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Communication

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PLATINUM OPEN ACCESS

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Abstract: Reliable population estimate of apex predators, such as the Leopard *Panthera pardus fusca*, is important as they indicate ecosystem health, enable evaluation of the effectiveness of conservation efforts and provide a benchmark for future management decisions. The present study is the first to estimate abundance of Leopard along with possible prey profile in Kuno Wildlife Sanctuary (KWLS), in central Madhya Pradesh (M.P.), India. For systematic sampling, two study habitats, 15km² each, were identified, one close to the park entrance and the other away from the park entrance. Sampling was carried out between March and April 2017, for a period of 18 days in each of the two study habitats, 'good' and 'poor', initially based on situation in reference to park-entry. Each habitat was divided into five blocks each, and each block subdivided into three, 1km² observation units. In all, 16 trail cameras were placed in pairs, one set at a time in five of the blocks, over a six–day period. The total sampling effort was 180 trap-nights. The trigger speed was set to 3 frames per 10 seconds, and repeated only after 20 minutes interval on infra-red detection of object. The data was analysed using closed population capture–recapture analyses in Program MARK, to estimate Leopard abundance. Seventy-eight Leopard detections representing eight unique individuals were found in the 30km² study site. Seven Leopards were detected in the good habitat and one in the poor habitat. The estimate for Leopard abundance for the good habitat was 11 Leopards (SE 4.6, 95% CI = 8 – 31 individuals). Due to limited captures/recaptures in the poor habitat, abundance could not be estimated for this habitat class.

Keywords: Camera trap, capture-recapture, Kuno Wildlife Sanctuary, Leopard abundance, prey diversity.

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INTRODUCTION

The Kuno watershed and the Kuno Wildlife Sanctuary (KWLS) form an important stepping-stone ecosystem between the Ranthambore National Park in Rajasthan, the Madhav and the Panna national parks, in Madhya Pradesh, India (Johnsingh et al. 2007). Historically, Kuno was known to support populations of both the Bengal Tiger *Panthera tigris* and Asiatic Lions *Panthera leo persica* (Kinnear, 1920). However, lions have been extirpated from Kuno in the last century due to excessive hunting (Kinnear 1920), and in recent years, poaching is one of the prime threats to the survival of Leopards and tigers in India (Wildlife Protection Society of India, 2017). A solitary male tiger was recorded in the sanctuary after it moved into Kuno from Ranthambore Tiger Reserve in December 2010 (Sharma et al. 2013). Based on verbal communication with the forest department, Leopards *Panthera pardus fusca* are thought to be the primary apex predator at this site.

KWLS is one of the sites selected for Asiatic Lion reintroduction (Johnsingh et al. 2007). In 2009, the sanctuary was considered for reintroduction of Cheetah (Ranjitsinh & Jhala 2010). There is always a possibility that the tiger population may grow as more animals immigrate into the sanctuary from the neighbouring Ranthambore Tiger Reserve (Sharma et al. 2013). Therefore, an estimate of the Leopard abundance could provide useful baseline against which the distribution of all three large cats can be compared in the future. No published studies could be traced by the authors on Leopard abundance in KWLS.

Leopard studies have acquired greater urgency with increased incidents of human–wildlife conflict due to increasing human encroachment around sanctuaries (Athreya 2006, 2012; Athreya et al. 2013). Leopards are also listed Vulnerable by the International Union for Conservation of Nature (IUCN) and have been consistently poached in large numbers over the years (Edgaonkar 2008; Wildlife Protection Society of India, 2017).

Although the method of pugmark tracking has been refined for determining the spatio-temporal distribution and population structure of a minimum number of tiger and Leopard (Singh 2000), the primary method used for estimating large carnivore abundance was the traditional system of pugmark detection and analysis (Choudhary 1970, 1971, 1972; Sawarkar 1987; Sharma et al. 2001). The pugmark method has been replaced by camera trapping and associated mark and recapture analysis, which yield robust estimates of population parameters (Otis et al. 1978; Pollock et al. 1990; Karanth & Nichols 1998, 2000a). However, problems persist in accurate population estimation due to factors such as low numbers, poor detection probability, hardware, logistics and manpower cost (Smallwood & Fitzhugh 1995).

Capture–recapture studies on Leopards using camera traps have been conducted in many parts in India previously, as well as in other countries (Khorozyan 2003; Balme et al. 2007; Henschel 2009; Gray & Prum 2012). The studies in India on Leopard abundance were performed in Sariska (Chauhan et al. 2005), Manas (Borah et al. 2014), Sanjay Gandhi (Surve 2017) and Satpura National Parks (Edgaonkar 2008). A study in Rajaji National Park (Harihar et al. 2009), reported on the density of Leopards. The goal of the present study was to use remotely triggered camera traps and closed population estimators (Otis et al. 1978; Pollock et al. 1990), to assess the abundance of Leopards in KWLS.

MATERIALS AND METHODS

Study site

The 345km² Kuno Wildlife Sanctuary, established in 1981, lies between -25.500^{0}N and 77.433^{0}E longitude (Figure 1). It extends over the districts of Sheopur and Morena in north-west Madhya Pradesh, and is a part of the Sheopur-Shivpuri forested landscape, about 6800km^2. An area of 890km² buffer zone was added to the sanctuary later to form the 1,235km² Kuno Wildlife Division (Sharma et al. 2013). Between 1996 and 2001, a total of 24 villages with 1547 families got voluntarily relocated outside the protected area to leave behind a pristine area for wildlife conservation, on which the KWLS was established (Johnsingh et al. 2007). The Kuno River, one of the main tributaries of river Chambal, flows south to north across almost the entire length of the sanctuary and bisects it into the Palpur West and Palpur East ranges (Figure 1) (Johnsingh et al. 2007; Sharma et al. 2013). The altitude varies from 238–498 m above sea level, with temperature ranging from 47.4^{0}C in the summer to a minimum of 0.6^{0}C during the winter, and the average annual precipitation is 760mm (Sharma et al. 2013). Ecologically, KWLS falls within the Kathiawar-Gir dry deciduous forest eco-regions, which include northern and southern tropical dry deciduous forests, *Anogeissus pendula* forests and scrub, *Boswellia* forests, *Butea* forests, dry savannah forests and grasslands, and tropical riverine forests (Champion & Seth 1968).

KWLS hosts a diverse mammalian community

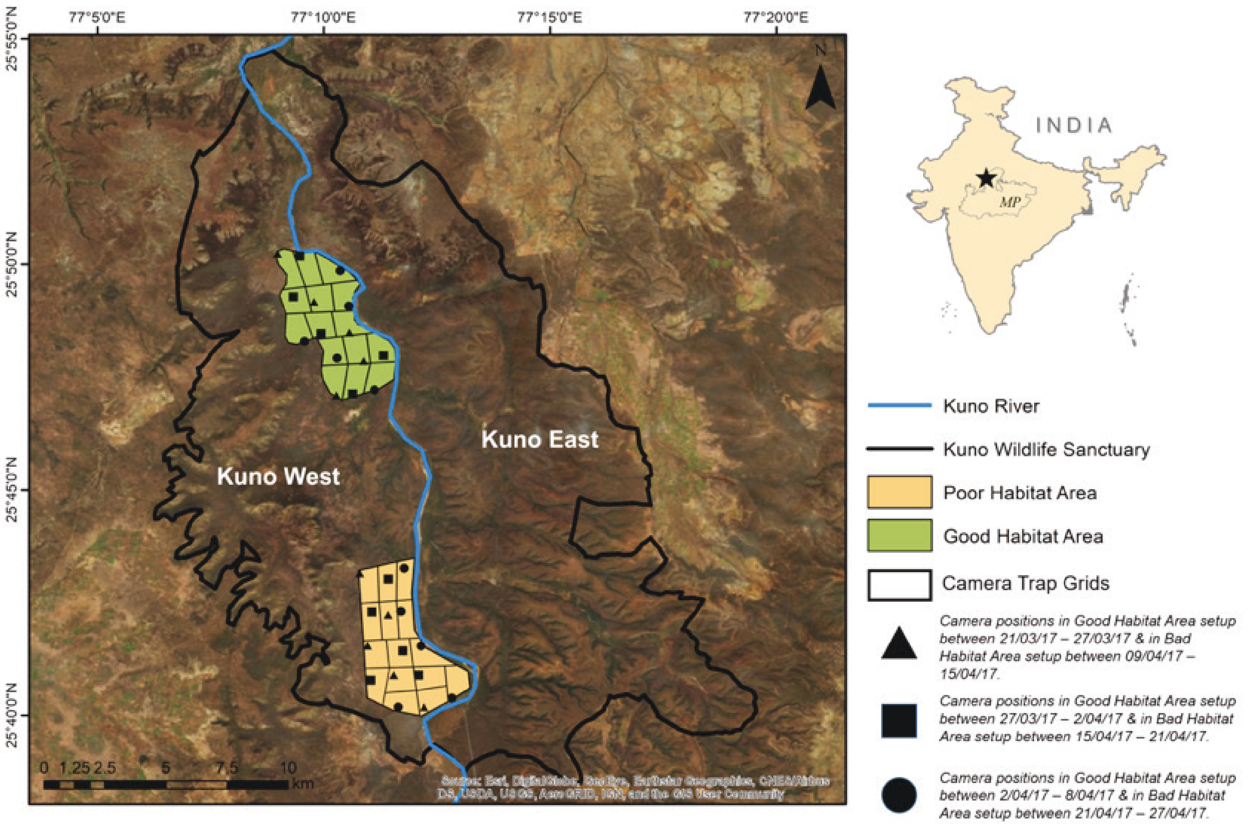

Figure 1. Outline of Kuno Wildlife Sanctuary showing the camera trap locations, river Kuno and the two good and poor study habitats selected for the study.

including Chital *Axis axis*, Sambar *Rusa unicolor*, Nilgai *Boselaphus tragocamelus,* Wild Pig *Sus scrofa*, Chinkara *Gazella bennetii*, Chousingha or Four-horned Antelope *Tetracerus quadricornis* and Indian crested-porcupine *Hystrix indica*. Other carnivorous species, apart from the Leopards recorded at KWLS include Sloth Bear *Ursus melursinus*, Striped Hyaena *Hyaena hyaena,* Indian Fox *Vulpes bengalensis* and Honey Badger *Mellivora capensis*. Additionally, a large population of feral cattle, which were left by the villagers behind during the relocation, also roam the forests and number around 700, that has come down from a high of 2500 cattle recorded in 2005 (Johnsingh et al. 2007).

The dominant tree species here include Khair *Acacia catechu*, Kardhai *Anogeissus pendula*, Salai *Boswellia serrata*, Tendu *Diospyros melanoxylon*, Palash *Butea monosperma*, Dhok *Anogeissus latifolia* and Ber *Zizyphus mauritiana* (Sharma et al. 2013).

Field surveys and 'observation units'

The study was conducted over a 40–day period from 18 March to 26 April 2017 during the summer season when the average temperature was 42° C during the day and 22^{0}C during the night. Confined to the administrative jurisdiction of Palpur West Forest Range of KWLS data were obtained from 30 observation units in 10 observation blocks under two study habitats each of 15km^2 (Figure 1). The size of each observation unit was 1km^2 and the blocks of about 3 km^2 each. The basis for considering study habitats of 15km^2 each was inspired from Odden & Wegge (2005) who mentioned the smallest home range of a female Leopard as 15–17 km^2.

One of the two study habitats, the 'poor study habitat' was identified close to the entrance of KWLS and the other, the 'good study habitat' was approximately 7km apart and away from the park entrance. Unpublished Forest Department reports were consulted and a preliminary survey was conducted for three days from 18 March to 20 March in 2017 to distinguish and demarcate the two 'good' and 'poor' study habitats. The distinction was based on previously used criteria such as carnivore signs, prey species abundance, proximity to the park boundary, signs of human interference, poaching evidence, predation by domestic dogs and water availability (Chauhan et al. 2005; Borah et al. 2014;

Thapa et al. 2014; Hedges et al. 2015). The poor habitat had reduced evidence of prey species, with presence of domestic dogs, increased human activity and signs of forest fire. On the other hand, the good habitat was away from the park entrance, had increased prey base, absence of domestic dogs, reduced human activities and had more patrolling posts in the forest (Image 1). The boundaries of each 15km² 'study habitat' were demarcated using GPS (Garmin Etrex 10) and imported into Google Earth (Google Earth, Digital Globe, version 2017).

Trail camera placements

Sixteen trail cameras, with PIR (passive-infra-red) motion sensor (Bushnell Trophy Cam HD Aggressor No-Glow, 20 MP resolution, 0.2 second trigger, Kansas, USA), were used. The cameras were deployed in pairs, either on trees or on wooden stakes at a height of approximately 40cm, and angled slightly away from each other, four to six metres apart. Paired camera ensured capture of both flanks of an animal under normal conditions, and the availability of at least one functional camera in case of malfunctioning of the other camera (Ancrenaz et al. 2012). Vegetation was cleared between the camera pairs to enable a clear line of sight. Trigger motion was physically checked by crouching in front of the camera before leaving the camera site (Karanth & Nichols 1998; Ancrenaz et al. 2012). The trigger speed was set to 3 frames per 10 seconds to balance the detection probability and conserve battery power. To minimise the possibility of double counting, an interval of at least 20 minutes was taken before recording the same object again.

Within each observation unit the camera traps were fixed so that inter-camera distances during a six–day trapping session were between 1.25km and 2.5km. Where the theoretical sites for fixing a camera were impractical because of locations like ponds, rocky cliffs etc., the cameras were shifted within 100–150 m. The cameras were moved to nearby locations with evidence of Leopard presence ascertained from scats, pugmarks, roads and water holes (Sankar et al. 2005). This reduced the probability that any Leopard in the survey-grid went undetected. Most camera sites were either accessible by road or by walking a distance of less than 2km.

Due to time constraints and the unavailability of cameras, trapping was conducted over two survey periods of 18 days for each habitat. Each 18–day period was further sub-divided into three episodes of six days each. This study approach is similar to a study by Chauhan et al. (2005) in Sariska National Park in which 10 camera traps were deployed for a comparable period of 10 days. In the present study, the camera traps were inspected once every alternate day for the good study habitat and once every three days for the poor study habitat.

Data analysis

Estimation of Leopard abundance from closed population capture–recapture model was performed using Program MARK version 8.2 (Otis et. al. 1978; White 2008). As the surveys were carried out within a relatively short period of approximately five weeks the Leopard population was assumed to be closed geographically and as there was no permanent migration of the animals into or off the grid, we also assumed that there was demographic closure, i.e., no deaths occurred in the population during the survey (White 2008).

Several alternate parameterisations of closed population capture–recapture models were fit to account for variation in detection probability. Various models such as the Mt model (time-varying capture probability), Mh model (individual heterogeneity in capture probability) and M0 model (null model) were considered (White 2008). The data was analysed using modelling procedures that were suitable for small sample sizes (Gerber et al. 2014). The model support was evaluated using Akaike information criterion (AICc).

Individual animals were identified based on rosette patterns, using images of both flanks (Trolle & Kerry 2003; Jackson et al. 2006; Harihar et al. 2009; Hedges et al. 2015) and observing the sexual organs in the images. To minimise identification error, independent verifications of identifications, based on rosette patterns, was undertaken by four observers. These data were entered into a matrix with individuals along the rows, and occasion-wise capture events in columns, with a one or zero representing capture and non-capture respectively for each 18–day period.

RESULTS

In total, 78 photographs of Leopards were taken in both good and poor study habitats. Of these, 38 were of sufficient quality to enable identification of individual Leopards. All the Leopards except one were captured nocturnally. In all photographs but one, Leopards were solitary.

In the good study habitat, on the basis of the rosette patterns on the right and left flanks, a total of six Leopards were identified and one Leopard was identified on the

Table 1. Identification of individual Leopards by Right, Left and both Right & Left Flanks in good study habitat.

Leopard ID	Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Dates	21/03	22/03	23/03	24/03	25/03	26/03	27/03	28/03	29/03	30/03	31/03	01/04	02/04	03/04	04/04	05/04	06/04	07/04
L1 M		None	None	Left	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None
L2 M		None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	Right Left	Right Left
L3 M		None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	Right Left
L4 F		None	Right	None	None	None	None	None	None	None	None	Right Left	None	None	None	None	None	None	None
L5 F		None	None	None	Left	Right Left	None	None	None	None	None	None	None	None	None	None	None	None	None
L6 F		None	None	None	None	None	Right Left	None	None	None	None	None	None	None	None	None	None	None	None
L7 F		None	None	None	None	None	Right Left	None	None	None	None	None	None	None	None	None	None	None	None

Table 2. Capture-recapture (CA-RC) history of individually identified, sex determined Leopards in good study habitat. L - Leopard | M - male | F- female | CA - capture | RC - recapture

Date	March 21 – March 26						March 27 – April 1						April 2 – April 7					
Day	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
L1 M	0	0	CA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L2 M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	RC	RC
L3 M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CA
L4 F	0	RC	0	0	0	0	0	0	0	0	RC	0	0	0	0	0	0	0
L5 F	0	0	0	RC	RC	0	0	0	0	0	0	0	0	0	0	0	0	0
L6 F	0	0	0	0	0	CA	0	0	0	0	0	0	0	0	0	0	0	0
L7 F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CA

basis of the rosette pattern on the left flank only (Table 1). Therefore, a total of seven Leopards were identified in the good study habitat (Table 2; Images 2-8). Only one individual was identified based on its left flank rosette pattern in the poor study habitat (Table 3,4; Image 9). One Leopard was unable to be classified into the good or poor study habitat due to the poor quality of the captured image.

In the good study habitat, three of seven Leopards were recaptured including one male and two females (Table 2). Of the remaining four Leopards, which were not recaptured, two were males and two were females (Table 2). There was only a single capture of a male Leopard in the poor study habitat (Table 4).

During the camera trapping exercise, a total of nine Leopard sightings also occurred on eight occasions in the good study habitat and two were sighted in the poor study habitat (directly seen by the team) (Figure 2).

Leopard Abundance

The estimate for Leopard abundance for the good study habitat was 11 Leopards (SE4.6, 95% CI = 8 – 31 individuals). Due to the small sample size and sparse recaptures, M0 (null) was the only model that converged. Consequently, the estimate was associated with wide confidence intervals. In the poor study habitat due to the capture of only a single Leopard, analysis could not be performed. For both the good and poor study habitat the detection/capture probability was 0.15 (SE= 0.07, 95% CI= 0.05–0.35).

Details of pictures from camera traps

A total of 1,95,408 pictures were clicked during the camera trapping exercise, out of which 97,270 pictures were clicked in the good study habitat and 98,138 pictures were clicked in the poor study habitat. False trigger images were obtained in majority across both the study sites. Among carnivores, photos of Indian jackals (112) were the highest followed by those of Striped Hyena (26) (Table 5; Images 10–12).

Among prey species, chital (736+86) and cattle (194+141) were the most frequently detected on

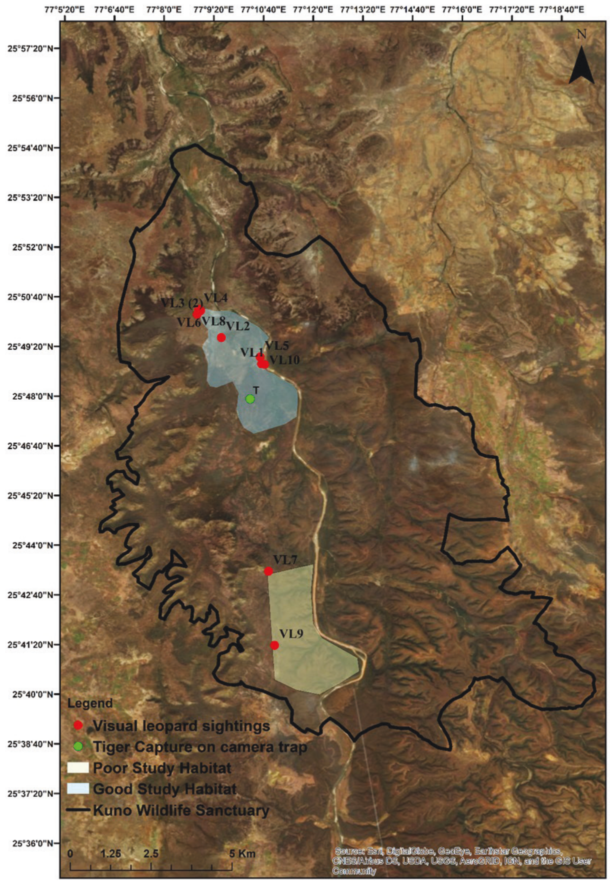

Figure 2. Locations of Leopards visually encountered during drives and on foot in Kuno Wildlife Sanctuary. In the map, L denotes Leopards and the number denotes the sighting number of the Leopard. The location of the camera trap on which the tiger was captured is also indicated in the map and is denoted by T.

the camera traps in both the good and the poor study habitats (Table 5; Images 10–12). Based on the locations of the camera traps and visual sightings in the good study habitat, chital numbers were concentrated around water holes, grassland and riverbank while cattle were concentrated around water holes and open forest habitats. In the poor study habitat, cattle were mostly concentrated in grasslands, open forests and hilly scrub forests, followed by chital which were concentrated around riverbanks.

Some of the rarer species detected by the camera traps included the sole known tiger in the sanctuary (Figure 2), a honey badger, an Asiatic Wildcat/Indian Desert Cat *Felis silvestris ornata* and a slightly darker morph of Jungle Cat *Felis chaus*, perhaps a male. A four feet long Marsh Crocodile *Crocodylus palustris* was also detected at a small stream, away from the Kuno River. The total number of times the animals were photographed support the distinction of the two study habitats into good and poor study habitats (Image 1), i.e., 22 species (mammals, reptiles and bird) yielded 1644 images in the good study habitat while, 23 species (mammals and bird) yielded 475 images in the poor study habitat (Table 5; Image 10).

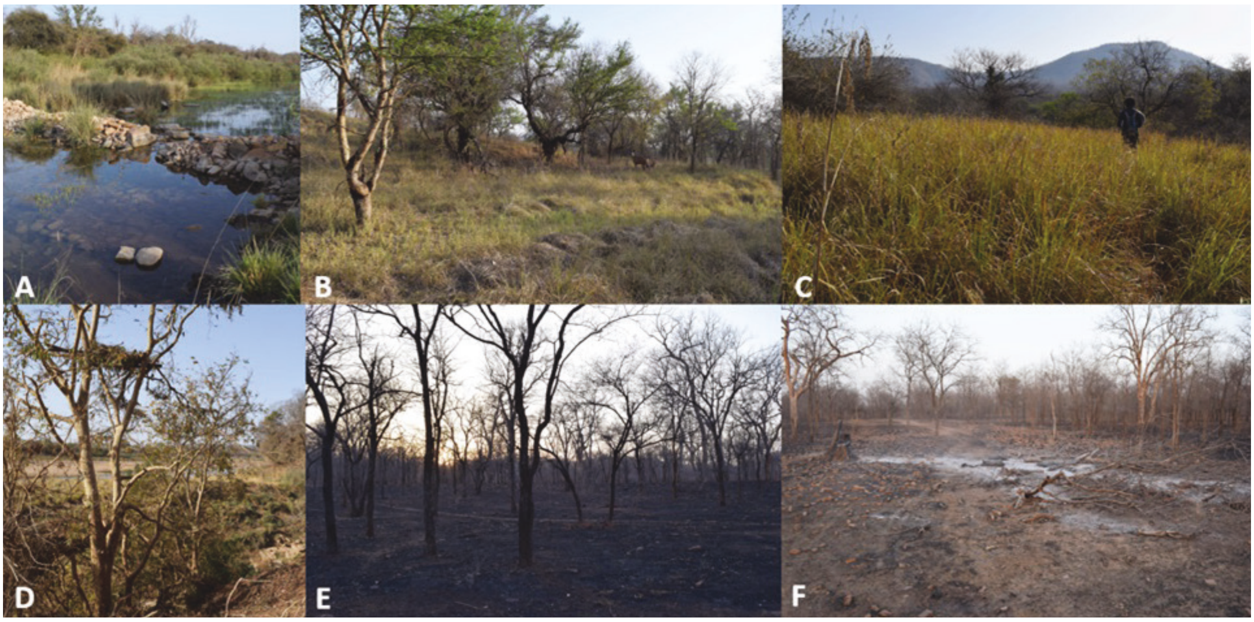

Image 1. Top panel shows representative images indicating the condition of the good study habitat with presence of water sources (A) and vegetation (B, C). On the other hand, the bottom panel shows representative images from the poor study habitat which showed signs of human activities such as the presence of a machan (tree-top platform made for animal observation) (D) and extensive forest fires (E, F).

Table 3. Identification of individual Leopards by Right, Left and both Right & Left Flanks in poor study habitat.

Leopard ID	Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Dates	9/04	10/04	11/04	12/04	13/04	14/04	15/04	16/04	17/04	18/04	19/04	20/04	21/04	22/04	23/04	24/04	25/04	26/04
Leopard 8 M		None	None	None	Left	None	None	None	None	None	None	None	None	None	None	None	None	None	None

Image 2.L1 M - male, captured in the good study habitat.

Image 4. L3 M - male, captured in the good study habitat.

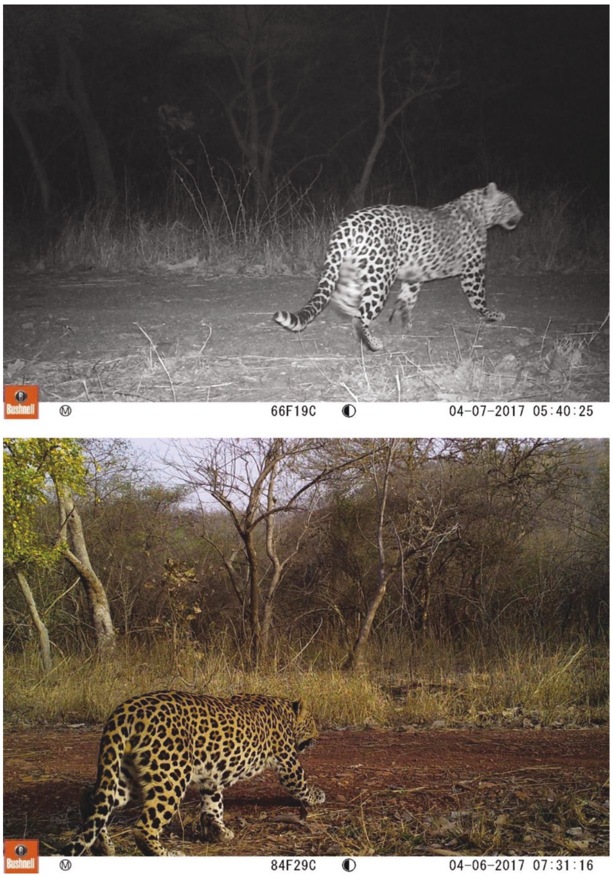

Image 3. L2 M - - male, captured in the good study habitat.

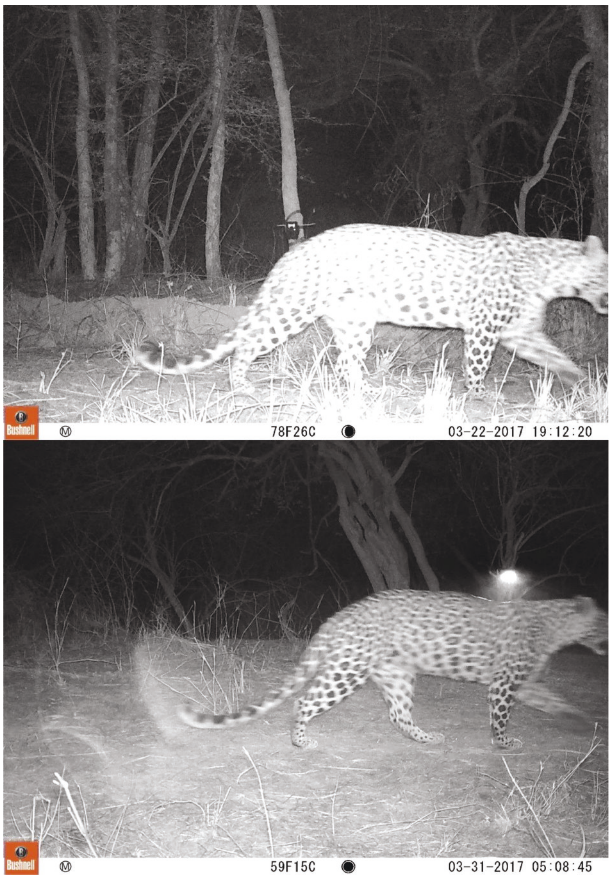

Image 5. L4 F - female, captured in the good study habitat.

Table 4. Showing capture–recapture history of individually identified, sex determined Leopards in poor study habitat.

Date	April 9 - April 14						April 15 -April 20						April 21 - April 26					
Day	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
L8 M	0	0	0	CA	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DISCUSSION AND CONCLUSION

In adjunct to previously unpublished work by the Forest Department of Madhya Pradesh, this study is the first on Leopard abundance in KWLS. Previous studies have focussed on estimating herbivore populations as prey available for future introduction of lions, and baseline population estimates of existing carnivore populations have remained unpublished (Johnsingh et al. 2007; Sharma et al. 2013).

To increase the probability of detection for all Leopards and to avoid violations of closure norms we sampled over six–day periods to cover the entire area chosen, and used a small size of observation units covered by each camera trap location – 1km² each and small inter-trap distances of around 2km (Hedges et al. 2015). However, a paucity of time, equipment and the adoption of an experimental design to interpret for the full area of KWLS limited the applicability of the capture–recapture computer modelling, leading to a high level of standard error. Despite these limitations, the present study revealed the number of Leopards inhabiting the study areas in KWLS along with indices of prey base. As shown in Table 1, seven individual Leopards were captured in the good study habitat and the estimate for Leopard abundance was found to be 11 ± 4.6 for an area of 15km^2. As shown in Table 3, only one Leopard was captured in the poor study habitat.

Previous studies provide estimates of abundance of 16 ± 6.85 Leopards in an area of 68km^2 in Sariska National Park (Chauhan et al. 2005), 35.60 ± 5.50 in an area of 500km^2 in Manas National Park (Borah et al. 2014) and 35.59 + 0.51 in an area of 140km^2 in Sanjay Gandhi National Park (Surve 2015). The Leopard estimate (11 ± 4.6) in the present study in 15km^2 of KWLS appears high, which might be due to the absence of other predators such as tigers and dholes/wild dogs *Cuon alpinus* (Chauhan et al. 2005; Edgaonkar 2008).

During the study, only one tiger was captured on a single camera trap in the good study habitat. Throughout the duration of the study, no other tiger captures were recorded and thus it is possible that the captured tiger's movement was transient in the area. Additionally, the relatively high Leopard abundance suggests that the presence of the tiger did not affect the presence of Leopards in the good study habitat based on the visual sightings of Leopards and the number of camera trap captures of the Leopard (Figure 2; Table 5).

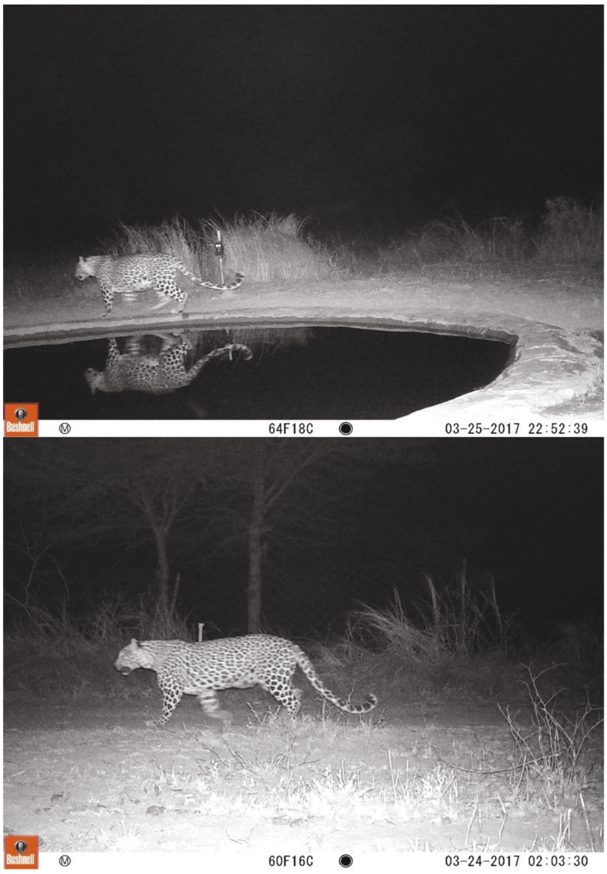

Image 6. L5 F - female, captured in the good study habitat.

The prey base photos captured in the study support the reflection in this study on Leopard abundance in KWLS. The high captures of Leopards in the good study habitat could have been influenced due to the presence of a large number of chital (736) and feral cattle (194) (Table 5). The number of feral cattle (141) in the poor habitat was about 73% that of the good habitat, but the number of chital (86) was significantly low, only 12% of the good habitat (Table 5). Low prey base in the poor habitat may have attributed to the reduced captures of Leopard. According to a previous study, chital and cattle are a part of Leopard's diet (Ramesh 2010; Forest

Image 7. L6 F - female, captured in the good study habitat.

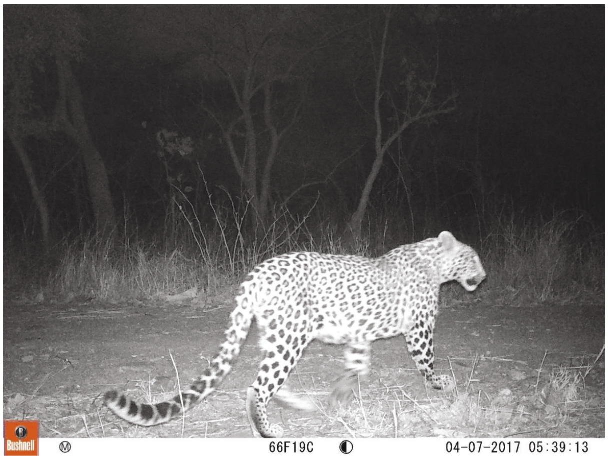

Image 8. L7 F - female, captured in the good study habitat.

Image 9. L8 M- male, captured in the poor study habitat.

Table 5. The numbers of pictures obtained for varying species from the camera trapping study in Kuno Wildlife Sanctuary.

	Species captured	Good habitat area (21/03/2017 to 8/04/2017 - 18 days)	Poor habitat area (09/04/2017 to 27/04/2017 - 18 days)	Total Captures
		Number of Pictures	Number of pictures	
1	Leopard	12	1	13
2	Tiger	2	0	2
3	Cattle	194	141	335
4	Asian Palm Civet	1	7	8
5	Asiatic Wild Cat	0	1	1
6	Bengal Fox	6	18	24
7	Blue Bull	62	11	73
8	Chinkara	7	0	7
9	Chital Deer	736	86	822
10	Feral Dog	0	1	1
11	Four Horned Antelope	1	5	6
12	Gray Langur	21	63	84
13	Honey Badger	2	3	5
14	Indian Boar	118	20	138
15	Indian Crested Porcupine	21	9	30
16	Indian Grey Mongoose	1	0	1
17	Indian Hare	61	3	64
18	Indian Jackal	88	24	112
19	Jungle cat	17	20	37
20	Rhesus Macaque	0	2	2
21	Ruddy Mongoose	0	3	3
22	Sambar Deer	42	21	63
23	Sloth Bear	0	3	3
24	Small Indian Civet	15	10	25
25	Striped Hyena	21	5	26
26	Indian Peafowl	214	18	232
27	Marsh Crocodile	2	0	2
	Total	**1644**	**475**	**2119**

department of KWLS). In the poor habitat, the number of cattle were the highest compared to the other species, which may be due to increased human activity in this area.

The dry summer season, human activities (Image 1) and extensive forest fire noticed during the study may have resulted in outflux of the prey animals from the poor study habitat into the good study habitat, and subsequently movement of Leopards to the good area.

As the study was conducted during summer, the high temperatures of 40° C - 44° C may have influenced the movement of the animals towards the water sources, as a result in both the good and poor study habitats, the highest numbers of animals were recorded in association with water.

The goal of this study was to provide baseline population data for the Leopards in KWLS, thereby providing a useful starting point for future studies. Since KWLS has been considered at different times for possible reintroduction of Asiatic lion and Cheetah (Johnsingh et al. 2007, Ranjitsinh & Jhala 2010), it was important to understand the existing profile of carnivores and prey base of the sanctuary. Future studies may lead to better understanding of predator-prey coexistence, competition interfaces, behaviour and prey selection in the context of their distribution and abundance in KWLS.

There is rapid evolution and adoption of methods of estimating occurrence, abundance, densities and associated behavioural-patterns of cryptic carnivores (Singh 1999; Karanth & Sunquist 2000b; Sharma et al. 2001; Wang & Macdonald 2009; Jhala et al. 2011). Advances in camera trapping equipment, theory, computer modelling, softwares and analysis tools (e.g., via Mark, Capture, R, etc.), have led to increased accuracy, replicability and comparability in data obtained from various locations and time frames (Otis et al. 1978; Pollock et al. 1990; Karanth & Nichols 1998, 2000). O'Brien et al. (2003) were the first to demonstrate that the relative abundance of tigers and their prey, as measured by camera traps, is directly related to independently derived estimates of densities for these species. However, challenges remain.

The current study was limited by financial and logistical constraints and the loss of two cameras towards the end of the study due to theft and damage by wildlife. Despite these limitations we expect that the present study provides a baseline. It is suggested that future studies may deploy a substantial number of cameras and allow for a large number of detections in an extensive area over prolonged periods of time repeated in different seasons to discern long-term trends.

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Author contribution: DP - contributed to the study initiation, study conception and design, data collection, monitoring study progress, choice of analytic strategy, manuscript preparation, critical revisions for intellectual content and final manuscript approval. HPN - Contributed to monitoring study progress, choice of analytic strategy, manuscript preparation, critical revisions for intellectual content and final manuscript approval. DRLP - Contributed to monitoring study progress, data analysis, manuscript preparation, critical revisions for intellectual content and final manuscript approval. SK - Contributed to monitoring study progress, data collection, manuscript preparation, and final manuscript approval.

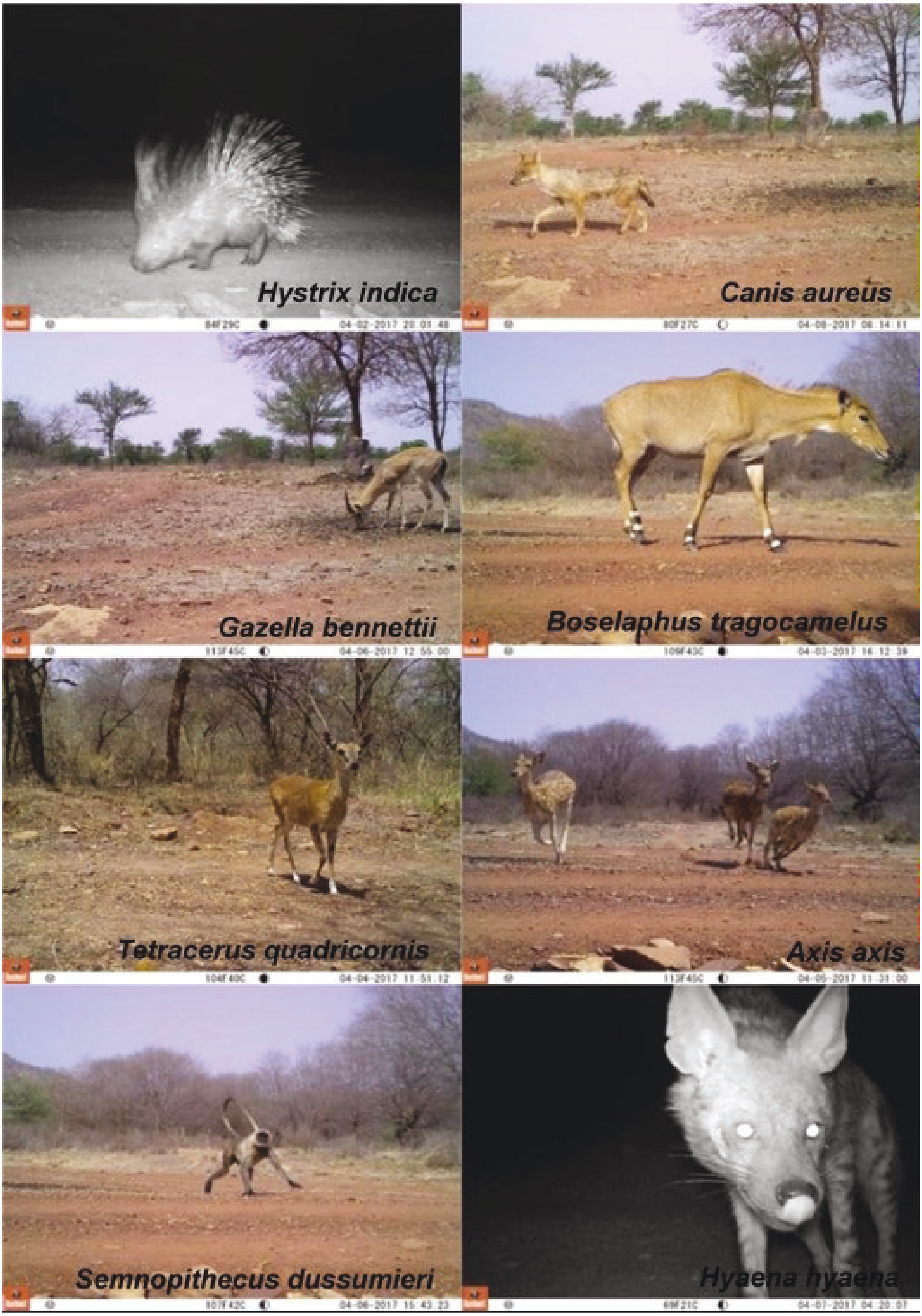

Image 10. Other species recorded from the camera trapping study in Kuno Wildlife Sanctuary.

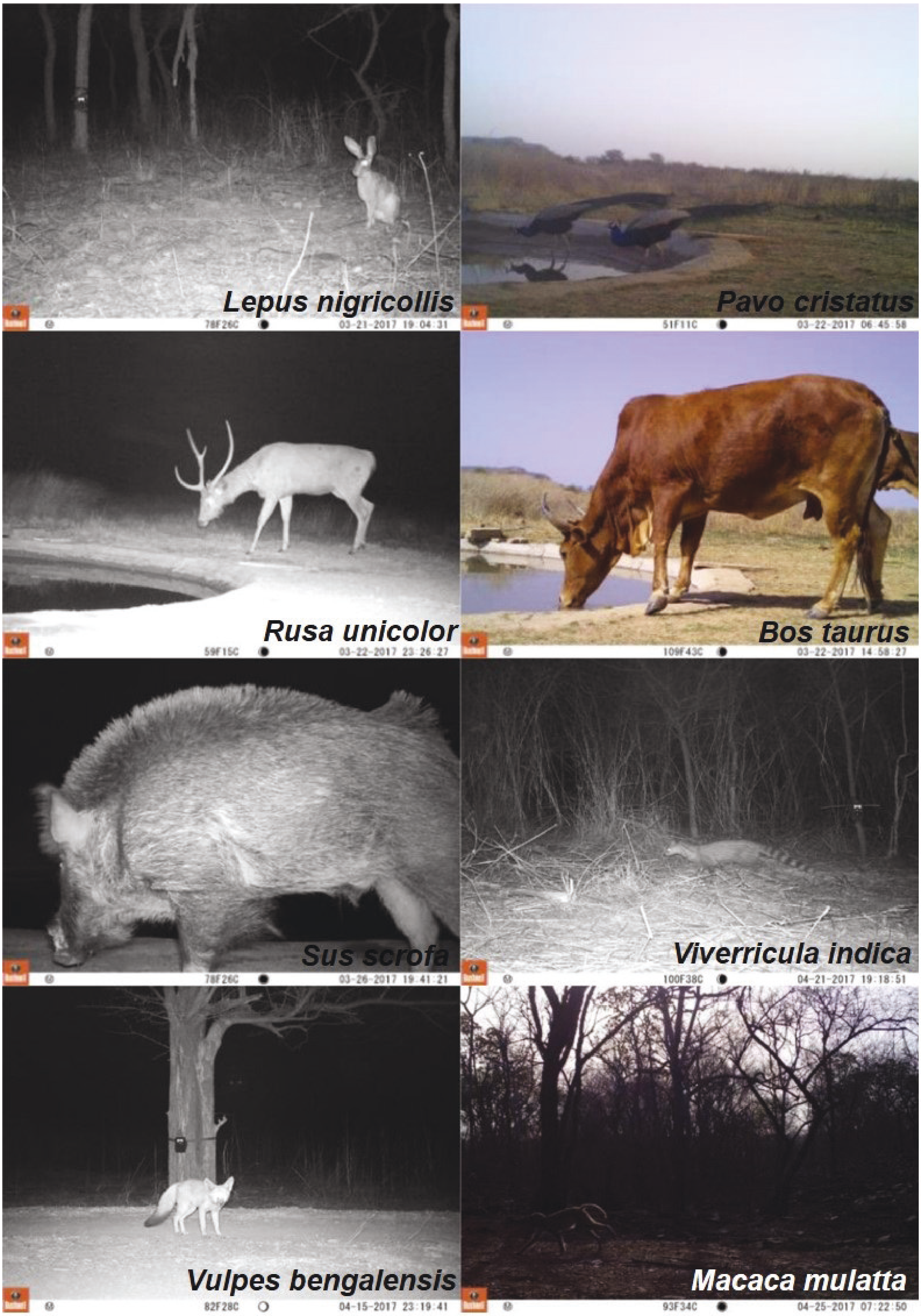

Image 11. Other species recorded from the camera trapping study in Kuno Wildlife Sanctuary.

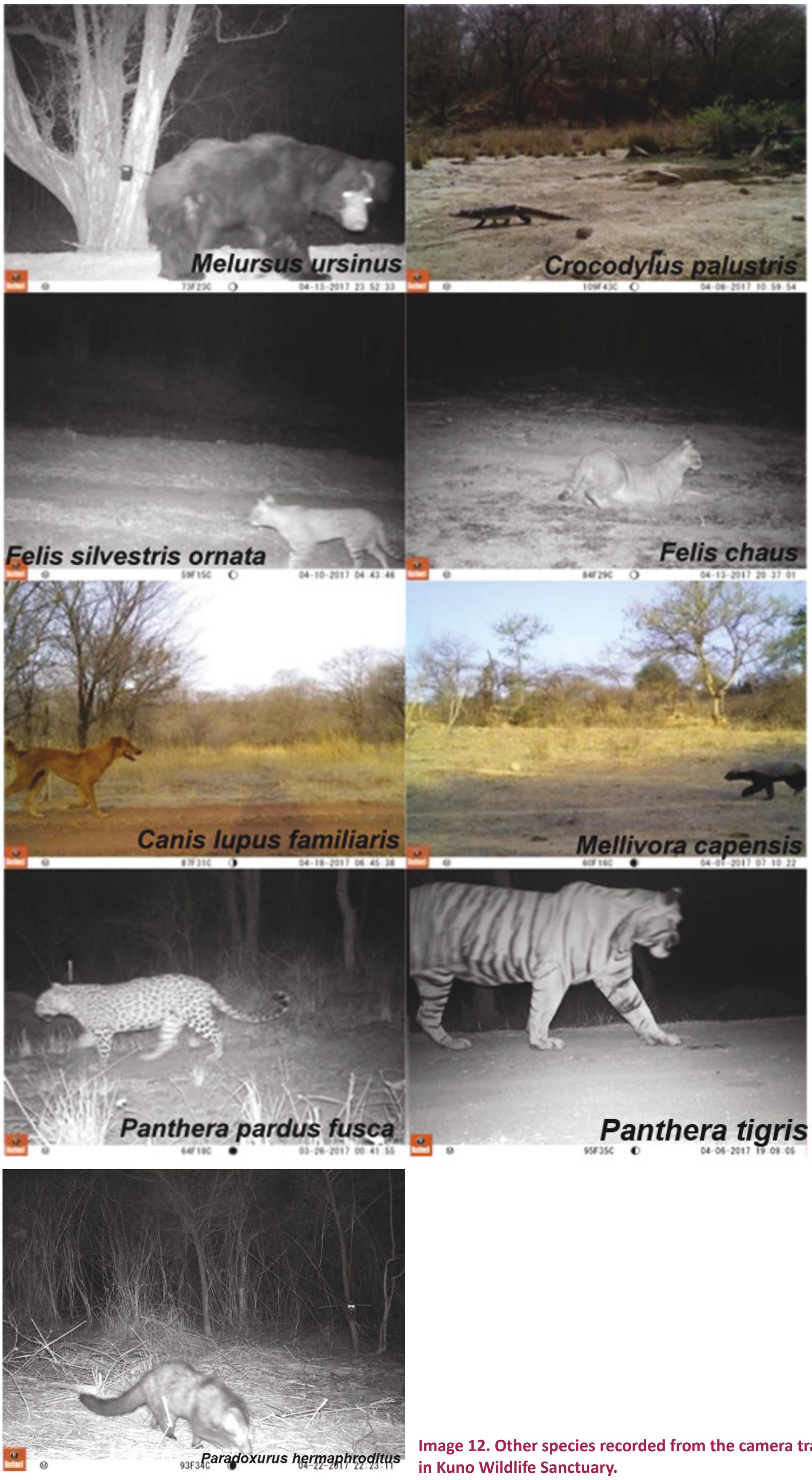

Image 12. Other species recorded from the camera trapping study in Kuno Wildlife Sanctuary.

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