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Cover: Coromandal Sacred Langur *Semnopithecus priam* - made with acrylic paint. © P. Kritika.

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COMMUNICATION

Camera trap surveys reveal a wildlife haven: mammal communities in a tropical forest adjacent to a coal mining landscape in India

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Abstract: Having knowledge of the status and distribution of species in a specific geographic area is crucial for creating efficient conservation strategies. In this study, we evaluated the abundance and diversity of medium- to large-sized mammals in a tropical forest in India that has been adjacent to a coal mining landscape. Using camera traps between June and December 2018, we recorded 27 mammal species over 3,432 trap-nights in 81 camera trap stations in the study area. The photo-captured species included Tiger *Panthera tigris*, Leopard *P. pardus*, Sloth Bear *Melursus ursinus*, Asian Elephant *Elephas maximus*, Gaur *Bos gaurus*, Indian Pangolin *Manis crassicaudata*, and Four-horned Antelope *Tetracerus quadricornis*. Wild Boar *Sus scrofa* was found to be the most frequently photo-captured and widespread species. Our study provides data on the species inventory and the relative abundance of species in the area, highlighting its significance for mammal conservation. It emphasizes the need for effective management strategies to protect the remaining forest fragments around mining or highly operated areas having a high diversity of mammals.

Keywords: Occurrence, Odisha, *Panthera tigris*, population, relative abundance index, Sundargarh Forest Division, threatened species.

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Author contributions: NCP—developed the study concept, field data collection, and manuscript writing; BPR—conducted field survey, camera trapping and provided feedback to the final manuscript, HSP- Analysed the data and manuscript writing, AKM—developed the study concept, provided feedback to the final manuscript and supervised the project. All authors contributed to the article and approved the submitted version.

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INTRODUCTION

Mammals play a crucial role in the functioning of forest ecosystems. They interact with other biotic and abiotic components of the forest, influencing nutrient cycling, seed dispersal, and plant growth (Lacher et al. 2019). Mammals can also act as apex predators, regulating the populations and behavior of their prey, which can impact the structure and composition of the forest community (Ripple et al. 2014). Despite their vital role in forest ecosystems, they face a multitude of threats that can significantly impact their populations. Habitat destruction and fragmentation due to human activities such as deforestation, mining, and urbanization are some of the most significant threats to mammal communities in the world (Ripple et al. 2014, 2015; Nayak et al. 2020). Additionally, overhunting and poaching for their meat, hides, or other body parts are leading to a decline in mammal populations in most parts of the world (Brodie et al. 2009; Ripple et al. 2016; Rija et al. 2020). Therefore, it is essential to monitor the presence of mammal species in their habitat, as this is critical for the development of effective conservation management strategies (Nichols & Williams 2006).

Several important tools are available for monitoring mammal populations including camera trap, DNA analysis, radio telemetry, acoustic monitoring, satellite tracking, and transect surveys, which provide valuable data on their distribution, abundance, movement, and behavior (Buckland et al. 2023). However, camera traps are increasingly widely used tools for monitoring the mammal populations as they provide non-invasive and accurate data on their presence, behavior, and abundance (O'Connell et al. 2010; Forrester et al. 2016). In India, several camera trap studies have been conducted to assess mammal diversity in various ecosystems (Sathyakumar et al. 2011; Palei et al. 2016; Singh & Macdonald 2017; Lahkar et al. 2018; Rege et al. 2020; Ahmed et al. 2021; Chakraborty et al. 2021; Pal et al. 2021). Camera trap studies have the potential to explore not only species inventories and diversity of mammals but also to examine population size and density (Karanth 1995; Jhala et al. 2008; Singh & Macdonald 2017), demographic structure (Gardner et al. 2010; Harmsen et al. 2017), habitat utilization (Ramesh et al. 2012; Srivathsa et al. 2017), as well as spatio-temporal activity patterns (Ramesh et al. 2012; Palei et al. 2021).

As one of the mega-biodiverse countries, India is home to ~427 extant mammal species, representing about 8% of the world's mammal diversity (Srinivasulu 2018). However, large-scale modifications due to the growing human population and rapid economic growth have transformed the natural habitats into irregular mosaics among human-dominated spaces. The central Indian landscape with rich biodiversity, is currently facing significant habitat loss and fragmentation. This region has experienced rapid environmental changes due to the expansion of mining and agricultural activities since the 18th century (Soni 2020). The wildlife in these fragmented areas outside protected areas is relatively unexplored and yet important for conservation. Several studies have revealed that these remaining forest fragments contain high diversity of mammals, including threatened species (Rege et al. 2020; Ahmed et al. 2021; Chakraborty et al. 2021). Therefore, understanding the conservation status of mammal communities in these areas is crucial for conservation management strategies.

In this study, we used camera-trap surveys to study the presence of large- and medium-sized mammals on the northwestern periphery of Odisha State. We focused in a multiuse forest landscape of Sundargarh forest division with a strong presence of human and mining activities in the surrounding and inside forest. Our aim was to create a species inventory and evaluate the relative abundance of species to determine the potential significance of this area for conservation purposes.

MATERIAL AND METHODS

Study area

The study area covers an area of 450 km^2 and is located between 21.7752–22.0603 ^{0}N & 83.5445–83.8490 ^{0}E (Figure 1). It is situated in the southern part of the Sundargarh Forest Division of Odisha State, India, and includes reserved forests (RF) and protected forests (PF), such as Dhanubaunsha RF, Garjanpahar RF, Chhengapahar RF, Garjanjor RF, Rohini RF, Barghumra RF, Kanthidungri PF, and Kharudaldali PF. The western part of the study area is connected to Chhattisgarh State. The vegetation of the area is represented by tropical dry deciduous, northern tropical dry deciduous and northern dry mixed deciduous forest (Champion & Seth 1968). The mean minimum and maximum temperature varies 6–20 °C in January and 35–45 °C in May. The mean annual rainfall is 1,100–1,500 mm during the monsoon between June and September. Most villagers residing in the forest fringes are tribal, and their activities inside the forest are grazing livestock and collection of forest products (e.g., fodder for livestock, non-timber forest produce, and fuel wood). The major land-use that have been recorded in this area are forests, agriculture, habitations,

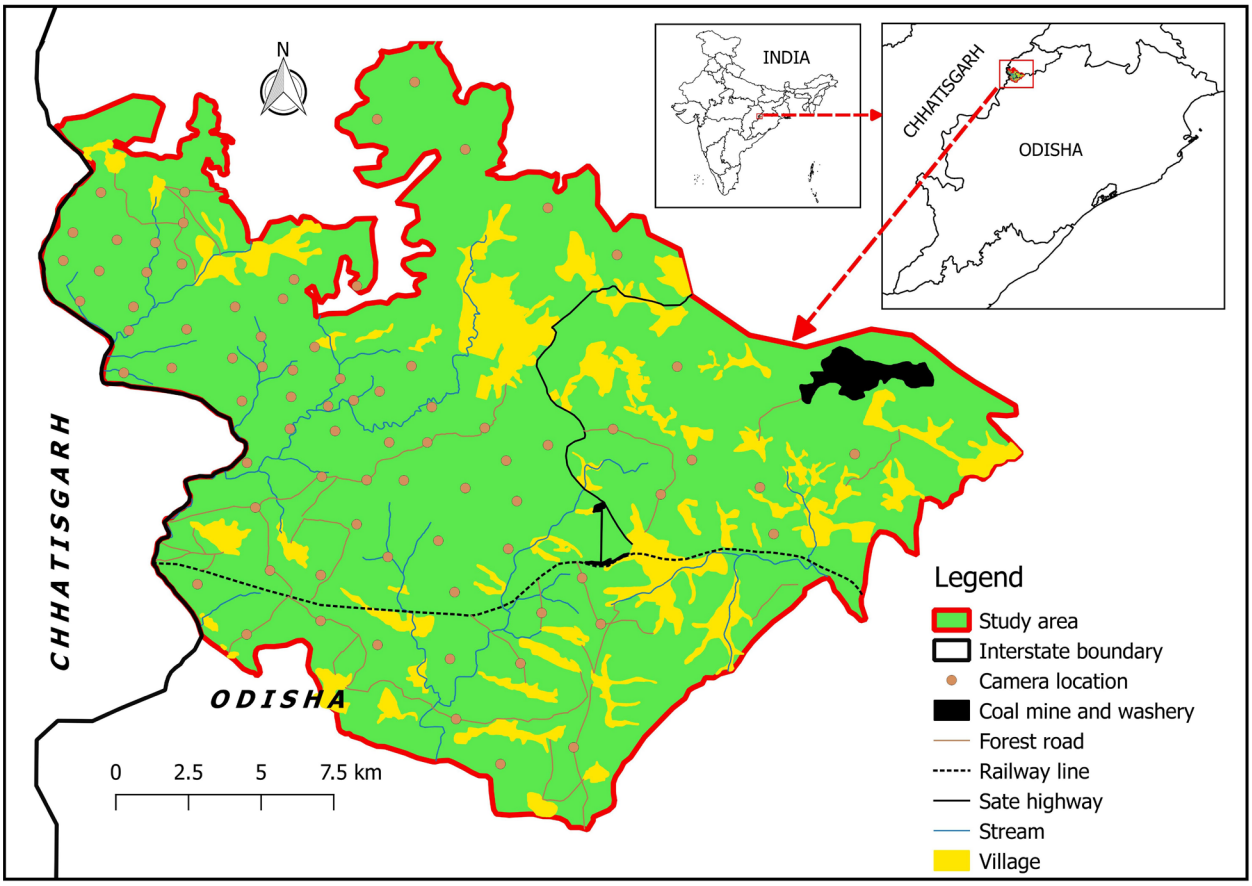

Figure 1. Study area and location of camera traps in the Sundargarh Forest Division, Odisha State, India.

waterbodies, road and railway lines, and open coal mining area.

Camera trapping

We surveyed mammals using camera traps during June–December 2018, at 81 camera trap stations in the study area. At each station, we collected data on geographical coordinates and altitude using a GPS. Camera-trap stations consisted of one camera trap, strategically positioned along trails, roads, or river banks in order to optimize the chances of capturing large- and medium-sized mammals, which have a tendency to move along linear features (Rasphone et al. 2019; Ouboter et al. 2021; Palei et al. 2021; Widodo et al. 2022). The mean distance between neighboring cameras was 1.64 ± SD 0.85 km, with placement carefully planned to ensure maximal geographical coverage. We used automated motion-triggered digital camera-traps (Cuddeback Model C1; Non-Typical, Inc., Green Bay, WI), mounted approximately 30–40 cm above the ground. The cameras were programmed to take high sensitivity photographs, with a 2 s interval between consecutive images. We checked camera traps every 15 days to replace batteries and to clear understory growth, reducing the risk of false triggers and vegetation obstructing the photographs. We aimed to leave camera traps in the forest for the 45 days, but due to work schedule conflicts, cameras were often picked up earlier or later in some locations.

Data analysis

Each photograph was manually checked to identify the species. Date, time and temperature were noted for each identified species. To avoid pseudo replication, animal detections were treated as separate events if they occurred more than 30 min after the previous photographs, unless individuals were distinguishable by unique pelage patterns, colors, or different sex/age categories (O'Brien et al. 2003). Multiple individuals of the same species in one photograph were counted as a single observation. For each species, we calculated the relative abundance index (RAI) by dividing the number of independent events by the number of trap-nights and then multiplying by 100 (O'Brien et al. 2003). We determined the naïve occupancy for each species by

Image 1. Camera trap images of threatened mammals recorded in the study area of Sundargarh Forest Division, Odisha, India: a—Tiger *Panthera tigris* | b—Leopard *Panthera pardus* | c—Sloth Bear *Melursus ursinus* | d—Asian Elephant *Elephas maximus* | e—Gaur *Bos gaurus* | f—Four-horned Antelope *Tetracerus quadricornis* | g—Indian Pangolin *Manis crassicaudata*.

dividing the total number of sites where the species was trapped by the overall number of sites. To evaluate the sampling effort, a species accumulation curve was plotted using Vegan package in R 4.2.2 (Gotelli & Colwell 2001).

RESULTS

The total number of camera trap nights was 3,432 with a mean of 42 trap nights (SD ± 16.61) per camera trap station. Site-specific species accumulation curves appeared to be asymptotic, suggesting that sampling effort was sufficient (Figure 2). We recorded 27 species of mammals belonging to 17 families in eight orders (Table 1). Carnivora was the most diverse order with 14 species, followed by Artiodactyla with five, Rodentia with two, Primates with two, and all other orders with a single species each. Of the 27 species recorded, eight are threatened (four 'Endangered', four 'Vulnerable'), two are 'Near Threatened' and 17 are 'Least Concern' on the IUCN Red List (IUCN 2023).

The most abundant mammal in the study area was Wild Boar *Sus scrofa* (RAI = 7.34), followed by Indian Hare *Lepus nigricollis* (6.63), Four-horned Antelope *Tetracerus quadricornis* (4.14), Rhesus Macaque *Macaca mulatta* (3.67), Jungle Cat *Felis chaus* (3.36), and Bengal Sacred Langur *Semnopithecus entellus* (3.26) (Table 1, Figure 3). We observed large variations in naïve occupancy estimates for mammals in the study area (0.01–0.75). The highest naïve occupancy estimates were for Wild Boar (0.75), followed by Bengal Sacred Langur (0.59), Jungle Cat (0.47), Rhesus Macaque (0.45),

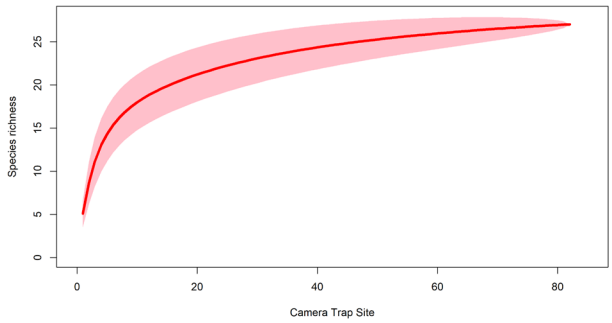

Figure 2. Randomized species accumulation curve based on the number of camera traps in the study area. Shaded area indicates the 95% CI.

Four-horned Antelope (0.43), and Leopard (0.40) (Table 1, Figure 4). Throughout the study area, four threatened species were regularly captured: the Asian Elephant (n = 50, in 19 locations), Four-horned Antelope (n = 142, in 29 locations), Sloth Bear (n = 61, in 32 locations), and Leopard (n = 61, in 33 locations) (Table 1).

DISCUSSION

Our study confirms that the study area is home to a diverse population of terrestrial mammals, including many important and threatened species such as Tiger,

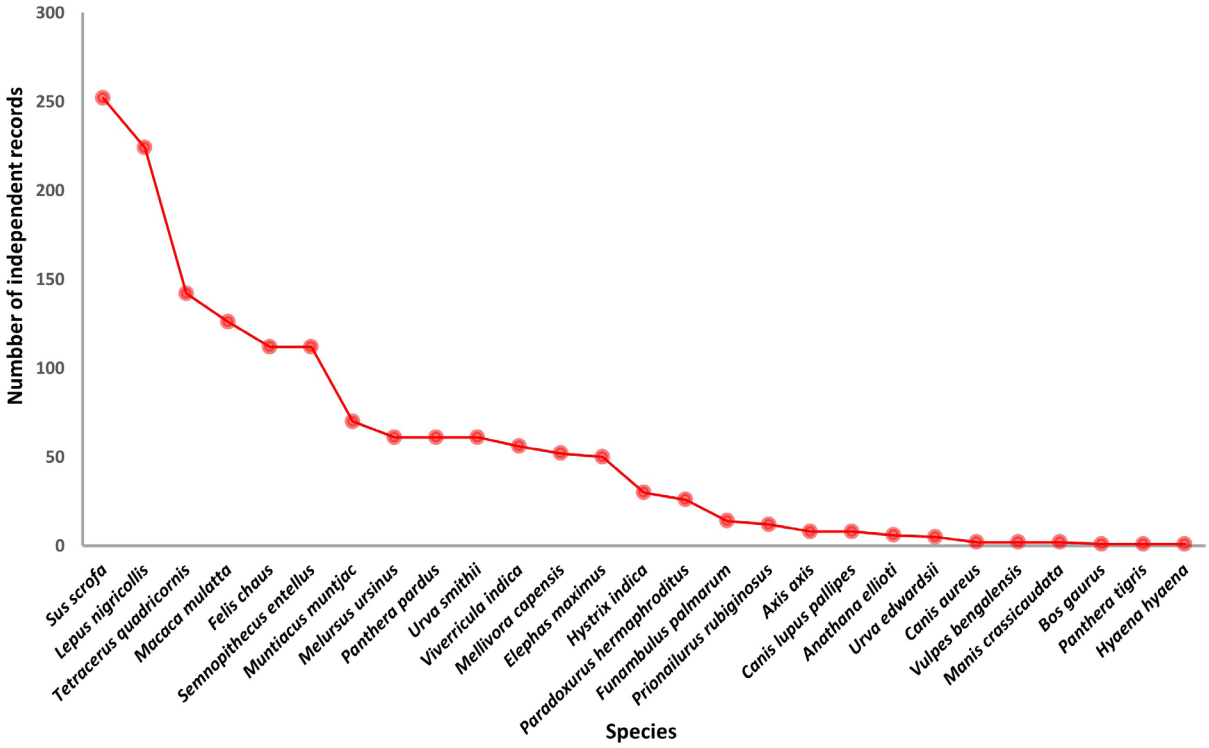

Figure 3. Capture frequency of mammals in the study area of Sundargarh Forest Division, Odisha, India.

Table 1. Relative Abundance Index (RAI) of Wildlife species and others captured photos.

	Species name	Scientific name	Food habit	IUCN Red List status	CT stations	Independent record	RAI	Naïve occupancy
	A. ORDER: ARTIODACTYLA							
	Family: Cervidae							
1	Barking Deer	*Muntiacus muntjac*	H	LC	21	70	2.04	0.25
2	Spotted Deer	*Axis axis*	H	LC	3	8	0.23	0.03
	Family: Suidae							
3	Wild Boar	*Sus scrofa*	H	LC	61	252	7.34	0.75
	Family: Bovidae							
4	Four-horned Antelope	*Tetracerus quadricornis*	H	VU	35	142	4.14	0.43
5	Gaur	*Bos gaurus*	H	VU	1	1	0.03	0.01
	B. ORDER: PROBOSCIDEA							
	Family: Elephantidae							
6	Asian Elephant	*Elephas maximus*	H	EN	19	50	1.46	0.23
	C. ORDER: CARNIVORA							
	Family: Ursidae							
7	Sloth Bear	*Melursus ursinus*	O	VU	32	61	1.77	0.39
	Family: Felidae							
8	Tiger	*Panthera tigris*	C	EN	1	1	0.03	0.01
9	Leopard	*Panthera pardus*	C	VU	33	61	1.78	0.40
10	Rusty-spotted Cat	*Prionailurus rubiginosus*	C	NT	3	12	0.35	0.03
11	Jungle Cat	*Felis chaus*	C	LC	38	112	3.36	0.47
	Family: Canidae							
12	Indian Wolf	*Canis lupus pallipes*	C	LC	6	8	0.23	0.07
13	Golden Jackal	*Canis aureus*	C	LC	1	2	0.06	0.01
14	Bengal Fox	*Vulpes bengalensis*	C	LC	1	2	0.06	0.01
	Family: Hyaenidae							
15	Striped Hyena	*Hyaena hyaena*	C	NT	1	1	0.03	0.01
	Family: Mustelidae							
16	Ratel	*Mellivora capensis*	C	LC	27	52	1.51	0.33
	Family: Viverridae							
17	Small Indian Civet	*Viverricula indica*	C	LC	30	56	1.63	0.37
18	Common Palm Civet	*Paradoxurus hermaphroditus*	O	LC	16	26	0.76	0.19
	Family: Herpestidae							
19	Ruddy Mongoose	*Urva smithii*	C	LC	6	61	1.78	0.07
20	Indian Grey Mongoose	*Urva edwardsii*	C	LC	4	5	0.15	0.05
	D. ORDER: PRIMATES							
	Family: Cercopithecidae							
21	Rhesus Macaque	*Macaca mulatta*	H	LC	37	126	3.67	0.45
22	Bengal Sacred Langur	*Semnopithecus entellus*	H	LC	48	112	3.26	0.59
	E. ORDER: PHOLIDOTA							
	Family: Manidae							
23	Indian Pangolin	*Manis crassicaudata*	I	EN	2	2	0.06	0.02
	F. ORDER: LAGOMORPHA							
	Family: Leporidae							
24	Indian Hare	*Lepus nigricollis*	H	LC	42	224	6.53	0.51

	Species name	Scientific name	Food habit	IUCN Red List status	CT stations	Independent record	RAI	Naïve occupancy
	G. ORDER: RODENTIA							
	Family: Hystricidae							
25	Indian Crested Porcupine	*Hystrix indica*	H	LC	20	30	0.87	0.24
	Family: Sciuridae							
26	Indian Palm Squirrel	*Funambulus palmarum*	H	LC	5	14	0.41	0.06
	H. ORDER: SCANDENTIA							
	Family: Tupaiidae							
27	Madras Treeshrew	*Anathana ellioti*	H	LC	4	6	0.17	0.05

RAI—Relative Abundance Index | CT—Camera Trap | EN—Endangered | VU—Vulnerable | NT—Near Threatened | LC—Least Concern | C—Carnivore | H—Herbivore | I—Insectivore | O—Omnivore.

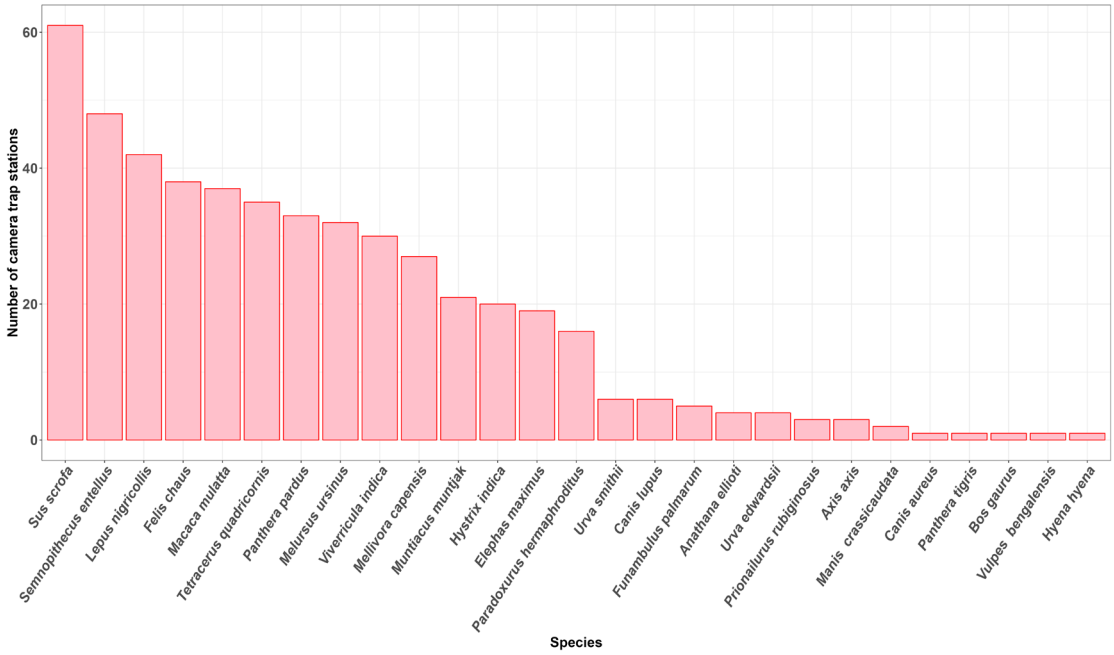

Figure 4. Mammal species recorded in camera stations in Sundargarh Forest Division, Odisha, India.

Leopard, Sloth Bear, Asian Elephant, Gaur, and Indian Pangolin. Our study area exhibits a high diversity of terrestrial mammals, which becomes evident when compared to camera trap studies conducted in other parts of India, e.g., 24 mammals over 6,413 trap-nights in 187 camera trap stations in Similipal Tiger Reserve, Odisha (Palei et al. 2016), 20 mammals over 916 trap-nights in 65 camera trap stations in Kuldiha Wildlife Sanctuary, Odisha (Debata & Swain 2018), 24 mammals in 52 camera traps over 660 trap-nights in the Bandhavgarh-Sanjay Corridor (Vaishnav et al. 2021), and 27 mammals in 123 camera trap locations over 3,250 trap-nights in Debrigarh Wildlife Sanctuary, Odisha (Palei et al. 2023).

While photographic capture rates can be a helpful indicator of relative abundance (Carbone et al. 2001), it may not be directly comparable between different species due to differences in detectability (Jennelle et al. 2002). As a result, we refrained from comparing relative abundance across species. However, despite its limitations, photographic rates can still yield valuable insights into comparing the relative abundance of specific species across various locations and identifying general patterns of species richness.

A major finding of our study is the detection of Tiger, Leopard, and Four-horned Antelope in the study area, as former one is classified as 'Endangered' and latter two as 'Vulnerable' by the IUCN Red List of Threatened

Species. In this region, information on the distribution of the Tiger is limited (Debata & Palei 2020). The presence of tigers in our study area is a positive indication of the forest's ecological richness and the region's potential for tiger conservation. The study area is connected to central Indian tiger landscape, which is home to a substantial population of tigers (Jhala et al. 2008). This connectivity provides opportunities for the long-term survival prospects of tigers in the region. Although leopards are widely distributed throughout the state, their vulnerability to poaching is a real concern across the state and the country (Mondol et al. 2015). In Odisha, the Four-horned Antelope is considered rare and was only reported 20 years ago from the Similipal Tiger Reserve (Singh & Swain 2003). The presence of these threatened species in this human dominated landscape emphasizes the need for regular monitoring of them and their habitat.

Our study shows widespread presence of Sloth Bears and Asian Elephants, which may result in an escalation of human-wildlife interactions. Sloth Bears are known for raiding crops and can become aggressive towards humans if they perceive a threat (Debata et al. 2017; Delgado et al. 2020), while Asian Elephants can cause significant damage to crops and property, and can also pose a serious threat to human life (Palei et al. 2017, 2019). Therefore, it is crucial to develop effective management strategies to mitigate human-wildlife negative interactions for the region.

Within the study area, a coal mine is present along with transportation networks that bisect the forest, including railways and roads. Additionally, there are proposed coal mine projects or expansions that have the potential to further degrade the forest (CIRTD & CPR 2020). Large mammals, such as Asian Elephants, Tigers, and Gaurs, are particularly vulnerable to these disturbances as they require large areas and are easily disrupted by human activities (Ripple et al. 2014, 2015). There have already been negative consequences, as evidenced by a female elephant being killed in a train accident within the study area in 2017. Therefore, regular evaluation of the mammal community in light of surrounding development activities would help to assess the effectiveness of measures taken to increase protection and restore habitats.

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