Camera trapping of large mammals in Chhep Wildlife Sanctuary, northern Cambodia

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មូលន័យសង្ខេប

ដែនជម្រកសត្វព្រៃឆែបស្ថិតនៅភាគខាងជើងនៃប្រទេសកម្ពុជា សម្បូរដោយព្រៃរបោះ (DDF) យ៉ាងធំសម្បើម។ ការសង្កេតដោយម៉ាស៊ីនថតស្វ័យប្រវត្តិត្រូវបានធ្វើឡើងនៅក្នុងដែនជម្រក ក្នុងរយៈពេលពីររដូវប្រាំងបន្តបន្ទាប់គ្នាគឺ ឆ្នាំ២០១២ ដល់ ២០១៣ និង ២០១៣ ដល់ ២០១៤។ លទ្ធផលបានពីការដាក់ម៉ាស៊ីនថតស្វ័យប្រវត្តិ ៧៤៨៣យប់ ទទួលបានកំណត់ត្រា ៣៧៦៧ នៃថនិកសត្វធំ ៣០ប្រភេទ។ លទ្ធផលរបស់យើងបញ្ជាក់ពីភាពបន្តមាននៃថនិកសត្វធំក្នុងព្រៃរបោះមានដូចជា រមាំង(*Rucervus eldii*) ទន្សោង (*Bos javanicus*) និងឆ្មាព្រៃ(*Felis chaus*)។ សំខាន់ជាងនេះទៅទៀតគឺវត្តមានសំពោចធំ(*Viverra megaspila*) ជាប្រភេទរងគ្រោះជាសកល តែរូបថតរបស់វាត្រូវឃើញច្រើនលំដាប់ទី៤ ក្នុងចំណោមប្រភេទទាំងអស់នៅក្នុងដែនជម្រក។ នេះបង្ហាញពីសារៈសំខាន់ជាសកលនៃដែនជម្រកសត្វព្រៃឆែប សម្រាប់ការអភិរក្សក្រុមថនិកសត្វក្នុងដែនទេសភាពសម្បូរព្រៃរបោះទំនាប តែជាការពិតព្រៃរបោះនិងព្រៃទំនាបមិនត្រូវដាក់ជាតំបន់ការពារគ្រប់គ្រាន់នៅឡើយនៅអាស៊ីអាគ្នេយ៍ដីគោក។

Abstract

Chhep Wildlife Sanctuary in northern Cambodia comprises a large tract of deciduous dipterocarp forest (DDF). A camera trap survey was conducted in the wildlife sanctuary during two successive dry seasons, 2012–2013 and 2013–2014. A total of 7,483 camera-trap-nights yielded 3,787 records of 30 large mammal species. Our results confirm the continued occurrence of DDF-associated large mammals such as Eld's deer *Rucervus eldii*, banteng *Bos javanicus*, and jungle cat *Felis chaus*. Importantly, large-spotted civet *Viverra megaspila*, a globally Endangered species, was the fourth-most commonly photographed species in the wildlife sanctuary. This highlights the global significance of Chhep Wildlife Sanctuary for conservation of mammal assemblages in a lowland DDF-dominated landscape, given that DDF and lowland forests are under-represented by protected areas in mainland Southeast Asia.

Keywords

Carnivores, deciduous dipterocarp forest, large-spotted civet, Preah Vihear Protected Forest, semi-evergreen forest, *Viverra megaspila*.

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Introduction

Large areas of seasonally dry forest have disappeared across continental Southeast Asia and <10% of remaining deciduous dipterocarp forest (hereafter DDF) is in protected areas (McShea *et al.*, 2005). In Thailand, DDF is under-represented in protected areas (Tantipisanuh & Gale 2013) and experienced 4.44% of annual tree cover losses between 2000 and 2012 (Johnson, 2015). Similarly, in Myanmar, Laos, and Vietnam, DDF has received limited protection (Wohlfart *et al.*, 2014). In Cambodia, the large areas of DDF in the north and east of the country have received relatively better protection (Wohlfart *et al.*, 2014).

Chhep Wildlife Sanctuary, formerly Preah Vihear Protected Forest, is a protected area containing part of the largest contiguous tract of DDF in the northern plains of Cambodia. The wildlife sanctuary supports globally threatened species associated with DDF, such as Eld's deer *Rucervus eldii* (McShea *et al.*, 2005; Owen, 2009; McShea & Baker, 2011) and giant ibis *Thaumatibis gigantea* (BirdLife International, 2016). Despite its importance, ecological information on large mammals is limited in the landscape. This study aims to document records of large ground-dwelling mammals in Chhep Wildlife Sanctuary from intensive camera trapping surveys.

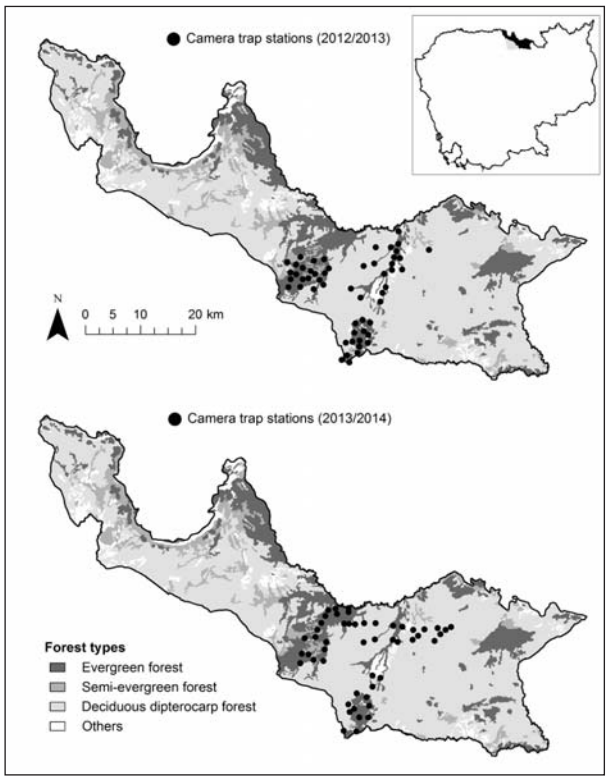

Fig. 1 Vegetation within Chhep Wildlife Sanctuary (Forestry Administration, 2010), and camera trap stations in the 2012–2013 (upper) and 2013–2014 (lower) dry seasons. Upper right: the location of Chhep Wildlife Sanctuary (black area) and Preah Roka Wildlife Sanctuary (grey area) in Cambodia.

Methods

Study area

Chhep Wildlife Sanctuary is located in northern Preah Vihear Province, and borders Thailand and Laos (Fig. 1). The southwestern part of the wildlife sanctuary is contiguous with Preah Roka Wildlife Sanctuary which forms a corridor between Chhep Wildlife Sanctuary and Kulen Promtep Wildlife Sanctuary. Chhep Wildlife Sanctuary covers 1,900.27 km^2 and comprises three main forest types: DDF (66.9%), evergreen forest (18.8%), and semi-evergreen forest (9.6%) (Forestry Administration, 2010) (Fig. 1). The wildlife sanctuary also contains smaller areas of seasonally-flooded grasslands, bamboo forests, seasonally-flooded riparian habitats and a network of temporary and permanent forest pools and streams.

Data collection

Our survey was conducted over two successive dry seasons from 2012 to 2014. Surveys during the wet season were not possible due to logistical and financial constraints. The purpose of the survey in the 2012–2013 dry season was to investigate the presence of carnivores as a part of feasibility study to determine future research targets among four carnivores: large-spotted civet *Viverra megaspila*, large Indian civet *Viverra zibetha*, leopard cat *Prionailurus bengalensis*, and jungle cat *Felis chaus*. Passive infrared digital cameras were mainly set on animal trails, footpaths, motorbike tracks and waterways in semi-evergreen forest, evergreen forest, and DDF, under the assumption this would maximize detection of these species. At other sites, the two *Viverra* species were frequently recorded from cameras set in such areas (Gray *et al.*, 2010) and leopard cats showed higher detectability along roads than off-trail locations (Sollomann *et al.*, 2013). Compared with these species, records of jungle cat in Indochina are very limited, but scats have mostly been found on roads, trails, and dry river beds in India (Majumder *et al.*, 2011), suggesting the species uses trails. Due to camera malfunctions, sampling efforts in DDF were limited and a total of 49 camera stations were set in the 2012–2013 dry season. Cameras were mounted approximately 30–50 cm above ground on trees at least 1 km apart and set to operate for 24 hours each day. No stations were baited.

In the 2013–2014 dry season, the survey purpose was to understand occupancy patterns of civets of the subfamily Viverrinae. A total of 53 camera stations were set and as six of these were <50 m from stations set in the previous season, they were considered the same stations in analysis. Camera placement was similar to the 2012–2013 dry season, except that more sampling effort was undertaken in DDF. Both survey periods employed trail-based sampling, which biases measurements of relative abundance (Sollmann *et al.*, 2013; Wearn *et al.*, 2013) and probably fails to detect large mammals that use off-trail areas (Blake & Mosquera, 2014). In terms of species detected, however, trail-based sampling is less likely to differ from random sampling where sampling efforts exceed 1,400 camera-trap-nights, especially during the dry season (Cusack *et al.*, 2015). Recognising the limitations of our non-random sampling approach, we consequently documented where species were detected and did not consider their relative abundances or compare levels of species richness with other sites.

Species identification

Species identifications employed the nomenclature of Wilson & Mittermeier (2009) for carnivores and Francis & Barrett (2008) for other species, and incorporated the taxonomic revisions of IUCN (2017). Because the survey targeted large non-volant mammals, small mammals such as treeshrews and most rodents were excluded (although porcupines were included). Species identifications for some mammals were unclear. For instance, though the presence of large-toothed ferret badger *Melogale personata* has been documented in Cambodia, it cannot be assumed that all ferret badgers recorded in the country represent this species (Schank *et al.*, 2009). Second, Meijaard & Groves (2004) suggest chevrotains (*Tragulus*) in Cambodia could be *T. kanchil affinis*, but Gray *et al.* (2012) cautiously identified *Tragulus* only to genus level in the eastern plains, which is bordered by Vietnam and close to where the silver-backed chevrotain *T. versicolor* occurs (Meijaard & Groves, 2004). In this study, all photographs of *Tragulus* were assigned to *T. kanchil*. Third, hybrid individuals of crab-eating macaque *Macaca fascicularis* and rhesus macaque *M. mulatta* have been reported in northeastern Cambodia (Heng *et al.*, 2010). The best feature for identifying these species is relative tail length, this being >90% for *M. fascicularis*, <60% for *M. mulatta*, and between these figures for hybrid individuals (Heng *et al.*, 2010). Because relative tail length could not be determined confidently from photographs, however, all macaques with characters similar to *M. fascicularis* were assigned to this species.

Data analysis

Because Yasuda (2004) found a large number of camera trap photographs of the same species occurred less than one minute after the first photograph and reached a plateau after 30 minutes, we defined a camera trap record as an independent record if it occurred at least 30 minutes after a photograph of the same species at a given station. Total sampling effort is expressed as the total number of camera-trap-nights, one camera-trap-night being defined as a continuous 24 hr period of normal camera operation. Records of large mammals in the two dry seasons are expressed as the proportion of camera stations where species were detected at least once (naïve occupancy), and encounter rates were calculated as the number of records / 1,000 camera-trap-nights.

Detection of large mammals within each forest type was calculated as a percentage, namely the number of stations where a species was detected in the forest type divided by the total number of stations which detected the species. Forest types at each camera trap station were determined by calculating the proportion of dominant forest types within a 500 m buffer area around each camera station using ArcGIS. Classification of forest types followed Forestry Administration (2011). Although this classification has limited accuracy, observations of forest types at camera trap stations suggested it is suitable for indicative purposes. Of the 53 camera trap stations set during the 2013–2014 season, 42 stations matched DDF, semi-evergreen forest or evergreen forest. However, difficulties were experienced in distinguishing between evergreen and semi-evergreen forest because 21 of 23 stations identified as being located in evergreen forest by FA (2011) were observed to be semi-evergreen forest in the field. We therefore adopt "semi-evergreen and evergreen forest" (hereafter S/EGF) as a combined forest category. When a dominant forest type comprised >70% of a buffer zone, the station was defined as either deciduous dipterocarp forest (DDF) or semi-evergreen and evergreen forest (S/EGF). When both forest types occurred in the 500 m buffer zone, the location was defined as a mosaic of DDF and S/EGF. Another limitation of the FA classification was that nine stations in small areas of semi-evergreen forest were broadly identified as DDF. Buffer analysis helped to determine that two of these were not in DDF but in a mosaic of DDF and S/EGF; however, seven camera stations remained in error.

Activity patterns for four daily periods (dawn, day, dusk, and night) were examined for species with >20 records. Local sunset and sunrise times during the survey were obtained from the US Department of Commerce, National Oceanic and Atmospheric Administration (http://www.esri.noaa.gov/). During the survey period,

sunrise varied from 05:55 to 06:30 hrs and sunset from 17:29 to 18:11 hrs. Dawn was defined as the period from 05:00 to 07:00 hrs and dusk from 17:00 to 19:00 hrs.

Results

Thirty large mammal species were detected over the course of the two dry season surveys (Table 1). Asiatic black bears *Ursus thibetanus*, Sunda pangolins *Manis javanica*, and Indochinese silvered langurs *Trachypithecus germaini* were detected only in the 2012–2013 dry season while Eld's deer were recorded only in the 2013–2014 dry season (Fig. 2).

Survey effort during the 2012–2013 dry season was 2,370 camera-trap-nights and produced 1,198 records of confidently identified species (Table 1). Twenty-nine species representing seven orders were recorded, including, per IUCN (2017), one Critically Endangered species (Sunda pangolin *Manis javanica*) and six Endangered species including Asian elephant *Elephas maximus* (Fig. 2). The three most commonly photographed species were common palm civet *Paradoxurus hermaphroditus*, Eurasian wild pig *Sus scrofa*, and red muntjac *Muntiacus muntjak*.

Survey effort during the 2013–2014 dry season was 5,113 camera-trap-nights and produced 2,589 records of 27 confidently identified species (Table 1). The three most commonly photographed species were golden jackal *Canis aureus*, Eurasian wild pig and common palm civet.

Species occurrence and activity patterns

Of the 21 mammal species detected at more than five camera trap stations, five (leopard *Panthera pardus*, lesser Oriental chevrotain *Tragulus kanchil*, gaur *Bos gaurus*, northern pig-tailed macaque *Macaca leonina*, and Asian elephant) were almost exclusively detected in S/EGF (Table 2). Large Indian civets were detected at 31 stations, only one of which was in DDF. Conversely, jungle cats were not detected in S/EGF, but only in DDF or a mosaic of DDF and S/EGF.

Activity patterns of species with >20 records are shown in Fig. 3. Eleven species (comprising seven carnivores, two ungulates, Burmese hare *Lepus peguensis* and Malayan porcupine *Hystrix brachyura*) exhibited nocturnal patterns of activity, whereas five (two carnivores, one ungulate and two primates) exhibited diurnal patterns and lesser Oriental chevrotain showed crepuscular activity.

Discussion

Our results provide preliminary information on large mammal communities during the dry season in Chhep Wildlife Sanctuary. Over two successive dry seasons, 30 large mammal species were detected including one Critically Endangered species and six Endangered taxa per IUCN (2017). This confirms the conservation importance of the sanctuary and our records, particularly those of two DDF-associated Endangered species—banteng *Bos javanicus* and Eld's deer—highlight its significance in light of the under-representation of DDF in protected areas in Indochina.

Tordoff *et al.* (2005) emphasized the importance of semi-evergreen forest in DDF landscapes in Indochina. Our findings corroborate this: 27 of the 30 species we detected were recorded by at least one station in S/EGF. Though we are unable to infer species habitat preferences due to sampling bias, these clearly use S/EGF despite its relatively small extent, at least in the dry season. In particular, leopards, lesser Oriental chevrotains, northern pig-tailed macaques, and Asian elephants were almost exclusively detected in S/EGF, with no records in DDF. Though our data are confined to the dry season and further work is required to determine seasonal movements of large mammals in the wildlife sanctuary, it is possible that some species may use S/EGF seasonally or much less during the wet season. In Thailand, banteng use dry evergreen forests in the day during the dry season, especially in the late dry season whereas they remain in DDF throughout the day in the wet season (Bhumpakphan & McShea, 2011; N. Bhumpakphan pers. comm.). Similarly, large Indian civets were observed shifting the centre of their home range from mixed deciduous forest to evergreen forest in the early dry season, and small Indian civets were observed shifting from DDF to evergreen forest in the late dry season (Rabinowitz, 1991).

Carnivores

Our data confirms the occurrence of 16 carnivore species at Chhep Wildlife Sanctuary. Bears and leopards were recorded less frequently and only in S/EGF. The latter is somewhat surprising as leopards were recorded at approximately 70% of the camera trap stations in DDF in the eastern plains of Cambodia (Gray *et al.*, 2012) where un-baited camera trap pairs were spaced approximately 2–3 km apart along roads, trails, animal paths and ridgelines in mixed habitat types, with the highest proportion in DDF (R. Crouthers, per. comm.). Other studies in Indochina, where DDF persists, have also not found a strong association of leopards with evergreen forests and semi-evergreen forest (Simcharoen *et al.*, 2008; Gray

Table 1 Records of large mammals in Chhep Wildlife Sanctuary during the 2012–2013 and 2013–2014 dry seasons. IUCN status: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Concern. ND = Not detected.

Species	IUCN status	2012–2013 dry season		2013–2014 dry season	
		Naïve occupancy[1]	Encounter rate[2]	Naïve occupancy[1]	Encounter rate[2]
Golden jackal *Canis aureus*	LC	0.26	23.63	0.61	84.88
Dhole *Cuon alpinus*	EN	0.02	0.42	0.02	0.20
Jungle cat *Felis chaus*	LC	0.06	1.69	0.11	2.74
Clouded leopard *Neofelis nebulosa*	VU	0.02	0.42	0.03	0.39
Leopard *Panthera pardus*	VU	0.06	2.95	0.06	1.56
Leopard cat *Prionailurus bengalensis*	LC	0.22	9.28	0.35	9.97
Small Asian mongoose *Herpestes javanicus*	LC	0.02	2.11	0.03	0.39
Crab-eating mongoose *Herpestes urva*	LC	0.22	14.77	0.26	13.69
Yellow-throated marten *Martes flavigula*	LC	0.10	2.11	0.19	4.11
Ferret badger *Melogale* sp.	LC	0.12	6.75	0.13	6.45
Sun bear *Helarctos malayanus*	VU	0.02	0.42	0.02	0.20
Asiatic black bear *Ursus thibetanus*	VU	0.02	0.42	ND	ND
Common palm civet *Paradoxurus hermaphroditus*	LC	0.66	81.01	0.69	61.22
Large-spotted civet *Viverra megaspila*	EN	0.44	62.45	0.56	59.07
Large Indian civet *Viverra zibetha*	LC	0.28	10.97	0.37	24.84
Small Indian civet *Viverricula indica*	LC	0.24	14.77	0.37	39.31
Gaur *Bos gaurus*	VU	0.08	1.69	0.05	1.76
Banteng *Bos javanicus*	EN	0.04	0.84	0.02	0.20
Sambar *Rusa unicolor*	VU	0.24	6.75	0.19	4.69
Eld's deer *Rucervus eldii*	EN	ND	ND	0.02	0.20
Red muntjac *Muntiacus muntjac*	LC	0.70	64.14	0.76	35.60
Eurasian wild pig *Sus scrofa*	LC	0.80	80.59	0.87	68.06
Lesser Oriental chevrotain *Tragulus kanchil*	LC	0.22	27.85	0.19	11.34
Burmese hare *Lepus peguensis*	LC	0.10	7.59	0.23	35.79
Sunda pangolin *Manis javanica*	CR	0.02	0.42	ND	ND
Crab-eating macaque *Macaca fascicularis*	LC	0.38	20.68	0.29	15.84
Northern pig-tailed macaque *Macaca leonina*	VU	0.26	18.99	0.26	9.00
Indochinese silvered langur *Trachypithecus germaini*	EN	0.06	1.27	ND	ND
Asian elephant *Elephas maximus*	EN	0.04	3.38	0.06	0.98
Malayan porcupine *Hystrix brachyura*	LC	0.36	37.13	0.27	13.89

[1] Proportion of stations a species was detected at least once; [2] Number of records / 1,000 camera-trap-nights.

& Phan, 2011; Gray, 2012). Although sampling effort in DDF increased during the second survey period at Chhep Wildlife Sanctuary, leopards were not detected there or at stations in mosaics of DDF and S/EGF. Lower detectability in DDF is unlikely to be the only plausible explanation and it may be that leopards occur at relatively low densities in the wildlife sanctuary. Severe declines have occurred in leopard populations across Indochina (Rostro-García *et al.*, 2016), and Chhep is unlikely to be an exception. The reasons for this decline are many, but hunting for external markets has played a role, at least in the 1990s (Loucks *et al.*, 2009). According to a hunter living near Chhep Wildlife Sanctuary, a leopard body was previously sold to a middleman for its skin and bones for about 200 USD. Bears were also were in demand. The gall bladder and bones of each Asiatic black bear sold for ca.

Table 2 Percentage of camera trap stations in three forest types where mammal species were recorded in Chhep Wildlife Sanctuary during the 2012–2013 and 2013–2014 dry seasons.

Species	No. of stations detected	DDF (n=28)[1]	S/EGF (n=43)[1]	DDF & S/EGF mosaic (n=19)[1]
Golden jackal *Canis aureus*	44	40.91	34.09	25.00
Dhole *Cuon alpinus*	2	50.00	50.00	0.00
Jungle cat *Felis chaus*	8	87.50	0.00	12.50
Clouded leopard *Neofelis nebulosa*	3	0.00	66.67	33.33
Leopard *Panthera pardus*	6	0.00	100.00	0.00
Leopard cat *Prionailurus bengalensis*	31	32.26	38.71	29.03
Small Asian mongoose *Herpestes javanicus*	3	66.67	33.33	0.00
Crab-eating mongoose *Herpestes urva*	24	25.00	42.00	33.00
Yellow-throated marten *Martes flavigula*	17	41.18	29.41	29.41
Ferret badger *Melogale* sp.	14	42.86	28.57	28.57
Sun bear *Helarctos malayanus*	2	0.00	100.00	0.00
Asiatic black bear *Ursus thibetanus*	1	0.00	100.00	0.00
Common palm civet *Paradoxurus hermaphroditus*	71	27.78	45.00	25.00
Large-spotted civet *Viverra megaspila*	52	42.31	25.00	30.77
Large Indian civet *Viverra zibetha*	31	3.13	74.00	23.00
Small Indian civet *Viverricula indica*	32	50.00	28.13	18.75
Gaur *Bos gaurus*	7	14.29	71.43	14.29
Banteng *Bos javanicus*	2	50.00	0.00	50.00
Sambar *Rusa unicolor*	23	21.74	52.17	26.09
Eld's deer *Rucervus eldii*	1	100.00	0.00	0.00
Red muntjac *Muntiacus muntjac*	76	31.58	46.05	21.05
Eurasian wild pig *Sus scrofa*	85	31.00	46.00	22.00
Lesser Oriental chevrotain *Tragulus kanchil*	20	0.00	90.00	10.00
Burmese hare *Lepus peguensis*	18	55.56	11.11	27.78
Sunda pangolin *Manis javanica*	1	0.00	100.00	0.00
Crab-eating macaque *Macaca fascicularis*	37	18.92	48.65	29.73
Northern pig-tailed macaque *Macaca leonina*	26	0.00	76.92	23.08
Indochinese silvered langur *Trachypithecus germaini*	3	33.33	33.33	33.33
Asian elephant *Elephas maximus*	6	0.00	83.33	16.67
Malayan porcupine *Hystrix brachyura*	32	12.12	60.61	27.27

[1] n = Number of camera trap stations. Stations used in both dry seasons are counted as one.

100 USD and those of sun bear were sold for 30 USD in the 1990s. Near the Thailand border in 1994, prices for these species were 140 USD for a leopard skin, 3.20 USD/kg for sun bear bones, and 80 USD for gall bladders from unidentified bears (Martin & Phipps, 1996).

Besides the leopard, three medium or small cat species were recorded in Chhep Wildlife Sanctuary: clouded leopard *Neofelis nebulosa*, jungle cat, and leopard cat. Clouded leopards were recorded at three stations including the edge of riverine forests and a juvenile was photographed in S/EGF. Leopard cats were recorded in all forest types, and a kitten with an adult was recorded in late December. The latter species (n=73) exhibited nocturnal (53.4%) and crepuscular (30.1%) behaviour in our study (Fig. 3) and its activity pattern varies from

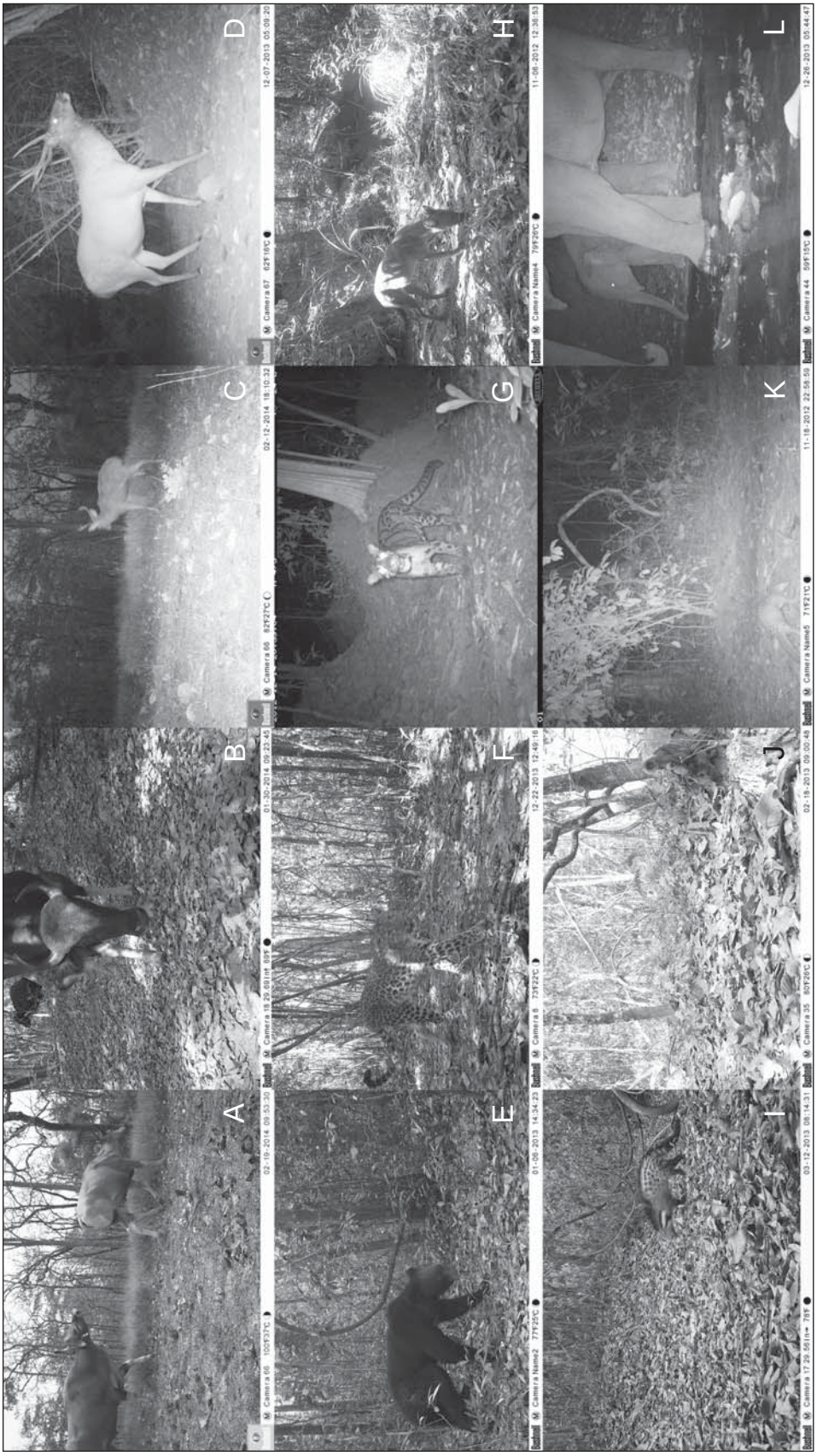

Fig. 2 Mammal species recorded during the 2012–2013 and 2013–2014 dry seasons in Chhep Wildlife Sanctuary. A) Banteng *Bos javanicus*; B) Gaur *Bos gaurus*; C) Eld's deer *Rucervus eldii*; D) Sambar *Rusa unicolor*; E) Asiatic black bear *Ursus thibetanus*; F) Leopard *Panthera pardus*; G) Clouded leopard *Neofelis nebulosa*; H) Dhole *Cuon alpinus*; I) Large-spotted civet *Viverra megaspila*; J) Indochinese silvered langur *Trachypithecus germaini*; K) Sunda pangolin *Manis javanica*; L) Asian elephant *Elephas maximus*.

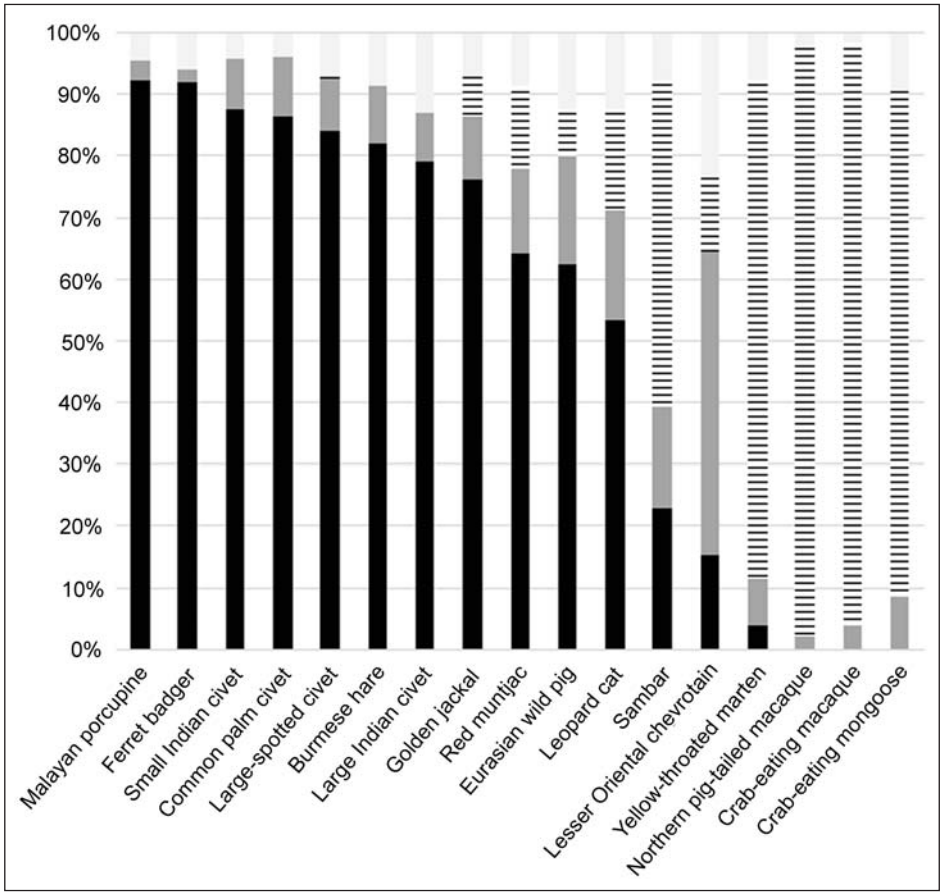

Fig. 3 Activity patterns of mammal species detected >20 times during the 2012–2013 and 2013–2014 dry seasons in Chhep Wildlife Sanctuary. Dawn (light grey): 05:00–7:00 hrs, day (horizontal lines): 07:01–16:59 hrs, dusk (dark grey): 17:00–19:00 hrs, night (black): 19:01–04:59 hrs.

arrhythmic to nocturnal in Indochina (e.g., Rabinowitz, 1990; Grassman *et al.*, 2005a; Austin *et al.*, 2007; Kitamura *et al.*, 2010; Gray *et al.*, 2012). Jungle cats were almost exclusively detected in DDF and not in S/EGF despite greater sampling effort in the latter. This species was photographed 18 times at eight camera trap stations in total, including near a small pool, motorcycle trails, and a very small pocket of semi-evergreen forest in DDF. This is consistent with data from eastern Cambodia, where 96% of encounters were in DDF (Gray *et al.*, 2012), and supports the idea that the species is strongly associated with DDF in Indochina (Duckworth *et al.*, 2005). Jungle cats are likely to be naturally rare, or have become rare in Indochina (Duckworth *et al.*, 2005) and recent studies suggest that the species is very rare in Vietnam (Willcox *et al.*, 2014) and Thailand (Simcharoen *et al.*, 2014; Tantipisanuh *et al.*, 2014). Our records consequently highlight the importance of Chhep Wildlife Sanctuary for jungle cats in Indochina, together with the eastern plains (Gray *et al.*, 2014). Fishing cats *Prionailurus viverrinus*, Asiatic golden cats *Catopuma temminckii*, and marbled cats *Pardofelis marmorata* were not recorded in our study, although all three species have previously been recorded in other areas in the northern plains (Rainy & Kong 2010; Edwards & Demski 2012; Suzuki *et al.*, 2015). Tigers *Panthera tigris* were also not recorded, although there are also historical records from the northern plains, including documentation that a minimum of 34 tigers was killed in 1998 (Sun, 2000).

The golden jackal was the most commonly photographed carnivore while dholes *Cuon alpinus* were recorded only twice in two dry seasons. Golden jackals were detected in all forest types, however, naïve occupancy and encounter rates increased greatly in the 2013–2014 survey period. Although comparisons between years in our dataset must be viewed with caution, this could be partially due to increased sampling effort in DDF in 2013–2014 (=22 camera trap stations vs. 8 in 2012–

2013). Like eastern Cambodia, where 98% of encounters were made in DDF (Gray *et al.*, 2012), encounter rates of this species were probably high in DDF at Chhep Wildlife Sanctuary. Of six camera stations where jackals were photographed >20 times, five were in DDF and one in a small area of semi-evergreen forest approximately 20 m from DDF.

In contrast to the golden jackal, dholes may occur in low densities at Chhep Wildlife Sanctuary. During our survey period, canine distemper virus (CDV) had possibly spread across Cambodia and could have lowered our detections of dholes which are susceptible to the disease (Kamler *et al.*, 2015). Although dholes are less likely to occur in human-dominated landscapes than golden jackal (Jenks *et al.*, 2015), they could be more susceptible to CDV (J. Kamler, pers. comm.) due to: 1) their requirement for larger group sizes to kill larger prey compared to jackals which hunt smaller prey (Johnsingh, 1982; Moehlman, 1983; Mukherjee *et al.*, 2004; Jaeger *et al.*, 2007); 2) amicable behaviour between within-group individuals (Fox, 1984). Further, when local people enter Chhep Wildlife Sanctuary they often bring dogs and dholes are often killed in snares in Cambodia (J. Kamler, pers. comm.).

Two species of mongoose (Herpestidae) were confirmed during our survey: small Asian mongoose *Herpestes javanicus* and crab-eating mongooses *H. urva*. Encounter rates of small Asian mongoose were very low in both survey periods, but may not accurately reflect their status in the area; rather, they likely reflect sampling bias (see Duckworth *et al.*, 2010). Villagers stated that the species is relatively common around villages (where no camera traps were set) and attacks poultry. In contrast, crab-eating mongooses were often photographed traveling in groups of up to four individuals during the day time in the wildlife sanctuary. The species was frequently recorded at three camera trap stations in particular. The first was at a river bed in DDF, and records began when the water became very shallow at the start of January. This station was set in both survey seasons, and produced the highest number of photographs of the species in both years, similar to the experience of Than Zaw *et al.* (2008) near a stream in the Hakaung Valley of Myanmar. The two other stations were in a small pocket of semi-evergreen forest near a dirt road in DDF and at a shallow water pool where water remains until February under the tangled branches of a shrub.

Two species of Mustelidae were recorded, yellow throated-marten *Martes flavigula* and ferret badger. Hog badgers *Arctonyx collaris* were not recorded, although the species is thought to occur, or have occurred, in the wildlife sanctuary. Villagers reported using hog badger oil for traditional medicinal use. Yellow-throated martens exhibited diurnal activity in line with previous studies (Grassman *et al.*, 2005b; Johnson *et al.*, 2009), and were recorded in both DDF and S/EGF. This species was mostly photographed once at each station where it was detected, but was photographed more than four times at two in particular. One of the latter stations was in a small dry stream (<5 m width) in DDF. The other was

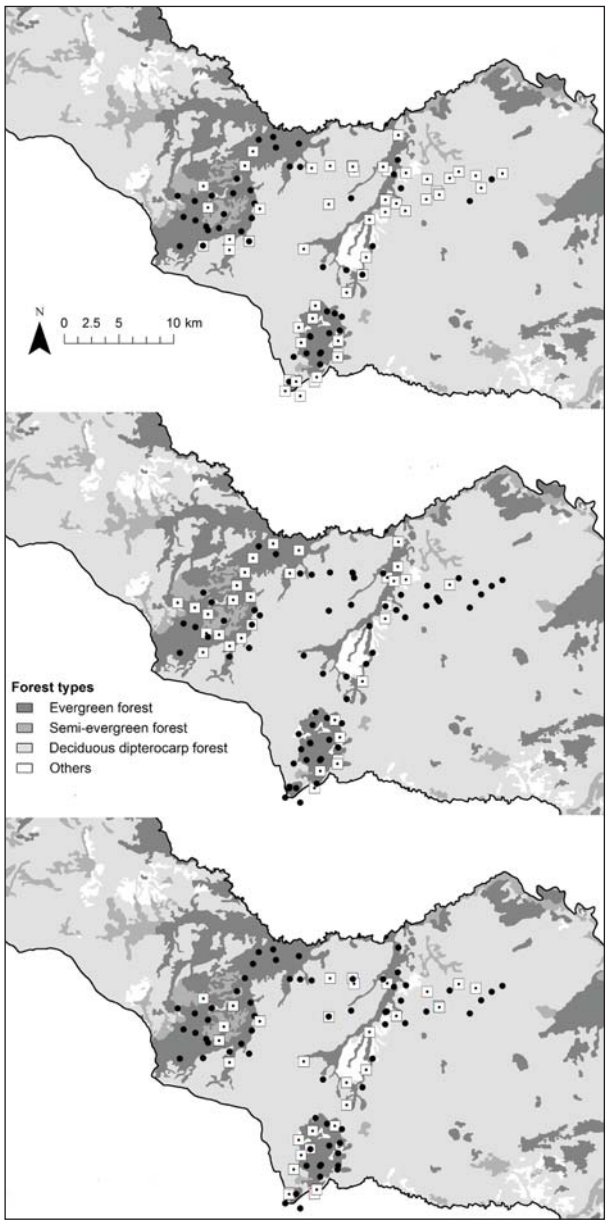

Fig. 4 Camera trap stations where large-spotted civet (top), large Indian civet (middle), and small Indian civet (bottom) were surveyed at Chhep Wildlife Sanctuary. White squares represent detections and black points non-detections.

in a small patch of bamboo forest close to a large pond in DDF where a leaf litter fire was observed at the end of February in the 2013–2014 dry season. Local people were also frequently photographed at this station. Ferret badgers were photographed at 14 camera trap stations. The most frequent capture station was in a dry river bed at the edge of S/EGF with 21 records from December to March. In Cambodia, the presence of large-toothed ferret badger is confirmed and the presence of small-toothed ferret badger *Melogale moschata* also remains a possibility (Schank *et al.*, 2009).

Four species of civet (Viverridae) were recorded with high encounter rates. This is likely due in part to bias in camera trap placement as the original purpose of the second survey was to investigate the occupancy of the subfamily Viverrinae. Nevertheless, the high encounter rate of the Endangered large-spotted civet is significant. This species is rarely recorded in Myanmar (Than Zaw *et al.*, 2008), southwestern Cambodia (Holden & Neang 2009), Malaysia (Hamirul *et al.*, 2015), Thailand (except for Khao Ang Rue Nai Wildlife Sanctuary) (Chutipong *et al.*, 2014), Laos, and Vietnam (W. Duckworth pers. comm.). In our study, the large-spotted civet was the second and third most commonly photographed carnivore in the 2012–2013 and the 2013–2014 dry seasons respectively, and the species was detected in all forest types (Fig. 4). This highlights the global conservation significance of Chhep Wildlife Sanctuary for the species and accords with records from Thailand (Chutipong *et al.*, 2014) and across its range (Timmins *et al.*, 2016). The camera trap stations with the top three highest encounter rates in our study were within or close to DDF, namely a shallow waterhole in a mosaic of DDF and S/EGF, a temporary pond in DDF, and a dry river bed in DDF. A high encounter rate was also reported near water sources in Thailand (Jenks *et al.*, 2010) and southwestern Cambodia (Holden & Neang 2009). In contrast, large Indian civets were rarely detected in DDF (Fig. 4). This is consistent with Gray *et al.* (2010), but differs from Thailand where the species is common in DDF (Chutipong *et al.*, 2014). The three stations with the highest encounter rates in our study comprised two at the intersection of animal trails in S/EGF and one on an animal trail close to a pond in S/EGF. The degree of spatial overlap between the sympatric large Indian civet and large-spotted civet is largely unknown (Gray *et al.*, 2010), and likewise with small Indian civet *Viverricula indica*. In our study, the former two species were both photographed at 15 of the same camera stations. Eight of these were in S/EGF, five in a mosaic of DDF and S/EGF, and two in DDF (Fig. 4). Large-spotted civets were photographed with small Indian civets more often at the same station (20 stations) than large Indian civets (3 stations). An occupancy study is currently underway to understand habitat use of these three Viverrinae in DDF-dominated landscapes at Chhep Wildlife Sanctuary.

Large ungulates

Large ungulates were detected at a minority of camera trap stations during our survey. However, gaur, banteng, Eld's deer and sambar *Rusa unicolor* were all photographed at a single station which targeted a trail a few meters from a relatively small water hole in DDF, approximately 2 km from semi-evergreen forest. The water hole was surrounded by grass which was burnt in January and became dry in February. The area surrounding the waterhole was open, lacking tall grass or scrubs, allowing large ungulates easy access from many directions. This also increased the detection range of the camera beyond the targeted trail resulting in photographs of these ungulates travelling off-trail. Away from this seasonal water hole, gaur was detected only in an area of contiguous evergreen forest, stretching from southern Laos to Preah Roka Wildlife Sanctuary (Cambodia). These cameras were located at the intersections of animal trails and along a dry river bed in S/EGF. Gaur occur in a wide range of habitats (Bhumpakphan & McShea, 2011), and their use of different forest types varies according to season (Ahrestani *et al.*, 2012), social class (Steinmetz *et al.*, 2008), and their populations in relation to the availability of and competition over high-quality habitat (Steinmetz *et al.*, 2010).

Encounter rates of gaur, banteng, sambar and Eld's deer were relatively low. This partly reflects bias in our placement of camera traps. Our surveys originally targeted small carnivores, and thus, if locations were deemed unsuitable for these or no signs of small carnivores were found, cameras were not set in locations even where salt licks or places where signs of large ungulates were present. This bias is evident when our results are compared with previous studies in Chhep Wildlife Sanctuary. For example, encounter rates of gaur and banteng were higher during small-scale camera trap surveys in 2010 and 2011 which targeted kouprey *Bos sauveli* (Wildlife Conservation Society, unpublished data). Although sampling bias must therefore be considered, large ungulates populations are likely to be decreasing in the wildlife sanctuary as well as many other places within their range. The status of banteng is especially of concern. Banteng almost exclusively uses DDF where plant species preferred by the species are common (Bhumpakphan & McShea, 2011), and the species was recorded in DDF during line transect surveys at Chhep Wildlife Sanctuary (Rainy *et al.*, 2010). However, sightings of banteng were

very rare during our monthly visits to camera traps in DDF over two successive dry seasons. Though the potential for sightings would be less if banteng used evergreen forests in the wildlife sanctuary more in the day time during the dry season, as in West Thailand (Bhumpakphan & McShea, 2011), sightings were very rare even in mornings and evenings.

Conservation implications

DDF-dominated landscapes are threatened and poorly represented in protected areas in mainland Southeast Asia (McShea *et al.*, 2005; Tantipisanuh & Gale, 2013; Wohlfart *et al.*, 2014; Johnson, 2015). Lowland forests are also poorly protected: >90% of protected areas created after 1965 are located above 200 m a.s.l. (Déry & Vanhooren, 2011). Given this situation, the confirmed occurrence of DDF-associated species—namely jungle cat and two globally Endangered species, Eld's deer and banteng—highlights the conservation importance of Chhep Wildlife Sanctuary. In addition, the Endangered large-spotted civet, which likely prefers lowland areas, was commonly photographed in the wildlife sanctuary, suggesting potential for the site to provide a stronghold for the species. Consistent with Tordoff *et al.* (2005), small areas of S/EGF were used by 27 large mammal species, indicating that these areas are likely to be important components of DDF-dominated landscapes for some large mammals during the dry season. Further research on seasonal habitat use and movements would assist conservation management of large mammals in Chhep Wildlife Sanctuary.

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