

Mammal records and conservation threats in Siem Pang Wildlife Sanctuary and Siem Pang Khang Lech Wildlife Sanctuary, Cambodia

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មូលនិយមសង្ខេប

ដែនជម្រកសត្វព្រៃសៀមបាំង និងសៀមបាំងខាងលិច បង្កើតជាផ្នែកមួយនៃបណ្តាញនៃតំបន់ការពារធម្មជាតិ ដែលមានទំហំ ១១២១៧គ.ម^២ ស្ថិតក្នុងប្រទេសឡាវ កម្ពុជា និងវៀតណាម ដែលវាជាតំបន់ការពារទេសភាពធម្មជាតិដ៏ធំមួយនៅក្នុងតំបន់អាងទន្លេមេគង្គ។ ការសិក្សារបស់យើងចូលរួមបំពេញបន្ថែមទៅលើចំណុចខ្វះខាតនៃចំណេះដឹងសម្រាប់ដែនជម្រកសត្វព្រៃទាំង២កន្លែងនេះ ដោយមានការបំពាក់ម៉ាស៊ីនថតរូបស្វ័យប្រវត្តិជាប្រព័ន្ធ (មានម៉ាស៊ីនថតរូបស្វ័យប្រវត្តិនៅចំនួន៦០ទីតាំង ដែលថតបានចំនួន ១៥៧៤៤យប់) ក្នុងឆ្នាំ២០១៦ និងទិន្នន័យបន្ថែមតាមរយៈការបំពាក់ម៉ាស៊ីនថតរូបស្វ័យប្រវត្តិតាមវិធីសាស្ត្រ ឆ្លៀតឱកាស (មានម៉ាស៊ីន ថតរូបស្វ័យប្រវត្តិនៅចំនួន៤៧ទីតាំង ដែលថតបានចំនួនប្រហែល១១០០យប់) ក្នុងឆ្នាំ២០១២ ដល់ ២០១៣ និង ការអង្កេតដោយ ផ្ទាល់លើថតរូបនៅចន្លោះឆ្នាំ២០១២ ដល់ ២០១៦។ ដោយរាប់បញ្ចូលទាំងទិន្នន័យដែលបានបោះពុម្ពផ្សាយរួចហើយ មានថតរូប សត្វមាន២២ប្រភេទ និងមានដំ ដែលរងការគំរាមកំហែងជាសាកលចំនួន១៧ប្រភេទ ត្រូវបានកត់ត្រានៅក្នុងដែនជម្រកទាំង២ដែលនៅ ជាប់គ្នានោះ ដោយមានវត្តមានបង្កប្រភេទដែលឆ្លុះបញ្ចាំងពីស្ថានភាពធ្លាក់ចុះនៃប្លូយឡាស្យុងថតនាពេលបច្ចុប្បន្ននៅប្រទេស កម្ពុជា។ ដោយរួមជាមួយតំបន់ការពារធម្មជាតិផ្សេងទៀតដែលស្ថិតនៅជាប់គ្នា ដែនជម្រកសត្វព្រៃសៀមបាំងអាចទ្រទ្រង់ប្លូយឡា ស្យុងដ៏សំខាន់ជាសាកលនៃជីវមណ្ឌល និងខ្លី និងប្លូយឡាស្យុងស្លាកន្ទុយសដើមក្រហមរបស់កម្ពុជា រីឯដែនជម្រកសត្វព្រៃសៀម បាំងខាងលិចទ្រទ្រង់ប្លូយឡាស្យុងដ៏សំខាន់ជាសាកលនៃមេរោគ។ កត្តាគំរាមកំហែងទៅលើដែនជម្រកសត្វព្រៃទាំង២រួមមាន៖ ការ បំបែកទីជម្រកជាបំណែកតូចៗ និងការកែប្រែដីព្រៃទៅជាដីកសិកម្ម លើសពីនេះទៅទៀតគឺការកសាងផ្លូវ និងការបរបាញ់។ តំបន់ ការពារទេសភាពធម្មជាតិនេះមានផ្ទៃដីគ្រប់គ្រាន់ក្នុងការទ្រទ្រង់ប្លូយឡាស្យុងថតរូបទាំងប្រភេទមេគង្គ និងមានមធ្យមឱ្យរស់រាន មានជីវិត និងស្ថិតស្ថេរ។ តែទោះជាយ៉ាងណាក្តី ភាពស្ថិតស្ថេររបស់សត្វទាំងនោះគឺតម្រូវឱ្យមានការអភិវឌ្ឍខាងផ្នែកគ្រប់គ្រង តាមរយៈការដឹងពីប្រភេទ និងការវាយតម្លៃពីកត្តាគំរាមកំហែង ដើម្បីគាំទ្រសកម្មភាពអភិរក្ស។

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Abstract

Siem Pang Wildlife Sanctuary and Siem Pang Khang Lech Wildlife Sanctuary form part of a 11,217 km² network of protected areas in Laos, Cambodia and Vietnam, one of the largest protected landscapes in the Mekong basin. Our study contributes to filling a knowledge gap for the two wildlife sanctuaries and consisted of a systematic camera trap survey (comprising 60 camera trap stations and 1,574 trap-nights) in 2016, complemented by an opportunistic camera trap survey (comprising 47 camera trap stations and ≈1,100 trap nights) in 2012–2013 and direct observations of mammals between 2012 and 2016. Including previously published data, seventeen globally threatened medium and large-bodied mammals are recorded from the two contiguous sanctuaries, which contain a species assemblage that reflects the depressed status of mammal populations in Cambodia. Together with other contiguous protected areas, Siem Pang Wildlife Sanctuary may support nationally important populations of Asian elephants and gaur and a globally important red-shanked douc population, whereas Siem Pang Khang Lech Wildlife Sanctuary supports a globally important Eld's deer population. Threats to the two wildlife sanctuaries include habitat fragmentation and forest conversion to agriculture which are exacerbated by road construction and hunting. The protected landscape they form part of provides sufficient land area to support viable populations of medium and large-bodied mammals. However, the continued persistence of these will require improved management supported by rigorous species and threat assessments to underpin conservation actions.

Keywords

Asian elephant, camera trapping, clouded leopard, hunting, landscape connectivity, red-shanked douc, roads, semi-evergreen forest.

Introduction

Southeast Asia is a biodiversity hotspot (Myers *et al.*, 2000), yet the region is the most biologically threatened large continental area (Schipper *et al.*, 2008; Duckworth *et al.*, 2012). Despite the urgent need to conserve its biodiversity, significant knowledge gaps remain regarding species occurrence at sub-national scales (WWF, 2014; Bryant *et al.*, 2016; Proosdij *et al.*, 2016). This information is crucial to aid identification of viable species sub-populations (Mace *et al.*, 2008; Pimm *et al.*, 2014).

Siem Pang Wildlife Sanctuary (SPWS) and Siem Pang Khang Lech Wildlife Sanctuary (SPKLWS) form part of a network of protected areas in Laos, Cambodia and Vietnam, which together comprise a protected land area of 11,217 km² (UNEP-WCMC & IUCN, 2017). This is one of the largest nominally protected landscapes in the Mekong basin (Souter *et al.*, 2016), yet the only published information on the mammals of the two wildlife sanctuaries is presented in BLCF (2012) and Eames (2014). The former report compiles mammal records which are mainly drawn from reliable unpublished sources, whereas the latter includes some additional records as part of a more general treatment on biodiversity. Prior to the present study, faunal surveys within the two sites primarily focused on the deciduous dipterocarp

forests, while semi-evergreen forests remained under surveyed. This was because the deciduous dipterocarp forests support globally irreplaceable populations of five Critically Endangered bird species and a population of the Endangered Eld's deer *Rucervus eldii siamensis*, and were therefore prioritised for conservation over semi-evergreen forest (which is unsuitable for these species) (BLCF, 2012). Aside from these works, no systematic surveys had been undertaken of mammals in SPWS and prior to our study only incidental mammal data existed, which comprised opportunistic photographs and sightings of a few species such as the Endangered Germain's langur *Trachypithecus germaini*.

The aim of our study was therefore to contribute to filling a knowledge gap on medium and large-bodied mammals present in both wildlife sanctuaries. The study comprised a systematic camera trap survey in SPWS in 2016, complemented by opportunistic camera trap placement and direct observations of mammals in SPWS and SPKLWS in 2012–2013 and 2012–2016 respectively. We report the results of this work and detail conservation threats observed during the field surveys, incorporate previous records of medium and large-bodied mammals in BLCF (2012) and Eames (2014), and discuss the findings in relation to the regional significance of selected mammals and conservation threats present at both sites.

Methods

Study sites

Siem Pang Wildlife Sanctuary (SPWS) covers 66,932 ha and is centred on 14°17' N, 106°27' E (Fig. 1). First designated in 2014, SPWS connects a patchwork of contiguous protected areas including Xe Pian National Protected Area, Nam Ghong Provincial Protected Area, Dong Ampham National Protected Area in Laos, Virachey National Park, Veun Sai-Siem Pang National Park, Siem Pang Khang Lech Wildlife Sanctuary in Cambodia and Chu Mom Ray National Park in Vietnam (here collectively referred to as 'the protected landscape'). SPWS supports mainly semi-evergreen forest at low elevations e.g., <150 m above sea level (a.s.l.). Maximum elevations (350 m a.s.l.) are found close to the border with Virachey National Park. The adjoining Siem Pang Kang Lech Wildlife Sanctuary encompasses 65,389 ha, centres on 14°11'N, 106°13'E and supports mainly deciduous

dipterocarp forest with numerous trapeangs (water-holes) and riverine semi-evergreen forest along larger rivers. Minimum elevations of 60 m a.s.l. occur near the Sekong River which increase to 400 m a.s.l. next to the Laos border in the north-western area of the sanctuary (United States Army Map Service, 1967). Our field work at these sites comprised a systematic camera trap survey in SPWS in 2016, complemented by opportunistic camera trap placement in 2012–2013 and direct observations of mammals in SPWS and SPKLWS between 2012 and 2016.

Systematic camera trap survey

Our systematic camera trap survey of medium and large-bodied ground dwelling mammals was undertaken during the dry and early wet seasons (between March and June) in 2016. Camera trapping focused on the semi-evergreen habitat, east of the Sekong River in SPWS. The survey covered an area 106 km² of semi-evergreen forest out of the total of 600 km² of semi-evergreen forest (Fig.

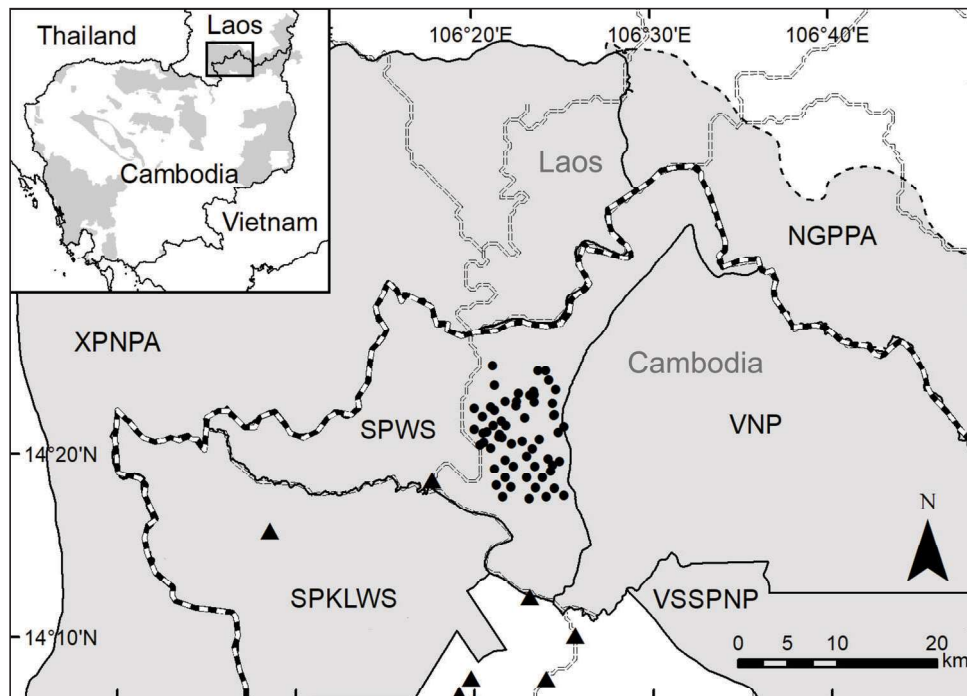


Fig. 1 Siem Pang Wildlife Sanctuary (SPWS) and adjoining Siem Pang Kang Lech Wildlife Sanctuary (SPKLWS), Virachey National Park (VNP) and Veun Sai-Siem Pang National Park (VSSPNP) in Northeast Cambodia, together with Xe Pian National Protected Area (XPNPA) and Nam Ghong Provincial Protected Area (NGPPA) in Laos. Black circles represent systematic camera trap survey locations, black triangles represent permanent settlements in Cambodia and solid lines represent protected area boundaries. The dashed thick black and white line is the international border between Cambodia and Laos and the dashed thin double lines are navigable rivers. The NGPPA border is given in a single dashed line due to uncertainty regarding its status. The inset map includes protected areas in Cambodia and Dong Ampham National Protected Area (Laos) and Chu Mom Ray National Park (Vietnam) which are contiguous with the protected landscape.

1). Deployment of camera traps followed principles of the Terrestrial Ecology and Monitoring Network's vertebrate camera trapping protocol; positioning of camera traps 30 cm above the ground, thereby targeting medium and large-bodied species (Jansen *et al.*, 2014). Sixty camera trap (Bushnell 12MP Natureview Cam Essential HD) sampling points were deployed in three grids of 20 cameras for four weeks per grid. A systematic sampling grid was developed in ArcGIS 10.4.1 (ESRI, 2015), deploying cameras at a density of one camera every 2 km². Camera traps were positioned within 800 m of planned locations, and targeted at animal trails so as to maximize the likelihood of photographing ground-dwelling, trail-following mammal species (Jansen *et al.*, 2014), although this biased against non-ground-dwelling, trail-following mammals. No baits or lures were used. Cameras were configured to take three consecutive photographs per trigger and operated 24 hours per day. The cameras shot in colour during daylight, and in black and white during darkness. Sightings, faeces and photographic documentation of other species were also recorded opportunistically along trails at dawn and during travel to and from camera trap locations.

We calculated the encounter rate per 100 camera trap days for each species photographed by dividing the total number of notionally independent events across all camera stations by the total number of camera trapping days, and multiplying by 100 (Carbone *et al.*, 2001; O'Brien *et al.*, 2003). For a given species, notionally independent capture events at the same camera station were arbitrarily defined as being separated by more than 30 minutes from the previous photograph of what could have been the same 'event' (O'Brien *et al.*, 2003). The number of camera trap stations where each species was captured was also recorded.

For the most commonly trapped species—those with more than an arbitrary number of 20 detection events—detection/non-detection at a camera trap station were modelled as a function of environmental covariates collected at the same spatial scale—using binomial generalized linear models (GLMs). A square root transformation was applied to distance to river and rescope score to reduce skew. Variance Inflation Factors (VIF) and Pearson correlation coefficients were used to assess collinearity among seven predictor variables (Appendix 1). In the event that explanatory variables showed high collinearity (Pearson $r \geq 0.7$ and / or $VIF \geq 3$), the variable with the strongest univariate relationship with the response variable was retained (Zuur *et al.*, 2010). GLMs included the log of camera station-specific effort in days as an offset to account for differences in the number of days that cameras were in operation. Model selection was

undertaken using backwards-forwards selection with Akaike's information criterion (Akaike, 1974; Murtaugh, 2009).

Opportunistic camera trap survey

Our opportunistic camera trap survey was undertaken between 2012 and 2013 in SPWS and SPKLWS and consisted of 47 camera trap stations and approximately 1,100 camera trap nights. Encounter rates were not calculated. Camera traps were located across a 75 km² area in riverine semi-evergreen forest along the northern tributaries to the Sekong River, specifically along the smaller O'Khampa and Stung Tin Hiang rivers, and in the block of semi-evergreen forest that extends to the border with Laos. These were placed in natural clearings in the forest, at forest pools (although it was unknown whether these were seasonal or permanent), salt/mineral licks and next to carnivore latrines or where there were signs of wild cattle. Our opportunistic camera trap survey did not focus on trails. Cameras were set approximately one metre above ground throughout the 24 hr cycle and no baits were used.

Incidental mammal records and threat assessment

We collated data on mammals observed at SPWS and SPKLWS from 2012 to 2016 and included these in the present study for completeness. These do not include reports from villagers or footprint data. Records of other medium to large sized mammal species from both wildlife sanctuaries in BLCP (2012) and Eames (2014) were also collated. An indication of threats facing mammal populations at both sites was derived from 1) protected area enforcement team reports arising from patrols using Spatial Monitoring And Reporting Tool software (SMART, 2014), 2) quantification of levels of habitat disturbance observed at camera trap stations following Wearn *et al.* (2013) (Appendix 1), 3) description of the extent of anthropogenic forest use identified from camera trap photographs (per Azlan, 2006; Hossain *et al.*, 2016), 4) opportunistic threat monitoring and documentation of evidence of hunting activity observed during the fieldwork in SPWS.

Results

Including data presented in BirdLife International Cambodia Programme (2012) and Eames (2014), 38 species of medium and large-bodied mammal are confirmed to occur in SPWS and SPKLWS (Table 1). This figure includes 28 taxa recorded in BLCP (2012) and Eames (2014) and 10 taxa exclusively recorded during our surveys. It also comprises one Critically Endangered,

Table 1 Medium and large-bodied mammal species recorded to date at Siem Pang Wildlife Sanctuary (SPWS) and Siem Pang Kang Lech Wildlife Sanctuary (SPKLWS). Taxonomy follows IUCN (2018) except for northern yellow-cheeked crested gibbon *Nomascus annamensis* (after Vu *et al.*, 2010). Record: CT = camera trap record, P = photograph (non-camera trap record of wild animal), S = sighting (without photograph). Source: A = BLCP (2012), B = Eames (2014), C = This study.

Species	Status	Record	Source	Site
Sunda pangolin <i>Manis javanica</i>	CR	P ¹	A	SPWS?
Northern treeshrew <i>Tupaia belangeri</i>	LC	S	A	SPKLWS
Northern slender-tailed treeshrew <i>Dendrogale murina</i>	LC	S	A	SPKLWS
Pygmy slow loris <i>Nycticebus pygmaeus</i>	VU	P	C	SPWS, SPKLWS
Northern pig-tailed macaque <i>Macaca leonina</i>	VU	S	A, C	SPWS
Long-tailed macaque <i>Macaca fascicularis</i>	LC	S, CT	A, C	SPWS, SPKLWS
Germain's langur <i>Trachypitecus germaini</i>	EN	S, P ² , CT	A, B, C	SPWS, SPKLWS
Red-shanked douc <i>Pygathrix nemaeus</i>	EN	P	C	SPWS
Northern yellow-cheeked crested gibbon <i>Nomascus annamensis</i>	EN	S	A, C	SPWS, SPKLWS
Golden jackal <i>Canis aureus</i>	LC	P	A, B	SPKLWS
Dhole <i>Cuon alpinus</i>	EN	CT	B	SPWS
Sun bear <i>Helarctos malayanus</i>	VU	CT	B, C	SPWS
Yellow-throated marten <i>Martes flavigula</i>	LC	P	C	SPKLWS
Greater hog badger <i>Arctonyx collaris</i>	VU	P ³	C	Origin unclear
Smooth-coated otter <i>Lutrogale perspicillata</i>	VU	CT	B	SPWS
Large-spotted civet <i>Viverra megaspila</i>	EN	CT	B	SPWS
Small Indian civet <i>Viverricula indica</i>	LC	CT	C	SPWS, SPKLWS
Common palm civet <i>Paradoxurus hermaphroditus</i>	LC	CT	A, C	SPWS, SPKLWS
Small-toothed palm civet <i>Arctogalidia trivirgata</i>	LC	S, P	C	SPWS
Leopard cat <i>Prionailurus bengalensis</i>	LC	CT, P	A, B, C	SPWS, SPKLWS
Asiatic golden cat <i>Catopuma temminckii</i>	NT	CT	C	SPWS
Mainland clouded leopard <i>Neofelis nebulosa</i>	VU	CT	C	SPWS
Asian elephant <i>Elephas maximus</i>	EN	P ⁴	C	SPWS
Wild pig <i>Sus scrofa</i>	LC	CT, P	A, B, C	SPWS, SPKLWS
Lesser oriental chevrotain <i>Tragulus kanchil</i>	LC	CT	A, C	SPWS
Sambar <i>Rusa unicolor</i>	VU	CT	B, C	SPWS
Eld's deer <i>Rucervus eldii</i>	EN	P, S	B, C	SPKLWS
Northern red muntjac <i>Muntiacus vaginalis</i>	LC	CT, P, S	A, B, C	SPWS, SPKLWS
Gaur <i>Bos gaurus</i>	VU	CT, P, S	B, C	SPWS, SPKLWS
Banteng <i>Bos javanicus</i>	EN	CT	B	SPWS
Black giant squirrel <i>Ratufa bicolor</i>	NT	S	A	SPKLWS
Variable squirrel <i>Callosciurus finlaysonii williamsoni</i>	LC	S	A	SPKLWS
Cambodian striped squirrel <i>Tamiops rodolphii</i>	LC	S	A	SPKLWS
Red-cheeked squirrel <i>Dremomys rufigenis</i>	LC	S	A	SPKLWS
Berdmores' squirrel <i>Menetes berdmorei</i>	LC	S	A	SPKLWS
Giant flying squirrel sp. <i>Petaurista</i> sp.	-	S	A ⁵	SPKLWS
East Asian porcupine <i>Hystrix brachyura</i>	LC	CT	C	SPWS
Siamese hare <i>Lepus peguensis</i>	LC	S	A, C	SPKLWS

¹ Skins and confiscated animals, probably originating from SPWS. ² Photograph of dead animal. ³ Two skins photographed in house in Siem Pang on 9 December 2016. ⁴ Footprints and dung observed between 10 and 12 June 2016. ⁵ Originally identified as *P. philippensis* on range grounds but *P. petaurista* is now known to occur in Cambodia as well and therefore cannot be ruled out.

eight Endangered, eight Vulnerable, two Near Threatened and 18 Least Concern mammal species.

Systematic camera trap survey

Eleven mammal species were recorded over the course of the systematic camera trap survey in SPWS in 2016 (Table 2). With respect to notionally independent detection events, northern red muntjac *Muntiacus vaginalis* (Least Concern) was the most commonly recorded mammal, followed by lesser oriental chevrotain *Tragulus kanchil* (Least Concern), gaur *Bos gaurus* (Vulnerable) and wild pig *Sus scrofa* (Least Concern).

Modelling of species detection/non-detection showed that the presence of gaur at a camera station was most strongly predicted by the variables semi-evergreen forest habitat (%D = 36, $p = 0.002$) and camera trapping grid number (%D = 12, $p = 0.008$), with the more northerly grid further from settlements detecting gaur significantly more frequently than the more southerly grids. Similarly, detection of the common palm civet *Paradoxurus hermaphroditus* (Least Concern) was significantly predicted by increasing distance to settlements (Table 3). In contrast, wild pigs were detected significantly more frequently at camera trap stations with higher levels of forest disturbance (Table 3). There were no significant factors influencing detection of northern red muntjac or lesser oriental chevrotain.

Aside from the globally Vulnerable gaur, one globally threatened species not previously confirmed in SPWS or SPKLWS was also recorded during the systematic survey: mainland clouded leopard *Neofelis nebulosa* (Vulnerable). This was camera-trapped in a dry streambed within semi-evergreen forest (14°19'32" N, 106°24'43" E) on 6 April 2016.

Opportunistic camera trap survey

Fourteen mammal species were recorded during the opportunistic camera trap survey in SPWS and SPKLWS in 2012–2013. These included four Endangered species (Germain's langur, dhole *Cuon alpinus*, large-spotted civet *Viverra megaspila* and banteng *Bos javanicus*). At least nine Germain's langurs were camera-trapped together at a salt/mineral lick along the Stung Tin Hiang River on 30 December 2013 (approximately 14°20'51" N, 106°16'21" E). Dholes were camera-trapped twice at two camera trap stations set along the Stung Tin Hiang River (approximately 14°20'51" N, 106°16'21" E), both on the 25 December and 29 December 2013. One photograph on the 29 December 2013 contained two animals. One large-spotted civet was camera-trapped on 20 January 2013 along the Stung Tin Hiang River (approximately 14°20'51" N, 106°16'21" E) and at least three bantengs comprising one adult male, an adult female and a juvenile were camera-trapped on 7 April 2013 between the Stung Tin Hiang and O'Kul rivers (14°19'53.8" N, 106°16'25.2" E).

Table 2 Medium and large-bodied mammal species recorded during the systematic camera trap survey in Siem Pang Wildlife Sanctuary. The number of events is the number of notionally independent captures. Encounter rate is the number of events across all camera stations divided by the total number of camera trapping days, multiplied by 100.

Species	No. of events	Encounter rate	No. of stations
Northern red muntjac <i>Muntiacus vaginalis</i>	100	6.35	40
Lesser oriental chevrotain <i>Tragulus kanchil</i>	35	2.22	10
Gaur <i>Bos gaurus</i>	31	1.97	7
Wild pig <i>Sus scrofa</i>	22	1.4	17
Common palm civet <i>Paradoxurus hermaphroditus</i>	15	0.95	14
East Asian porcupine <i>Hystrix brachyura</i>	10	0.64	7
Northern pig-tailed macaque <i>Macaca leonina</i>	5	0.32	4
Leopard cat <i>Prionailurus bengalensis</i>	2	0.13	2
Long-tailed macaque <i>Macaca fascicularis</i>	2	0.13	2
Mainland clouded leopard <i>Neofelis nebulosa</i>	1	0.06	1
Sambar <i>Rusa unicolor</i>	1	0.06	1

Table 3 Significant explanatory variables in minimum adequate GLMs predicting species detection/non-detection. %D = % deviance explained (100 x [1 - residual deviance/null deviance]); + = positive trend.

Species	Explanatory variable(s)	%D	Degrees of freedom	p
Gaur <i>Bos gaurus</i>	Grid+	12	57	0.008
	Semi-evergreen+	36	57	0.002
Wild pig <i>Sus scrofa</i>	Forest disturbance+	10	58	0.019
Common palm civet <i>Paradoxurus hermaphroditus</i>	Distance to settlements+	9	58	0.022

Four Vulnerable species were also recorded, namely smooth-coated otter *Lutrogale perspicillata*, sun bear *Helarctos malayanus*, gaur and sambar *Rusa unicolor*. Photographs of a smooth-coated otter, possibly the same animal, were obtained from one camera-trap station on 26 and 28 November 2013 along the Stung Tin Hiang River (approximately 14°20'51" N, 106°16'21" E). Sun bears were camera-trapped on 4 and 5 January 2013 and 23 February 2013 along the O'Kul, west of the Sekong River (approximately 14°17'24.42" N, 106°16'20.60" E). Following the systematic camera trapping, sun bears were also recorded in opportunistically deployed camera traps east of the Sekong River on 21 July and 5 November 2016 (14°21'87" N, 106°22'89" E). Gaur were camera-trapped during the opportunistic survey as follows: one on 27 January 2012, four on 20 April 2013, one on 11 May 2013 and three on 22 May 2013 (all at approximately 14°20'51" N, 106°16'21" E). Following the opportunistic survey, one gaur was photographed on 27 January 2012, four on 20 April 2013, one on 11 May 2013 and three on 22 May 2013 (all at 14°18'37" N, 106°18'19" E). Sambar were photographed at nine camera trap stations (at approximately 14°20'51" N, 106°16'21" E) between December 2012 and January 2013.

Incidental mammal records

Nineteen species were incidentally recorded during fieldwork in the two wildlife sanctuaries between 2012 and 2016 (Table 1), including four Endangered taxa: red-shanked douc *Pygathrix nemeaus*, Germain's langur, northern yellow-cheeked crested gibbon *Nomascus annamensis* and Asian elephant *Elephas maximus*. Two Vulnerable taxa, pygmy slow loris *Nycticebus pygmaeus* and northern pig-tailed macaque, were also recorded.

Red-shanked doucs were identified from photographs of a dead individual (14°20'59.42" N, 106°20'36.12" E within the camera trap block, east of the Sekong River) found on 14 April 2016 and a live captive juvenile

observed at the 101 Army station within SPWS on the west bank of the Sekong River (14°19'24.41" N, 106°18'36.16" E; Fig. 2). Douc langurs, identified as red-shanked, were also observed (two adults and one juvenile) in semi-evergreen habitat close to the Stung Mulu River (14°19'34.86" N, 106°22'59.19" E) on 11 April 2016, as were two feeding in association with a northern yellow-cheeked crested gibbon (14°20'59.36" N, 106°20'35.95" E) on 13 April 2016. Footprints and dung boluses of Asian elephant were detected in three areas between 10 and 12 June 2016 (exact locations are not reported here due to security concerns). Troops of Germain's langurs were observed and photographed on most field excursions between 2012–2016 along the Sekong River, including one on 2 January 2013 and three together on 22 October 2012. The largest was a troop of 40 observed on 29 March 2015 (at 14°18'21.08" N, 106°20'1.32" E). Pygmy slow lorises were sometimes confiscated and released by the protected area enforcement team including one released on 30 May 2015 and four in March 2016. Two northern pig-tailed macaques were observed along the Sekong River on 29 March 2015 (near 14°18'21.08" N, 106°20'1.32" E).

Conservation threats

Threats to mammals documented in SPWS and SPKLWS during the study period included habitat loss and fragmentation due to road construction and subsequent forest conversion to agriculture and settlement along roads and riverbanks, together with hunting and live animal capture.

Connectivity within the protected landscape is threatened by a road construction project that began in 2016 along the Cambodia-Laos border between SPWS and Xe Pian National Protected Area in Laos. By January 2018, construction of a road bridge across the Sekong River (at 14°26'5.11" N, 106°19'48.98" E) was well advanced and road construction continues along the international frontier along the northern boundary of Virachey National

Park (Fig. 1). Construction of a second road bridge ca. 3 km south of this point began in 2018. A road has also been built from Siem Pang town northwards and almost parallel in places to the Sekong River through SPKLWS and SPWS to both bridge sites. Thus, SPKLWS and the portion of SPWS west of the Sekong are now completely encircled by roads.

A dispute with Laos in 2017 associated with border road construction has resulted in a greater number of Cambodian army personnel being stationed in SPWS. Army personnel have cleared forest to establish a camp along the road (at 14°26'N 106°19'E) and proposed that ca. 5,000 ha of land within SPKLWS be set aside for military facilities. SMART reports for SPKLWS show a consistently high level of attempted land demarcation and clearance along these roads and the Sekong River, with 101 instances reported from 352 patrols in 2015, 83 instances from 397 patrols in 2016 and 122 instances from 379 patrols in 2017.

Hunting activity recorded by field teams during the systematic camera trapping survey in SPWS included gunshots heard on all six deployment expeditions and two snare lines comprising 22 snares were encountered and removed by field teams. People not associated with the systematic survey were camera-trapped at 14 of the 60 camera trap stations and were detected across all three camera trapping grids. These were in the company of hunting dogs in 19 out of 33 notionally independent records, including one photograph of people in possession of a dead lesser oriental chevrotain. Field teams during the systematic survey also encountered a community member with hunting dogs in possession of a dead common palm civet and a group in possession of a dead wild pig. People were also recorded regularly during the opportunistic camera trap survey in 2013, although none were accompanied by hunting dogs. Snare lines and other traps were not recorded during the opportunistic survey, nor during the earlier camera trap survey.

Live mammal capture, documented through opportunistic threat monitoring by field teams, included the first confirmed case of a red-shanked douc being held in captivity in SPWS (Fig. 2). On two occasions in 2015, single juvenile long-tailed macaques were observed on public transport from Siem Pang town. A pygmy slow loris and a juvenile leopard cat *Prionailurus bengalensis* were also confiscated by the protected area enforcement team in 2015 (BLCP, 2015). The same enforcement team also confiscated a live juvenile male sun bear from villagers who reportedly obtained the animal in SPWS in July 2018.

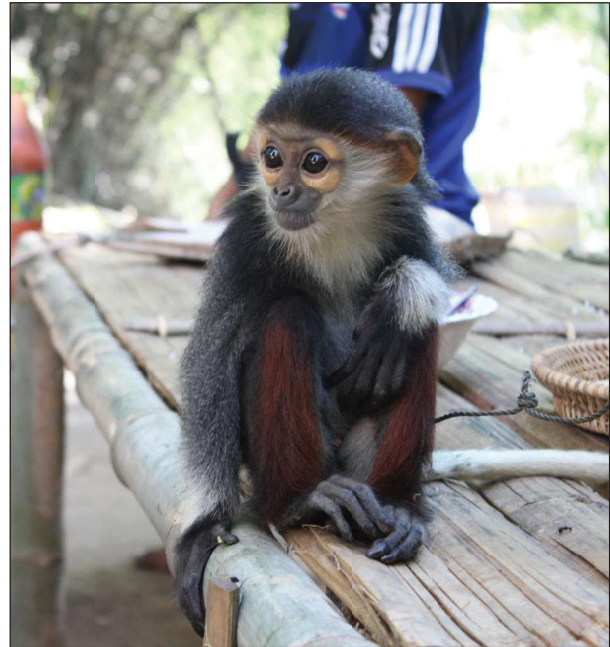


Fig. 2 Captive juvenile red-shanked douc *Pygathrix nemaeus* at the 101 Army station (14°19'24.41" N, 106°18'36.16" E) on 1 December 2016 (© Phat Chandra).

Discussion

The severe threats facing Southeast Asia's mammal community have resulted in many sites losing their top native predators and other medium and large-bodied mammals persisting at very low densities (Steinmetz *et al.*, 2006). This pattern was found in SPWS with tiger *Panthera tigris* and leopard *P. pardus* both unrecorded in our survey, although both are reported to have been present historically in SPKLWS (Mem Mai, pers. comm. 2018). These absences are consistent with recent camera trap studies of other large protected landscapes in Cambodia (Gray *et al.*, 2017; Suzuki *et al.*, 2017), although the latter were neither extensive or of sufficient duration to rule-out their continued presence. Despite significant survey effort, other threatened mammals including Asian elephant and mainland clouded leopard were only recorded on a single occasion despite some 600 km² of seemingly suitable semi-evergreen forest habitat in SPWS. As such, SPWS contains an assemblage of medium and large-bodied mammal species which reflects the depressed status of mammal populations in Cambodia. However, the continued presence of 17 globally threatened medium and large-bodied mammal species and the geographic location of SPWS and SPKLWS within a continuous network of 11,217 km² of protected areas

suggests these sites have potential regional importance as a refuge for wide ranging mammals.

Remarks on selected mammal species

The Sunda pangolin *Manis javanica* (Critically Endangered) was not detected in our camera trapping surveys. This may be a reflection of the high hunting pressure pangolins face throughout their ranges, their partly arboreal, non-trail-following nature, camera trap placement and/or the duration of the survey. Previously skins had been recorded in houses in Siem Pang town (BLCP, 2012) and from live animals confiscated from hunters in SPKLWS (which was assumed to be the source of the animals).

Our records of the red-shanked douc extend its global range west from the first documented record for Cambodia by 50 km. We identified the species based on photographs of the remains of an individual found shot and a juvenile held in captivity, both with pronounced red pelage on the legs (Fig. 2), but acknowledge that they might be hybrid forms of unknown genetic provenance. The largest known population of red-shanked doucs are in Laos (Coudrat *et al.*, 2012). The species was recorded until 1999 in Nam Ghong Provincial Protected Area and Dong Ampham National Protected Area in Laos (Timmins & Duckworth, 1999), part of the protected landscape considered in our study. Recent reports of the species from these protected areas are not available, although Coudrat *et al.* (2012) suggest they may retain a fairly large population characterized by relatively high genetic diversity, which could include introgression with other douc species. Given that these sites are connected to two protected areas in Cambodia where the genus is confirmed, the protected landscape may be an important stronghold for the red-shanked form in the southern part of its range. Further surveys across the landscape are required to confirm the status of this population.

Germain's langur appears to be restricted to riverine tracts of semi-evergreen forest in SPWS and SPKLWS and has yet to be documented beyond this ecotone. The species is largely arboreal but does come to the ground to visit mineral licks. For example, Eames (2014) includes a photograph of a Germain's langur at a mineral lick on the junction of the Sekong and O'Khampa rivers. The species is known from 17 protected or proposed protected areas including six in Cambodia (Mittermeier *et al.*, 2013). Our study recorded sightings of northern yellow-cheeked crested gibbon (Endangered), which was previously documented in SPWS (BLCP, 2012) and is known from along the Stung Tin Hiang River. It has also been recorded from several points along the recently constructed border road in the north-west of SPWS

(Jonathan C. Eames, unpublished data). The species remains widely distributed in SPWS, both west and east of the Sekong River and is known from 18 protected or proposed protected areas including Virachey National Park in Cambodia (Mittermeier *et al.*, 2013).

We erroneously anticipated our systematic camera trapping might record dhole and large-spotted civet as both inhabit semi-evergreen forest (in addition to deciduous dipterocarp forest and mixed deciduous forest in the case of dhole). Their detection east of the Sekong River could possibly have been prevented by a naturally low density or reduced density as a result of snaring, disease transmission (rabies and distemper) from domestic dogs, or the short duration of the camera trapping study. Our few records preclude assessment of the potential significance of local populations of these species. Detection of the mainland clouded leopard in SPWS was anticipated due to extensive areas of suitable habitat and as snaring levels appear to remain relatively low. The species has experienced declines across its range, including Myanmar, Vietnam (Wilcox *et al.*, 2014; Grassman *et al.*, 2016) and Laos (Duckworth *et al.*, 2014). In Cambodia, the species has recently been camera-trapped in Virachey National Park (McCann & Pawlowski, 2017), in three protected areas in the eastern plains of Cambodia (Gray *et al.*, 2012) and in the Cardamom Mountains and Chhiep Wildlife Sanctuary (Gray *et al.*, 2017; Suzuki *et al.*, 2017). Further survey work is required to determine the status of the species nationally.

Asian elephants were previously documented in Siem Pang District, although it is unknown whether this record was from the area now encompassed by SPWS (Desai *et al.*, 2002). It was also recently recorded in the Yak Yeuk grassland area near the Laos border in Veun Sai District, Stung Treng Province and at other locations in Virachey National Park, which adjoins SPWS (Pawlowski & McCann, 2017). We are aware of historical reports of captive Asian elephants brought through Xe Pian National Protected Area up to and over the Cambodia border in 1992–1993 (William Duckworth, pers. comm. 2018), but know of no current or historical records of captive elephants held in Siem Pang District. Since elephants have not been used for logging in Cambodia within the authors memory, we regard the recent records from Virachey National Park as wild elephants and because Veun Sai District adjoins Siem Pang District, our records likely represent the first confirmed use of SPWS by wild elephants. A minimum area for long-term elephant conservation is $\approx 4,400$ km² (Sukumar, 1992) and four protected landscapes meet this requirement in Cambodia: the Eastern Plains Landscape (300 individuals), the Cardamom Mountains (175), the

Northern Plains Landscape around Chhep wildlife Sanctuary (5) and Virachey-Siem Pang protected landscape (unknown). The total wild population in Cambodia is estimated at 400–600 individuals, whereas 500–1,000 are estimated in Laos, 70–150 in Vietnam and 2,500–3,200 in Thailand (Sukumar, 2003; Maltby & Bouchier, 2011; Gray *et al.*, 2014). Thus, while the little-known population in the Virachey-Siem Pang area may have limited regional significance, it may be important for supporting the precariously low national population.

Although not recorded by our camera trapping surveys, Eld's deer has been regularly recorded in SPKLWS since 2003 when a population likely larger than 50 animals was reported (BirdLife International Cambodia Programme, 2012). This is somewhat expected as the species largely occurs in deciduous dipterocarp forest within its Southeast Asian range and SPKLWS contains large tracts of this habitat. Eld's deer are reported regularly from areas of open, or park-like deciduous dipterocarp forest in the central and southern parts of the site (BLCP, 2015–2018) and are most conspicuous during the rut in April. Fifty different animals were recorded between 16–19 April 2015, lesser numbers in 2016 and 2017 and a survey in 2018 counted 39 different animals (Eames, 2018). While no conclusions can be drawn regarding population trends due to inconsistencies in survey methods, we regard SPKLWS as a priority site for the Eld's deer on the basis that no site in Cambodia is known to hold more animals. A systematic study of the population at SPKLWS is therefore a conservation priority and research has recently begun.

Because banteng show a preference for deciduous dipterocarp and mixed deciduous forests in the Mekong Basin, we would not have expected to detect the species in the semi-evergreen forests of SPWS. Our camera trap records in 2013 remain the most recent for the site. Gaur were the third most frequently trapped mammal during our systematic camera trap survey. This species was previously camera-trapped in SPWS west and east of the Sekong River, and in SPKLWS. The only daytime photographic record in SPKLWS is of a male on 28 May 2015 (Anon. 2015). Although detected by camera trapping studies across several protected areas in the Cardamom Mountains landscape (e.g., Gray *et al.*, 2017), the conservation status of the Cambodian population has yet to be determined. Sambar was only detected once during the 2016 camera trap study, which is surprising given the higher detection rate of gaur. However, it was detected at nine camera trap stations during the 2012–2013 camera trap survey.

Conservation threats

Roads can have devastating impacts on biodiversity, acting as new frontiers for development and fragmenting landscapes (Perz *et al.*, 2008; Laurence *et al.*, 2009). Once complete, the road now being built along the Cambodia-Laos border will separate Xe Pian National Protected Area from SPWS and Virachey National Park (Khy, 2017; McCann, 2017). As such, road construction poses the single greatest threat to mammal populations in SPWS and SPKLWS. This is due to the cascade of secondary threats, which result from increased access to the forest, including unregulated settlement and land clearance (Cropper *et al.*, 2001).

The combination of 1) extensive anthropogenic presence in SPWS, 2) hunting activity, 3) species modelling of commonly detected species (gaur and common palm civet) showing higher detection rates further from villages, and 4) absence of hunting sensitive species such as large predators, suggest that some species are being hunted at unsustainable levels. While detections of wild pig did not show the same spatial pattern, this is likely due to its high reproductive rate which makes it more resilient to hunting pressure (Oliver & Leus, 2008).

Our data provides a cursory insight into hunting behaviour. We recorded firearm use, which is of particular concern for large-bodied mammals and primates. For instance, red-shanked doucs are commonly hunted by firearms in Laos (Coudrat *et al.*, 2012). The availability of firearms has increased with the increasing presence of the Cambodian military within SPWS. In 2012, a Germain's langur was photographed being prepared for consumption at the 101 Army station on the west bank of the Sekong River in SPWS (Eames, 2014). On 5 May 2018, a report was received of a dead gaur in SPWS, which upon investigation was found to have been shot by army personnel (Anon. 2018).

In contrast to the high incidence of firearm use, our seemingly low (although anecdotal) detection of snares compared to other sites in Southeast Asia (Harrison *et al.*, 2016) may explain the continued persistence of relatively healthy populations of mammals commonly snared, particularly gaur. This may not actually be the case however because as most law enforcement patrols are undertaken on motorbike, snare lines set in cover are likely to be missed. In addition, while collection of non-timber forest products is permitted within the wildlife sanctuaries, more than half of the people photographed in SPWS were accompanied by hunting dogs. While it was not possible to infer from our photographs whether the dogs had been actively hunting, this raises a cause for

concern and suggests research into hunting practices and social norms is needed.

Study limitations

Our systematic camera trap sampling strategy was biased towards ground-living medium to large bodied mammal species that use trails (Wearn *et al.*, 2013). It was recognised at the design stage that our approach would not capture the full mammal community of SPWS and would exclude arboreal species, most semi-arboreal species, species that actively avoid trails and most ambush predators. For example, our methods were not suitable for recording primates. We also acknowledge that the short duration of the survey limited detection of species, especially taxa that avoid trails. An alternative approach would have set more cameras in a wider variety of microhabitats over a longer period, although this was by limited funds available. Nonetheless, some species may have been under reported, or reported as absent when they actually occur at very low density.

Opportunistic camera trapping in 2012 and 2013 recorded several globally threatened mammal species which were not detected by the systematic camera trapping in 2016. Although variations in hunting pressure and habitat may explain some of these differences, camera trap placement was likely also a significant factor. For example, we would not have detected smooth-coated otter had a camera-trap not been attached to a wooden stake that was then driven into a sandbank facing a latrine. Such techniques are rarely used in conventional systematic camera trapping, although targeted placement reflecting the known ecology of a species is valuable where the objective is to document rare and low-density taxa.

Finally, our threat data is largely anecdotal and provides an indication of the threats present, rather than a rigorous threat assessment. To compare the severity of different threats, their recorded incidences should be standardised in terms of observer research effort, such as number of incidents per patrols. This could be achieved by more systematic planning of threat data collection and analysis using SMART software. This would also facilitate comparisons with other sites in the region.

Prognosis

The assemblage of medium and large-bodied mammal species present in SPWS and SPKLWS reflects the depressed status of most remaining mammal populations in Cambodia. The severe threats facing the site

have likely reduced mammal species in-situ to remnant populations.

Although a report on the environmental impacts of the Cambodia-Laos border road has been submitted to the Government of Cambodia (Eames, 2016), road development has not halted. Conservation action to limit the impact of this road must therefore employ a triage approach following principles of the mitigation hierarchy (SCBD & UNEP-WCMC, 2012). Priority mitigation actions would be 1) ban settlement in SPWS and SPKLWS to maintain connectivity across the landscape; and 2) identify and prioritise protection of core areas used by of Asian elephant, gaur and Eld's deer within the protected landscape to minimise the impact of human presence on their movement (Songhurst *et al.*, 2016).

The presence of military installations in SPWS makes the army a powerful actor that must be constructively engaged to reduce encroachment and hunting and improve protected area management. Strengthened enforcement operations are required to combat encroachment and the prevalent use of firearms (Lunstrum, 2014; Gray *et al.*, 2016). Army border patrol teams could provide one such source of support. Hunting poses an increasing threat to mammals and other wildlife in SPWS and SPKLWS. Understanding and dismantling local trade networks—where villagers sell bush-meat to local middlemen who in turn sell this, which is then sold on Siem Pang and Stung Treng markets—is also required. Indigenous Kavet communities living along the border of SPWS and Virachey National Park engage in hunting and have a tradition of animist beliefs and culture closely associated with the forest. Consequently, understanding social norms, particularly hunting behaviour and meat-consumption preferences will be key to developing management strategies aligned to local values that successfully build community support for conservation (Infield, 2001; Steinmetz *et al.*, 2006).

Sufficient land area is now included in the protected landscape and nationally in Cambodia to conserve viable populations of remaining medium and large-bodied mammals. However the protected estate is becoming increasingly degraded and depleted of harvest sensitive species (Petersen *et al.*, 2015). To strengthen mammal conservation, attention should turn from expansion of the protected area estate to increased investment in existing protected areas (Watson *et al.*, 2014). Ultimately, the persistence of medium and large-bodied mammals across the protected landscape will depend on building a coalition of actors with the political weight, economic resources and vision needed to conserve the integrity of the landscape.

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Appendix 1 Habitat variables recorded at each sampling location during the systematic camera trap survey in Siem Pang Wildlife Sanctuary

Variables	Description
Distance to settlements	Straight line distance to the nearest permanent settlement calculated in ArcGIS 10.4.1 (ESRI, 2015).
Distance to river (km)	Straight line distance to the Sekong river calculated in ArcGIS 10.4.1 (ESRI, 2015).
Grid	Three camera trap grids were established running from south to north. Each camera trap station was assigned to a grid.
Habitat type	Four habitat types were recognised: semi-evergreen forest, deciduous dipterocarp forest, bamboo stands, dry river beds. Each habitat type was categorised as a separate binary variable (present/absent).
Average tree height (m)	A laser rangefinder (Nite Hawk Pin Predator 400) was used to estimate the height of four trees at each listening station. Tree selection was randomized by selecting tree stems closest to bearings of north, south, east and west from the camera trap station. The average of these trees was then calculated.
Tree density (m ² /ha)	A relascope (Gove et al. 2001) was held at eye level 53cm from the researcher whilst a 360° rotation was made about the central position of the spool track. The number of trees viewed as larger than the 1cm opening in the relascope was counted and the number multiplied by two to give an estimate of tree basal area per hectare (m ² /ha).
Forest disturbance score	A four level categorical variable from low to high forest disturbance: 1 = No evidence of recent logging; 2 = Occasional single tree stumps and single trees felled; 3 = Frequently encounter felled trees, some evidence of trails cleared for vehicle access; 4 = Frequently encounter felled trees grouped into piles, recent trail clearance for vehicle access, land clearance and evidence of forest conversion with intent of settlement, recent / active logging camps.