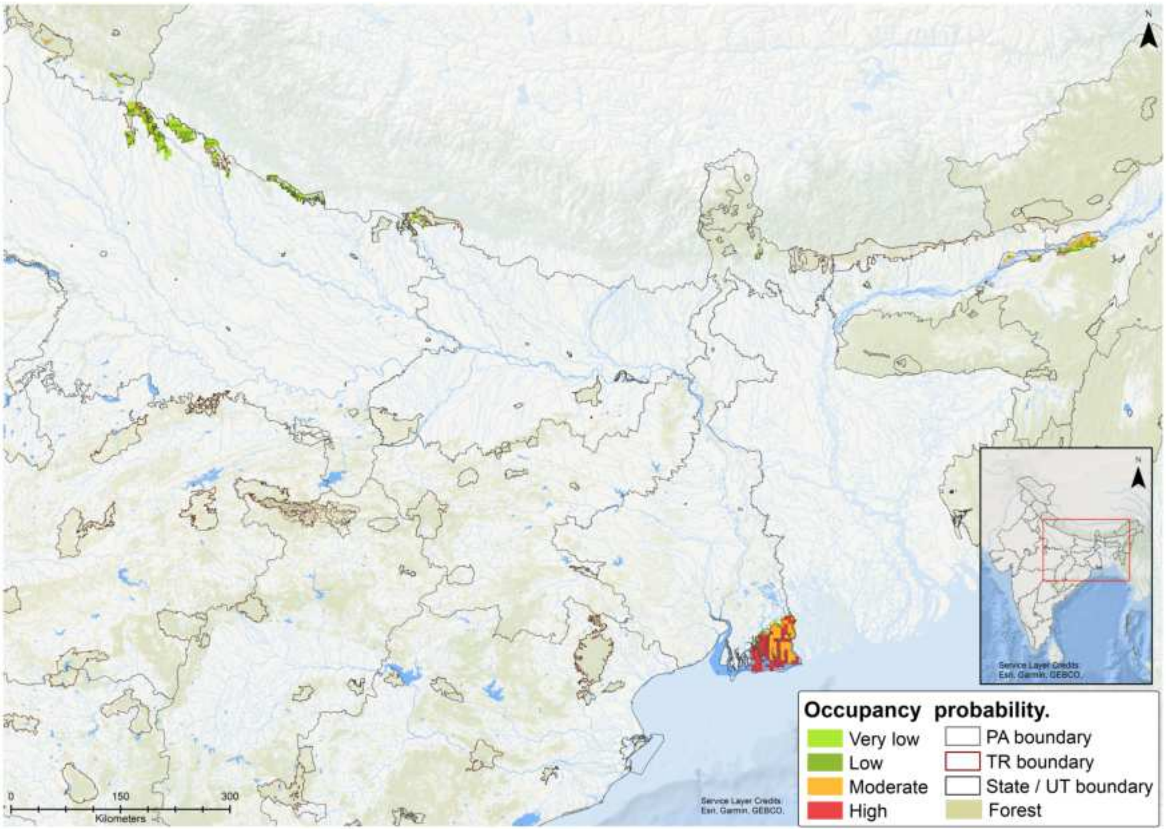


Figure 7.3. Estimated occupancy (Ψ) of the Fishing cat based on camera-trap surveys conducted in tiger-range forests of India in 2022.

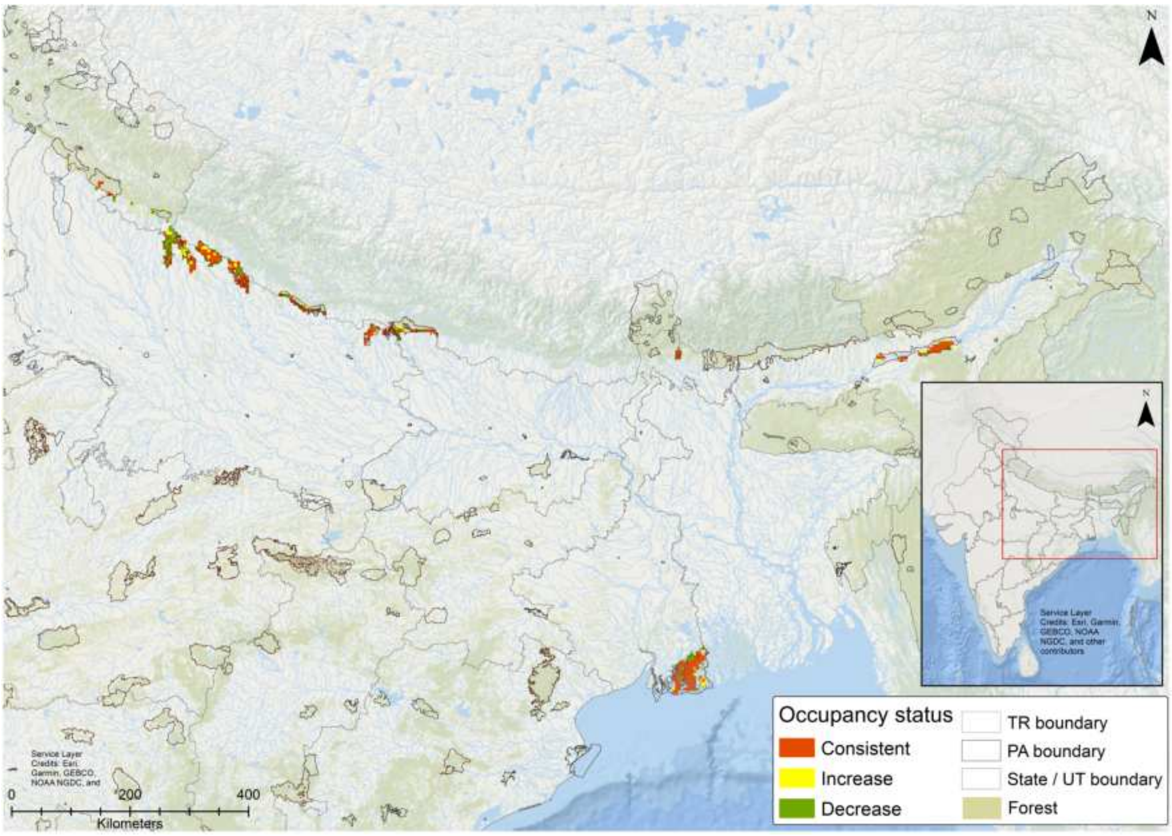


Figure 7.4. Occupancy (Ψ) dynamics of the Fishing cat across consistently sampled camera trap grids in 2018 and 2022 within tiger-range forests of India.

JUNGLE CAT
(Felis chaus)

© Anuradha Marwah

8.1. Introduction

Jungle cat has a wide but uneven distribution, spanning Egypt and Southwest Asia through Central Asia and the Indian subcontinent, primarily inhabiting lowland forests (Gray *et al.,* 2021). It is the most widespread wild cat species in India that inhabits diverse habitats ranging from wetlands and grasslands to dry deciduous and scrub forests. Its range extends from the foothills of the Himalayas in the north to the southern regions of Indian peninsula also prevalent in the dry semi-arid zones in India (Jhala *et al.,* 2021). Jungle cats have also been observed in agricultural landscapes, in proximity to human settlements suggesting a degree of tolerance to anthropogenic environments (Mukherjee *et al.,* 2004). Despite their adaptability, jungle cats tend to avoid dense tropical rainforests and extreme arid conditions, underscoring their preference for habitats that offer a balance between cover and openness (Chaterjee *et al.,* 2020, Jhala *et al.,* 2021). Jungle cats are primarily crepuscular and solitary hunters, relying on stealth and agility to capture their prey. Their diet predominantly consists of small mammals, rodents, birds, reptiles and insects. Studies suggest that rodents make up approximately 70% of their diet (Mukherjee *et al.,* 2004). Highly adaptable, jungle cats are skilled swimmers capable of diving into shallow water to catch fish and are also proficient climbers. However, populations are decreasing in many areas, primarily due to habitat loss, poaching, and retaliatory killings (Gray *et al.,* 2021). Conservation efforts are essential to address the challenges posed by habitat loss and human activities to ensure the species' long-term survival. The majority of ecological studies on the jungle cat remain focused on its food habits, activity patterns, habitat suitability, and distribution range (Jhala *et al.,* 2021; Mukherjee *et al.,* 2004). A density estimate from Tadoba Andhari Tiger Reserve reported 4.01 individuals per 100 km² (Chatterjee *et al.,* 2020). However, large-scale assessments of status and trends are still lacking, posing a significant challenge to understanding and conserving the species.

To model the occupancy of the jungle cat, we incorporated a suite of ecologically relevant covariates. NDVI difference to indicate forest deciduousness, reflecting the species' preference for open, mixed woodlands. Terrain complexity was included *via* ruggedness, as jungle cats are known to inhabit lowland forests. Detection probability was modelled using sampling effort to account for variations in survey intensity. Annual precipitation was included to constrain the models within the jungle cat's known tolerance range for precipitation.

8.2. Status of occupancy

Jungle cats occupied 1929 out of 4530 sites (naïve occupancy, 0.43) based on 6004 detections in 2018, and 2397 out of 5842 sites (naïve occupancy 0.41) based on 6704 detections in 2022. Average estimated site occupancy in 2022 was 0.55 (SE 0.01).

Jungle cat occupancy was positively associated with greater NDVI difference (β = 0.86, SE = 0.05; P < 0.001). This suggests a preference for open-canopy woodlands that likely offer suitable hunting grounds and cover. In contrast, occupancy was negatively influenced by higher annual precipitation (β = -0.97, SE = 0.07; P < 0.001) and terrain ruggedness (β = -0.71, SE = 0.04; P < 0.01), indicating the species' affinity for drier, low-lying forested areas. These patterns may reflect the species' tendency to avoid wet and rugged habitats where prey activity may be lower or movement more constrained. Detection probability increased with sampling effort (β = 0.03, SE 0.003, P = <0.001), suggesting the model effectively accounted for variation in detection rates due to sampling effort.

The results from the dynamic occupancy model were consistent with those from the single-season occupancy models. Both initial occupancy (Ψ) and colonization probability (γ) were negatively associated with higher annual precipitation and greater terrain ruggedness, while positively associated with increased deciduousness of forests (Table 8.2). This suggests that jungle cats prefer drier, less rugged areas with deciduous forests for both establishing presence and expanding their range. However, none of the covariates significantly explained extinction probability. Additionally, detection probability increased with sampling effort, indicating that the model effectively accounted for variation in detectability based on sampling intensity.

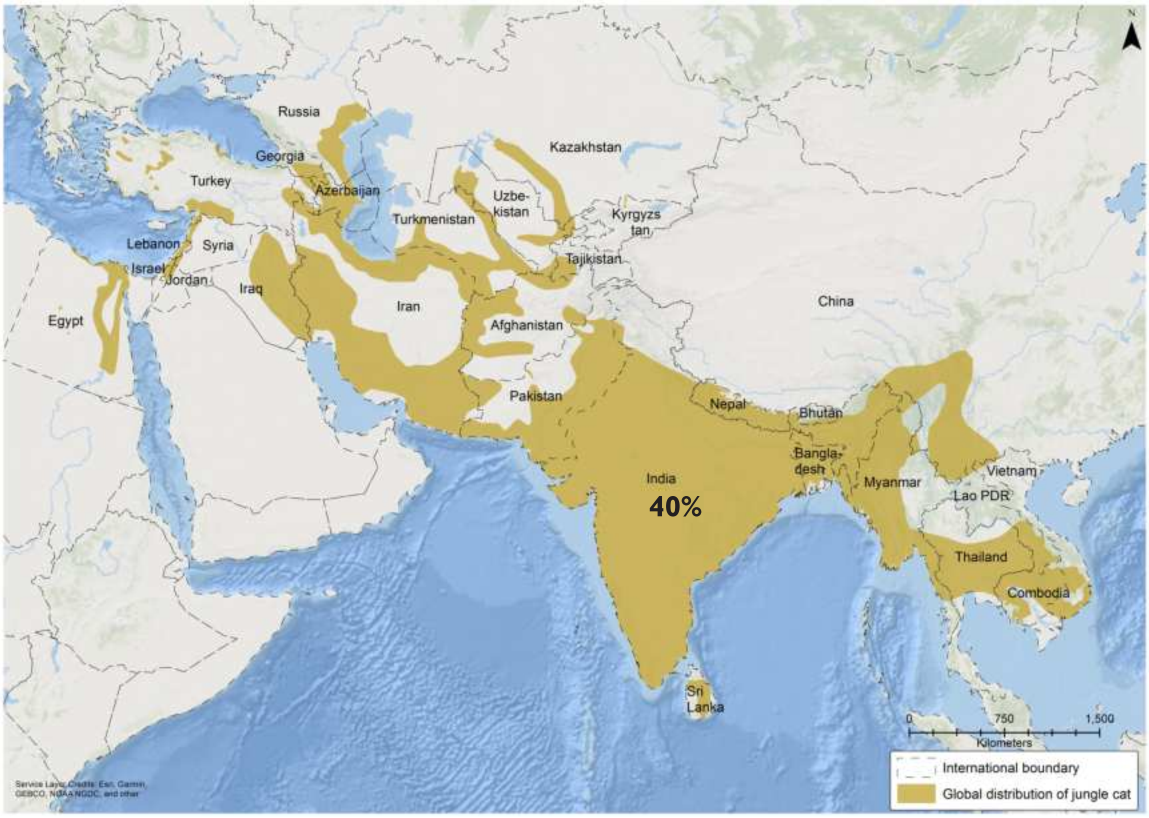


Figure 8.1. Global distribution range of the jungle cat (*Felis chaus*) based on IUCN Red List data. About 40% of the species' global distribution occurs within India.

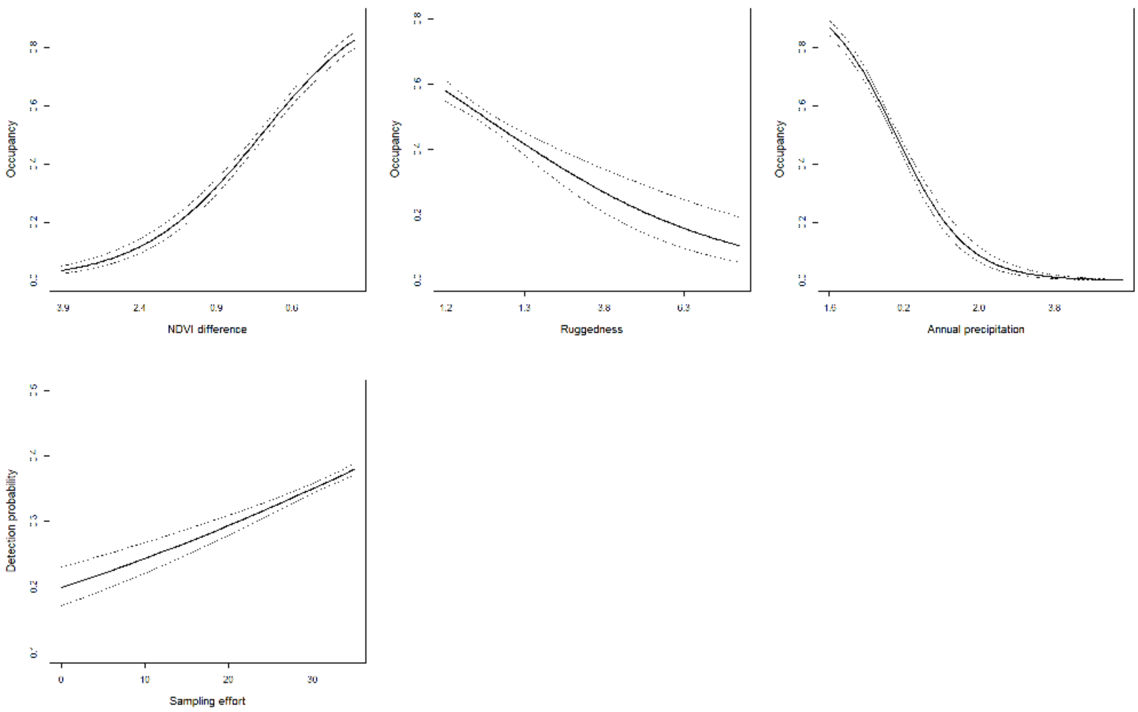


Figure 8.2. Estimated occupancy (Ψ) of the jungle cat in response to NDVI difference, ruggedness and annual precipitation along with detection probability (p) in relation to sampling effort, across tiger-range forests of India based on 2022 camera-trap data.

Table 8.1. Comparison of occupancy models with different covariate combinations for the jungle cat across tiger-range forests of India in 2018 and 2022.

Model Type	Model	K	AICc	∆ AICc	AIC-cWt	Cum. Wt	LL
Occupancy status (single-season)	Ψ(ndvid+rug+bio12) p(effort)	6	27970.07	0	1	1	-13979.03
	Ψ(dof+rug+bio12) p(effort)	7	28332.99	362.92	0	1	-14160.49
	Ψ(.) p(effort)	3	29350.31	1380.24	0	1	-14672.15
	Ψ(.) p(.)	2	29465.4	1495.2	0	1	-14730.7
Occupancy dynamics (multi-season)	Ψ(bio12+rug+ndvid18) γ(bio12+rug+nd-vid) ϵ(.) p(effort)	11	44562.41	0	1	1	-22270.17
	Ψ(bio12+rug+ndvid18) γ(bio12+rug+dpa) ϵ(floss) p(effort)	11	44608.75	46.34	0	1	-22293.34
	Ψ(.) γ(.) ϵ(.) p(effort)	5	45735.11	1172.69	0	1	-22862.54

In single-season: ndvid = ndvi difference, rug = terrain ruggedness index, bio12 = annual precipitation, dof = distance to open forest, effort = camera trap days, (.) = constant.

In multi-season: rug = terrain ruggedness index, bio12 = annual precipitation, ndvid18 = NDVI difference in 2018, nd-vid= NDVI difference in 2018 and 2022, floss = forest loss in 2018 and 2022, dpa = distance to protected area.

Table 8.2. Estimated β coefficients for covariates influencing the occupancy of the jungle cat in India.

Model	Parameters	Coefficients	Estimate	SE	P-value
Occupancy status (single-season)	Occupancy	Intercept	0.02	0.05	0.70
		ndvid	0.86	0.05	0.00
		bio12	-0.97	0.07	0.00
		rug	-0.71	0.04	0.00
	Detection	Intercept	-1.42	0.09	0.00
		effort	0.03	0.00	0.00
Occupancy dynamics (multi-season)	Initial occupancy	Intercept	0.20	0.05	0.00
		bio12	-0.49	0.07	0.00
		rug	-0.24	0.05	0.00
		ndvid18	0.95	0.06	0.00
	Colonisation	Intercept	-1.00	0.09	0.00
		bio12	-0.53	0.12	0.00
		rug	-0.41	0.09	0.00
		ndvid	0.67	0.11	0.00
	Extinction	Intercept	-1.35	0.07	0.00
	Detection	Intercept	-1.09	0.09	0.00
		effort	0.02	0.00	0.00

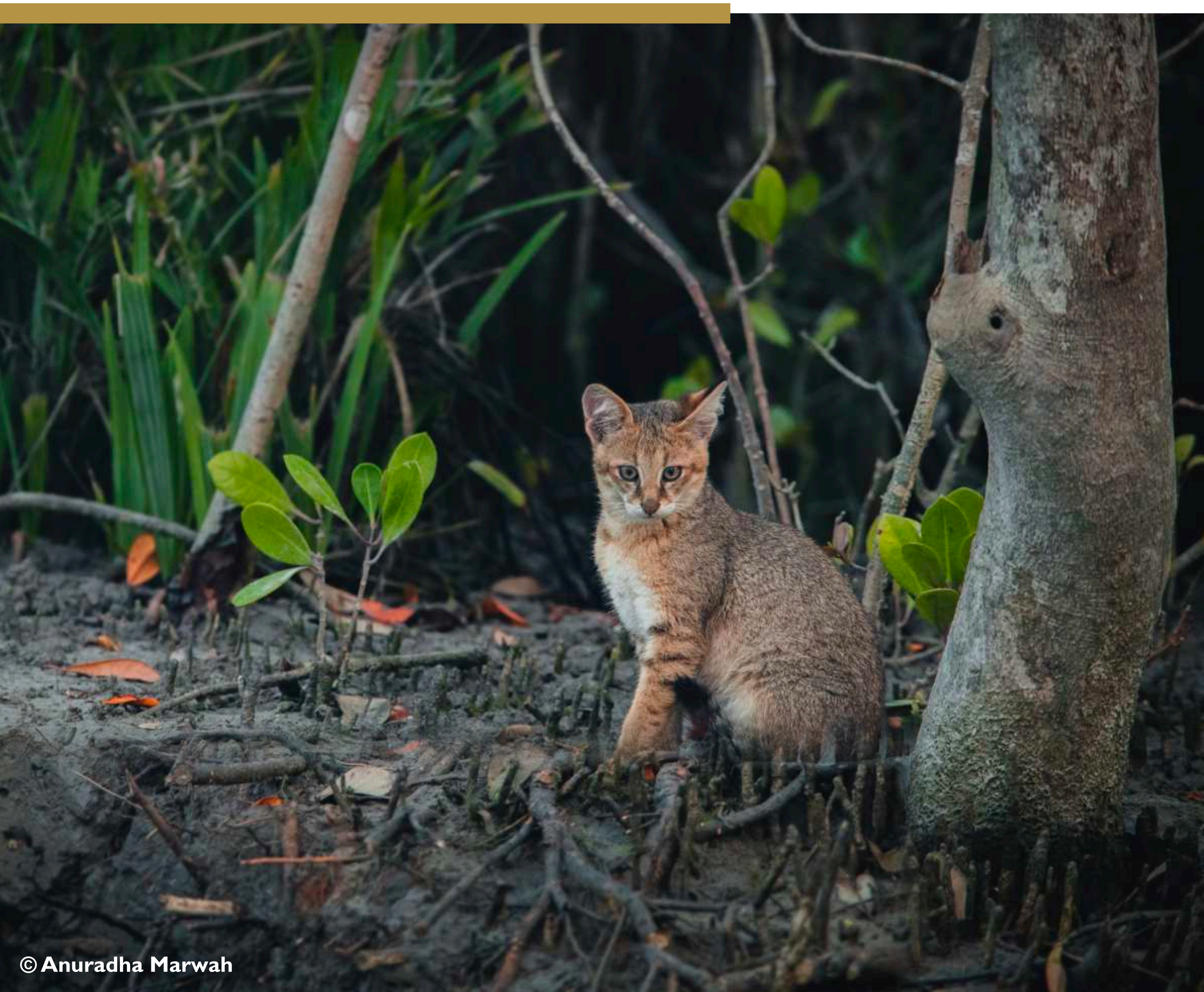
In single-season: ndvid = ndvi difference, rug = terrain ruggedness index, bio12 = annual precipitation, effort = camera trap days.

In multi-season: rug = terrain ruggedness index, bio12 = annual precipitation, ndvid18 = NDVI difference in 2018, ndvid= NDVI difference in 2018 and 2022.

8.3. Discussion

Although the jungle cat is widely distributed across a variety of habitats from semi-arid regions to dense rainforests, its occupancy shows marked variation across landscapes. The highest occupancy probabilities were recorded in the dry deciduous forests of Central India, particularly in Madhya Pradesh, eastern Maharashtra, and the semi-arid protected areas of Rajasthan. In Northeast India, areas such as Kaziranga, Nameri, and the lower elevations of Pakke Tiger Reserve supported relatively low occupancy. The Terai region also exhibited low occupancy across its protected areas, while the Western Ghats generally showed low occupancy (Figure 8.3). Smaller forest patches in Telangana and Karnataka exhibited a mix of moderate to high occupancy. In contrast, the Sundarbans mangrove ecosystem showed predominantly low occupancy, with only isolated pockets of moderate to high occupancy along its northern fringes. Similarly, the moist deciduous forests of Similipal recorded low occupancy by jungle cats.

Occupancy of the jungle cats was consistent throughout all the landscapes (Figure 8.4). Across all sampled regions, minor fluctuations in occupied sites were noted between the two years, likely reflecting natural variations in occupancy, rather than substantial shifts in the species' range.



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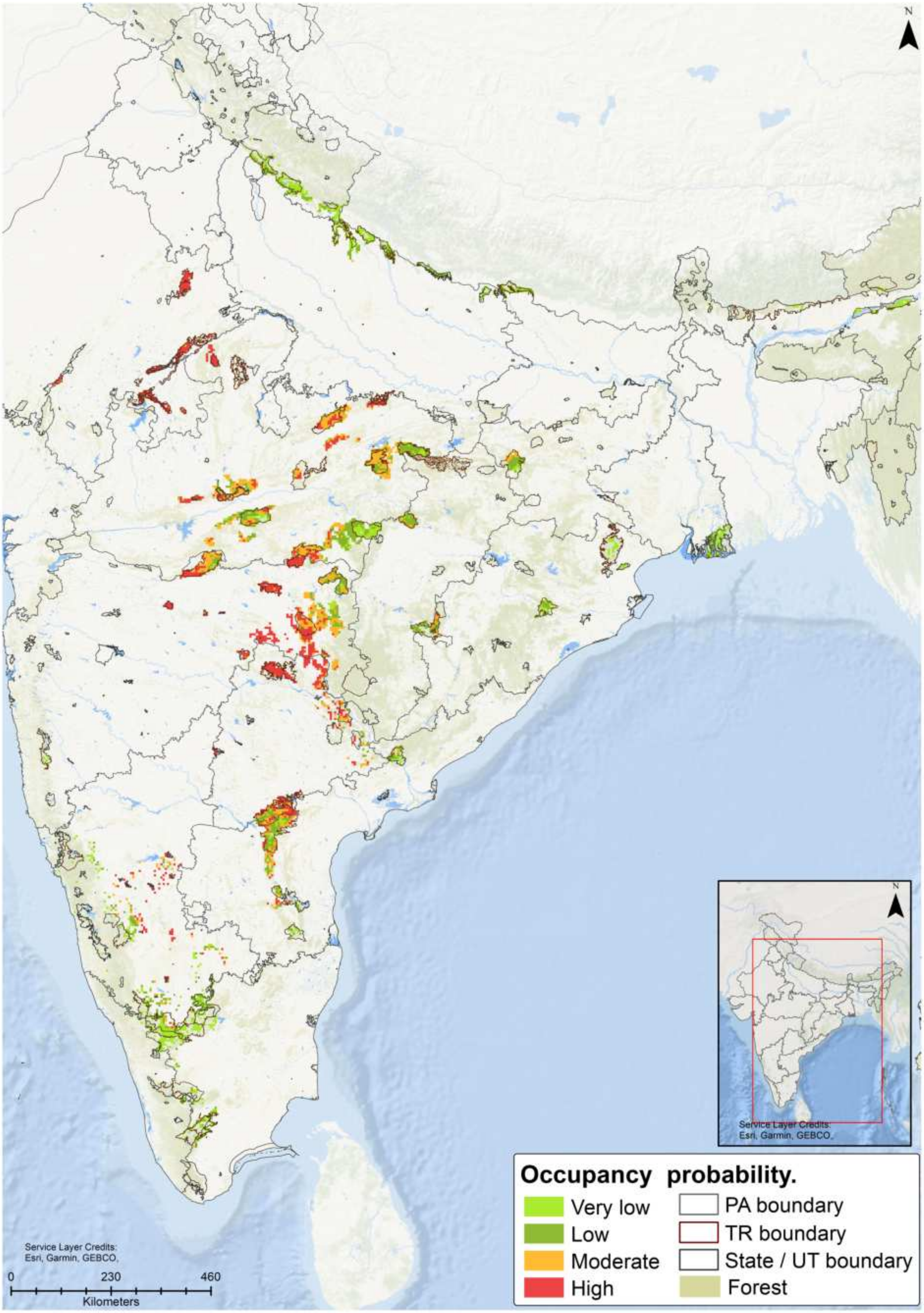


Figure 8.3. Estimated occupancy (Ψ) of the jungle cat based on camera-trap surveys conducted in tiger-range forests of India in 2022.

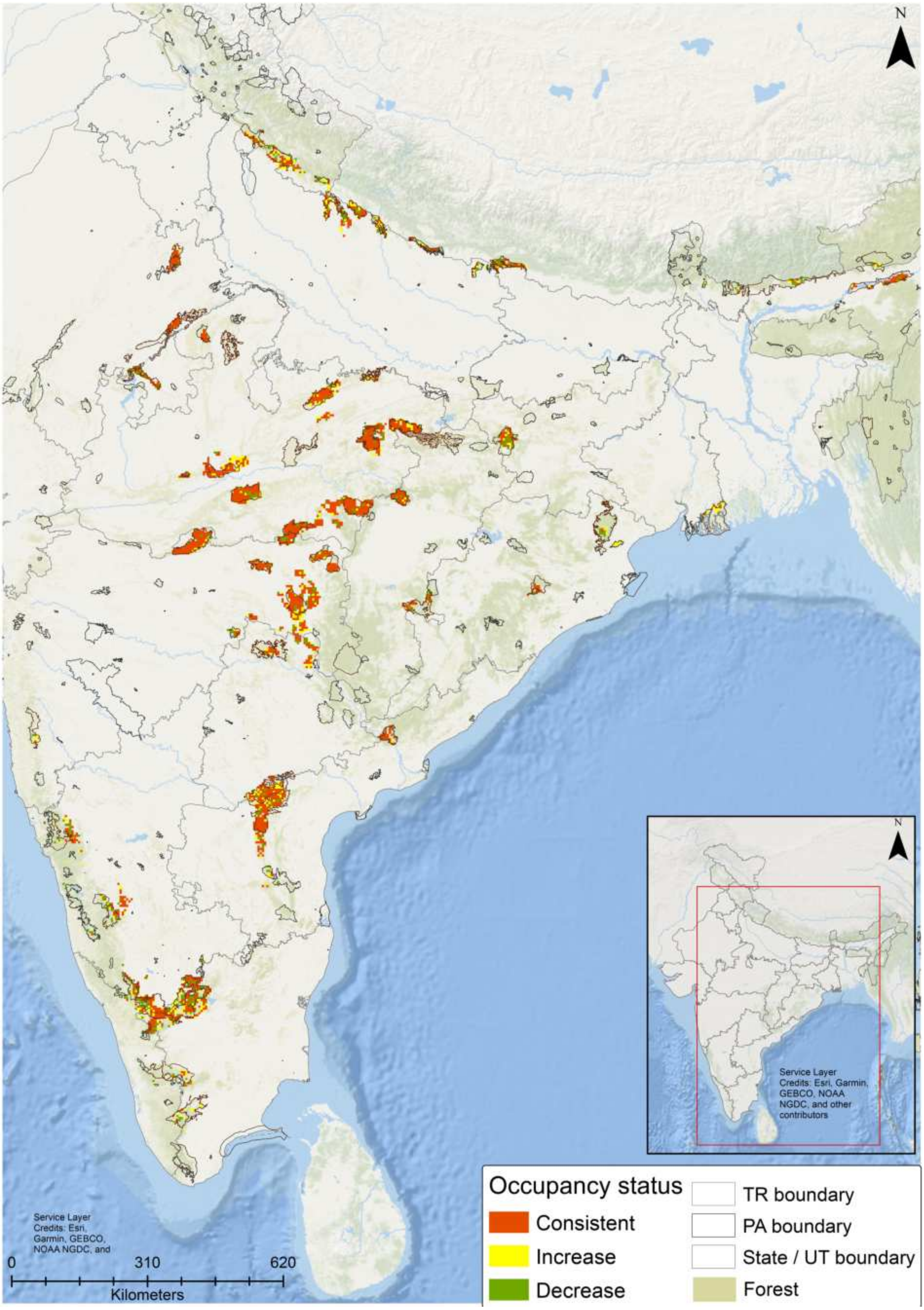


Figure 8.4. Occupancy (Ψ) dynamics of the jungle cat across consistently sampled camera trap grids in 2018 and 2022 within tiger-range forests of India.

LEOPARD CAT
(Prionailurus bengalensis)

9.1. Introduction

The leopard cat is one of the most widely distributed small cats in Asia. In India, it is distributed throughout the Himalayas, Terai Arc landscape, northeastern states, the Duars and Sundarbans in West Bengal and the eastern and western ghats (Srivathsa *et al.,* 2015, Ghimirey *et al.,* 2022 & Menon, 2023), with a strong preference for moist and thick canopied forests with low levels of human disturbance. However, studies also show that they have adapted to monoculture plantation habitats like coffee and tea (Srivathsa *et al.,* 2015), agricultural landscapes and human settlement areas, as these can be attributed to high availability of prey. They are solitary & nocturnal, depending mostly on rodents and to some extent on birds, reptiles and amphibians (Mukherjee *et al.,* 2004; Shehzad *et al.,* 2012; Xiong *et al.,* 2017). Their home range sizes vary from 4.1 km^2 in males to 2.5 km^2 in females (Grassman, 2000). It is considered as Least Concern in the IUCN Red List (Ghimirey *et al.,* 2022) and categorized as a schedule I species under The Wild Life (Protection) Act, 1972. Despite being protected, leopard cats are subjected to threats from illegal activities such as trade for their pelts, pet trade, and hunting (Selvan *et al.,* 2013; Ghimirey *et al.,* 2022). Additionally, deforestation, climate change and road-kill have become significant threats, leading to habitat degradation and a shrinking range for the species (Silva *et al.,* 2020). Leopard cats are observed more frequently compared to other small cat species; however, information about their status remains limited due to the lack of focused studies. Population density estimates (per 100 km^2) from various landscapes reveal variation, ranging from 2.9 individuals in Pakke (Selvan *et al.,* 2014), 10.45 individuals in Bhadra (Srivathsa *et al.,* 2015), to 17.52 individuals in the Khangchendzonga Biosphere Reserve (Bashir *et al.,* 2014). The leopard cat was recently documented for the first time in Central India at Pench Tiger Reserve, Maharashtra (Shukla *et al.,* 2025), suggesting a potential expansion of its habitat range.

Ecologically relevant covariates were selected to construct occupancy models for the species. Post-monsoon and pre-monsoon NDVI were incorporated to represent favorable habitats. Since the species is typically absent in dry, semi-arid regions, annual precipitation was included to limit the distribution range in the model (Fick & Hijmans, 2017). Tiger densities were also factored in as indicators of habitat integrity, as this apex predator generally thrives in less disturbed environments (Jhala *et al.,* 2020, 2021; Qureshi *et al.,* 2023, 2024). Additional covariates such as ruggedness, human disturbance indices (distance to road and human footprint index), were used to refine the occupancy modelling for leopard cats. Sampling effort was utilized to model the site-level detection probability of leopard cats.

9.2. Status of occupancy

Leopard cat occupied 766 out of 2451 sites (naïve occupancy, 0.31) based on 1911 detections in 2018 while 876 out of 3174 sites (naïve occupancy, 0.28) based on 2300 detections in 2022 in the tiger-range landscapes of India. The average modelled site occupancy in 2022 was 0.40 (SE 0.02).

We developed multiple single-season occupancy models using various combinations of site covariates (Table 9.1). The top-ranked model indicates that leopard cat occupancy is positively associated with post-monsoon NDVI (β = 0.45, SE = 0.04, $P < 0.001$), annual precipitation (β = 0.21, SE = 0.05, $P < 0.001$) and habitat integrity (β = 1.33, SE = 0.16, $P < 0.001$) reflecting the species' preference for dense, wetter and undisturbed habitats. In contrast the positive association of the species's occupancy with increasing distance to road (β = 0.38, SE = 0.04, $P < 0.001$), highlighting the species' sensitivity to human infrastructure. Detection probability increased with sampling effort (β = 0.03, SE = 0.003, $P < 0.01$), demonstrating that the model effectively accounted for variation in detection rates linked to survey intensity (Table 9.2).

In the dynamic occupancy model, initial occupancy of leopard cats showed a positive association with dense (β = 0.36, SE = 0.08, $P < 0.001$), wet (β = 0.14, SE=0.06, $P < 0.05$) and undisturbed (β = 0.2, SE = 0.04, $P < 0.001$) forests. Colonization probability increased in wetter (β = 0.39, SE = 0.09, $P < 0.01$) and undisturbed (β = 0.36, SE = 0.08, $P < 0.01$), habitats. Conversely, extinction probability was significantly higher near roads (β = -0.94, SE = 0.28, $P < 0.001$), likely due to increased anthropogenic disturbances associated with road proximity.

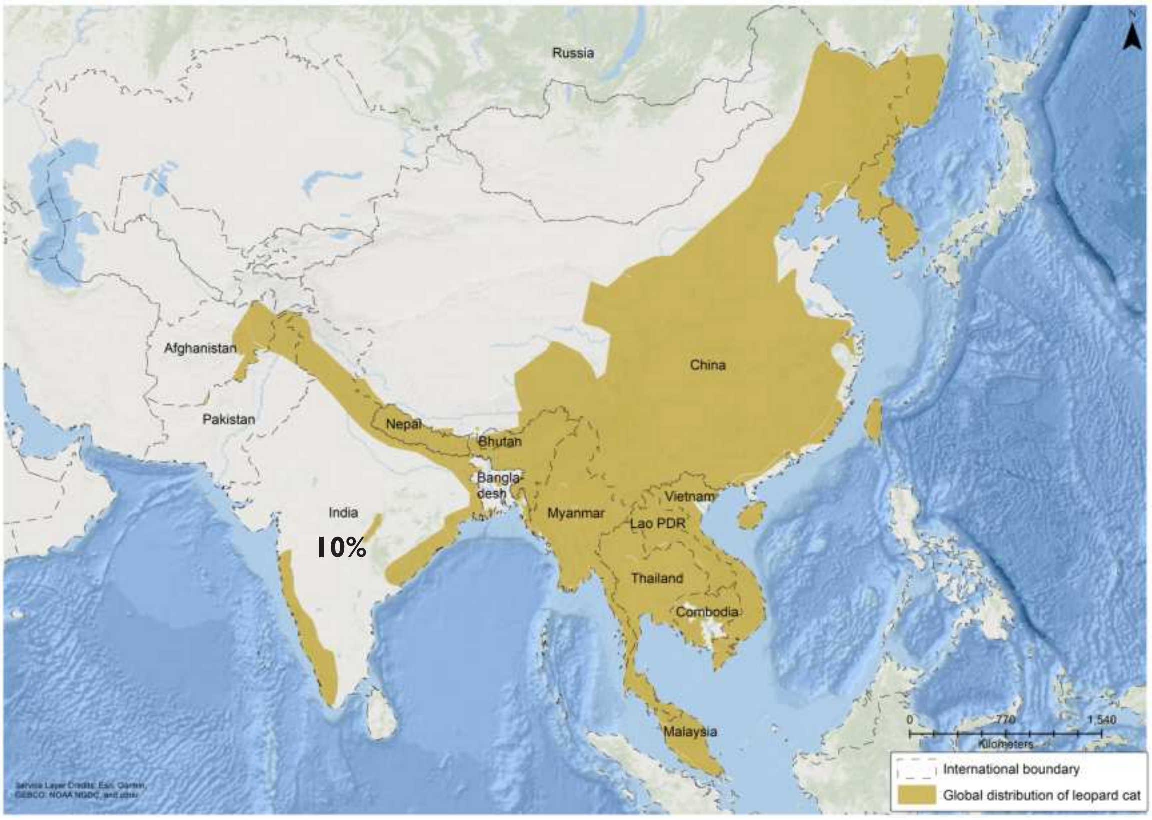


Figure 9.1. Global distribution range of the leopard cat (*Prionailurus bengalensis*) based on IUCN Red List data. About 10% of the species' global distribution occurs within India.

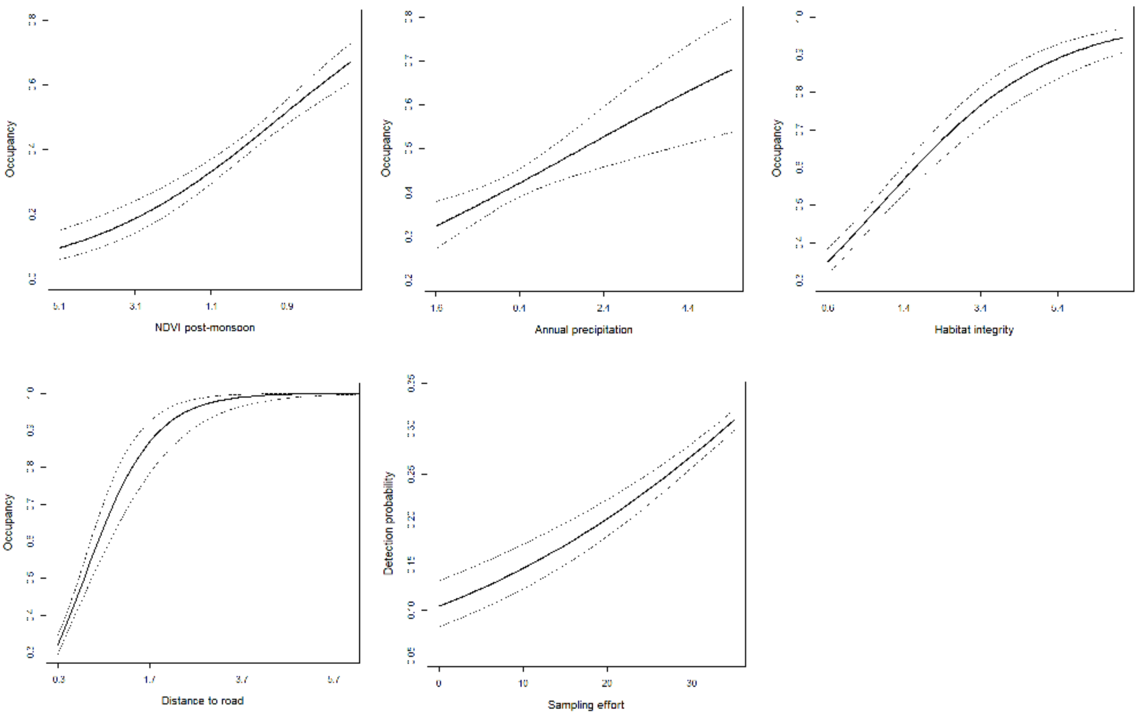


Figure 9.2. Estimated occupancy (Ψ) of the leopard cat in response to NDVI post-monsoon, annual precipitation, habitat integrity and distance to road along with detection probability (p) in relation to sampling effort, across tiger-range forests of India based on 2022 camera-trap data.

Table 9.1. Comparison of occupancy models with different covariate combinations for the leopard cat across tiger-range forests of India in 2018 and 2022.

Model Type	Model	K	AICc	∆AICc	AICcWt	Cum. Wt	LL
Occupancy status (single-season)	Ψ(bio12+droad+ndvips+integ) p(efffort)	7	11174.32	0	1	1	-5580.14
	Ψ(bio12+droad+integ) p(efffort)	6	11240.18	65.85	0	1	-5614.07
	Ψ(bio12+hfp+ndvipr+integ) p(efffort)	7	11351.62	177.29	0	1	-5668.79
	Ψ(.) p(efffort)	3	11609.5	435.18	0	1	-5801.75
	Ψ(.) p(.)	2	11756.57	582.25	0	1	-5876.28
Occupancy dynamics (multi season)	Ψ(ndvipr18+bio12+integ18) γ(bio12+integ) ϵ(droad) p(effort)	11	18439.86	0.00	1	1	-9208.87
	Ψ(ndvips18+bio12+integ18) γ(bio12+ndvips) ϵ(droad) p(effort)	11	18462.28	22.41	0	1	-9220.07
	Ψ(ndvips18+bio12) γ(bio12+integ) ϵ(droad) p(effort)	10	18495.44	55.58	0	1	-9237.67
	Ψ(.) γ(.) ϵ(.) p(effort)	5	18586.63	146.76	0	1	-9288.3
	Ψ(.) γ(.) ϵ(.) p(.)	4	18653.42	213.56	0	1	-9322.7

In single season: bio12 = annual precipitation, droad = distance to road, integ = habitat integrity, ndvips = NDVI post-monsoon, ndvipr = NDVI pre-monsoon, hfp = human footprint, effort = camera trap days, (.) = constant.

In multi season: bio12 = annual precipitation, ndvipr = NDVI pre-monsoon in 2019, ndvips = NDVI post-monsoon in 2018, ndvips = NDVI pre-monsoon in 2018 and 2022, droad = distance to road in 2018 and 2022, integ = habitat integrity in 2018 and 2022, effort = camera trap days, (.) = constant.

Table 9.2. Estimated β coefficients for covariates influencing the occupancy of the leopard cat in India.

Model type	Parameters	Coefficients	β Estimate	SE	P-value
Occupancy status (single-season)	Occupancy	Intercept	-0.46	0.0665	0.00
		bio12	0.212	0.0578	0.00
		ndvips	0.453	0.0437	0.00
		integ	1.331	0.1632	0.00
		droad	0.386	0.0483	0.00
	Detection	Intercept	-2.1474	0.1363	0.00
		effort	0.0384	0.00378	0.00
Occupancy dynamics (multi-season)	Initial occupancy	Intercept	-0.554	0.0755	0.00
		ndvipr18	0.363	0.0813	0.00
		bio12	0.149	0.0659	0.02
		integ18	0.278	0.0453	0.00
	Colonization	Intercept	-1.913	0.1347	0.00
		bio12	0.395	0.0956	0.00
		integ	0.368	0.0852	0.00
	Extinction	Intercept	-1.344	0.134	0.00
		droad	-0.945	0.283	0.00
	Detection	Intercept	-1.8755	0.13019	0.00
		effort	0.0274	0.00344	0.00

In single-season: bio12 = annual precipitation, ndvips = NDVI post-monsoon, , integ = habitat integrity, droad = distance to road, effort = camera trap days, (.) = constant.

In multi-season: integ = habitat integrity in 2018 and 2022, integ18 = habitat integrity in 2018, bio12 = annual precipitation, ndvipr18 = NDVI pre-monsoon in 2018, droad = distance to road, effort = camera trap days, (.) = constant.

9.3. Discussion

Leopard cats demonstrate preference for dense, moist, and relatively undisturbed habitats. Within the Terai Arc Landscape, the species shows variable patterns of occupancy. Moderate to high occupancy is observed in the eastern Rajaji region, Corbett, the western and central Terai divisions, and the northern parts of Valmiki, while the remaining areas of the landscape exhibit low occupancy. In Northeast India, occupancy is generally moderate to high, likely influenced by the prevalence of tropical moist deciduous and evergreen forests, as well as consistently high rainfall. In contrast, the Central Indian landscape shows limited presence of leopard cats. Detections are primarily confined to Similipal and Satkosia in Odisha, with moderate to high and low occupancy, respectively. In the Western Ghats, the Nilgiri cluster—including Nagarhole, Bandipur, and Mudumalai—as well as the Periyar cluster, support moderate to high occupancy levels. Other regions within this landscape show comparatively lower occupancy. Notably, the Sundarbans represent a key stronghold for the species, characterized by consistently high occupancy (Figure 9.3).

Leopard cat occupancy remained broadly consistent across the various landscapes, though localized fluctuations were observed. In the Terai landscape, stability in occupancy was evident across Rajaji, Corbett, Pilibhit, Valmiki, parts of the Terai West Forest Division, Nandhaur, Katerniaghat, and Suhelwa. Notable increases were detected in Dudhwa, as well as in select areas of Rajaji and Suhelwa. Conversely, certain grid cells, particularly those located near forest edges, showed a decline in occupancy. In Northeast India, occupancy patterns remained largely stable. Similarly, in Central India, the Satkosia and Similipal landscapes exhibited consistent occupancy. Within the Western Ghats, overall occupancy was stable, though interspersed with some grid cells reflecting both increases and decreases. These relatively minor year-to-year variations in occupancy may likely be attributed to natural fluctuations in habitat use or detection (Figure 9.4).

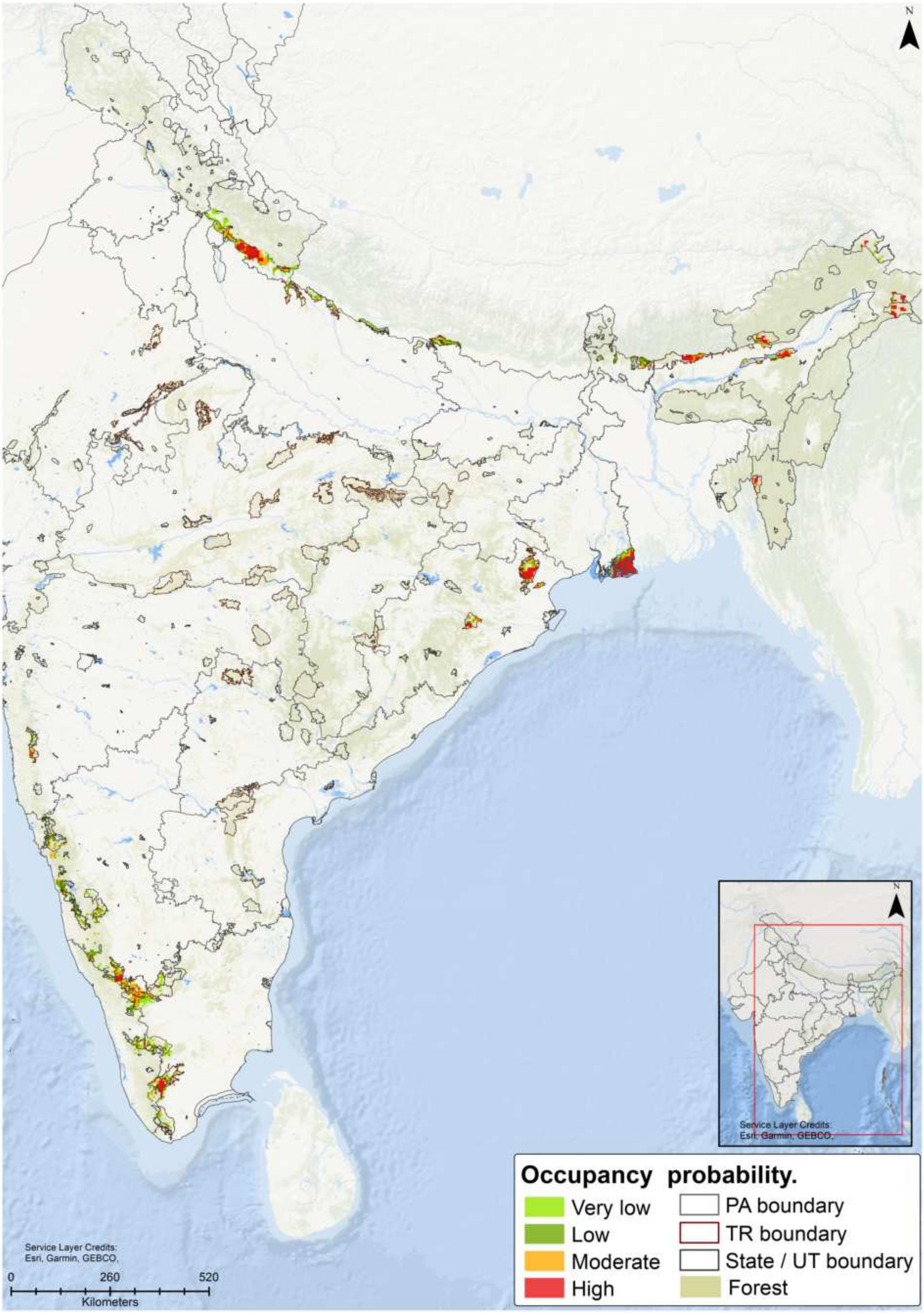


Figure 9.3. Estimated occupancy (Ψ) of the leopard cat based on camera-trap surveys conducted in tiger-range forests of India in 2022.

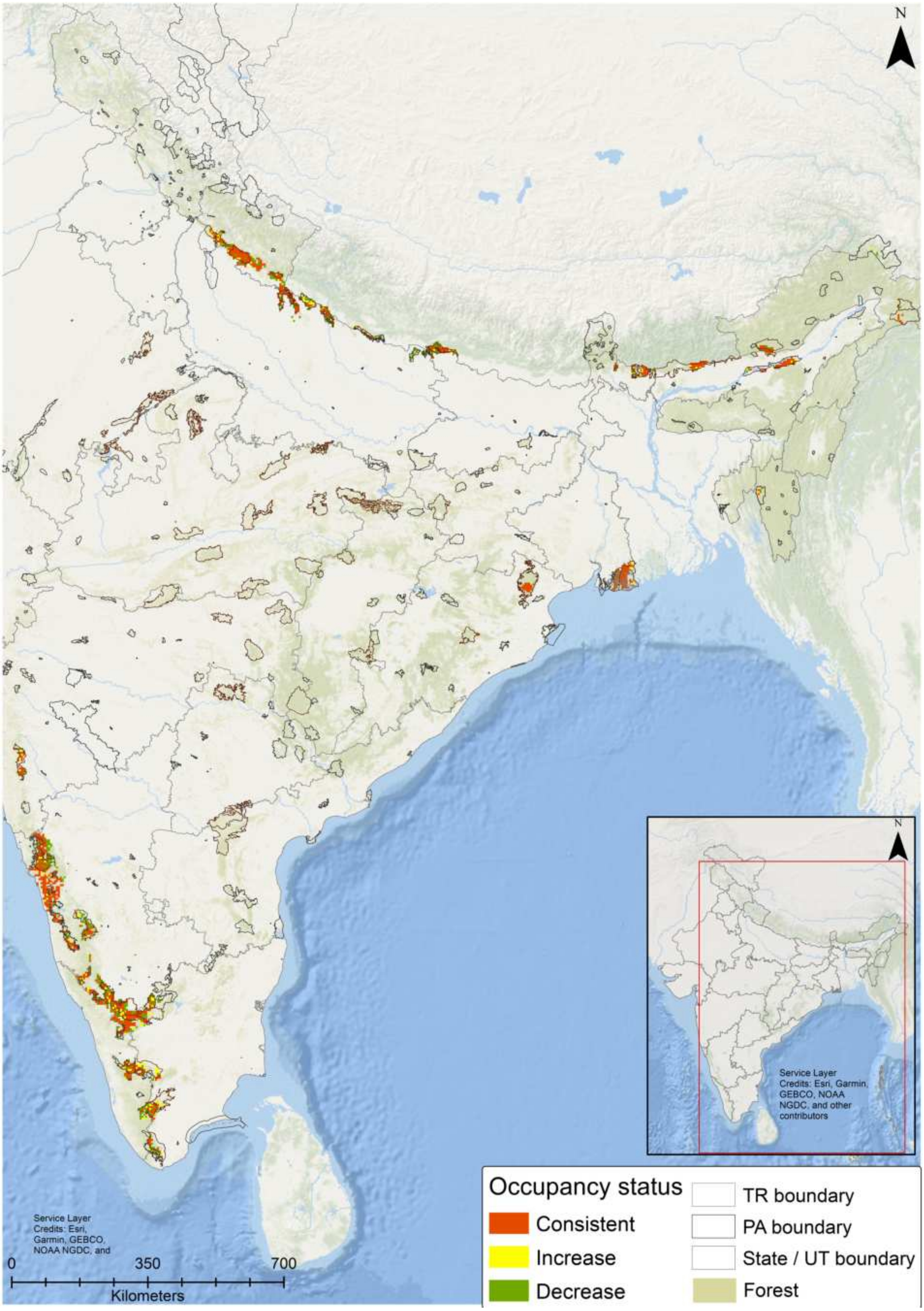
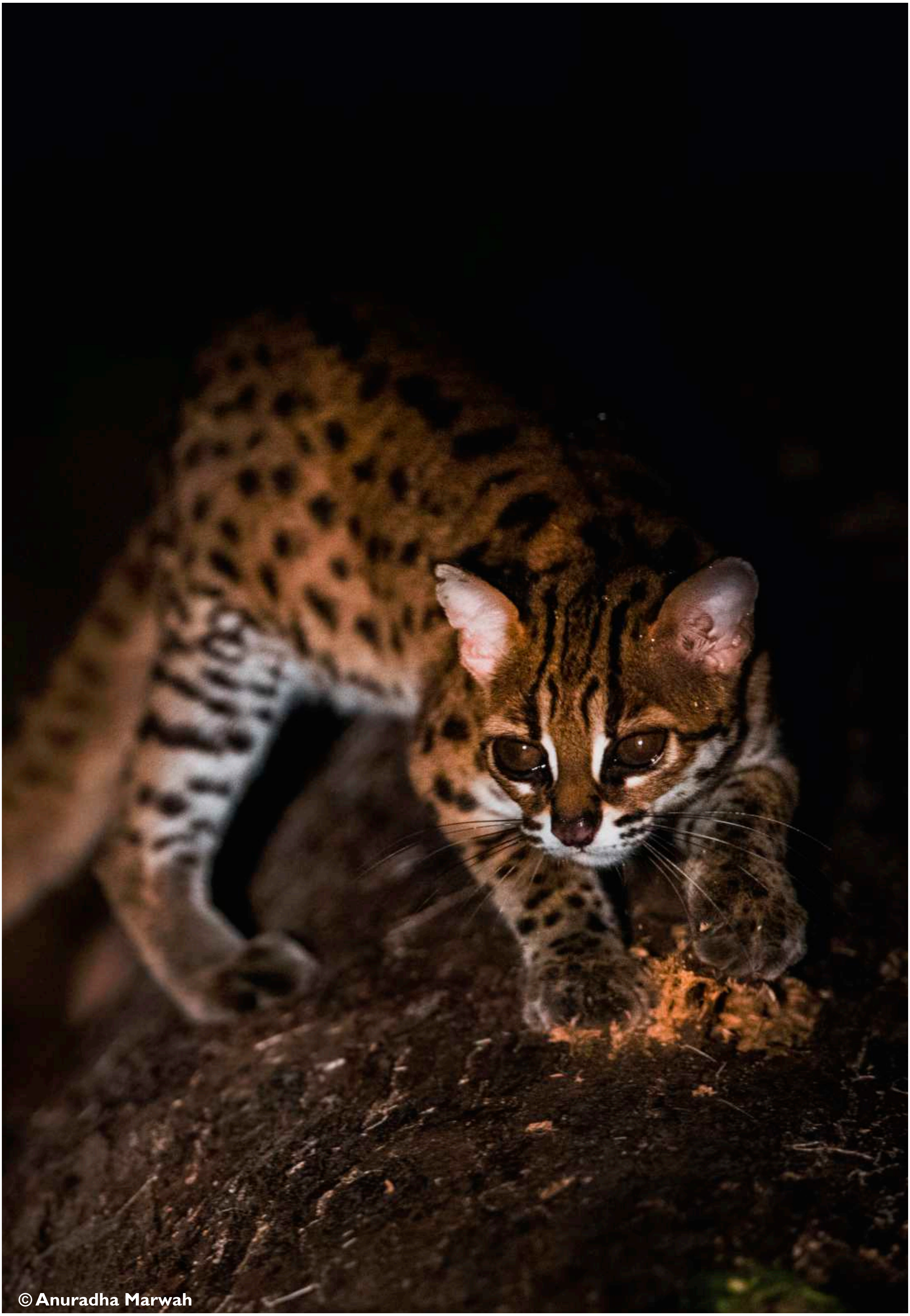


Figure 9.4. Occupancy (Ψ) dynamics of the leopard cat across consistently sampled camera trap grids in 2018 and 2022 within tiger-range forests of India.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MARBLED CAT
(Pardofelis marmorata)

10.1. Introduction

A small wild feline endemic to the tropical forests of South and Southeast Asia, marbled cat represents one of the earliest felid radiations along with Asiatic golden cat (Johnson *et al.,* 2006). Marbled cat was earlier considered to be closely related to the genus *Neofelis* based on morphological context (Corbett & Hill 1992), however, recent molecular studies identified the species having Bay cat lineage (O'Brien & Johnson 2007). Marbled cat is protected as Schedule I species under Wild Life (Protection) Act 1972, and listed on CITES Appendix I. Status of marbled cat listed as Near Threatened from Vulnerable in IUCN in 2016 primarily due to confirmed records of marbled cats across previously predicted distributional range through extensive camera trap sampling (Ross *et al.,* 2016, Singh & Mcdonald, 2017). Globally marbled cat is distributed from the central and eastern Himalayan foothills of Nepal, Bhutan, Northeast India (Jhala *et al.,* 2021; Norbu *et al.,* 2024). Further its range extends to Yunan province, China, and throughout peninsular Southeast Asia in Bangladesh, Myanmar, Cambodia, Malaysia, and to the Sumatran and Bornean islands (Huang *et al.,* 2022; Ross *et al.,* 2016). In India, photographic evidence of marbled cat is reported form northern hilly districts of West Bengal, Arunachal Pradesh, Assam, Mizoram, and Nagaland (Jhala *et al.,* 2020, 2021; Joshi *et al.,* 2019). Although there are photographic evidences of the species from different locations, very little is known about the ecology of the species.

Marbled cats are mostly found in the moist and mixed deciduous-evergreen tropical forests, however, they seem to prefer hill forests (Ross *et al.,* 2016). These cats can live at altitudes up to 2, 750 meters (Lama *et al.,* 2019). In India, marbled cats are mainly located in the eastern foothills of the Himalayas, particularly in moist deciduous and semi-evergreen forests (Jhala *et al.,* 2021). The diet of marbled cats is not well recorded, but their semi- arboreal nature suggests they likely eat small animals like rodents, squirrels, and birds (Nowell & Jackson 1996, Wilson and Mittermeier 2009). Marbled cats are usually solitary animals. However, recent camera trap images have captured a pair together (Grassman & Tewes 2002). Although they have not been studied extensively, a preliminary study by Grassman *et al.,* (2005) estimated the home range of an adult female marbled cat at about 5.3 km² in Thailand's Phu Khieu National Park. Previously thought to be mainly active at night and during twilight hours, recent studies indicate that marbled cats may also be active during the day (Mukherjee *et al.,* 2019; Jhala *et al.,* 2021). Singh & Mcdonald (2017) reported a population density of 5.03 individuals/ 100 km² in Dampa tiger reserve, Mizoram. The species presence is recorded mostly from protected areas; however, also recorded from community managed forest of Nagaland (Joshi *et al.,* 2019). Although there are photographic evidences of the species from different locations, very little is known about the ecology of the species. Photo-capture rate of the species is also very low as compared to other sympatric felid species, which even makes it difficult to study (Ross *et al.,* 2016; Singh & Mcdonald, 2017; Jhala *et al.,* 2020, 2021).

To model occupancy of marbled cat, we examined a range of environmental factors based on the available ecological information about the species. Given that the species primarily inhabits moist and mixed deciduous-evergreen tropical forests, vegetation indices such as NDVI and tree cover were included as potential determinants of its distribution (Table 10.1). As the species is known to inhabit hilly landscapes, we included terrain ruggedness an important covariate to model its occupancy. To account for human impact, we incorporated the human footprint index .

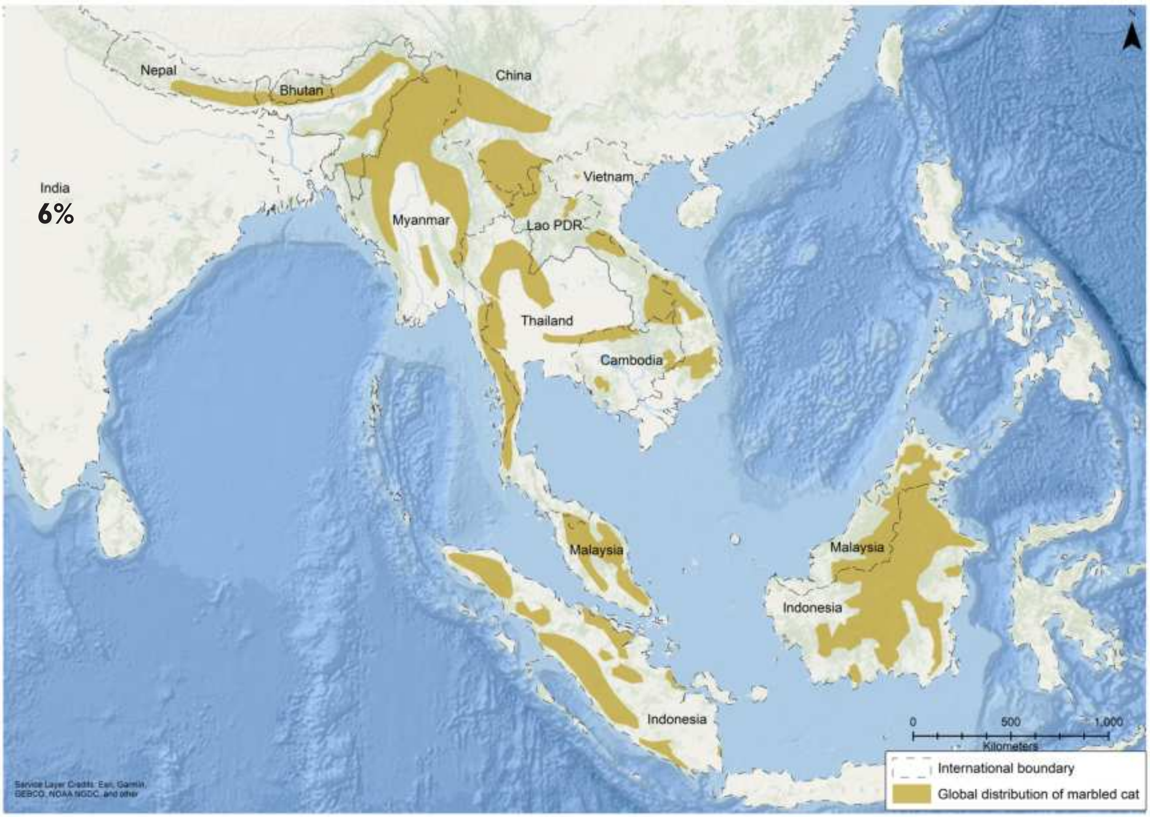

Figure 10.1. Global distribution range of the marbled cat (*Pardofelis marmorata*) based on IUCN Red List data. About 6% of the species' global distribution occurs within India.

10.2 Status of occupancy

During the camera trap surveys, marbled cat occupied 21 out of 143 sampled sites (naïve occupancy, 0.15) based on 25 detections in 2018, and 26 out of 253 sampled sites (naïve occupancy, 0.10) based on 34 detections in 2022. Average modelled site occupancy in 2022 was 0.34 (SE 0.11) with low detection probability 0.08 (SE 0.02).

Our analysis indicated that marbled cat occupancy increased significantly with higher post-monsoon NDVI (β = 2.75, SE = 1.09, P = 0.01), highlighting the species' strong association with dense vegetation (Table 10.2). As a rare and elusive felid, the marbled cat may depend heavily on forest cover for concealment and prey availability. Occupancy was also positively associated with terrain ruggedness (β = 1.42, SE = 0.56, $P < 0.05$), suggesting a preference for hilly, forested landscapes. Detection probability increased with greater survey effort (β = 0.05, SE = 0.02, $P < 0.05$), indicating that our model effectively accounted for variation in detection driven by sampling intensity. Similar to the clouded leopard, we could not identify any covariates that significantly explained occupancy dynamics of marbled cat between 2018 and 2022.

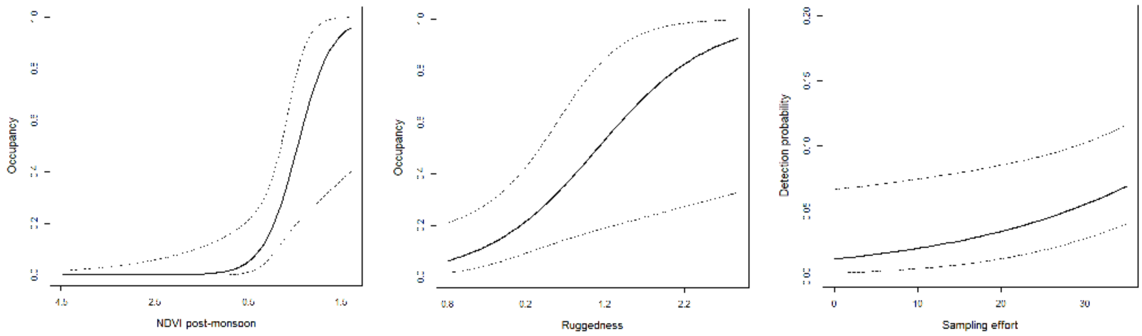

Figure 10.2. Estimated occupancy (Ψ) of the marbled cat in response to NDVI post-monsoon and ruggedness, along with detection probability (p) in relation to sampling effort, across tiger-range forests of India based on 2022 camera-trap data.

Table 10.1. Comparison of occupancy models with different covariate combinations for the clouded leopard across tiger-range forests of India in 2018 and 2022.

Model Type	Model	K	AICc	∆ AICc	AIC-cWt	Cum. Wt	LL
Occupancy status (single-season)	Ψ(ndvips+rug) p(efffort)	5	281.48	0	0.92	0.92	-135.62
	Ψ(trcov+hfp) p(efffort)	5	286.29	4.81	0.08	1	-138.02
	Ψ(.) p(effort)	3	308.33	26.84	0	1	-151.11
	Ψ(.) p(.)	2	313.54	32.06	0	1	-154.75

In single season: ndvips = NDVI post-monsoon, rug = terrain ruggedness index, trcov = tree cover, hfp = human footprint, effort = camera trap days, (.) = constant.

Table 10.2. Estimated β coefficients for covariates influencing the occupancy of the marbled cat in India.

Model type	Model	Parameters	Estimate	SE	P-value
Occupancy status (single-season)	Occupancy	Intercept	-1.58	0.50	0.00
		ndvips	2.75	1.09	0.01
		rug	1.42	0.56	0.01
	Detection	Intercept	-4.31	0.85	0.00
		effort	0.05	0.02	0.01

In single-season: ndvips = NDVI post-monsoon, rug = terrain ruggedness index, effort = camera trap days.

10.3 Discussion

The marbled cat exhibited a very low photo-capture rate, reflecting its elusive nature and likely low densities. Marbled cat showed high occupancy in dense and hilly forests. The highest occupancy was recorded in the Namdapha–Kamlang cluster and Dampa Tiger Reserve (Figure 10.3), followed by Neora Valley National Park and Dibang Wildlife Sanctuary. Moderate occupancy was observed in Pakke Tiger Reserve. In contrast, low occupancy was found in Buxa, Manas, and Nameri Tiger Reserves, as well as Jaldapara and Gorumara National Parks. Occupancy probabilities were relatively higher in deciduous forests, followed by evergreen forests.

We did not identify any covariates that significantly explained the changes in occupancy dynamics of the marbled cat between 2018 and 2022. However, the species was consistently detected in Buxa, Dampa, Kamlang, and Pakke Tiger Reserves across both years (Figure 10.4). An increase in occupied grids was observed in 2022 within Buxa, Manas, Namdapha Tiger Reserves, and Neora Valley National Park. In contrast, a decrease in occupied grids was recorded in parts of Pakke and Nameri Tiger Reserves.

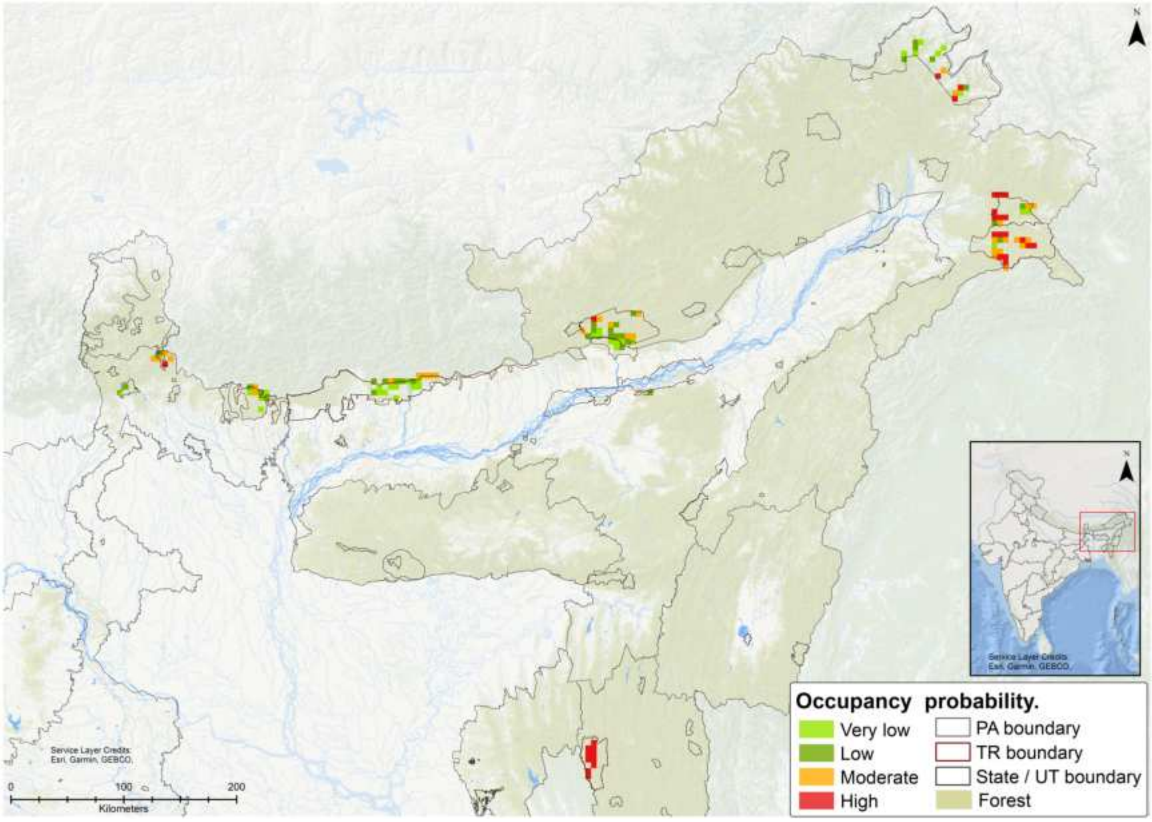

Figure 10.3. Estimated occupancy (Ψ) of the marbled cat based on camera-trap surveys conducted in tiger-range forests of India in 2022.

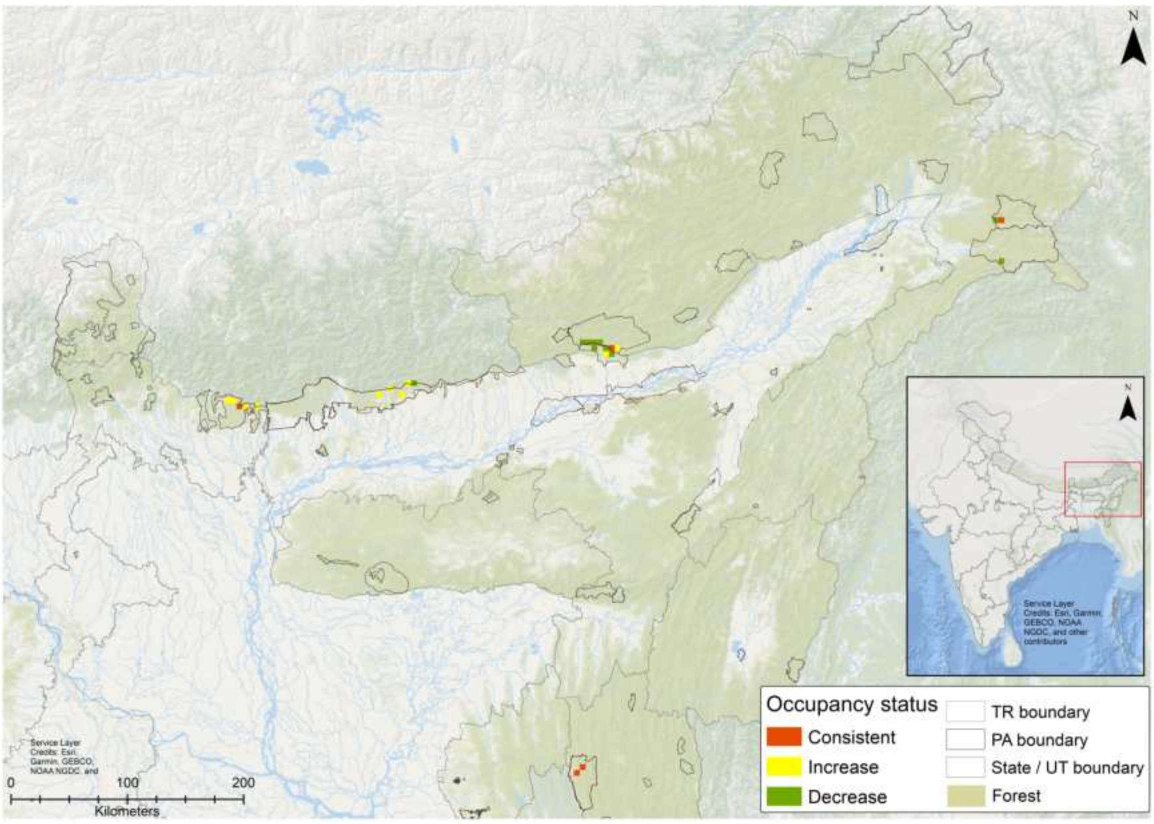

Figure 10.4. Occupancy (naïve) dynamics of the marbled cat across consistently sampled camera trap grids in 2018 and 2022 within tiger-range forests of India.

RUSTY-SPOTTED CAT

(Prionailurus rubiginosus)

11.1. Introduction

The rusty-spotted cat, the world's smallest wildcat, is a rare and elusive species endemic to India, Nepal, and Sri Lanka (Mukherjee *et al.,* 2016; Nowell & Jackson, 1996). It inhabits a variety of habitats, including tropical dry, moist deciduous and thorn forests, across five broad biogeographic regions: the Western Ghats, Deccan Peninsula, Himalayan foothills, Gangetic Plains, and Semi-arid regions (Bora *et al.,* 2020; Jhala *et al.,* 2021). Despite its wide distribution, the species is classified as Near Threatened on the IUCN Red List (Mukherjee *et al.,* 2016) and is protected under Schedule I of India's Wild Life (Protection) Act (1972), highlighting its conservation significance. However, its current distribution is likely fragmented and increasingly threatened by human-induced land-use changes, habitat loss, linear infrastructure development such as roadways, along with other anthropogenic pressures (Mukherjee *et al.,* 2016). It is a solitary carnivore and primarily preys on small mammals, birds, reptiles, and insects, playing a crucial role in regulating prey populations and maintaining ecological balance (Mukherjee *et al.,* 2016). There remains a critical lack of knowledge regarding its ecology and population status across its range. Most existing studies on the rusty-spotted cat focus on distribution records, habitat suitability assessments, and activity patterns derived from camera trap data (Bora *et al.,* 2020; Jhala *et al.,* 2021). Chatterjee *et al.,* (2020) attempted to estimate the species' population in Tadoba-Andhari Tiger Reserve, but such targeted efforts remain rare across its range.

We used sampling effort to model site-level detection probabilities. Ecological covariates likely to influence the occurrence of the rusty-spotted cat were selected based on prior research (Bora *et al.*, 2020; Jhala *et al.*, 2021). The species is primarily distributed in mixed deciduous forests of peninsular India and is notably absent from evergreen rainforests. Habitat suitability models indicate a strong association with deciduous forests, leading us to include NDVI difference as a proxy for forest deciduousness (Jhala *et al.*, 2021). We also incorporated the area of deciduous, bamboo, and scrub forests as key predictors of suitable habitat. Given the species' absence from extreme environments such as deserts, the high Himalayas, and humid rainforests, we included annual precipitation (bio12) to constrain its predicted range (Fick & Hijmans, 2017). Additionally, terrain ruggedness and human disturbance variables, including distance to protected areas, human footprint, and forest loss, were used to assess their influence on occupancy (Table 11.1).

11.2. Status of occupancy

Camera trap sampling demonstrated that rusty spotted cats occupied 757 out of 4248 sites (naïve occupancy, 0.18) based on 1190 detections in 2018, and 1063 out of 5707 sites (naïve occupancy 0.19) based on 1823 detections in 2022. Averaged modelled site occupancy was 0.38 (SE 0.02).

Rusty-spotted cat occupancy declined significantly with increasing annual precipitation (β = -2.83, SE = 0.16; P < 0.001) and terrain ruggedness (β = -0.36, SE = 0.07; P < 0.001), indicating a preference for dry, low-lying forests. Occupancy was positively associated with greater deciduous forest cover (β = 0.21, SE = 0.05; P < 0.01), likely reflecting favorable habitat. Additionally, occupancy decreased with increasing distance from protected areas (β = -0.45, SE = 0.18; P = 0.02), suggesting the species is more likely to occur within or near protected landscapes. Detection probability was low (0.14, SE = 0.01), consistent with the species' rarity, but increased significantly with survey effort (β = 0.06, SE = 0.01; P < 0.001), indicating that the model effectively accounted for variability in detection due to sampling intensity.

The occupancy dynamics of the rusty-spotted cat were consistent with patterns observed in the single-season models. Initial occupancy was higher in drier (β = 2.0, SE = 0.16; P < 0.001) and less rugged landscapes (β = -0.46, SE = 0.07; P < 0.001), particularly in areas dominated by deciduous (β = 0.42, SE =0.06, P < 0.001), bamboo (β = 0.16. SE= 0.07, P = 0.02), and scrub (β = 0.37, SE= 0.09, P <0.001) forests. Colonization probability was significantly lower in regions with higher precipitation (β = -1.98, SE = 0.25; P < 0.01) and rugged terrain (β = -0.18, SE = 0.09; P = 0.03), indicating that the species' occupancy increased in drier, flatter habitats. While extinction probability showed a positive association with human footprint, the relationship was not statistically significant. As with the single-season model, detection probability increased significantly with sampling effort (β = 0.04, SE = 0.004; P < 0.001), suggesting reliable model performance in accounting for survey intensity.

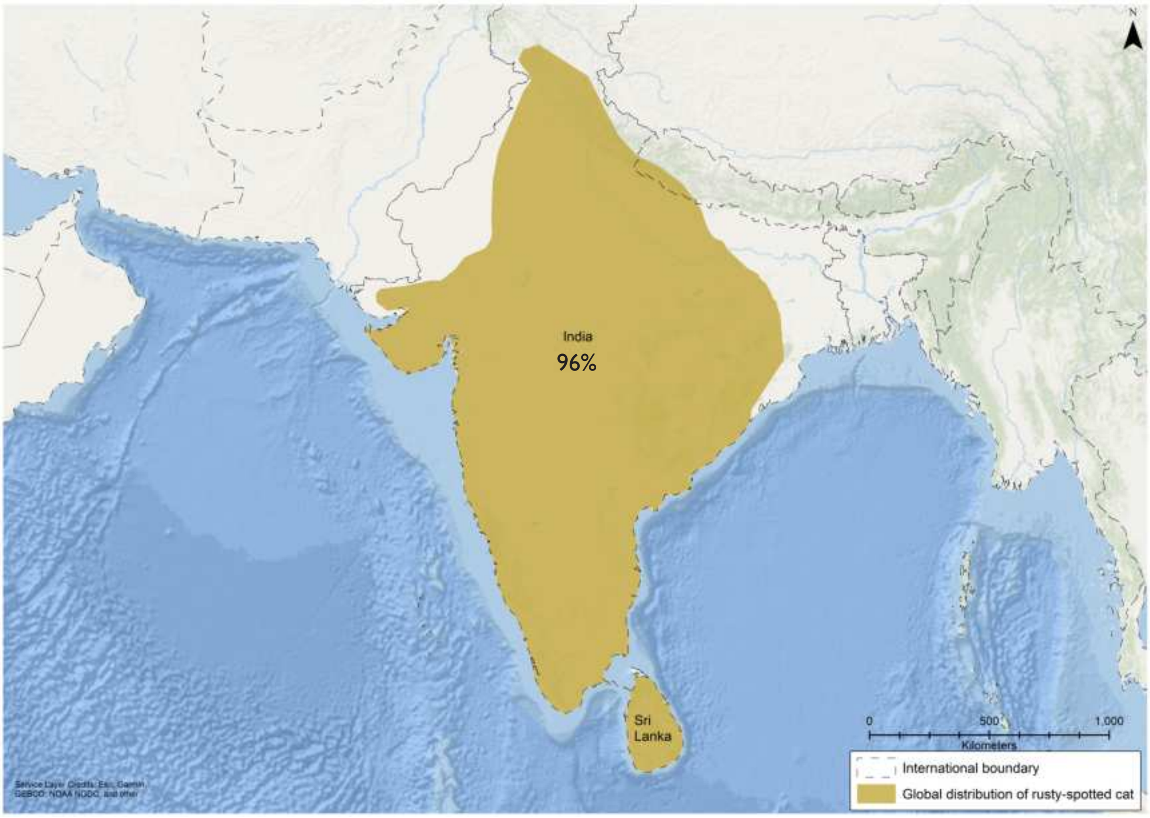

Figure 11.1. Global distribution range of the rusty-spotted cat (*Prionailurus rubiginosus*) based on IUCN Red List data. About 96% of the species' global distribution occurs within India.

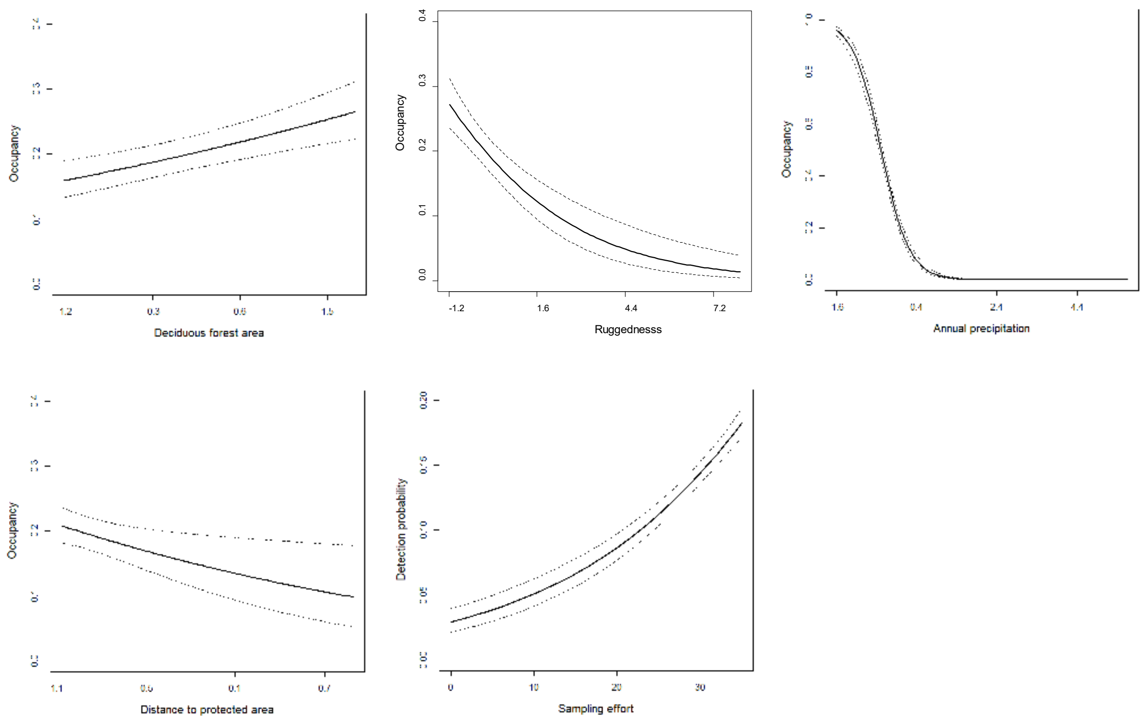

Figure 11.2. Estimated occupancy (Ψ) of the rusty-spotted cat in relation to deciduous forest area, terrain ruggedness index, annual precipitation, and distance to protected areas, along with detection probability (p) in relation to sampling effort, across tiger-range forests of India based on 2022 camera-trap data.

Table 11.1. Comparison of occupancy models with different covariate combinations for the rusty-spotted cat across tiger-range forests of India in 2018 and 2022.

Model Type	Model	K	AICc	∆ AICc	AIC-cWt	Cum. Wt	LL
Occupancy status (single-season)	Ψ(deci+rug+bio12+dpa) p(effort)	7	12186.34	0	0.74	0.74	-6086.16
	Ψ(ndvid+rug+bio12) p(effort)	6	12189.58	3.24	0.15	0.89	-6088.78
	Ψ(deci+rug+bio12) p(effort)	6	12190.16	3.82	0.11	1	-6089.07
	Ψ(.) p(effort)	3	12971.67	785.33	0	1	-6482.83
	Ψ(.) p(.)	2	13140.32	953.99	0	1	-6568.16
Occupancy dynamics (multi-season)	Ψ(bio12+rug+deci+bamboo+scrub) γ(bio12+rug) ϵ(hfp) p(effort)	13	18610.7	0	0.9	0.9	-9292.3
	Ψ(bio12+rug+deci+bamboo+scrub) γ(bio12+rug) ϵ(floss) p(effort)	13	18615.12	4.42	0.1	1	-9294.51
	Ψ(ndvid18+bio12+rug) γ(bio12+rug) ϵ(hfp) p(effort)	11	18638.43	27.73	0	1	-9308.18
	Ψ(bio12+rug+deci) γ(bio12+rug) ϵ(hfp) p(effort)	11	18716.9	106.2	0	1	-9347.41
	Ψ(.) γ(.) ϵ(.) p(.)	4	19657.2	1046.5	0	1	-9824.6
	Ψ(.) γ(.) ϵ(.) p(effort)	5	19781.27	1170.57	0	1	-9885.63

In single-season: bio12 = annual precipitation, rug = terrain ruggedness index, deci = deciduous forest area, dpa = distance to protected area, ndvid = NDVI difference, effort = camera trap days, (.) = constant.

In multi-season: bio12 = annual precipitation, rug = terrain ruggedness index, deci = deciduous forest area, bamboo = bamboo forest area, scrub = scrub forest area, ndvid18 = NDVI difference in 2018, hfp = human footprint in 2018 and 2022, floss = forest loss in 2018 and 2022, effort = camera trap days, (.) = constant.

Table 11.2. Estimated β coefficients for covariates influencing the occupancy of the rusty-spotted cat in India.

Model	Parameters	Coefficients	Estimate	SE	P-value
Occupancy status (single-season)	Occupancy	Intercept	-1.81	0.19	0.00
		deci	0.21	0.05	0.00
		rug	-0.36	0.07	0.00
		bio12	-2.83	0.16	0.00
		dpa	-0.45	0.18	0.02
	Detection	Intercept	-3.50	0.16	0.00
		effort	0.06	0.01	0.00
Occupancy dynamics (multi-season)	Initial occupancy	Intercept	-1.38	0.08	0.00
		bio12	-1.96	0.16	0.00
		rug	-0.46	0.07	0.00
		deci	0.42	0.06	0.00
		bamboo	0.16	0.07	0.02
		scrub	0.37	0.09	0.00
	Colonisation	Intercept	-1.7	0.11	0.00
		bio12	-2.0	0.25	0.00
		rug	-0.18	0.09	0.03
	Extinction	Intercept	-1.19	0.14	0.00
		hfp	0.19	0.14	0.17
	Detection	Intercept	-3.0	0.15	0.00
		effort	0.04	0.004	0.00

In single-season:deci= deciduous forest area, rug = terrain ruggedness index, bio12 = annual precipitation, dpa = distance to protected area, effort = camera trap days, (.) = constant.

In multi-season: bio12 = annual precipitation, rug = terrain ruggedness index, deci = deciduous forest area, bamboo = bamboo forest area, scrub = scrub forest area, hfp = human footprint in 2018 and 2022, effort = camera trap days, (.) = constant.

11.3. Discussion

Our results align with the known affinity of rusty-spotted cats for forested environments. It thrives in deciduous forests, favouring less rugged, drier landscapes. The positive association of the species' occupancy with protected areas underscores the critical role of India's tiger reserves in securing viable populations of the world's smallest wild cat. Highest occupancy probabilities were estimated in several landscapes, including the Nagarjunasagar–Srisailam–Amrabad Tiger Reserves complex, Bandipur–Mudumalai–Sathyamangalam Tiger Reserves complex, Bhadravathi and Ballari forest divisions, Sariska and Ranthambore Tiger Reserves, Kuno National Park, Kumbhalgarh, Eturnagaram, Gundla Brahmeswaram, and Dhyanganga Wildlife Sanctuaries. These areas represent optimal habitats dominated by mixed deciduous forests. Moderate occupancy was observed in Pench, Bor, Kawal, Panna, and Mukundara hills Tiger Reserves, as well as in Kheoni and Shergarh Wildlife Sanctuaries and parts of the Western Ghats, particularly within the Bandipur, Mudumalai, and Sathyamangalam Tiger Reserves. In contrast, low occupancy was characteristic of moist forest ecosystems found in Udanti–Sitanadi, Satkosia, Ratapani, Satpura, and Kanha Tiger Reserves, the Terai landscape, and much of the Western Ghats (Figure 11.3).

Occupancy change across the landscapes did not exhibit any strong spatial pattern, with most areas showing a mosaic of consistent, increased, and decreased occupancy grid cells (Figure 11.4). The observed variations in the species' occupancy between the two sampling seasons likely reflect natural fluctuations in occupancy rather than substantial range shifts.

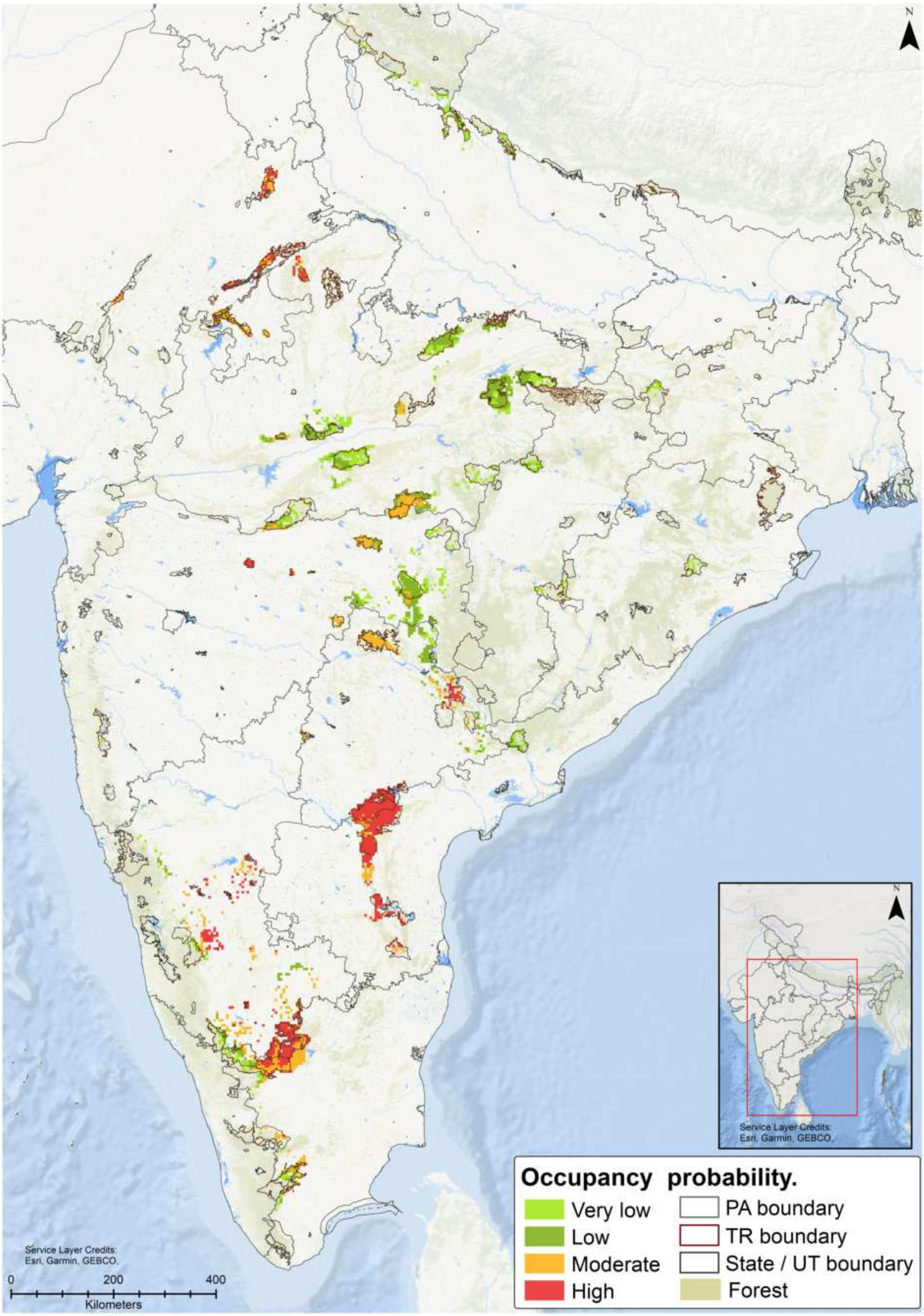

Figure 11.3. Estimated occupancy (Ψ) of the rusty-spotted cat based on camera-trap surveys conducted in tiger-range forests of India in 2022.

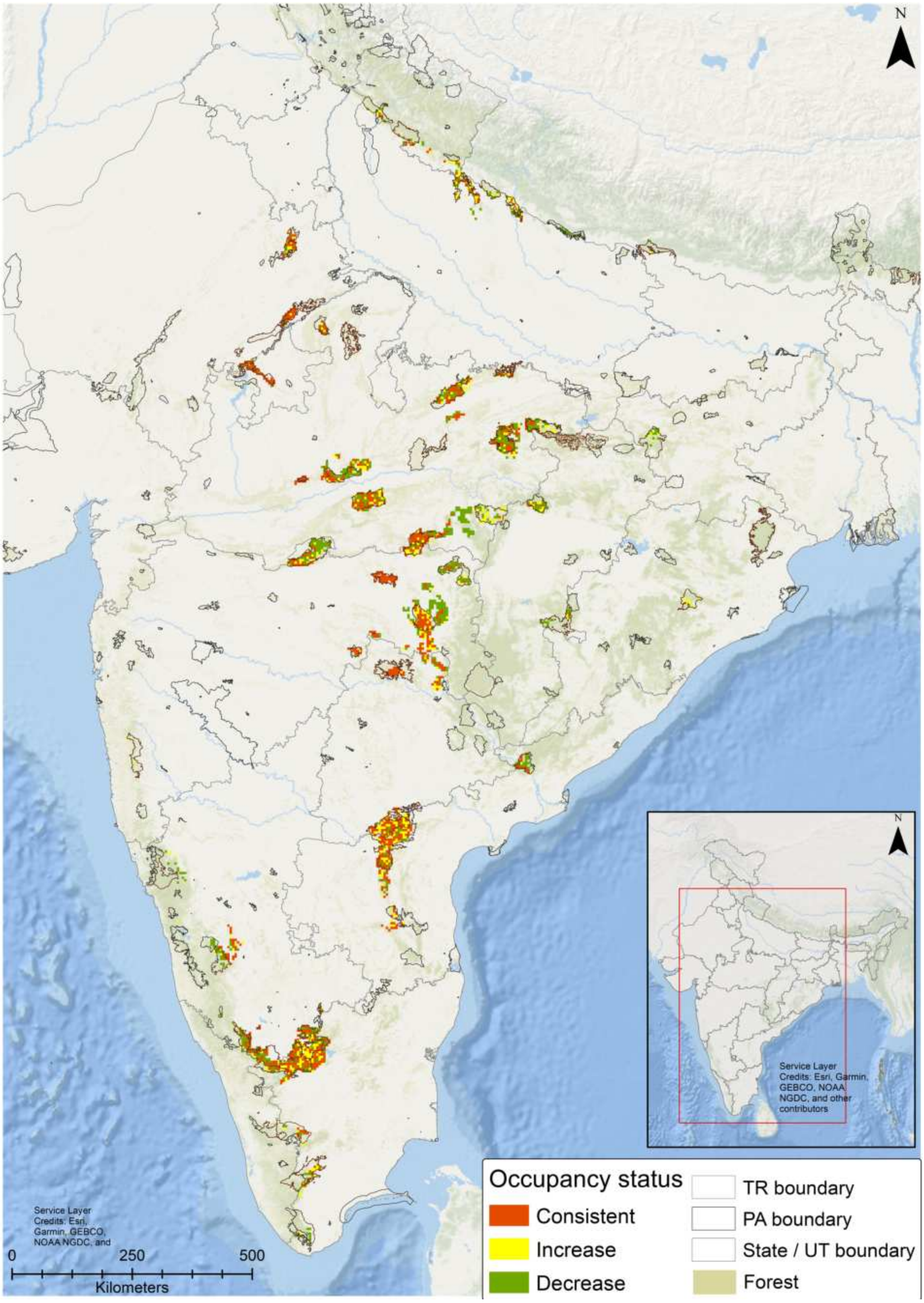

Figure 11.4. Occupancy (Ψ) dynamics of the rusty-spotted cat across consistently sampled camera trap grids in 2018 and 2022 within tiger-range forests of India.


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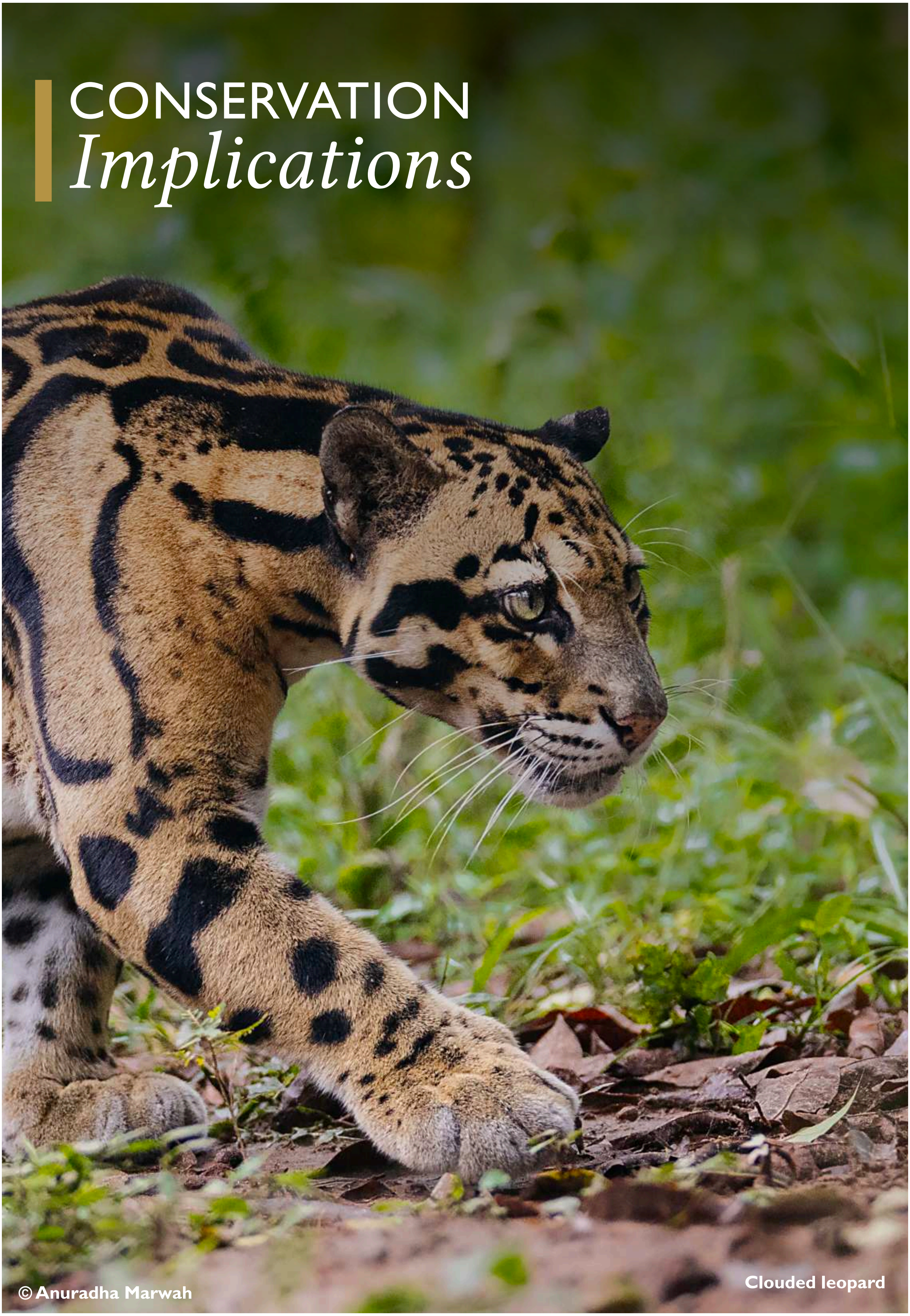
CONSERVATION *Implications*



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Clouded leopard

The small cats occupy a wide range of ecosystems across India, shaped by the country's diverse biogeographic zones. Despite listed under Schedule I of The Wild Life (Protection) Act, 1972, they continue to face significant threats, including habitat degradation and fragmentation, hunting for trade, and road mortality. The absence of focused research has resulted in a lack of knowledge on their distribution, population status and ecological factors influencing their demographics. This report presents occupancy status and dynamics for nine small cat species occurring within India's tiger-range forests and offers valuable insights that can inform future research and conservation priorities.

Among the nine small cat species inhabiting India's tiger-range forests, the jungle cat has the widest distribution, occurring across all tiger landscapes, with the highest occupancy recorded in central India and the semi-arid region, attributable to its habitat generalist nature (Table 12.1). The rusty-spotted cat ranks second in terms of occupied area, being absent only from northeast India, and is most abundant in deciduous forests leopard cats, which prefer moist habitats with moderate to dense cover, are found across most tiger landscapes except central India. The caracal and desert cat are restricted to the semi-arid and arid regions of central India, with the caracal confined to western India, particularly Rajasthan. The Fishing cat, being a specialist to aquatic habitats, is limited to the Terai, Northeast India, and the Sundarbans, given non-tiger habitats of the species are not included in sampling. The Asiatic golden cat, marbled cat, and clouded leopard are restricted to the dense tropical forests of eastern Himalayas.

Table 12.1. Area occupied by small cats in India's tiger-range forests: naïve occupancy and estimated occupancy. Values in parentheses represent 95% confidence intervals.

Species	Naïve occupancy (km^2)	Estimated occupancy (km^2)
Asiatic golden cat	696	1850 (1400 - 3075)
Caracal	150	-
Clouded leopard	1455	3250 (2250 - 3725)
Desert cat	5021	12500 (10675 - 13850)
Fishing cat	4922	7575 (6125 - 8150)
Jungle cat	59881	96275 (90075 - 98100)
Leopard cat	22218	32800 (27950 - 35900)
Marbled cat	633	2325 (1375 - 3550)
Rusty-spotted cat	27108	70075 (66225 - 96075)

The occupancy patterns of small cats across different forest types indicate distinct habitat preferences and ecological niches (Figure 12.1). Forest specialists like the clouded leopard, marbled cat, and Asiatic golden cat showed higher occupancy in dense evergreen habitats. The fishing cat was strongly associated with wetland habitats like mangrove and swamp forests while leopard cat occupancy was higher in the moist and swamp forests. In contrast, generalist species like the jungle cat and rusty-spotted cat exhibited moderate to high occupancy across a range of forest types, including deciduous, bamboo, scrub and sal forests. The desert cat also occupied deciduous, bamboo, scrub and sal forests given that a major portion of its distribution range was not included in our sampling area. These findings highlight the need for habitat-specific conservation strategies, particularly for the specialist species.

The species-specific responses in occupancy of small cats to the presence of larger carnivores in demonstrated varying patterns (Figure 12.2). Asiatic golden cat, clouded leopard and marbled cat show reduced occupancy in areas with high tiger or leopard density. This is likely due to the naturally low tiger density in the major habitats of these species rather than direct competition or predation risk. Their presence within the Tiger Reserves of Northeast India underscores the protection they receive under the umbrella of tiger conservation. Interestingly, both the jungle cat and the rusty-spotted cat exhibited high occupancy in areas with low tiger density. This is likely because these species have widespread distributions and often occur in habitats where tigers are absent. In contrast, the rest of the species appear more tolerant, maintaining relatively higher occupancy in areas with moderate to high tiger and leopard densities likely due to distinct ecological niches. Fishing cats and leopard cats face severe threats from the pet trade and human–wildlife conflict. Their high occupancy within tiger reserves highlights the broader benefits of tiger-focused conservation efforts. Small cat's occupancy was higher in areas where mid-sized carnivores like dholes, jackals, wolves, hyenas, and sloth bears were less abundant. This pattern was different from how small cats responded to the presence of apex predators like tigers or leopards.

Similar to the conservation dependent large felids, small cats also exhibited a preference for relatively undisturbed habitats, as reflected in their higher occupancy within protected areas (Figure 12.3). Species such as the clouded leopard, marbled cat, fishing cat, leopard cat, and Asiatic golden cat exhibit marked declines in occupancy with increasing human disturbance, indicating their sensitivity to anthropogenic pressures. In contrast, generalist species like the jungle cat and rusty-spotted cat maintain relatively higher occupancy across disturbance gradients, suggesting greater adaptability. Species like the jungle cat and rusty-spotted cat, which also occur outside protected areas may face threats from human-wildlife conflicts. Despite their legal protection, forest habitats outside the protected areas in India face intense resource extraction pressures from communities residing around them. These habitats are increasingly fragmented by infrastructure such as roads and railways and face continual encroachment driven by expanding agricultural and developmental demands. Habitat specialists such as the fishing cat and clouded leopard are likely more vulnerable to the human induced habitat loss.

The occupancy dynamics reveal substantial variation across species (Table 12.2 & Appendix 1). Leopard cat (50%), jungle cat (46%), and fishing cat (39%) had the highest consistent occupancy, suggesting stable distributions. In contrast, marbled cat (85%), Asiatic golden cat (75%), and clouded leopard (65%) showed high consistent absence, likely due to rarity or limited ranges. Rusty-spotted cat and leopard cat showed high decline (21%), while clouded leopard and jungle cat had moderate colonization (14% each). Desert cats and fishing cats showed relatively stable dynamics. These findings should be interpreted cautiously, as they are based on just two sampling seasons (2018 and 2022), limiting inference about long-term trends. For rare species such as caracal, clouded leopard, and marbled cat, detections were too few to reliably estimate dynamics. Continued long-term monitoring is essential for robust trend assessments (MacKenzie *et al.,* 2006).

This study utilized data from a sampling framework primarily designed to estimate the populations of tigers, their co-predators, and associated prey species. As a result, it lacks fine-scale information on small cats and their principal prey, such as rodents, ground birds, reptiles, and other small mammals. Consequently, the relationship between the occupancy of most small cat species and prey availability could not be modelled. It may also have contributed to the observed lack of significant changes in small cat occupancy dynamics across the two sampling sessions. Despite these limitations, our study offers crucial insights into the status of small cats in India's tiger-range forests and serves as a stepping stone for prioritizing species-specific conservation actions both within and beyond protected areas under the umbrella of Project Tiger, supporting effective management and guiding future research efforts.

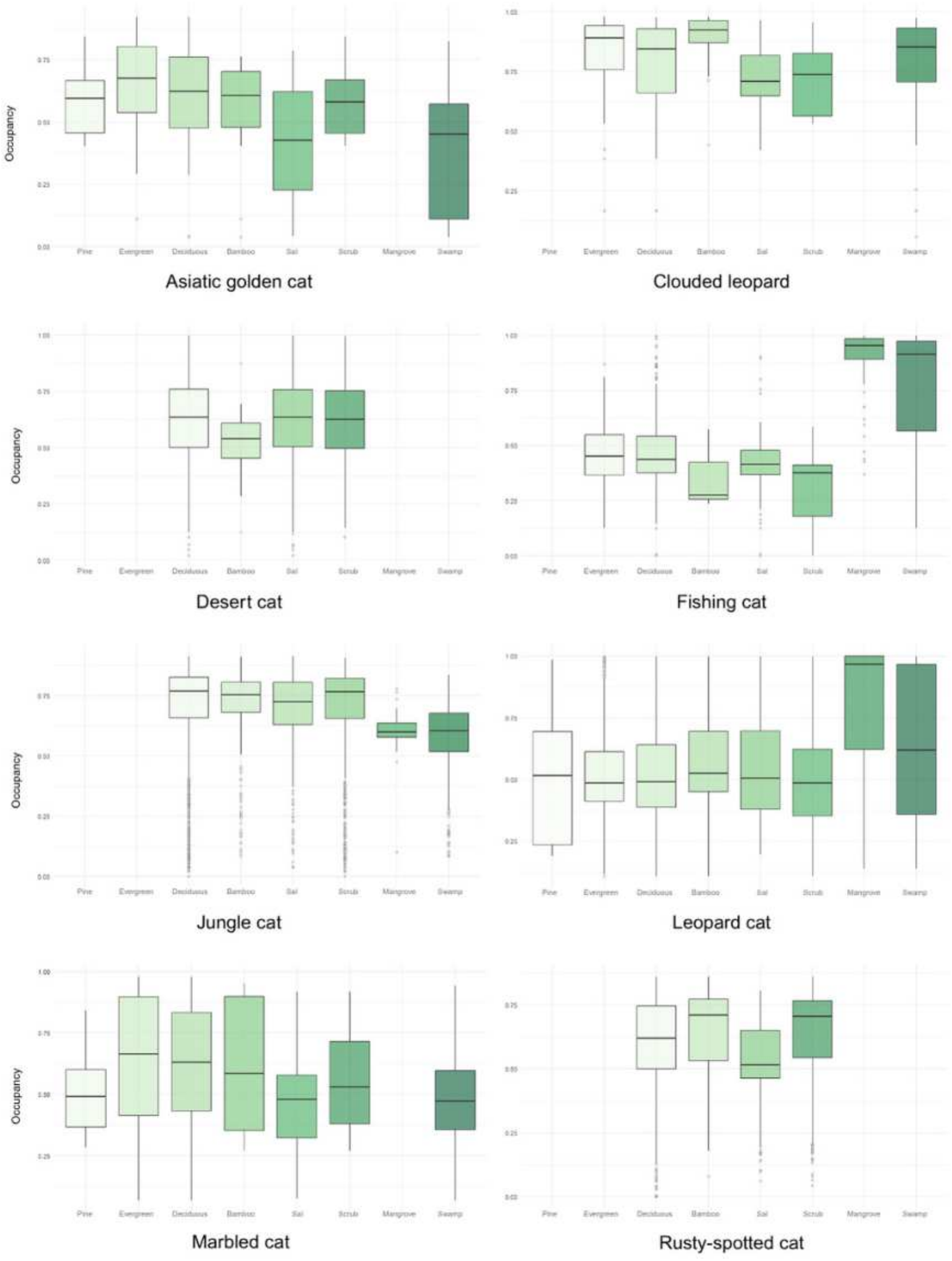

Figure 12.1. Occupancy of small cats in different forest types in the tiger-range forests of India.

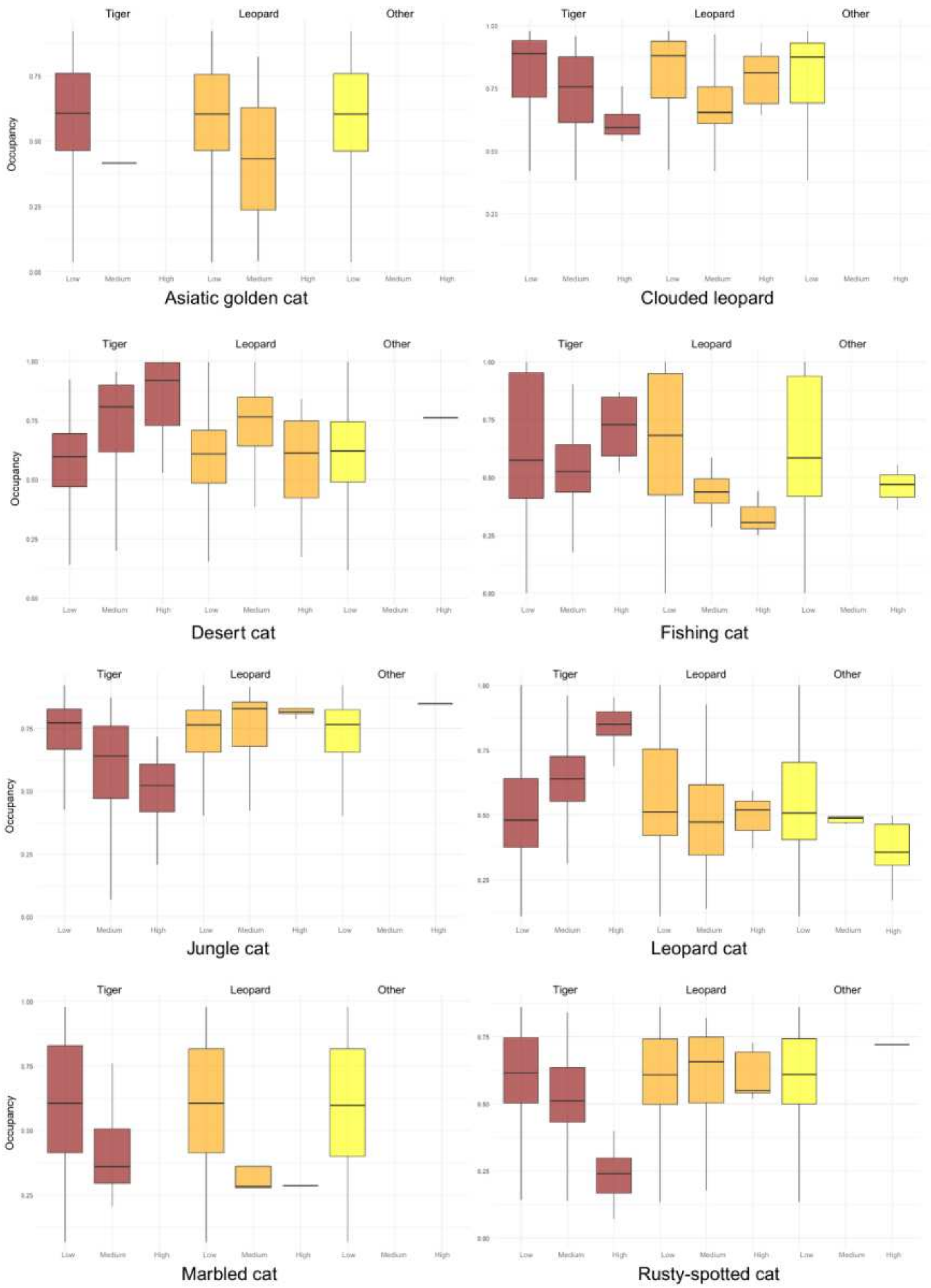

Figure 12.2. Response of small cat occupancy to densities of tiger and leopard, and encounter rates of other carnivores (jackal, wolf, dhole, sloth bear and hyaena) in the tiger-range forests of India.

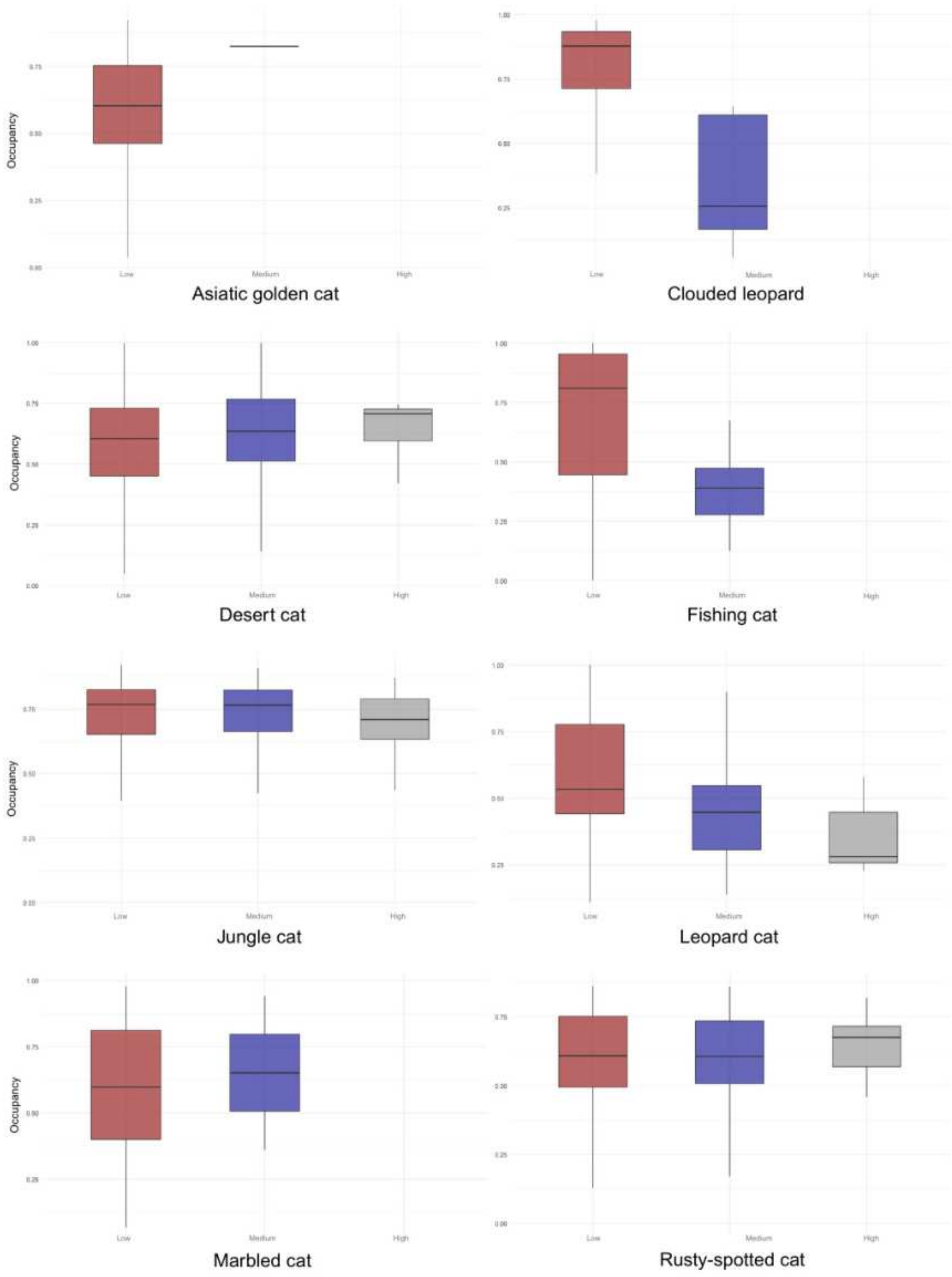

Figure 12.3. Response of small cat occupancy to human disturbance in the tiger-range landscapes of India.

Table 12.2. Occupancy dynamics of the small cat species in India's tiger-range forests, showing the proportion of areas with consistent presence, increases, decreases, and consistent absence between 2018 and 2022.

Species	Consistently present (%)	Increase (%)	Decrease (%)	Consistently absent (%)
Asiatic golden cat	14	6	4	75
Caracal*				
Clouded leopard*	11	14	9	65
Desert cat	33	11	8	48
Fishing cat	39	8	13	41
Jungle cat	46	14	12	29
Leopard cat	50	10	21	19
Marbled cat*	4	5	6	85
Rusty-spotted cat	25	13	21	42

*Occupancy dynamics of these species were not modelled

Fishing cat

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Rusty-spotted cat

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Desert cat

Appendix 1

Occupancy dynamics (consistent, increase, and decrease) in relation to forest types (Figure A1), tiger density (Figures A2a and A2b), and human disturbance (Figures A3a and A3b) classes to identify potential patterns across these ecological and anthropogenic gradients.

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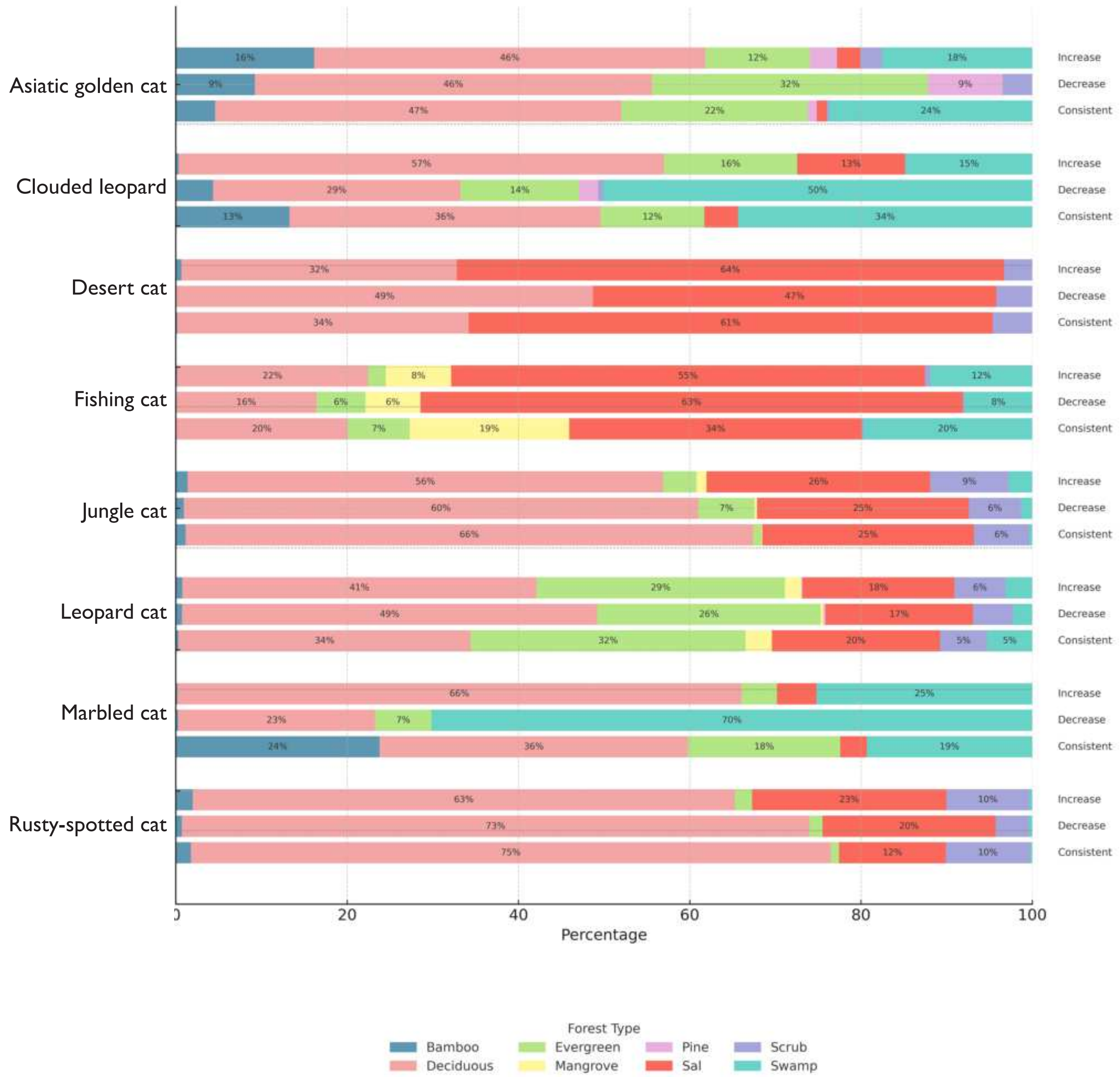


Figure A1. Proportion of forest types in consistent, increased and decreased occupancy sites for small cats in the tiger-range forests of India

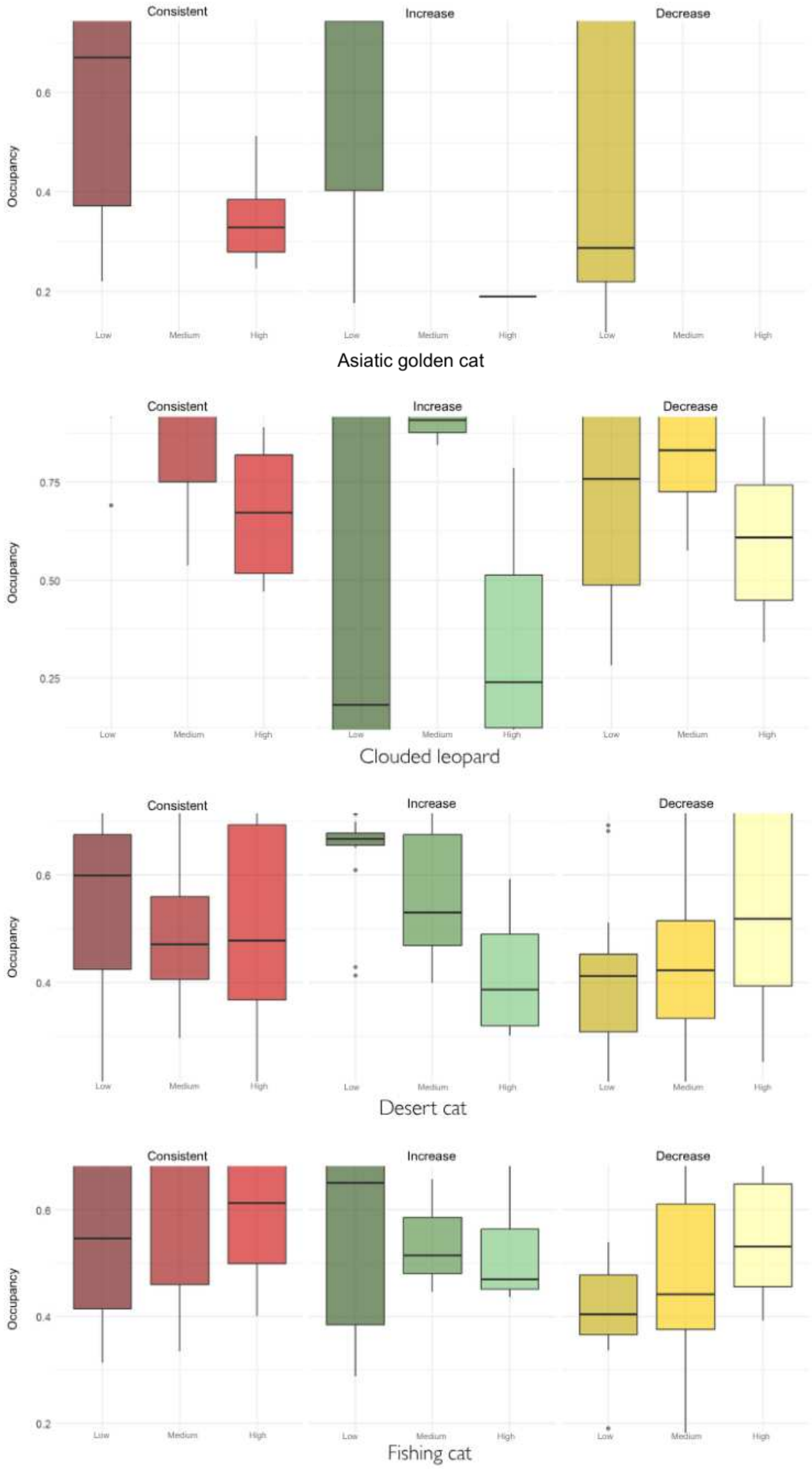


Figure A2a. Tiger density in consistent, increasing and decreasing occupancy of small cats in the tiger-range forests of India

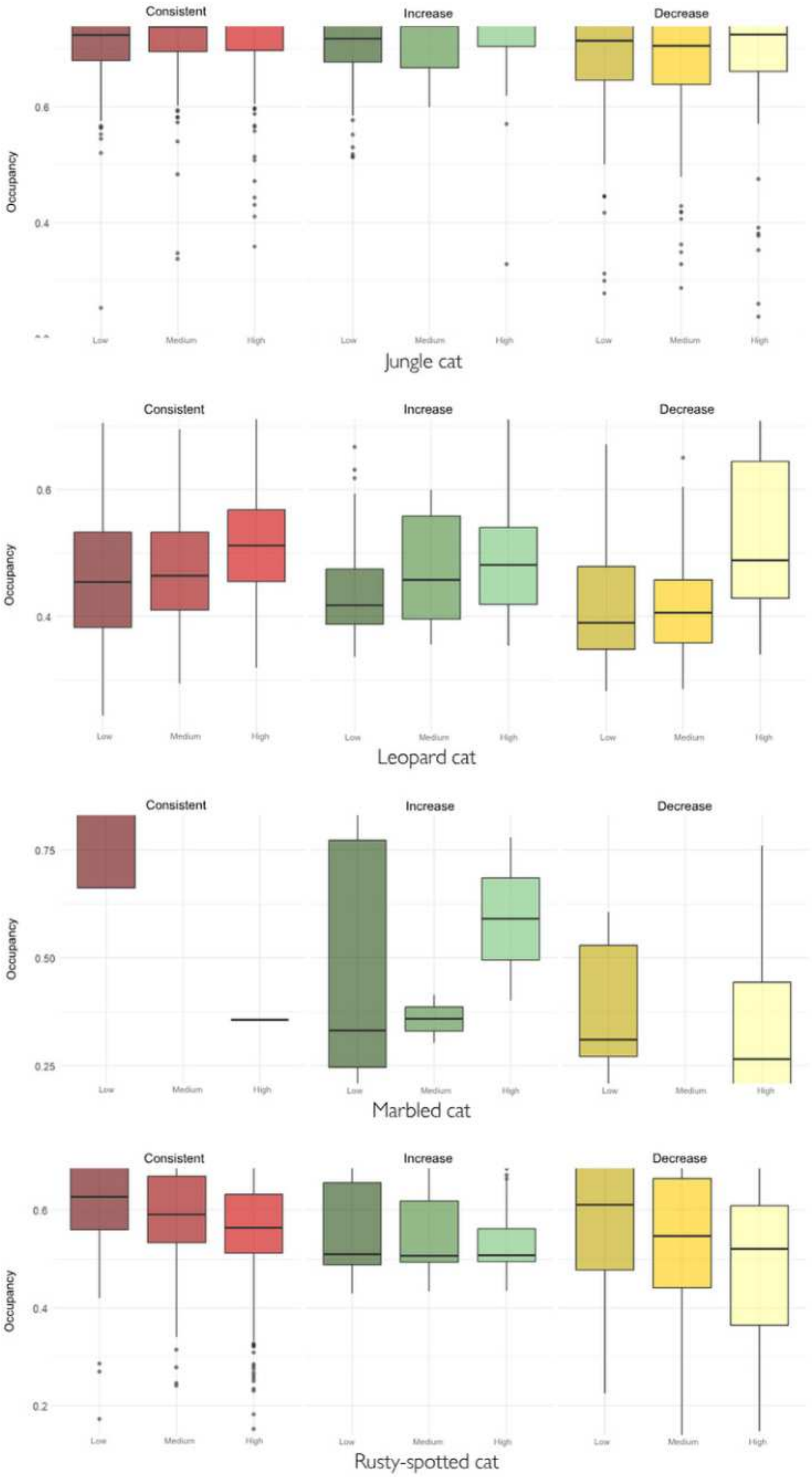


Figure A2b. Tiger density in consistent, increasing and decreasing occupancy of small cats in the tiger-range forests of India

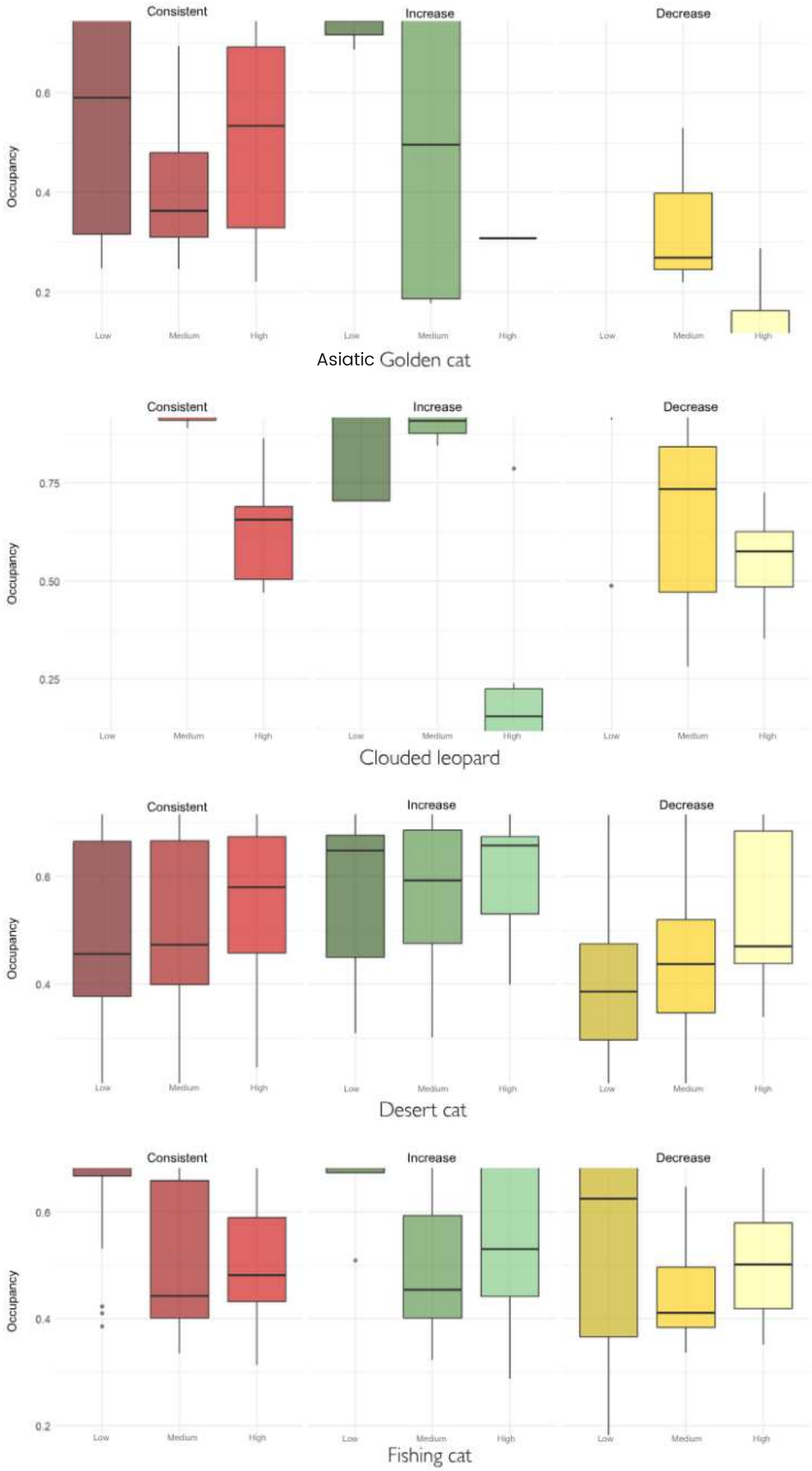


Figure A3a. Human disturbance in consistent, increasing and decreasing occupancy of small cats in the tiger-range forests of India

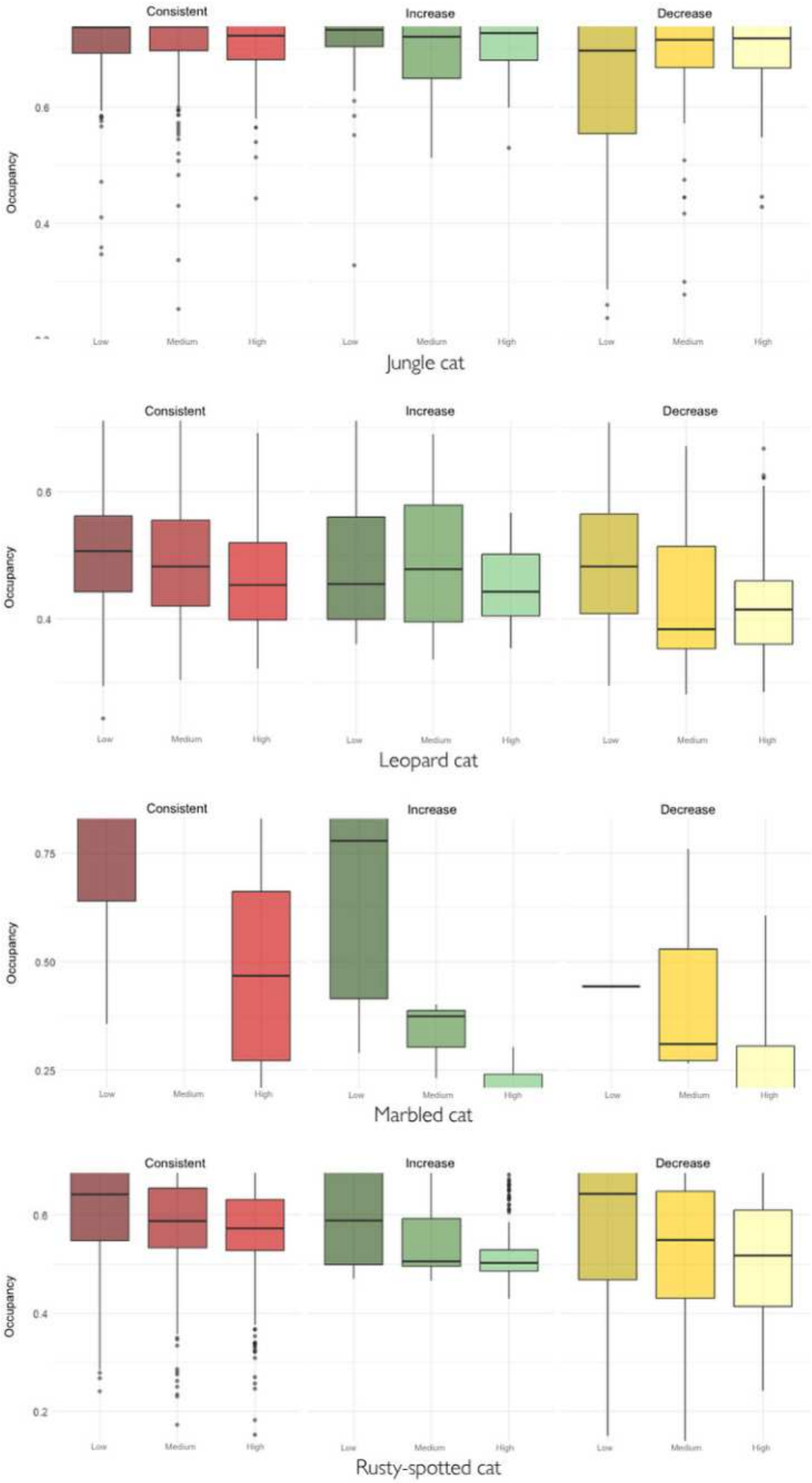
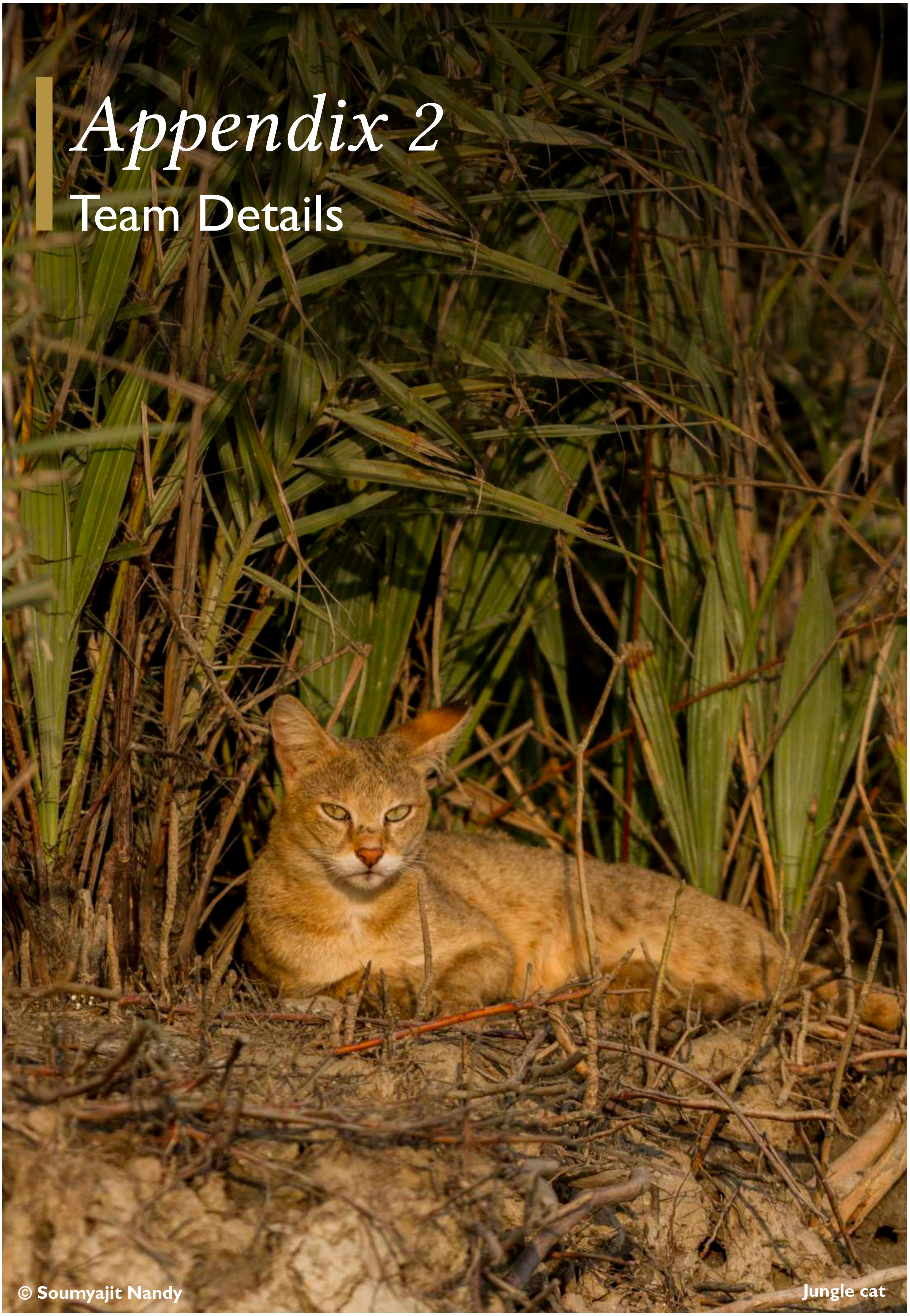


Figure A3b. Human disturbance in consistent, increasing and decreasing occupancy of small cats in the tiger-range forests of India

Appendix 2
Team Details



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Jungle cat

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