

Status and conservation significance of ground-dwelling mammals in the Cardamom Rainforest Landscape, southwestern Cambodia

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មូលនិយមសង្ខេប

តំបន់ទេសភាពព្រៃឆ្នាំងទឹកភ្លៀងជួរភ្នំក្រវាញមានទំហំ ១៧.០០០ គម^២ ដែលជាតំបន់ការពារទេសភាពស្ថិតនៅភាគនិរតីនៃប្រទេសកម្ពុជា ដែលមានរយៈកម្ពស់ចាប់ពីកម្ពស់នីវ៉ូសមុទ្រ រហូតដល់ជាង ១.៧០០ម។ ទោះបីជា តំបន់ទេសភាពនេះមានតម្លៃផ្នែកអភិរក្សក៏ដោយ ក៏ថ្មីៗនេះមានព័ត៌មានតិចតួចនៅឡើយត្រូវបានបោះពុម្ពស្តីពីស្ថានភាពនិងសារៈសំខាន់នៃការអភិរក្សប្លុយឡាស្យុងថនិកសត្វគោក។ យើងរាយការណ៍លទ្ធផលការសិក្សាដោយម៉ាស៊ីនថតស្វ័យប្រវត្តិចំនួនប្រាំពីរនៅក្នុងប្រាំតំបន់ការពារផ្សេងៗគ្នានៅក្នុងតំបន់ទេសភាពទាំងមូល រវាងឆ្នាំ២០១២និង២០១៦ ដែលមាន ២៥៥ ទីតាំងម៉ាស៊ីនថតស្វ័យប្រវត្តិនិងត្រូវបានជាង៣០.០០០ អន្ទាក់យប់។ យ៉ាងតិចណាស់ថនិកសត្វគោក ៣០ប្រភេទ ពីមាឌមធ្យមទៅធំត្រូវបានកត់ត្រា ក្នុងនោះមានមួយប្រភេទត្រូវបានចុះក្នុងបញ្ជីក្រហមរបស់អង្គការ IUCN ជាប្រភេទជិតផុតពូជធ្ងន់ធ្ងរ ពីរប្រភេទជិតផុតពូជ ប្រាំបីប្រភេទងាយរងគ្រោះនិងបីប្រភេទជិតរងគ្រោះជាសកល។ ខ្លាឃ្មុំភ្នំ *Helarctos malayanus* ខ្លាពពក *Neofelis nebulosa* និងផ្លែព្រៃ *Cuon alpinus* ត្រូវបានកត់ត្រាប្រាំមួយដងប្រើប្រាស់នេះ នៅក្នុងអំឡុងពេលសិក្សាចំនួនប្រាំពីរដង។ ទោះបីជាប្លុយឡាស្យុងនៃប្រភេទទាំងបីនេះនៅទាបជាងសមត្ថភាព

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ទ្រទ្រង់នៃអេកូឡូស៊ីក្នុងតំបន់ក៏ដោយ ក៏ពួកវាមានសារៈសំខាន់ណាស់នៅក្នុងតំបន់ទាំងមូល។ ទោះជាយ៉ាងណាក៏ដោយ គ្មានម៉ាស៊ីនថតស្វ័យប្រវត្តិទីតាំងណាមួយបានកត់ត្រានូវពពួកខ្លា *Panthera* នោះទេ នេះបង្ហាញថាប្រភេទខ្លាធំនិងខ្លាខ្លីទំនងជាផុតពូជនៅក្នុងតំបន់នេះទៅហើយ។ លើកលែងតែខ្លាពីរប្រភេទនេះចេញ និង ប្រភេទសត្វពាហនៈមានក្រចក (ungulates) ដែលជាអ្នកឯកទេសនៅក្នុងព្រៃបោះ ប្រភេទថនិកសត្វគោករងការគំរាមកំហែងក្នុងបញ្ជីក្រហមរបស់អង្គការ IUCN និងថនិកសត្វទឹកសាប ទំនងជាមានវត្តមានក្នុងតំបន់ទេសភាពព្រៃរងទឹកភ្លៀងជួរភ្នំក្រវាញ ដោយពួកវាត្រូវបានឃើញតាមរយៈម៉ាស៊ីនថតស្វ័យប្រវត្តិនាពេលថ្មីៗនេះ។ ដូច្នេះជួរភ្នំក្រវាញមានសារៈសំខាន់ណាស់សម្រាប់ការអភិរក្សជាសកល។ ផ្ទុយមកវិញ ការប្រមាញ់ជាពិសេសការដាក់អន្ទាក់ព្រមជាមួយនឹងការប្រើសត្វឆ្កែស្រុកជួយប្រមាញ់ក្នុងតំបន់ទេសភាពទំនងជាអាចធ្វើឲ្យមានការប៉ះពាល់យ៉ាងខ្លាំងលើតម្លៃផ្នែកអភិរក្សទាំងពេលបច្ចុប្បន្ននិងអនាគត។ ដើម្បីរក្សាឲ្យគង់វង្សនូវភាពចម្រុះនៃថនិកសត្វសំខាន់ៗបានគឺ តម្រូវឲ្យមានការផ្លាស់ប្តូរឲ្យប្រសើរឡើងនូវការទទួលខុសត្រូវទាំងរដ្ឋាភិបាលនិងសង្គមស៊ីវិលដើម្បីឆ្លើយតបទៅនឹងប្រភពនៃការបរាញ់នេះ។

Abstract

The Cardamom Rainforest Landscape (CRL) is a 17,000 km² protected landscape in southwestern Cambodia spanning an elevation range from sea-level to above 1,700 m. Despite the conservation value of the landscape there is little recent published information on the status and conservation significance of the ground-dwelling mammal populations. We report on seven camera trap studies conducted in five protected areas across the landscape between 2012 and 2016 with 255 trap-stations and >30,000 trap-nights. At least 30 species of medium to large ground-dwelling mammals were detected including one species included on the IUCN Red List as Critically Endangered, two as Endangered, eight as Vulnerable, and three as Near Threatened. Sun bears *Helarctos malayanus*, mainland clouded leopards *Neofelis nebulosa*, and dholes *Cuon alpinus* were detected from six or more of the seven studies. Populations of these three species in the landscape, though below ecological carrying capacity, are regionally significant. However we did not detect any *Panthera* cats, confirming that tigers *P. tigris* and leopards *P. pardus* are likely to have been extirpated. With the exception of these two species, and deciduous dipterocarp forest specialist ungulates, all globally threatened ground-dwelling and freshwater mammals likely to occur in the CRL have been detected in recent camera trapping surveys. The Cardamoms are thus of global conservation significance. However, poaching, particularly snaring, combined with the presence of domestic dogs across the landscape is likely to be impacting current and future conservation value strongly. The persistence of significant mammalian biodiversity requires a paradigm shift in both governmental and civil society responses to the drivers of poaching.

Keywords

Asian elephant, by-catch, camera trap, protected area, snare, small carnivore.

Introduction

The Cardamom Rainforest Landscape (CRL) is a conservation landscape covering >17,000 km² of protected areas in the southwestern Cambodian provinces of Koh Kong, Pursat, Kompong Speu, Preah Sihanouk, Battambang, and Kompong Chhnang (Table 1; Fig. 1). The landscape spans a large elevation range from sea level to the peak of Phnom Aural—at >1,700 m Cambodia’s highest mountain—and consequently a diversity of habitat types from mangroves and lowland rainforest to limited areas of montane cloud forest. The CRL forms part of a larger conservation landscape in southern and western Cambodia with 12 largely contiguous protected areas, from Bokor National Park to Samlaut Multiple Use

Area, covering 20,680 km². Since April 2016, the management of all protected areas in the landscapes has been under the General Department of Administration for Nature Conservation and Protection of the Ministry of Environment (MoE) (Souter *et al.*, 2016). A number of international conservation NGOs, including Wildlife Alliance, Fauna & Flora International, and Conservation International, are active in some of the protected areas in the CRL, supporting the MoE with protected area management, law enforcement, biodiversity monitoring, and conservation outreach and community development activities. Nevertheless, despite the presence of conservation activities in the landscape and presumed significance for biodiversity, little has been published on the conservation status of the landscape’s mammals

since pioneering surveys conducted at the turn of the century (e.g., Boonratana, 1999; Daltry & Momberg, 2000; Daltry & Traeholt, 2003; but see Holden & Neang, 2009; Royan, 2010; Coudrat *et al.*, 2011). The aim of this paper is to provide a compilation of recent (post 2012) camera trapping data from the landscape in order to provide an update on the status, and conservation significance, of the CRL's ground-dwelling mammals.

Methods

We collated data from seven discrete systematic camera trap studies conducted between 2012 and 2016 within five of the protected areas in the CRL (Table 2). Whilst camera trapping occurred in the landscape prior to this, 2012 was chosen as a start date for our analysis because data during the study period (2012–2016) were available to the authors and did not require significant additional analysis. All of the studies deployed at least 10 camera trap stations within clearly defined survey areas of between 10 and 200 km². Camera trapping on Phnom Dalai (site A; Fig. 1) was part of a monitoring programme for Asian elephant *Elephas maximus* conducted between 2010 and 2013; however we only use data from this site from between February 2012 and March 2013. Results from a camera trapping study in Peam Krasaop Wildlife Sanctuary between January and May 2015, which detected a number of threatened species, are being published separately (Thaung *et al.*, unpublished data). All of the studies had different objectives (Table 2), used

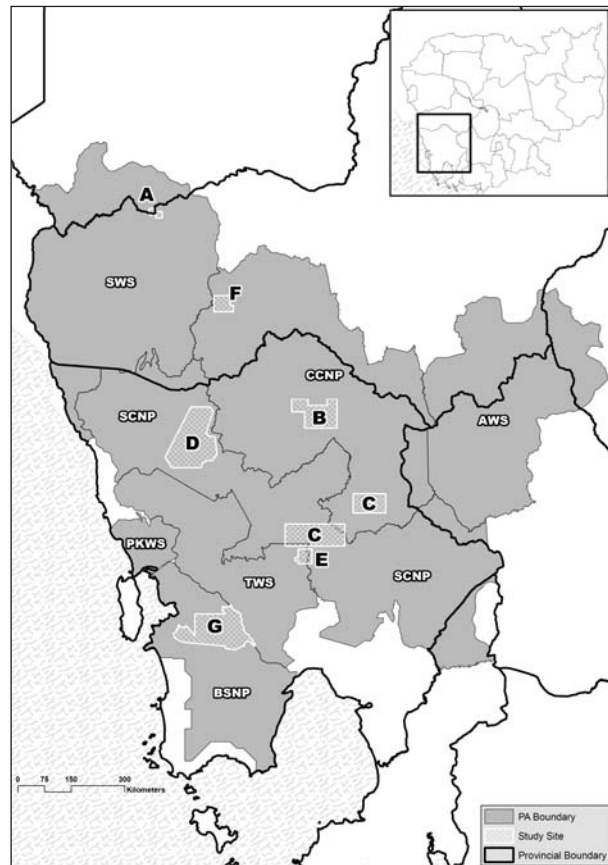


Fig. 1 Protected areas and locations of camera-trap studies within the Cardamom Rainforest Landscape, southwestern Cambodia. Abbreviations are given in Table 1 and individual letters refer to studies detailed in Table 2.

Table 1 Protected areas of the Cardamom Rainforest Landscape, southwestern Cambodia.

Protected Area	Size (km ²)	Elevation range (m a.s.l.)	% deforestation 2000–2015 ¹	% Economic Land Concession ²
Southern Cardamom National Park (SCNP)	4,104	10–980	2.7	0.3
Central Cardamom National Park (CCNP)	4,013	20–1,540	1.2	0
Phnom Samkos Wildlife Sanctuary (SWS)	3,338	10–1,717	8.2	2.3
Phnom Aural Wildlife Sanctuary (AWS)	2,538	60–1,740	8.6	20.2
Botum Sakor National Park (BSNP)	1,472	0–420	15.2	36.9
Tatai Wildlife Sanctuary (TWS)	1,443	10–520	3.1	0.5
Peam Krasaop Wildlife Sanctuary (PKWS)	238	0–240	5.7	0

¹ Estimated following Hansen *et al.* (2013).

² From datasets held by the Ministry of Agriculture, Forestry and Fisheries and the Ministry of Environment.

Table 2 Camera trap studies in the Cardamom Rainforest Landscape (2012–2016) included in this paper. NP = National Park; WS = Wildlife Sanctuary. Figures for survey area and elevation are approximate.

Study	Protected area	Dates	Locations & trap-nights	Survey area (km ²)	Elevation range (m)	Methodology & target species
A ¹	Phnom Dalai, Phnom Samkos WS	February 2012–March 2013	13 & 3,923	10	540–1,040	Asian elephant-targeted camera trapping with locations chosen to maximise detection of elephants
B ²	Central Cardamom NP	December 2012–March 2013	81 pairs & 8,152	95	460–1,220	Camera trap grid for clouded leopard capture-mark-recapture with cameras set as pairs in locations to maximise clouded leopard detections.
C ³	Central Cardamom NP	June 2015–June 2016	31 & 4,599	185	100–820	Approximate grid formation with cameras set at locations to maximise detections of large mammals.
D ⁴	Southern Cardamom NP	December 2015–June 2016	67 & 8,236	200	105–620	Random grid with cameras set within 50 m of predetermined random points.
E ⁵	Tatai WS	March–May 2016	14 & 969	20	140–440	Approximate grid formation with cameras targeting bears.
F ⁵	Central Cardamom NP	March–May 2016	14 & 865	30	540–660	Approximate grid formation with cameras targeting bears.
G ³	JW Concession, Botum Sakor NP	August–December 2016	35 & 3,425	180	10–380	Approximate grid formation with cameras set along trails (50%) and at random locations (50%).

Organisations leading data collection: ¹ Fauna & Flora International; ² Wildlife Conservation Research Unit; ³ Conservation International; ⁴ Wildlife Alliance; ⁵ Free the Bears. All work was done with the support of the Royal Government of Cambodia.

different methodologies, equipment, and survey teams. As such, their results are not directly comparable. Nevertheless they provide a useful summary of the current status of the ground-dwelling large mammal community across the landscape.

For every camera trap study we extracted records of all mammals detected excluding Scandentia (tree-shrews) and Rodentia apart from the two species of Hysticidae (Malayan porcupine *Hystrix brachyura* and Asiatic brush-tailed porcupine *Atherurus macrourus*). All records of primates were retained. Throughout the paper the taxonomy and nomenclature of IUCN (2016) is used. All photographs were verified for identification by three authors (TNEG, VHM, PC) with experience of camera trapping in the region. However, as many regional studies have shown (e.g., Hla Naing *et al.*, 2015), this approach is not foolproof and misidentifications may be present in the dataset. Images in which identifications were not possible (~6% of all encounters with ‘mammals’)

were excluded. The percentage of functioning (>20 nights of usable photographs) camera trap stations in each study from which each species was recorded was then calculated. We subsequently refer to this metric as ‘trap-prevalence’. For each camera trap site we also calculated a camera trap encounter rate (i.e. the number of photographic events per 100 trap-nights) for each species.

Results

Between February 2012 and December 2016, the seven studies generated data from 255 camera trap stations deployed for 30,169 trap-nights across approximately 720 km² of the CRL (Table 2). At least 30 species of mammal were detected including one listed as Critically Endangered (Sunda pangolin *Manis javanica*), two as Endangered (Asian elephant *Elephas maximus*, dhole *Cuon alpinus*), eight as Vulnerable, and three as Near Threatened (Table 3). Seven species were detected from

Table 3 IUCN status (CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened, LC = Least Concern), trap-prevalence (% of functioning camera traps recorded from) and camera trap encounter rate (number of photographic events per 100 trap-nights) of ground-dwelling mammals across seven camera trap studies in the Cardamom Rainforest Landscape, southwestern Cambodia (2012–2016). Study sites are identified in Table 2.

Species	IUCN status	Study sites						
		A	B	C	D	E	F	G
Northern pig-tailed macaque <i>Macaca leonina</i>	VU	100 / 6.4	27 / 0.4	35 / 0.5	38 / 0.7	36 / 1.3	64 / 3.4	51 / 0.7
Nicobar crab-eating macaque <i>Macaca fascicularis</i>	LC		1 / <0.1				7 / 0.9	3 / <0.1
Sunda pangolin <i>Manis javanica</i>	CR				17 / 0.1			3 / <0.1
Malayan porcupine <i>Hystrix brachyura</i>	LC	77 / 2.1	1 / <0.1	16 / 0.2	15 / 0.4	21 / 0.7	7 / 0.3	14 / 0.9
Asiatic brush-tailed porcupine <i>Atherurus macrourus</i>	LC		37 / 1.1	35 / 0.6	50 / 1.9	21 / 0.1	7 / 0.1	20 / 1.8
Dhole <i>Cuon alpinus</i>	EN	77 / 0.4	32 / 0.5	26 / 0.2	21 / 0.4		14 / 0.5	23 / 0.4
Sun bear <i>Helarctos malayanus</i>	VU	38 / 0.2	26 / 0.4	19 / 0.2	29 / 0.3	21 / 0.7	14 / 0.3	11 / 0.3
Asiatic black bear <i>Ursus thibetanus</i>	VU	54 / 0.2	1 / <0.1		2 / <0.1			
Yellow-bellied weasel <i>Mustela kathiah</i>	LC		4 / <0.1					
Crab-eating mongoose <i>Herpestes urva</i>	LC	62 / 1.5	17 / 0.2		6 / <0.1			3 / <0.1
Yellow-throated marten <i>Martes flavigula</i>	LC	8 / <0.1	36 / 0.8	6 / 0.1	2 / <0.1		21 / 0.4	
Ferret-badger <i>Melogale</i> sp.	LC	8 / <0.1						
Greater hog badger <i>Arctonyx collaris</i>	VU	77 / 0.6	4 / <0.1	3 / <0.1	2 / <0.1			34 / 0.9
Binturong <i>Arctictis binturong</i>	VU		2 / <0.1					
Common palm civet <i>Paradoxurus hermaphroditus</i>	LC	54 / 1.0	47 / 1.3	71 / 0.8	83 / 4.0	50 / 1.2	71 / 4.7	74 / 5.8
Masked palm civet <i>Paguma larvata</i>	LC		4 / <0.1					
Spotted linsang <i>Prionodon pardicolor</i>	LC		4 / <0.1					
Large Indian Civet <i>Viverra zibetha</i>	LC	69 / 2.1	58 / 2.0	13 / 0.1	6 / 0.1		7 / 0.3	
Small Indian civet <i>Viverricula indica</i>	LC						7 / 0.1	3 / <0.1
Spotted linsang <i>Prionodon pardicolor</i>	LC		4 / <0.1					
Clouded leopard <i>Neofelis nebulosa</i>	VU	31 / 0.3	14 / 0.1	3 / <0.1	9 / 0.1		7 / 0.1	9 / <0.1
Asiatic golden cat <i>Catopuma temminckii</i>	NT		14 / 0.2		6 / <0.1	7 / 0.1		
Marbled cat <i>Pardofelis marmorata</i>	NT		23 / 0.3	3 / <0.1	11 / 0.1		14 / 0.2	
Leopard cat <i>Prionailurus bengalensis</i>	LC	38 / 0.3	36 / 0.7	39 / 0.3	35 / 0.9			43 / 0.7
Asian elephant <i>Elephas maximus</i>	EN	85 / 1.9		19 / 0.2		29 / 0.7		
Wild pig <i>Sus scrofa</i>	LC	100 / 27.6	57 / 1.5	58 / 0.7	39 / 2.7	29 / 1.0	57 / 6.4	37 / 1.4
Lesser Oriental chevrotain <i>Tragulus kanchil</i>	LC	23 / <0.1	41 / 2.0	65 / 0.6	68 / 5.6	7 / 0.4	43 / 0.8	63 / 3.9
Sambar <i>Rusa unicolor</i>	VU		10 / 0.2	10 / 0.1	11 / 0.4	14 / 0.5	7 / 0.2	
Northern red muntjac <i>Muntiacus muntjak</i>	LC	100 / 26.9	78 / 3.7	61 / 0.9	58 / 1.8	36 / 1.3	50 / 2.1	49 / 1.6
Chinese serow <i>Capricornis milneedwardsii</i>	NT	8 / 0/6	10 / 0.1	3 / <0.1	15 / 0.7			
Gaur <i>Bos gaurus</i>	VU	85 / 11.0		6 / <0.1			7 / 0.1	

all studies including northern pig-tailed macaque *Macaca leonina*, sun bear *Helarctos malayanus* (both listed as Vulnerable), lesser Oriental chevrotain *Tragulus kanchil*, and northern red muntjac *Muntiacus vaginalis*. Mean trap prevalence varied from 64% for common palm civet *Paradoxurus hermaphroditus* to <0.5% (i.e. detected from a single camera trap location) for ferret badger *Melogale* sp.

Discussion

Few places in tropical Asia support a near-intact mammal species complement (Wilcove *et al.*, 2013) and our camera trap records confirm that the Cardamom Rainforest Landscape (CRL) is one such region. Rhinoceroses (Rhinocerotidae) have been extinct in Cambodia since at least the 1980s and the last record of tiger *Panthera tigris* from the country was in 2007 (Gray *et al.*, 2012). Nevertheless we present records of 11 globally threatened species and the CRL remains nationally and regionally significant for large mammal conservation. Although significant portions of the landscape were unprotected prior to the creation of the 4,100 km² Southern Cardamom National Park in May 2016, the CRL appears to have avoided the ecological extirpation of many medium to large mammals that has occurred due to hunting in many other protected landscapes in Indochina (Wilcox *et al.*, 2014; Harrison *et al.*, 2016). Almost all of the studies detected mainland clouded leopards *Neofelis nebulosa* (6 out of 7 studies; Fig. 2), dholes *Cuon alpinus* (6 out of 7; Fig. 2), and sun bears *Helarctos malayanus* (7 out of 7), which demonstrates that habitat quality and prey base remain reasonable within the CRL and that the pervasive snaring, which is impacting much of Southeast Asia (Gray *et al.*, 2017), has yet to drive massive declines in the populations of these moderately hunting-sensitive species.

We present camera trapping data in two forms: trap prevalence and encounter rate. However these metrics are unlikely to be directly correlated with species abundance or density. The term 'Relative Abundance Index' (*sensu* O'Brien *et al.*, 2003) for camera trap encounter rates is highly misleading and is increasingly regarded as a meaningless measure of species abundance or status (Sollmann *et al.*, 2013; Burton *et al.*, 2015). We therefore recommend trap-prevalence and encounter rate be used as the terms to report by-catch information from camera trap studies when more robust methodologies to account for non-detection (e.g., Capture Mark Recapture: Gray & Prum, 2012; Occupancy: Gray, 2012; Random Encounter Model: Rowcliffe *et al.*, 2008) are not employed. However, both trap-prevalence and encounter rate are likely to be biased. The former is likely a function of the size of the study area and, particularly, the duration of camera trap

deployment and the latter by camera trap placement in relation to a species' daily movements amongst a myriad of other factors (Sollmann *et al.*, 2013).

Status of selected species

The majority of the CRL comprises hilly evergreen forest and thus would have supported historically lower densities of ungulates and carnivores than the open deciduous dipterocarp forests of the northern and eastern plains (Gray *et al.*, 2013). The landscape's largest mammalian predators, tiger and leopard *Panthera pardus*, are likely to have been extirpated. Neither species has ever been recorded by camera trap from the CRL (though tiger was camera trapped from the adjoining Bokor National Park between 2000 and 2004) whilst there are no confirmed 21st century records of leopard from the Cardamom Mountains. Reliable surveys in the early 2000s recorded tiger pug-marks in a small number of locations (Daltry & Momberg, 2000; J. Holden pers. obs.) but there have been no records since 2005.

With the exception of bears, the dhole therefore remains the largest carnivore present in the landscape, as indeed Boonratana (1999) speculated was the case as long ago as the late 1990s. Dholes still appear to be relatively widespread: detected from six of the seven studies but pack size appears low (<5; many photographs show single individuals). However Kawanishi & Sunquist (2008) suggested dholes persist in smaller packs in the evergreen forests of Southeast Asia than in the Indian subcontinent probably due to the low prey biomass and small size of ungulate prey. It is also unclear how effective camera trapping is for estimating group size of species in dense evergreen forest. Nevertheless, videos (e.g., from sites D and G; Fig. 1) often show an individual dhole limping, presumably as a result of snare injuries. It is possible that dhole numbers in the CRL are depressed due to a combination of accidental mortality from snaring, interactions with domestic dogs, and reduced prey densities: threats which impact the species across its Asian range (Kamler *et al.*, 2015).

Although clouded leopards (Fig. 2) were detected in six of our studies, trap prevalence (10%) was lower than reported elsewhere in the species' range. For example, Tan *et al.* (2016) detected the species from 233 of 894 camera trap stations (trap-prevalence 26%) across nine sites in Peninsular Malaysia, with approximately 200 trap-nights required per clouded leopard photograph (compared to >750 trap-nights across our studies). This suggests that clouded leopard densities in the Cardamoms are likely to be below estimates from elsewhere in the species' range (e.g., between 2 and 5 individuals per



Fig. 2 Threatened and Near Threatened mammals in the Cardamom Rainforest Landscape. Clockwise from top-left: Asiatic golden cat *Catopuma temminckii* (site B, © WildCRU); Greater hog badger *Arctonyx collaris* (site G, © Wildlife Alliance); Marbled cat *Pardofelis marmorata* (site C, © Conservation International); Dhole *Cuon alpinus* (site G, © Wildlife Alliance); Chinese serow *Capricornis milneedwardsii* (site D, © Wildlife Alliance); Clouded leopard *Neofelis nebulosa* (site D, © Wildlife Alliance).

100 km²: Borah *et al.*, 2014; Mohamad *et al.*, 2015). Nevertheless the species is absent or very rare across many areas in Indochina (Wilcox *et al.*, 2014) including much of Cambodia (e.g., Gray *et al.*, 2014). Thus, given the size of the landscape, and detections of clouded leopard relatively close to villages and National Road 48 (e.g., <6 km at site G; Fig. 1), the CRL still seems likely to support a regionally significant population of the species.

Asian elephants remain in the landscape with the species detected from three of the seven studies, plus additional ad-hoc camera trapping in the core of Botum Sakor National Park (58 ‘encounters’ from five camera trap stations between December 2013–January 2014: Fauna & Flora International, unpublished data) and Tatai Wildlife Sanctuary (two camera trap locations between December 2014–March 2015: Wildlife Alliance, unpublished data). While Daltry & Traeholt (2003) reported strong local community support for Asian elephant conservation in the CRL, an estimated 38 indi-

viduals were poached between 2000 and 2004 (Gray *et al.*, 2016). However we believe poaching of elephant has been extremely limited in the landscape since 2006 and therefore elephant populations may be recovering with evidence of breeding (Gray *et al.*, 2016). Whilst population estimates and demographic data on the landscape’s elephant population have yet to be collated or analysed, field data collection for a faecal DNA capture-mark-recapture study was conducted across the core of the landscape during the 2015–2016 dry season by Fauna & Flora International. A population estimate is expected during 2017. The second largest herbivore extant in the landscape, the gaur, was only recorded from three of the seven camera trap studies in the landscape and its population seems likely to be small and potentially fragmented. Sambar *Rusa unicolor* and Chinese serow *Capricornis milneedwardsii* were recorded slightly more widely, particularly in more remote areas, but detection levels were low. Nevertheless the CRL is likely to support the most nationally important populations of these two

species, which are rarely detected in camera trap studies elsewhere in Cambodia (e.g., Phan *et al.*, 2010; Gray & Phan, 2012). Sambar are likely to have declined significantly throughout the country as much of Cambodia is suitable for the species (Timmins *et al.*, 2015). In contrast, mountainous habitat for Chinese serow (Fig. 2) is limited in Cambodia and the species is unlikely to have declined as precipitously. Nevertheless, recent camera trap records of serow appear restricted to the Cardamoms and Virachey National Park, where they were detected from 15 of 26 camera traps in 2014–2015 (G. McCann / HabitatID, pers. comm. 2017).

The status of small carnivores in the CRL warrants further research and more detailed analysis. The high trap-occupancy of the globally Vulnerable greater hog badger from Phnom Dalai (site A; Figs 1 & 2) and the JW Concession in Botum Sakor National Park (site G), at opposite ends of the range of elevations we camera trapped, is noteworthy. Only camera trapping in Virachey National Park, northeastern Cambodia (from 500–1,400 m. a.s.l., trap-occupancy 35% from 26 stations: McCann & Pawlowski, 2017) has detected the species as frequently in Cambodia in recent years. Believed to be highly susceptible to snaring (Duckworth *et al.*, 2016), the low number of detections of this species from the other sites is likely to reflect genuine declines driven by hunting. The JW Concession has the highest densities of patrol staff in the CRL (>8 per 100 km²). Combined with a unique management status (as an Economic Land Concession for ecotourism with Wildlife Alliance providing technical support for law enforcement), and the surrounding forest areas in Botum Sakor National Park receiving only nominal protection, such patrol levels may mean illegal activity, particularly snaring, may be low by regional and even landscape levels. It is possible that these levels of enforcement, instituted in 2014, may have allowed the recovery of hog badger and not slower breeding species (e.g., sambar). Alternatively, the JW Concession may represent prime habitat for the species differing in some respect from the majority of the landscape.

Our higher elevation sites (A and B; Fig. 1) produced a wider variety of small carnivores including the first national record of yellow-bellied weasels *Mustela kathiah* (for more details see Phan *et al.*, 2014) and supporting the finding of Holden & Neang (2009) that masked palm civets *Paguma larvata*, spotted linsangs *Prionodon pardicolor*, and ferret-badgers *Melogale* sp. are present at higher elevations within the Cardamom Mountains. Large-spotted civets *Viverra megaspila* was not detected in any of our studies despite records from other studies in the landscape with considerably less effort. Royan (2010)

reported a single camera trap photograph from Botum Sakor National Park in 2005, Timmins & Sechrest (2010) camera trapped two 'in the Andoung Teuk area' in 2008–2009, while the species has also been camera trapped around the Wildlife Release Station, Tatai Wildlife Sanctuary (N. Marx, pers. comm. 2017) and in areas of Central Cardamom National Park (Holden & Neang, 2009; Conservation International, unpublished data). Finally Thaug *et al.* (unpublished data) obtained 22 records from three of their six camera trap stations in and around Peam Krasaop Wildlife Sanctuary in 2015. Many of these sites are closer to villages and thus may experience higher hunting pressure than our study sites, making it appear unlikely that the absence of this species is due to hunting. The lack of large-spotted civet detections from the relatively well protected lowland and largely flat forests of the JW Concession (site G; Fig. 1) is perplexing. Large Indian civets *Viverra zibetha* were detected at more than 50% of camera trap stations in studies A and B (the two highest altitude sites) but only rarely elsewhere with no detections in studies E and G (Fig. 1). In sum, most of the survey areas did not record any *Viverra* at all despite recording a large complement of species conventionally considered to be more hunting sensitive than this genus. The reasons for the observed patterns of *Viverra* civet detections are unclear and may represent complex interactions involving the detectability of these species from large mammal focused camera trapping studies, hunting pressure, and habitat preferences.

The Critically Endangered Sunda pangolin *Manis javanica* was detected from two of the seven camera trap studies, both of which randomly deployed the cameras (sites D and G; Fig. 1). It is possible that detectability of pangolins from conventional large mammal focused camera trapping (in which cameras are often placed on trails, paths, water features etc.) may be very low and this would explain the paucity of records from camera trapping throughout tropical Asia. Sun bears *Helarctos malayanus* were detected from all camera trap studies and thus appears relatively widespread throughout the landscape. In contrast, the Asiatic black bear *Ursus thibetanus*, with only two records (at ~500 m a.s.l. at site D and ~800 m a.s.l. at site B; Fig. 1), was rarely detected away from Phnom Dalai (site A; Fig. 1) where the species was recorded by more than half of camera traps. This relatively high altitude site was the only study where Asiatic black bears were recorded more widely than sun bears.

The northern pig-tailed macaque was the most widely recorded globally threatened species (detected from all studies and on average from 50% of camera trap stations) and the CRL likely supports a large population. In Laos, Vietnam, and Myanmar, the species is predominantly

associated with lowland forests below 500 m (Boonratana *et al.*, 2008). However, our study includes multiple records above this elevation in sites A and B (Fig. 1) and the species was found across the full range of elevations camera trapped. Our analysis also supports the assertion of Coudrat *et al.* (2011) that stump-tailed macaque *Macaca arctoides* may not occur in the CRL. All confirmed Cambodian records are from east of the Mekong and it seems possible that previous claims (e.g., Kong & Tan, 2002) and assertions of occurrence in southwestern Cambodia (e.g., Walston, 2001) may have been in error.

Our studies did not detect any otter species but targeted camera trapping in the landscape recorded both hairy-nosed otter *Lutra sumatrana* and smooth-coated otter *Lutrogale perspicillata* between 2006 and 2012 (Heng *et al.*, 2016). As far as we can ascertain there are no records of Eurasian otter *Lutra lutra* from Cambodia and also no reliable (c.f. Daltry & Momberg, 2000) records of Asian small-clawed otter *Aonyx cinereus* west of the Mekong in the country. There has been little camera trapping in remnant areas of deciduous dipterocarp forest or grassland in the CRL. However, Thuang *et al.* (unpublished data) recorded large-spotted civets (see above), hog deers *Hyelaphus (porcinus) annamiticus*, and Sunda pangolins *Manis javanica* from grassland–*Melaleuca*–mangrove mosaics around Peam Krasaop Wildlife Sanctuary in 2015 (six camera trap stations; 511 trap-nights). More effort in remnant areas of deciduous dipterocarp forest is required, but it seems unlikely that significant, if any, populations of dry forest specialist species (e.g., banteng *Bos javanicus*, Eld’s deer *Rucervus eldii*, jungle cat *Felis chaus*, golden jackal *Canis aureus*, small Asian mongoose *Herpestes javanicus* and Burmese hare *Lepus peguensis*) remain in the landscape. The former two species and leopards are thus the only globally threatened terrestrial or freshwater mammals known to have occurred historically in Cambodia west of the Mekong, and still extant in the country, without recent (post 2012) camera trap records from the CRL.

Threats to Cardamom rainforest mammals

As is the case throughout Southeast Asia (Hughes, 2016) the mammal populations of the CRL are threatened by deforestation and hunting. Cambodia experienced the most rapid growth in deforestation rates globally between 2001 and 2014 (Petersen *et al.*, 2015) and approximately 1,150 km² of the CRL’s protected areas have been lost to Economic Land Concessions for industrial agriculture (Table 1; Davis *et al.*, 2015). This deforestation has disproportionately impacted lowland deciduous dipterocarp forest, particularly in protected areas with

limited NGO support for enforcement, and may have also isolated the core of Botum Sakor National Park from the rest of the landscape.

The widespread presence of domestic dogs in accessible areas (e.g., dogs were detected from 15 of 35 camera trap stations in site G; Fig. 1) is also an issue, particularly given the landscape’s dhole population. Domestic dogs are a significant threat to wildlife through disease transmission, predation, and non-lethal effects (Silva-Rodríguez & Sieving, 2012; Hughes & Macdonald, 2013). Free-ranging domestic dogs in the landscape require lethal management and protected area management authorities should be given the authority to implement this.

Illegal commercial hunting, particularly snaring, remains the major threat to the CRL’s ground-dwelling mammals and is likely to be impacting populations of most such species in the landscape (Gray *et al.*, 2017). For example, more than 109,000 snares were removed from the Southern Cardamom National Park and Tatai Wildlife Sanctuary between 2010 and 2015 (Wildlife Alliance, unpublished data) and law enforcement elsewhere in the landscape, with the notable exception of the JW Concession (see above), is minimal. This needs urgent attention through legislative reform criminalising the possession of materials used to construct snares and greater numbers of, and more efficient, protected area staff and rangers. It is hoped that the Natural Resource and Environmental Code of the MoE will sufficiently strengthen the Protected Area Law to ensure that snaring can be severely punished. Long-term social behaviour change communication, targeting the emotional and functional drivers of wild meat consumption in largely urban centres across Southeast Asia, is also critical. Any move to normalise wild meat consumption through wildlife farming needs to be strongly resisted given the potential for extremely negative impacts on biodiversity (Brooks *et al.*, 2010; Livingstone & Shepherd, 2016).

Despite the extirpation of some of Asia’s largest and most charismatic species of large mammal (e.g., two species, presumably, of rhinoceros, leopard, and tiger), our camera trap records show that the CRL remains regionally significant for the conservation of medium to large ground-dwelling mammals. However without urgent strengthening of legislation and law enforcement to reduce levels of snaring, and concurrent allocation of conservation resources to effective results-based protected area management and enforcement (Gray *et al.*, 2016), many of these species may soon disappear from the landscape and the spectre of “empty forests” will be realised.

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