Estimating Mammalian Diversity and Relative Abundance Using Camera Traps in a Tropical Deciduous Forest of Kuldiha Wildlife Sanctuary, Eastern India

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Original paper

Estimating mammalian diversity and relative abundance using camera traps in a tropical deciduous forest of Kuldiha Wildlife Sanctuary, eastern India

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Information on the status and distribution of species within a geographical region is vital for designing effective conservation plans. We assessed the diversity and abundance of medium to large sized mammals in Kuldiha Wildlife Sanctuary, eastern India by using remotely triggered camera traps from January 2013 to August 2013. A total 916 camera trap days at 65 trap stations were deployed. We recorded 912 independent photographs and identified 20 species of mammals. Based on photographic rate of each mammalian species, the small Indian civet *Viverricula indica* represented high relative abundance (RAI = 2.07) among the carnivore while the Asian elephant *Elephas maximus* among the herbivores (RAI = 9.72) and the sloth bear *Melursus ursinus* among the omnivores (RAI = 2.51). Large carnivores like the leopard *Panthera pardus* (RAI = 0.55) and the Asiatic wild dog *Cuon alpinus* (RAI = 0.11) were represented by a relatively low abundance. Frequency of various anthropogenic activities from movement of livestock, feral dogs and human traffic accounted for maximum photo capture (combined RAI = 30.7) and found to be negatively correlated with mammalian relative abundance. So an effective intervention incorporating the social and ecological components is desirable for wildlife conservation in Kuldiha Wildlife Sanctuary.

Key words: anthropogenic activity, Kuldiha Wildlife Sanctuary, livestock pressure, relative abundance index, stray dog.

Terrestrial mammals are important component of tropical forest communities being ecosystem service providers and indicators of ecosystem health, for which often makes them of particular conservation and management concern (Kitamura et al. 2010). Due to increasing anthropogenic pressure, half the world's 5491 known mammalian species are declining and a fifth are clearly at the verge of extinction (Anon 2016). So it is crucial to document their diversity, patterns of species richness, and compositions in different forest conditions in order to facilitate sound decisions regarding their conservation (Bernard et al. 2013). However, in the tropical forests it is extremely challenging to monitor these animals as they are illusive and mostly nocturnal, prefer dense vegetation, occur in low abundances and avoid human presence (Datta et al. 2008; Mohd-Azlan 2009; Gonthier and Castañeda 2013). In this regard, monitoring these animals using camera traps triggered by passing animals is an alternative and popular method (Ancrenaz et al. 2012).

Camera traps not only detect the rare, secretive or elusive wildlife species, but are more often used for estimating the population density of the natural marked animals by means of well consolidated spatially explicit capture-recapture models worldwide (Murray 2011; Rahel et al. 2011; Laetitia et al. 2013; Murray and Rachel 2013). Unfortunately for majority of the tropical animals such as the ungulates, bears, and other small mammals, it is not possible to distinguish individual animals from photographs, thus hindering the estimation of their population status and density at a larger spatial scale (Pollock et al. 2002). In this regard, photographic trapping rate (ratio of photographs to camera trapping time) has been widely used to estimate the relative abundance with an assumption that photo detection rate is influenced by animal

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abundance (Rovero and Marshall 2009; Jenks et al. 2011). Moreover, a significant correlation between trapping rates and independent density estimations supported its use as an index of relative abundance (Carbone et al. 2001; O'Brien et al. 2003). Although the use of relative abundance index (RAI) generated from camera trap encounter rates is controversial as it gets biased with animal body mass and study design (Sollmann et al. 2013), there are ample examples of a linear relationship between RAI and abundance, that is estimated through more precise ways (Rovero and Marshall 2009; Jenks et al. 2011; Palei et al. 2015).

In the state of Odisha, eastern India, large stretch of natural forests has been degraded and converted to human modified landscapes in the last few decades (Reddy et al. 2013). So it can be predicted that distribution and population status of many mammalian species might have been negatively affected. Even, some species could have been locally extinct. But, lack of adequate information makes it virtually impossible to assess their status. In the present study we carried out a camera trap survey in the tropical deciduous forest of Kuldiha Wildlife Sanctuary (KWLS), eastern India to estimate mammalian species richness, their abundance and occurrence of anthropogenic disturbances which will be useful in formulating appropriate management strategies.

Materials and methods

Study area

The KWLS is situated along the tropic zone between 21°30'–21°45'N and 86°30'–86°45'E spreading over an area of 272.75 km^2 in Odisha, eastern India (Fig. 1). Vegetation is mostly tropical mixed deciduous type (Champion and Seth 1968) dominated by *Shorea robusta*, *Terminalia tomentosa*, *Pterocarpus marsupium*, *Anogeisus latifolia*, *Dalbergia latifolia*, *Diospyros embryopteris*, *Emblica officinalis*, *Madhuca indica*, *Scleichera oleosa*, and *Mangifera indica*. The landscape is characterized by undulating hilly terrain and altitude ranges between 169 and 682 m above sea level and receives an annual average rainfall of 1460 mm form south-west monsoon. Based on the climatic condition, the area experience three distinct seasons; winter (October to January), summer (February to May), and monsoon (June to September). Temperatures vary from a minimum 8°C in December to a maximum 42°C in June.

For management purposes, KWLS is further divided

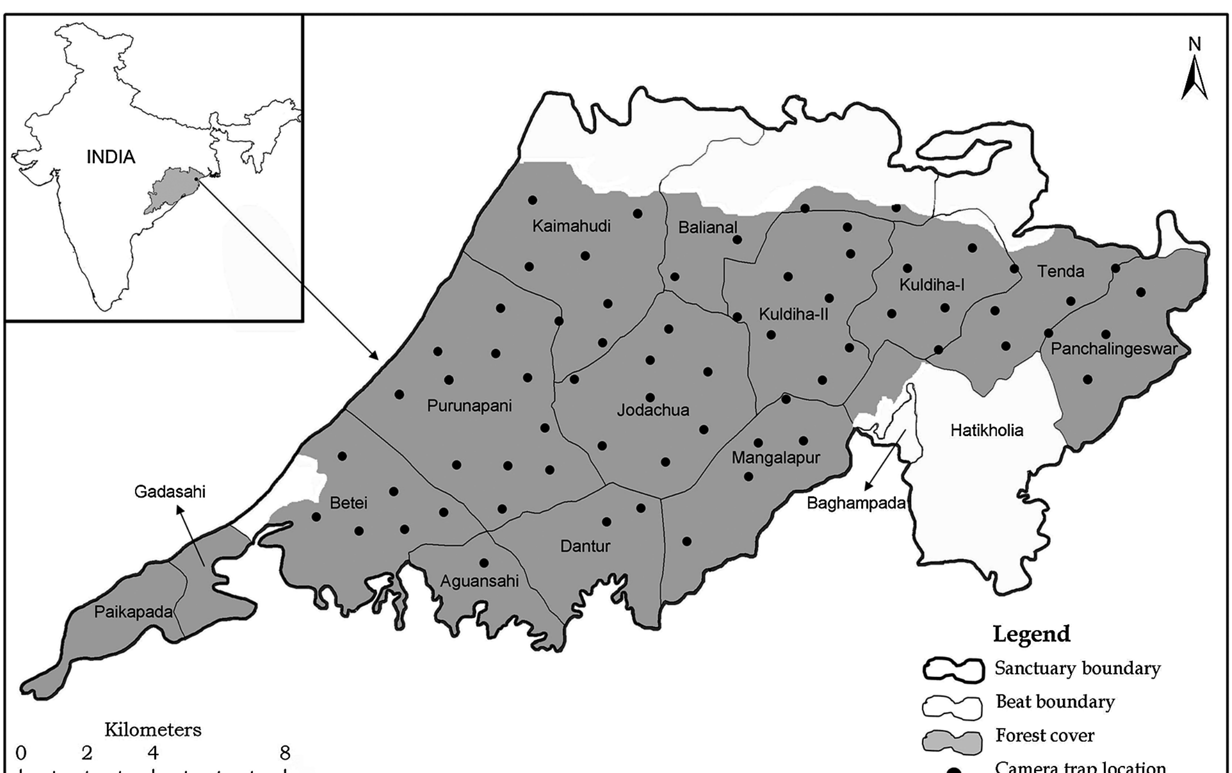

Fig. 1. Map showing the study area and camera trap locations.

into 16 small units (here in after "Beat") with area varying between 7.5 to 33 km^2 (Anon 2009).

Camera trapping

We carried out the study for eight months between January 2013 to August 2013 by using automatically triggered camera traps (Moultry D50, USA). Out of the 16 beats of KWLS (Fig. 1), we did not carry out the survey in four beats (Baghampada, Hatikholia, Gadasahi, and Paikapada) due to high anthropogenic activities. We first divided the study area into 2 km^2 squire sized grids and deployed 2–3 camera traps in each grid. At each station, we deployed one camera trap by strapping them on trees approximately 50 cm above ground along the motorable roads, foot paths, forest trails and off-road locations (e.g., near water bodies, natural salt licks, wallows) and aimed the sensor parallel to the ground to maximize the extension of the detection zone. Camera traps were set to operate 24 hours per day and programmed to take sequential photographs with 30 seconds delay registering date and time for each exposure. At each station, camera traps were installed for maximum 15 days and checked at weekly intervals for photo download and battery replacement. We recorded the time of installation and retrieval of each camera and calculated the total duration of sampling. For calculating the total number of camera trap days at each sampling site, we divided the total duration of sampling (in hours) by 24.

Data analysis

After retrieving all the camera traps we carefully observed all the photographs and identified the animals up to species level referring to Menon (2014). In case, where a species was not identified was treated as unidentified species. Besides wild animals, photographs of human traffic (forest staffs, tourists, poachers, and local villagers) and domestic animals (livestock and dogs) were also observed. We rated each photo as an independent event, if the time between consecutive photographs of the same subject was more than 30 minutes apart following the principle described by O'Brien et al. (2003). Because our study was not focused on identifying individual animals from photos, the arbitrary time between independent photos is unbiased. Photos with multiple individuals of the same species in the frame were counted as single detection for that species. We report number of animal detections and computed the RAI as

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

Where A is the total number of detections of a species by all cameras and N is the total number of camera trap days by all the cameras throughout the study area following Jenks et al. (2011).

We grouped all the photographs according to the following order, wild animals (herbivores, carnivores, and omnivores), human traffic (departmental staff, tourists, and local people) and movement of domestic animals (livestock and dogs) and performed chi-squire test (χ^2) to test for significant difference of RAI of between the types of photos captured. To elucidate the relationship between the relative abundance of human traffic and mammals, we calculated the correlation coefficient (r) between them. All the statistical analysis was carried out in windows based MS office excel work sheet using data analysis tool.

Results

We carried out camera trap survey at 65 locations (Fig. 1) for 916 trap days (Mean ± *SD*; 14.09 ± 1.52; range: 8–15) and classified 912 frames as independent photographs. Camera traps at an additional four locations did not yield data because they were either stolen or damaged by elephants before retrieval. Among all the photographs, we recorded 20 species of wild mammals of which two have been categorized as endangered, four as vulnerable, one as near threatened, and 13 as least concern by the IUCN Red List of threatened species (IUCN 2013; Table 1). We also recorded two photographs of an unidentified rodent species, but did not consider it for analysis to avoid unnecessary bias in species level relative abundance estimation. Besides that, camera traps also captured eight species of birds including the globally threatened pale-capped pigeon *Columba punicea*, three species of domestic animals and human activities inside the sanctuary.

Of all the photographs majority of 69.2% (*n* = 631) were wildlife and mostly of herbivore mammals (76.9%) followed by carnivores mammals (8.1%), birds (8.1%), and omnivore mammals (7.0%). Rest of the photographs (30.8%) was anthropogenic from the movement of livestock, feral dogs, and human traffic. Among all the mammals, Asian elephant *Elephas maximus* was the maximum (RAI = 9.72) and the Asiatic wild dog *Cuon alpinus* was the minimum photographed species (RAI = 0.11) (Fig. 2). More specifically, out of the 11 species of herbivore mammals recorded during the study period, the estimated relative abundance was maximum for the Asian elephant (RAI = 9.72) and minimum for the sambar *Rusa unicolor* (RAI = 1.97). Among the seven species of carnivores, the

Table 1. A comparative Reletive Abundance Index (RAI) of different wildlife species and others based on camera trap photographs in Kuldiha Wildlife Sanctuary in between January 2013 to August 2013 with Similipal Tiger Reseve (2750 km^2)

Photographs	Common Name	Food habits	IUCN Status	N° Camera trap stations with occurrence	% Occurrence	Total photos	RAI	
							Present study site	STR (Palei et al. 2015)
Mammals								
Family: Elephantidae								
Elephas maximus	Asian elephant	H	EN	61	93.85	89	9.72	2.09
Family: Bovidae								
Bos gaurus	Gaur	H	VU	22	33.85	42	4.59	0.06
Family: Tragulidae								
Moschiola indica	Indian chevrotain	H	LC	21	32.31	34	3.71	0.80
Family: Cervidae								
Muntiacus muntjac	Barking deer	H	LC	59	90.77	76	8.30	6.50
Axis axis	Spotted deer	H	LC	45	69.23	53	5.79	0.47
Rusa unicolor	Sambar	H	VU	5	7.70	18	1.97	1.39
Family: Cercopithecidae								
Macaca mulatta	Rhesus macaque	H	LC	31	47.69	39	4.26	2.01
Semnopithecus entellus	Hanuman langur	H	LC	22	33.85	37	4.04	3.60
Family: Hystricidae								
Hystrix indica	Indian crested porcupine	H	LC	30	46.15	34	3.71	1.34
Family: Leporidae								
Lepus nigricollis	Indian hare	H	LC	13	20.00	18	1.97	0.30
Family: Suidae								
Sus scrofa	Wild boar	H	LC	43	66.15	45	4.91	4.52
Family: Felidae								
Panthera pardus	Leopard	C	VU	3	4.61	5	0.55	1.68
Felis chaus	Jungle cat	C	LC	9	13.85	9	0.98	0.09
Family: Hyaenidae								
Hyaena hyaena	Striped hyaena	C	NT	3	4.61	3	0.33	0.03
Family: Canidae								
Cuon alpinus	Asiatic wild dog	C	EN	1	1.53	1	0.11	*
Family: Viverridae								
Viverricula indica	Small Indian civet	C	LC	15	23.08	19	2.07	0.22
Paradoxurus hermaphroditus	Common palm civet	O	LC	19	29.23	21	2.29	0.45
Family: Herpestidae								
Herpestes auropunctatus	Small Indian mongoose	C	LC	10	15.38	11	1.20	0.12
Family: Ursidae								
Melursus ursinus	Sloth bear	O	VU	16	24.62	23	2.51	0.46
Family: Mustelidae								
Mellivora capensis	Honey badger	C	LC	1	1.53	3	0.33	0.08
Birds								
Spilornis cheela	Crested serpent eagle		LC	1	1.53	1	0.11	0.08
Pavo cristatus	Indian peafowl		LC	8	12.31	13	1.42	0.48
Gallus gallus	Red junglefowl		LC	18	27.69	23	2.51	0.16
Chalcophaps indica	Emerald dove		LC	1	1.53	2	0.22	*
Streptopelia orientalis	Oriental turtle dove		LC	2	0.07	2	0.22	*
Columba punicea	Pale capped pigeon		VU	2	0.07	2	0.22	*
Caprimulgus asiaticus	Indian nightjar		LC	4	6.15	7	0.76	*
Anthracoceros albirostris	Oriental pied hornbill		LC	1	1.53	1	0.11	*
Human traffic and Livestock								
Forest Department Staff				21	32.31	24	2.62	9.53
Department Vehicle				6	9.23	29	3.17	0.98
Tourist Vehicle				21	32.31	54	5.90	*
Villagers				16	24.62	18	1.97	14.90
Poachers				4	6.15	14	1.53	0.67
Cattles and Buffalos				61	93.85	129	14.10	2.62
Dogs				7	10.77	13	1.41	2.09

Total number of camera trap location in the present study is 65.
STR, Similipal Tiger Reserve; H, Herbivore; C, Carnivore; O, Omnivore; EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern; RAI, Relative Abundance Index; *, Information not available.

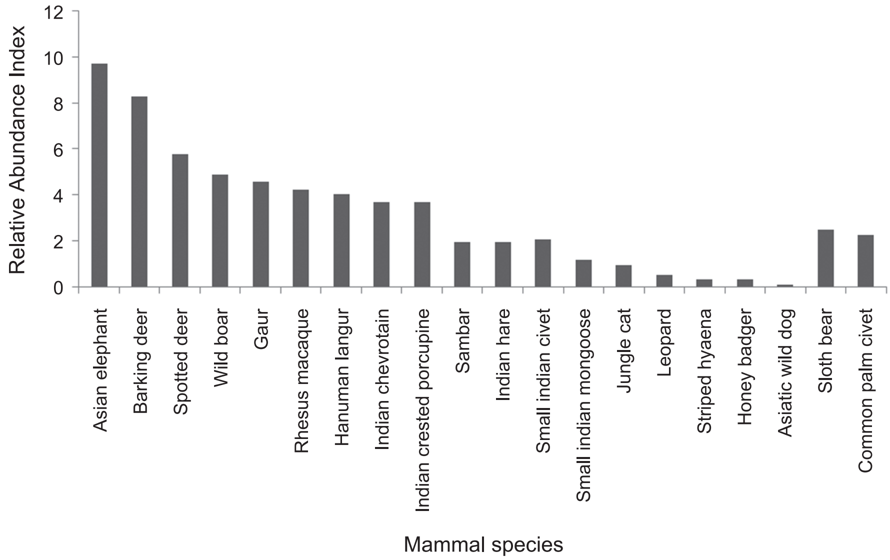

Fig. 2. Relative abundance index of mammals in Kuldiha Wildlife Sanctuary from January 2013 to August 2013.

Table 2. Species richness and relative abundance of mammals and different anthropogenic activities in 12 wildlife beats of Kuldiha Wildlife Sanctuary in between January 2013 to August 2013

Wildlife beats (Area in km^2)	Total number of			Species richness		RAI			
	Camera Trap stations	Trap days	Mammal photographs	Observed	% of total	Mammals	Human traffic	Domestic animals	Overall anthropogenic
Kuldiha-I (12.9)	6	90	103	17	85	11.23	0.11	0.87	0.98
Kuldiha-II (19.38)	8	120	108	16	80	11.81	0.22	0.87	1.09
Jodachua (22.7)	8	120	123	16	80	13.40	0.55	1.53	2.08
Balianal (24.38)	4	52	46	14	70	5.02	0.44	1.97	2.41
Panchalingeswar (14.61)	3	44	60	11	55	6.55	0.33	1.42	1.75
Tenda (18.6)	5	75	54	14	70	5.90	2.07	1.09	3.16
Mangalpur (15.57)	5	71	13	10	50	1.42	0.66	1.20	1.86
Purunapani (31.64)	10	132	27	9	45	2.95	0.55	1.31	1.86
Kaimahudi (33)	7	103	24	8	40	2.62	2.73	1.42	4.15
Betei (20.73)	6	84	8	7	35	0.87	2.51	1.42	3.93
Aguansahi (7.53)	1	10	8	5	25	0.87	2.51	1.31	3.82
Dantur (12.83)	2	15	6	5	25	0.66	2.51	1.09	3.60
Total (233.9)	65	916	914	20	100	63.30	15.19	15.50	30.69

RAI, Relative Abundance Index.

relative abundance was maximum for the small Indian civet *Viverricula indica* (RAI = 2.07) and minimum for the Asiatic wild dog (RAI = 0.11). Among the two species of omnivore mammals, the sloth bear *Melursus ursinus* was detected more (RAI = 2.51) than the common palm civet *Paradoxurus hermaphroditus* (RAI = 2.29). The detailed RAI of different mammalian species is summarized in Table 1. Among all the photographs of various anthropogenic activities (combined RAI = 30.70), human traffic was significantly higher (n = 139; $\chi^2_2 = 104.74$, $P < 0.01$) than movement of livestock and dogs. Human traffic was dominated by movement of tourist vehicles (n = 54; $\chi^2_4 = 35.57$, $P < 0.01$) than departmental vehicles, staffs, villagers, and poachers (Table 1). Detailed information on the species richness, RAI of mammals and various anthropogenic activities throughout the sampling areas is given in Table 2.

Mammalian photo capture rate and relative abundance varied between sampling areas and it was higher in Jodachua, Kuldiha-I, and Kuldiha-II, but lower in Betei, Aguansahi, and Dantur (Table 2). Overall, the species richness and relative abundance of mammals was found

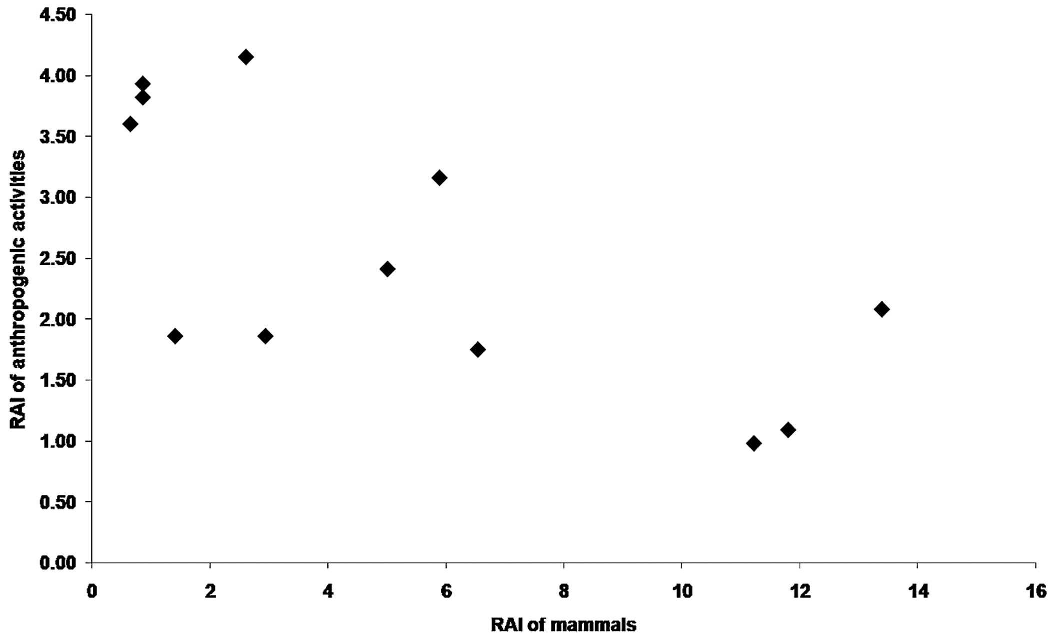

Fig. 3. Scattergram of observed RAI (relative abundance index) based on camera trap photographs of mammals and anthropogenic activities in Kuldiha Wildlife Sanctuary from January 2013 to August 2013.

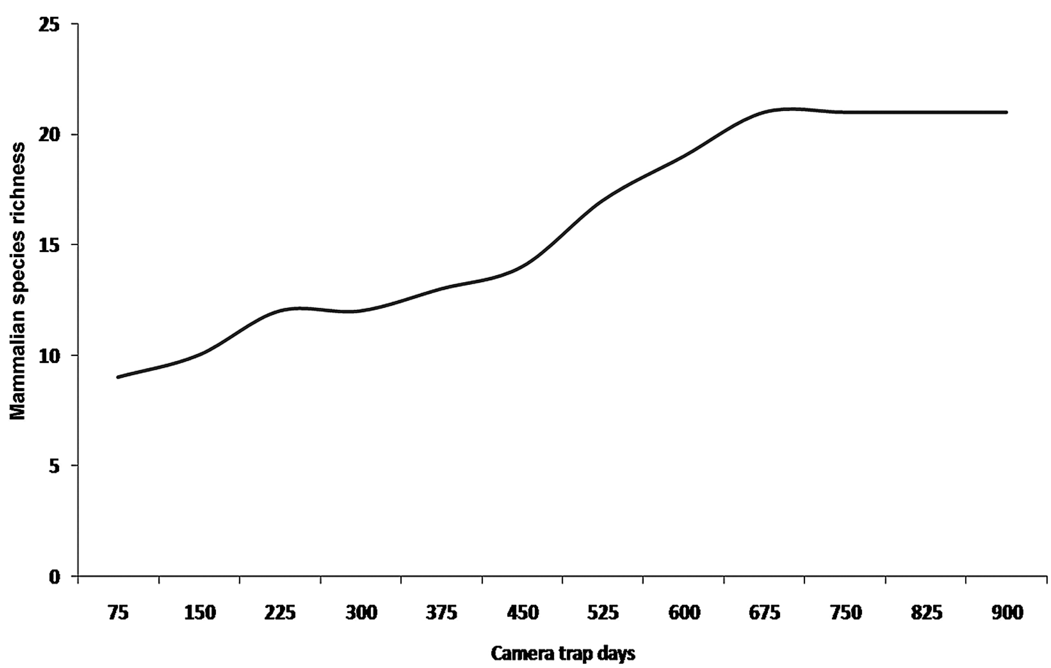

Fig. 4. Cumulative number of recorded mammalian species against camera trapping efforts in Kuldiha Wildlife Sanctuary from January 2013 to August 2013.

to be negatively correlated with level of anthropogenic disturbances ($r_{10} = -0.70$, $P < 0.01$; Fig. 3).

Cumulative number of recorded mammalian species against camera trapping efforts appeared to stabilize after examining 675 camera trap days (Fig. 4).

Discussion

KWLS is home to 42 species of mammals of which rodents, shrews, tree shrew, and bats are represented by 18 species (Sahu et al. 2014). So a comparison of our record of 20 species with rest of the species from earlier study suggests the completeness up to 83.34%. Our camera trap effort was found to be sufficient in documenting the species richness of medium to large sized mammals of KWLS (Fig. 4). The relative abundance of Asian elephants was reported much higher than any other species. It may be due to their large home range and frequent movement between habitats. Moreover, as the body size and behavior of individual animals greatly influence the detection probability (Sollmann et al. 2013), we accept the possibility of unintended biases on the estimated RAI of other mammalian species and therefore suggest to interpret our findings carefully. During the survey, species like the golden jackal *Canis aureus*, the Bengal fox *Vulpes bengalensis*, the ruddy mongoose *Herpestes smithii* and the grey mongoose *Herpestes edwardsii* were not detected. The camera traps were preferably installed in the forested regions and the former two undetected species mostly preferring open forests and agricultural areas might have missed out.

The mammalian species richness and relative abundance in KWLS can be comparable with Similipal Tiger Reserve (herein after 'STR') (Table 1; Palei et al. 2015). Moreover, the ungulate species along with two primates are preferred prey species of larger carnivores such as the tiger *Panthera tigris*, the leopard *P. pardus*, and the Asiatic wild dog in the tropical forests of India (Ramesh et al. 2012; Majumder et al. 2013). So KWLS may have the potential to harbor these large carnivores. Although camera traps were distributed throughout the sanctuary, we did not record the tiger in KWLS despite its connectivity with STR. Our informal discussion with the forest department staffs also revealed that there was no record of tiger population in KWLS since a long time. However during the year 2009 a carcass of a male tiger was recovered from Jodachua beat (Anon 2009), which could be a migrant individual from STR. Even other large carnivores like the leopard and Asiatic wild dog present relative low abundances. These large carnivores generally prefer large, contiguous, and less disturbed habitats and their abundance is determined by prey density (Karanth et al. 2004). Loss and degradation of habitat, hunting, livestock pressure, and poorly managed tourism are some of the major threats to the wildlife of India (Karanth et al. 2010).

There are 12 tribal villages with a human population of around 5257 individuals along with an additional 4094 livestock living within KWLS, those depend upon the forest for subsistence resource use and cattle grazing (Anon 2009). Whereas in STR the total number of inhabited villages and human population are 57 and 12 000 respectively, which are much higher than KWLS. Still the relative abundance of various anthropogenic activities in KWLS resembles that of STR (Table 1). Besides that, KWLS being one of the smallest and easily accessible protected areas in Odisha is one of the major attractions among nature tourists during tourist season. As a result, we reported high level of anthropogenic activities in the forms of human traffic and movement of livestock (combined RAI = 24.91; Table 2). Presence of domestic animals can have detrimental effect on distribution and assemblage of wild animal communities (Palei et al. 2015) and accounted for more than 50% of all the detections under anthropogenic disturbance in KWLS and much higher than STR (Table 1). Large herbivores are negatively affected by livestock through competitive interactions (Madhusudan 2004) and gaurs in particular are more profoundly influenced by transmitted infections from livestock than Asian elephants (Pasha et al. 2004; Debata and Swain 2017). So it may be the reason of population depletion of the gaur in KWLS resulting low relative abundance compared to Asian elephants (Table 1). In KWLS, although the photographs depicting hunting and poaching activities were accounted for low relative abundance than other threats (RAI = 1.53), in a long run it can adversely affect the relative abundance and total biomass of different animal communities (Melo et al. 2015) and can reduce the number of the top predators (Berger et al. 2008). Furthermore, local abundance and ranging behavior of domestic dogs can also be a major threat to wildlife through predation, competition or as sources of infectious diseases (Hughes and Macdonald 2013). Uncontrolled tourism can also invite unwitting damage to the ecosystem and negative effect on wildlife (Green and Giese 2004).

Conservation implications

From our camera trap study, tourism activities and movement of domestic animals were found to be major threats for the mammalian species in KWLS. To overcome this, it is vital to control and monitor the movement of livestock and dogs, and manage tourism activities. It can be implemented with effective management plans involving the local community and local non-government organizations (Singh and Gibson 2011; Palei et al. 2015). Although vaccination of livestock living in and around protected areas is a regular practice under protected area management plans, it needs to be regularized. Wherever possible, with local support coupled with awareness activities, the traditional livestock grazing areas need to shift outside KWLS. Studies have shown that wild herbivores benefit from the reduction of livestock presence in areas from where they have been previously excluded by livestock (Madhusudan 2004). In agreement with Palei et al. (2015), management strategies for dogs (both pets and stray dogs) should focus on reducing their number and ranging behavior. It can be achieved through adequate awareness among local people to have fewer dogs with reduced ranging activity. Lethal control and sterilization of stray dogs can be useful in controlling their population. Overcrowding of tourism can be minimized by regulating the entry permit to number of vehicles and their movement area through strict regulations. Poaching can be controlled with modern approaches through gathering and sharing intelligence, and law enforcement.

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