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RESEARCH ARTICLE

Estimating Mammalian Abundance Using Camera Traps in the Tropical Forest of Similipal Tiger Reserve, Odisha, India

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Abstract Knowledge on the occurrence and distribution of species is crucial for designing and evaluating conservation strategies within a geographical region. Similipal Tiger Reserve though confined to a small area needs information on the diversity and abundance of mammalian fauna to ensure conservation of tiger. Thus, we aimed to assess the diversity and abundance of medium to large sized mammals in Similipal Tiger Reserve by using remotely triggered camera traps. A total of 6413 camera trap days at 187 trap stations were deployed from November 2012 to July 2013 to estimate the status of mammal. We obtained 3763 independent photographs and detected 24 species of mammals. The relative abundance index of each mammalian species was calculated. Leopard (*Panthera pardus*) was the most abundant carnivore while barking deer (*Muntiacus muntjac*) was the most abundant prey. Anthropogenic activities like hunting, livestock grazing and free ranging domestic dogs were found to be the detrimental factors for the existing mammalian species. These activities should be addressed through conservation and development perception with an interdisciplinary approach, incorporating social and ecological components cautiously.

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Introduction

In the tropical forest communities terrestrial mammals act as key components as they are potential indicator of ecosystem health and provide important ecosystem services (Ahumada et al. 2011). Owing to the vulnerability of multiple human-driven threats and importance in forest system dynamics (Karanth et al. 2010); the medium and large sized terrestrial mammals are the focus of most of the biodiversity monitoring programs in the tropical forests of India (Karanth et al. 2009). However, their monitoring is difficult due to their elusive behavior and low abundances in the large and remote forest areas (Datta et al. 2008). Camera traps are recognized as an important tool for monitoring nocturnal and cryptic species. Furthermore, camera traps are also extensively used for population estimation of natural marked animals by means of well consolidated capture–recaptures models (Karanth 1995; Karanth and Nichols 1998). However, the most reliable abundance estimation method capture–recapture is difficult to achieve at larger spatial scales (Mackenzie et al. 2002; Pollock et al. 2002), and it is only possible to identify individual natural marked animals. Therefore, for the majority of tropical animals, including ungulates, bears and other small mammals, it is difficult to individually identify the animals. In this scenario, trapping rates (photographs/trapping effort)—another approach has been widely used in other studies (Carbone et al. 2001; Trolle and M. Kéry. 2005) to estimate abundance. A significant correlation between trapping rates and independent density estimations in a number of species supported its use as an index of relative abundance (Carbone et al. 2001; O'Brien et al. 2003). The use of relative abundance index (RAI) based on camera trap encounter rates for ecological studies is controversial particularly when comparing between species as a large number of variables (e.g. body size, average group size, behavior) are likely to affect trapping rates and detection probability, and thus, confound the relationship with actual abundance (Jennelle et al. 2002; Treves et al. 2010). However, there is increasing evidence for a linear relationship between RAI and abundance estimated through more rigorous methodologies (Rovero and Marshall 2008). Therefore, taking into account the caveats above, we estimated medium to large sized mammalian species abundances through RAI among fixed camera locations within our study area.

In this paper, we examined the occurrence and abundance of medium to large sized mammals and anthropogenic disturbances in Similipal Tiger Reserve (STR), which is one of the first nine Tiger Reserves declared in India in 1973. Populations of wild mammals sharing resources and habitat with livestock and human in this tropical forest of Similipal provide an opportunity to evaluate the mammal abundances and their interaction with livestock and other anthropogenic factors. Such data, if obtained using camera traps, can help formulate management strategies to protect wild animals and reduce conflict with human.

Study Area

The study was conducted in STR, Odisha, India (Fig. 1) covering an area of 2750 km^2, with a core area of 1194.75 km^2. The area lies within 20°17′–22°34′N latitude and 85°40′–87°10′E longitude. Terrain of the area is undulating and hilly with altitude ranging between 300 and 1200 m above MSL. Wikramanayake et al. (1998) classified the reserve as a Tropical moist deciduous forest. Being in a tropical zone, the climatic condition of the area experiences the three distinct seasons: monsoon (July–September), winter (October–February) and summer (March–June). The area receives an average annual rainfall of 1850 mm and the temperature ranged from 3 °C in winter to 38 °C in summer. Perennial rivers like the Budhabalanga, Palapala, West Deo, East Deo, Salandi, Bhandan, Khadkei, Khairi have originated from the reserve and act as the major source of water.

Like other tiger habitats of India, STR is not free from human interference as three villages are there inside core area followed by 57 villages in the buffer area of the reserve. Out of the total population of 12,000 (2001Census) in these villages tribal are predominated by 95 % whose livelihood are purely dependent upon utilization of forest resources for agriculture, livestock rearing and grazing, and collection of minor forest products.

Materials and Methods

Between November 2012 and July 2013, we deployed camera traps covering the 16 forest ranges of the study area to ascertain the status of the animals. We divided the study area into 2 km^2 grids and randomly selected grids for camera locations. Within the grid, cameras were predominantly set along park roads; at off-road locations and installed along game trails and footpaths. Each station consisted of one camera trap (Moultry D55, GameSpy Digital Camera, Alabaster, USA) and set to operate 24 h per day with programmed to delay sequential photographs by 30 s recording time, date and temperature for each exposure. Camera traps were strapped to trees or stakes approximately 50 cm above ground and 1–2 m from the monitoring area. The censor was parallel to the ground to monitor a colonial area approximately 1 m in diameter at 10 m distance. Cameras were checked at 10–14 day intervals for battery replacement and photo download. 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.

Number of trap nights was calculated for each camera location from the time the camera was mounted until the camera was retrieved. After the cameras were retrieved, all photos were downloaded for further study. We identified each photo of an animal to species, recorded the time and date, and rated each photos as a dependent or independent event. Animal detections were considered independent if the time between consecutive photographs of the same species was more than 0.5 h apart, a convention which follows O'Brien et al. (2003). Because our study was not focused on identifying individuals from photos, so the arbitrary time between independent photos should not introduce bias. Photos with more than one individual of similar species in the frame were counted as one detection for the species.

Camera traps also recorded human traffic (forest staffs, villagers, and poachers), domestic dogs and livestock. Poachers were identified if they were carrying any weapons and animal body parts or ambiguous people visited forest at mid or late night.

The RAI was calculated for all camera trapped mammal species and others based on following formula (O'Brien et al. 2003):

$$\mathrm{RAI} = \frac{\mathrm{A}}{\mathrm{N}} \times 100$$

In which 'A' represents the total number of captures of a species by all cameras, and 'N' equals to the total camera traps days during the study period.

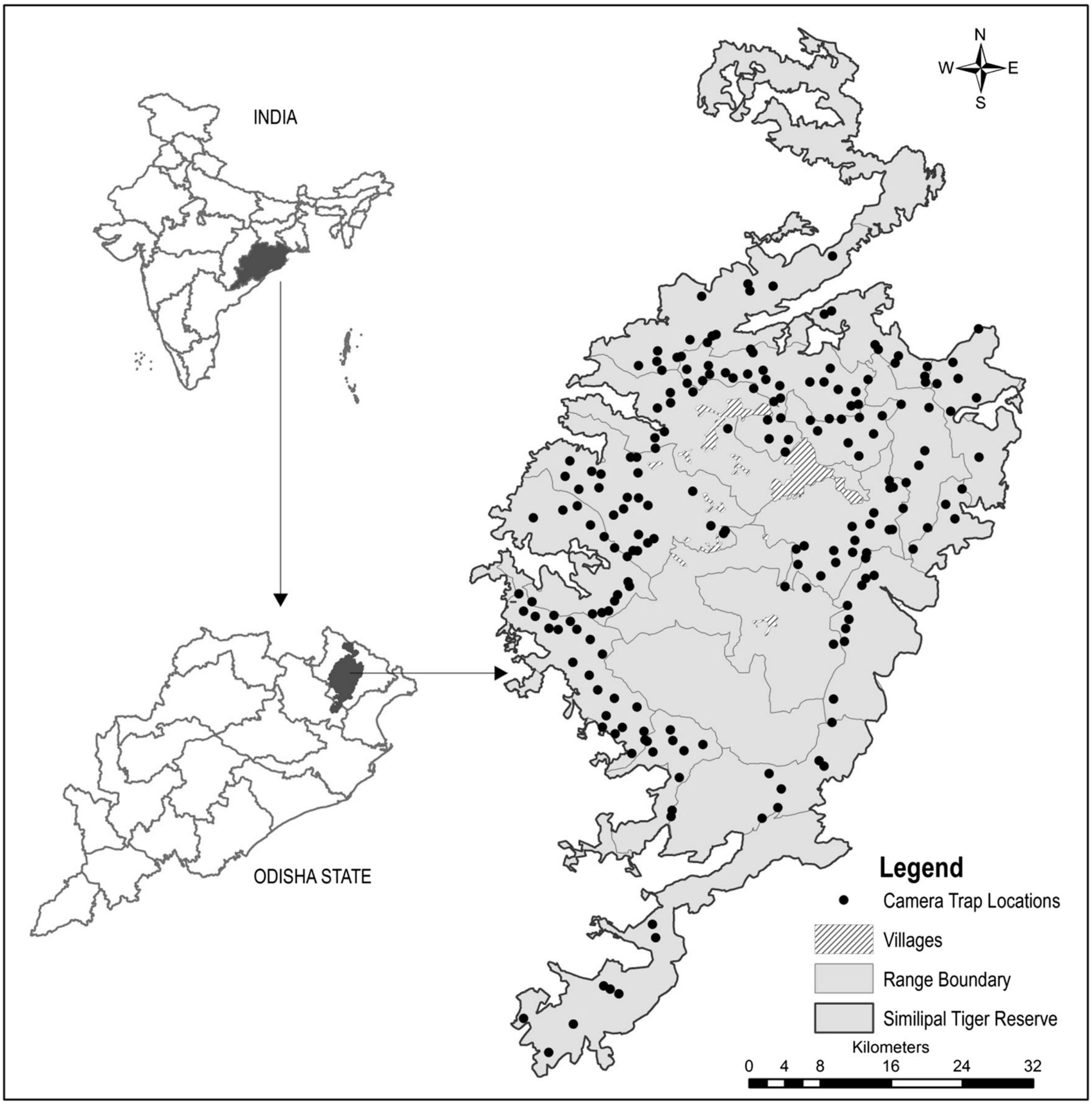

Fig. 1 Study area map and camera trap locations in Similipal Tiger Reserve

Results

We conducted camera surveys at 187 locations (Fig. 1), resulting in 6413 trap days (Mean: 34.48 ± 10.55 SD, range: 9–51). Camera traps at an additional 24 locations did not yield data because they malfunctioned or were stolen, or damaged by poachers and elephants. Among the photographs, we identified 24 mammal species (domestic mammal excluded) and seven bird species. We classified 3763 frames as independent photographs, of which 6.32 % (n = 238) were carnivores, 39.41 % (n = 1483) were non-carnivore mammals, 1.46 % (n = 55) were of birds, 25.4 % (n = 955) were villagers, 1.14 % (n = 43) were poachers, 16.2 % (n = 611) were staffs, and 8.03 % (n = 302) were domestic animal. Among these domestic animal 44.37 % (n = 134) were domestic dogs. We could not determine species in 0.35 % (n = 13) of the photographs due to poor focus, lighting, or angle. The relative abundance of animal is summarized in Table 1. The detailed relative abundances of mammal, domestic animal and villagers of each forest range are given in Table 2. Among the mammal, two species were endangered, three were vulnerable and three were near threatened species as classified by the 2013 IUCN Red List of threatened species (IUCN 2013).

Based on RAI value, barking deer *Muntiacus muntjac* was the most abundant species (RAI = 6.5) followed by the wild boar *Sus scrofa* (RAI = 4.52) and hanuman langur *Semnopithecus entellus* (RAI = 3.6) and the lowest abundance was tiger *Panthera tigris,* striped hyena *Hyaena hyaena*, Indian pangolin *Manis crassicaudata* and otter

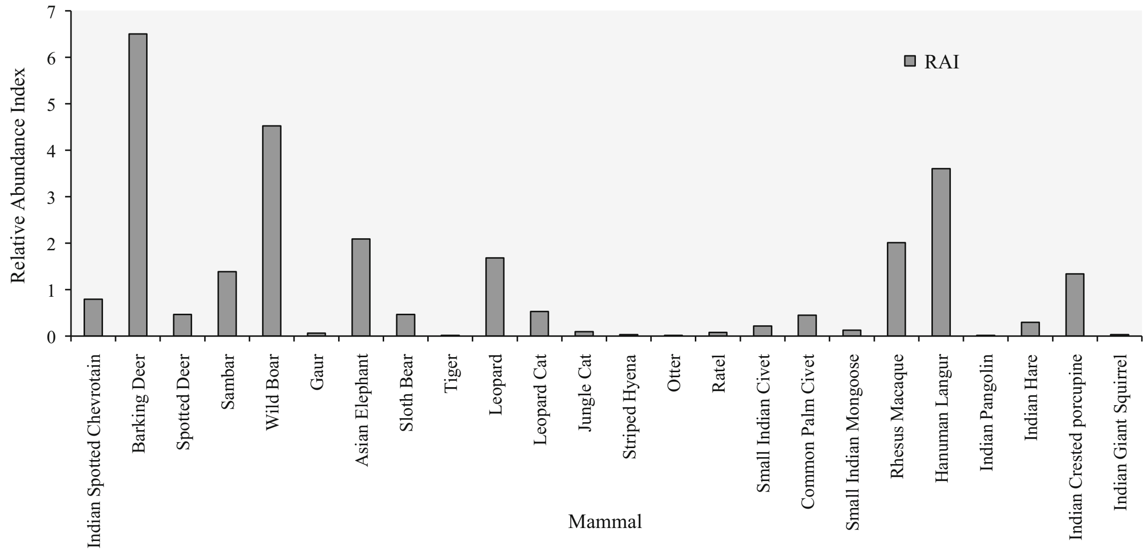

Fig. 2 Relative abundance index of mammals in Similipal Tiger Reserve

(RAI = 0.3) (Fig. 2).The carnivore community was represented by 11 species in the tiger reserve, including four felids, two viverrids, two mustelids, one ursid, one hyaenid and one herpestid (Table 1). Among the globally threatened species, Asian elephant *Elephas maximus* was the most abundant species (RAI = 2.09) followed by the leopard *Panthera pardus* (RAI = 1.68) and sambar *Rusa unicolor* (RAI = 1.39).

The relative abundances of anthropogenic activity photos were villagers (RAI = 14.9), poachers (RAI = 0.67), livestock (RAI = 2.62) and dogs (RAI = 2.09).

Discussion

(Annon. 2012) has been reported the occurrence of 34 species of medium to large sized mammals in STR. A comparison with 24 species of medium to large sized mammals recorded in present study and previous study suggests that the completeness of our species recorded was 70.59 %. Our camera trap effort was found to be sufficient as the occurrence of mammalian species appear to stabilize after examining 4000 camera trap nights (Fig. 3). Species like wild dog *Cuon alpinus* and four-horned antelope *Tetracerus quadricornis* which were reported previously were not recorded during our survey. These species may have become locally rare as a result of hunting or human induced disturbances. The lack of records of species like Indian gray wolf *Canis lupus pallipes*, golden jackal *Canis aureus* and Indian fox *Vulpes bengalensis* presents a relatively low local abundance in STR. These canids prefer open or degraded forests and agricultural areas (Vanak and Gompper 2010) and had been reported near human habitation of STR (Annon 2012). The tiger was recorded only once in the study area. The trap stations were in relatively disturbed area of the reserve and it must be considered before trying to extrapolate from our results to other parts of the reserve. With the common presence of leopard, prey species diversity (Primates-2, Ungulates-6) and relative abundance of some ungulate species (Table 1) in this tropical forest may be adequate to harbor large carnivores such as tiger and wild dog, which is the common features of the mammalian fauna of the same tropical forest at different protected areas (Ramesh et al. 2012; Majumder et al. 2013). The camera traps were deployed to gather information on terrestrial mammals and was not species specific. As a result, the camera traps were installed at a height of 50 cm above ground. There are possibilities of missing out mammalian species like otters and other arboreal species like Indian giant squirrel *Ratufa indica*. The detection probability of otter and Indian giant squirrel might be different and hence there may be a difference between estimated abundance and actual abundance. The authors cannot rule out the ambiguity in identifying of the otter species due to poor quality of camera-trap image. Though from the image it appeared to be Asian small-clawed otter *Aonyx cinereous*, which is recently reported from STR (Mohapatra et al. 2014); but Smooth-coated otter *Lutra perspicillata* also known to occur sympatrically (Annon 2012). Hence, the authors have mentioned it as otter to avoid confusion.

Our camera trap data provided the high level of anthropogenic activities inside the tiger reserve (Fig. 4). Anthropogenic activities usually have direct (e.g. through hunting) and indirect (e.g. through domestic animals)

Table 1 Relative abundance index (RAI) of wildlife species and others based on captured photos

Wildlife	Scientific name	Food habit	IUCN status 2013	CT stations	% occurrence in CT stations	Total photos	RAI
Mammals							
Family: Tragulidae							
Indian spotted chevrotain	*Moschiola indica*	H	LC	23	12.3	51	0.8
Family: Cervidae							
Barking deer	*Muntiacus muntjac*	H	LC	101	54	417	6.5
Spotted deer	*Axis axis*	H	LC	13	6.95	30	0.47
Sambar	*Rusa unicolor*	H	VU	30	16	89	1.39
Family: Suidae							
Wild boar	*Sus scrofa*	H	LC	99	52.9	290	4.52
Family: Bovidae							
Gaur	*Bos gaurus*	H	VU	3	1.6	4	0.06
Family: Elephantidae							
Asian elephant	*Elephas maximus*	H	EN	70	37.4	134	2.09
Family: Ursidae							
Sloth bear	*Melursus ursinus*	O	VU	22	11.8	30	0.47
Family: Felidae							
Tiger	*Panthera tigris*	C	EN	1	0.53	1	0.02
Leopard	*Panthera pardus*	C	NT	56	29.9	108	1.68
Leopard cat	*Prionailurus bengalensis*	C		19	2.67	34	0.53
Jungle cat	*Felis chaus*	C	LC	5	2.67	6	0.09
Family: Hyaenidae							
Striped hyena	*Hyaena hyaena*	C	NT	1	0.53	2	0.03
Family: Mustelidae							
Otter		C		1	0.53	1	0.02
Ratel	*Mellivora capensis*	C	LC	4	2.14	5	0.08
Family: Viverridae							
Small Indian Civet	*Viverricula indica*	C	LC	11	5.88	14	0.22
Common palm civet	*Paradoxurus hermaphroditus*	O	LC	13	6.95	29	0.45
Family: Herpestidae							
Small Indian mongoose	*Herpestes javanicus*	C	LC	6	3.21	8	0.12
Family: Cercopithecidae							
Rhesus macaque	*Macaca mulatta*	H	LC	55	29.4	129	2.01
Hanuman Langur	*Semnopithecus entellus*	H	LC	74	39.6	231	3.6
Family: Manidae							
Indian pangolin	*Manis crassicaudata*	I	NT	1	0.53	1	0.02
Family: Leporidae							
Indian hare	*Lepus nigricollis*	H	LC	9	4.81	19	0.3
Family: Hystricidae							
Indian crested porcupine	*Hystrix indica*	H	LC	45	24.1	86	1.34
Family: Sciuridae							
Indian giant squirrel	*Ratufa indica*	H	LC	1	0.53	2	0.03
Birds							
Black eagle	*Ictinaetus malayensis*	C		1	0.53	4	0.06
Un ID bird		C		1	0.53	1	0.02
Crested serpent eagle	*Spilornis cheela*	C		4	2.14	5	0.08
Owl		C		2	1.07	3	0.05
Red junglefowl	*Gallus gallus*	O		7	3.74	10	0.16

Table 1 continued

Wildlife	Scientific name	Food habit	IUCN status 2013	CT stations	% occurrence in CT stations	Total photos	RAI
Red spurfowl	*Galloperdix linulata*	O		1	0.53	1	0.02
Indian peafowl	*Pavo cristatus*	O		25	13.4	31	0.48
Human and domestic animal							
Forest department staff				138	73.8	611	9.53
Department vehicle				19	10.2	63	0.98
Villagers				140	74.9	955	14.9
Poachers				33	17.6	43	0.67
Livestock				40	21.4	168	2.62
Dogs				66	35.3	134	2.09
Un ID				11	5.88	13	0.2

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

Table 2 Mammals photo-captured in 16 ranges of Similipal Tiger Reserve

Forest ranges (Area km^2)	N of independent			Species richness		RAI		
	Trap-days	CT stations	Photo-captures (mammals)	Observed	As % of total	Humans	Domestic animal	Mammals
Satkosia (150)	256	7	85	7	29.2	5.86	4.3	33.2
Thakurmunda (69)	277	9	65	12	50	3.97	0.36	23.5
Kendumundi (125)	684	21	229	14	58.3	5.41	0.88	33.5
Gurguria (200)	905	22	197	15	62.5	7.29	2.43	21.8
Dudhiani (135)	385	11	108	15	62.5	7.79	3.9	28.1
Manada (188)	504	16	105	11	45.8	12.3	5.75	20.8
Bangiriposi (68)	261	7	49	9	37.5	36.4	21.1	18.8
Bisoi (226)	201	9	128	12	50	35.8	12.4	63.7
Kaptipada (230)	188	7	26	7	29.2	33	6.91	13.8
Udala (137)	275	9	34	9	37.5	21.5	12.4	12
Pithabata (Territorial) (103)	241	6	12	5	20.8	13.3	1.6	4.98
Pithabata (Wildlife) (102)	259	7	33	7	29.2	1.16	0.77	12.7
Dukura (50)	105	3	2	2	8.33	10.5	0.95	1.9
Chahala (132)	753	22	211	17	70.8	20.1	3.72	28
Nawana North (58)	570	16	210	17	70.8	20.5	5.96	36.8
Nawana South (135)	549	15	228	15	62.5	24	4.01	41.5
Total (2108)	6413	187	1721	24	100	14.9	4.71	26.8

effects on mammal assemblages. Hunting usually reduces the relative abundance and total biomass of the larger species, occasionally increasing the absolute abundance of the smaller, less preferred ones (Peres and Dolman 2000; Peres 2010). Cascades effect through the ecological community can also follow the reduction in the number of the large herbivores (Wright and Duber 2001), and top predators (Berger et al. 2008). Livestock grazing is an activity that usually has notorious effects on the structure and composition of natural communities (Mathai 1999; Madhusudan and Mishra 2003). Among the mammals, large herbivores may be negatively affected by cattle through competitive interactions (Madhusudan 2004). When prey density is low, the large carnivores predate on livestock and villagers consider them as pests that should be eradicated (Loveridge et al. 2010).It is evident that, the

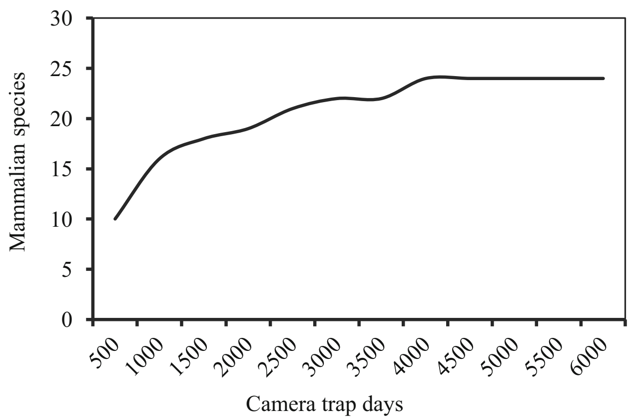

Fig. 3 Cumulative number of recorded mammalian species versus camera trapping effort in Similipal Tiger Reserve

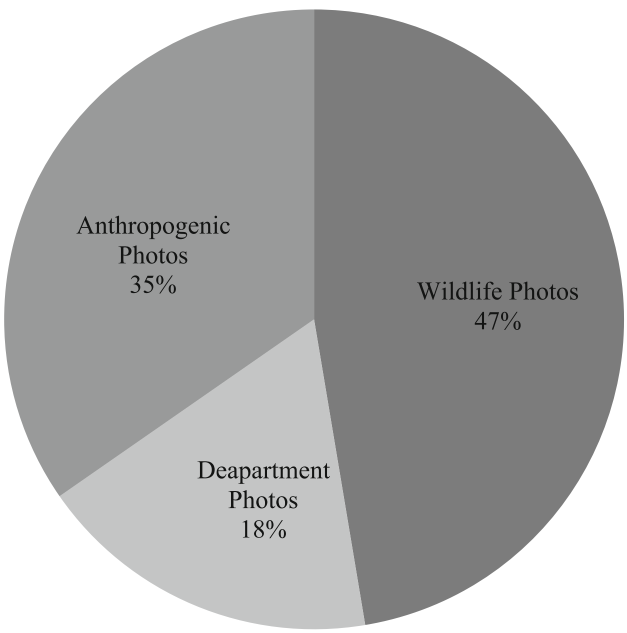

Fig. 4 Proportional contribution of different captured photos in Similipal Tiger Reserve

forest department seized >10 leopard skins from fringe villages of the STR in last 2 years (*per. obs.*).

Presence of domestic dogs in the study area is a serious issue and they accounted for 10.3 % detection of anthropogenic disturbances. The abundance and ranging behavior of domestic dogs are recognized as key factors determining their cumulative impacts on wild carnivore through exploitation, apparent and interface competition (Vanak and Gompper 2010). Dogs were accompanied by villagers and poachers in 48.5 and 8.21 % respectively of all dog detections, and the same individual dogs were detected alone. It is possible that some of the dogs detected were feral, and their presence in the study area needs to be addressed.

Implications for Conservation

Our camera trap data suggest that the main threat for wildlife conservation is probably the concomitant increase in incompatible human and domestic animal activities in the study area. To strengthen existing levels of protection in STR, managers need to be made aware of the need to monitor curb threats actively and manage this sensitive ecosystem knowledgeably; need to combat poachers with modern approaches through gathering and sharing intelligence, and law enforcement. Many studies suggest that successful conservation results from dedicated protected area management coupled with local community support for the protected area and involvement in its protection (Chauhan et al. 2006; Singh and Gibson 2011). For Similipal, these actions will be accelerated through involvement of non-government organizations and local communities.

Management strategies for dogs should aim to reduce both the number of dogs and their ranging behavior which determines the spatial extent of their impacts (Vanak and Gompper 2010; Silva-Rodríguez and Sieving 2012). Lethal control is a common and effective strategy for population reduction of nuisance predators but is not feasible when such predators are owned, as is the case in several areas where dog impacts have been reported (Lacerda et al. 2009; Silva-Rodriguez et al. 2010; Vanak and Gompper 2010). This highlights the need to educate people to have fewer dogs, accompanied with reducing ranging activity.

Despite numerous threats, our results suggest that Similipal plays an important role in conserving rare and endangered species in this region. This study also provides a framework for further research on biodiversity conservation in this region in presence of confounding factors. We recommend the need for detailed ecological research and greater awareness among villagers to conserve the wild animals of STR.

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