

Rewilding in Southeast Asia: an assessment of conservation opportunities in Western Siem Pang Wildlife Sanctuary, Cambodia

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មូលនិយមសង្ខេប

អាស៊ីអាគ្នេយ៍កំពុងស្ថិតនៅក្នុងស្ថានភាពវិបត្តិនៃការវិនាសផុតពូជជាសាកល ដែលនៅតាមតំបន់ការពារ និងតំបន់អភិរក្សទេសភាពជាច្រើនកំពុងតែបាត់បង់ប្រភេទសំខាន់ៗ ជាពិសេសពពួកមាំមងសាសី និងតិណាសីមាខ្លះៗ។ ការធ្វើឱ្យប្រសើរឡើងវិញនូវទីជម្រកគឺអាចជាវិធីសមរម្យមួយសម្រាប់ការស្តារឡើងវិញនូវប្រព័ន្ធអេកូឡូស៊ីនៅក្នុងតំបន់។ យើងបានធ្វើការវាយតម្លៃពីភាពសំខាន់នៃការរស់ ៥៦ប្រភេទដែលរងគ្រោះ (ជិតផុតពូជបំផុត ជិតផុតពូជ ងាយទទួលរងគ្រោះ) និងជិតរងគ្រោះនៃក្រុមថនិកសត្វ សត្វស្លាប និងល្អិតសម្រាប់គម្រោងធ្វើឱ្យប្រសើរឡើងវិញនូវទីជម្រក ដោយផ្ដោតលើដែនជម្រកសត្វព្រៃសៀមប៉ាងខាងលិច(WSPWS) ដែលមានទំហំ ១,៣២០គីឡូម៉ែត្រក្រឡា និងជាតំបន់ការពារភាគឦសាននៃប្រទេសកម្ពុជាដែលធ្លាប់មានការរំខានខ្លាំង និងថយចុះនៃប្រភេទសំខាន់ៗជាច្រើន។ ដោយមានការលើកទឹកចិត្តក្នុងការស្តារប្រភេទឡើងវិញនៅក្នុងដែនជម្រក យើងបានធ្វើកំណត់ថ្នាក់ប្រភេទដោយផ្អែកទៅលើស្ថានភាពនៃការគំរាមកំហែងជាសាកល តួនាទីក្នុងសេវាកម្មប្រព័ន្ធអេកូឡូស៊ី ភាពសំខាន់ និងទិដ្ឋភាពជាក់ស្តែង ដូចជាឱកាសដែលអាចរកប្រភេទទាំងនោះបាននៅកម្ពុជា។ ប្រភេទដែលមានចំណាត់ថ្នាក់ខ្ពស់ជាងគេទាំង១៤ សម្រាប់ស្តារឡើងវិញរួមមានប្រភេទដែលត្រូវនាំត្រឡប់មកវិញ (ឧ.ក្រពើភ្នំ) និងប៉ូពុយឡាស្យុងដែលត្រូវធ្វើឱ្យប្រសើរឡើងវិញ (ឧ.រមាំង) និងប្រភេទដែលមានពិន្ទុលើសពី១២នៅក្នុងការវិភាគរបស់យើង (>៦៥% នៃពិន្ទុគឺសម្រាប់ប្រភេទដែលចាំបាច់ត្រូវស្តារឡើងវិញ)។ ប្រភេទដែលមានចំណាត់ថ្នាក់ខ្ពស់ភាគច្រើនគឺថនិកសត្វ។ វិធីនេះបានជួយយើងក្នុងការកំណត់ប្រភេទសម្រាប់ស្តារឡើងវិញនៅក្នុង WSPWS ទោះបីជាប្រព័ន្ធធ្វើចំណាត់ថ្នាក់របស់យើងមិនបានបញ្ចូលការកំណត់អត្តសញ្ញាណជាក់លាក់នៃការគំរាមកំហែង និងលទ្ធភាពនៃការកាត់បន្ថយទាំងនេះក៏ដោយ។ ការវាយតម្លៃនេះមានសារៈសំខាន់ខ្លាំងណាស់មុនពេលចាប់ផ្តើមគម្រោងស្តារប្រភេទឡើងវិញ ក្នុងនោះមានទាំងការនាំត្រឡប់មកវិញនៃប្រភេទ និងការធ្វើឱ្យប្រសើរឡើងវិញនូវប៉ូពុយឡាស្យុង។ សកម្មភាពកាត់បន្ថយការគំរាមកំហែង ចាំបាច់សម្រាប់ក្រពើភ្នំ និងរមាំង រួមមានពង្រឹងការអនុវត្តច្បាប់ និងការគ្រប់គ្រងតំបន់ការពារ ជាពិសេសការកាត់បន្ថយអត្រាស្លាប់ដោយការប្រើប្រាស់ឧបករណ៍នេសាទ និងអន្ទាក់ រួមជាមួយការការពារតំបន់ ជាពិសេសការធ្វើរបងការពារ។

Abstract

Southeast Asia is at the centre of the global extinction crisis with many protected areas and conservation landscapes missing key species, particularly large carnivores and herbivores. The emerging field of rewilding may be a promising conservation tool to recover ecosystems in the region. We assessed the desirability of 56 globally threatened (Critically Endangered, Endangered, or Vulnerable) and Near Threatened mammal, bird, and reptile species for rewilding

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projects focused on Western Siem Pang Wildlife Sanctuary (WSPWS), a 1,320 km² protected area complex in northeast Cambodia which has experienced extirpations and declines of many iconic species. Based on explicit motivations for rewilding within the sanctuary, we ranked species according to their global threat status, ecosystem service roles, charisma, and aspects of practicality such as opportunities for sourcing founders from Cambodia. The top 14 ranked candidates for rewilding included species reintroductions (e.g., Siamese crocodile *Crocodylus siamensis*) and population reinforcements (e.g., Eld's deer *Rucervus eldii*) and scored >12 points in our analyses (>65% of the score for a perfectly desirable candidate for rewilding). Most of the highly-ranked candidate species were mammals, a likely artefact of our inclusion of charisma as a criterion. This approach has helped us to identify candidate species for rewilding in WSPWS, although our ranking system did not incorporate explicit identification of threats or the feasibility of mitigating these. Such assessments are critical prior to commencing rewilding projects including reintroductions and population reinforcements. Mitigating actions required for Siamese crocodile and Eld's deer would include strengthening of protected area management and law enforcement across the landscape, particularly to reduce mortality in fishing gear and snares respectively, combined with ensuring portions of the protected area are inviolate and strictly protected, potentially through fencing.

Keywords Cambodia, conservation optimism, protected area management, reinforcement, reintroduction, restoration, rewilding, species conservation.

Introduction

Southeast Asia is at the centre of the Anthropocene extinction crisis as it supports more threatened species and is experiencing faster rates of forest loss and habitat degradation than any comparable continental area (Hughes, 2017). Weak governance, corruption, and inequality are widespread in the region and all three are strongly correlated with biodiversity loss (Amano *et al.*, 2018). This is exemplified in Cambodia which experienced the fastest acceleration in deforestation rates globally between 2001 and 2014 (Petersen *et al.*, 2015). Despite recent deforestation, Cambodia's protected area network remains extensively forested with large expanses of deciduous dipterocarp forest (DDF) across northern and eastern Cambodia (Wohlfart *et al.*, 2014). These form the largest remnant of this threatened ecosystem globally (Tordoff *et al.*, 2012). However, much of the DDF in Cambodia has suffered extensive defaunation, having experienced major declines in herbivores and carnivores over the past 75 years (Loucks *et al.*, 2009; O'Kelly *et al.*, 2012).

Asian elephants *Elephas maximus*, the largest land mammal in Asia, occurred widely across Cambodia as recently as the 1980s (Maltby & Bourchier, 2011). Due to extensive hunting, however, the species is now restricted in the country to just two populations exceeding 50 individuals (in the Eastern Plains and Cardamom Rainforest Landscapes) and isolated small herds elsewhere (Gray *et al.*, 2014). The region's largest carnivores, tigers *Panthera tigris* and perhaps leopards *P. pardus*, are functionally extinct in Cambodia, with the last record of tigers in the country in 2007 (Gray *et al.*, 2017a; Rosto-Garcia *et al.*,

2018). In contrast to many temperate regions (Ripple & Beschta, 2012), the loss of top carnivores has not resulted in concurrent increases in ungulates nationally. Rather, ungulates have become scarce due to high levels of poaching, largely using wire snares for the commercial wildlife meat trade (Gray *et al.*, 2017b). For example, deer populations have been depleted to such an extent that they are now extremely rare across large areas of Indochina (*sensu* Cambodia, Laos and Vietnam). Further, of the four species of wild cattle (banteng *Bos javanicus*, gaur *B. gaurus*, kouprey *B. sauveli*, and wild water buffalo *Bubulus arnee*) whose abundance in the DDF of Cambodia in the 1950s was such that the landscape was dubbed the 'Serengeti of Asia' (Wharton, 1968), kouprey are almost certainly globally extinct (kouprey), wild water buffalo are likely extirpated from Cambodia, whereas gaur and banteng have experienced substantial declines. Densities of gaur are currently too low to estimate anywhere in Cambodia, whereas banteng are effectively restricted to a single population in two protected areas in the Eastern Plains Landscape which is experiencing significant hunting-driven declines (Gray *et al.*, 2016) and a relict population in Kampong Speu Province (N. Marx, pers. comm.).

Nevertheless, with extensive forested landscapes remaining across Cambodia's protected area estate (which covers ca. 40% of the country) and an apparently reform-minded Ministry of Environment, opportunities exist to recover ecosystems and populations of iconic species ('rewilding' *sensu* du Toit & Petterolli, 2019). A prime example of a landscape suitable for rewilding is Western Siem Pang Wildlife Sanctuary (WSPWS) in north-

east Cambodia. A protected area complex comprising the Siem Pang and Siem Pang Khang Lech wildlife sanctuaries and approximately 1,300 km², WSPWS supports a matrix of DDF and semi-evergreen forest and is globally significant for conservation of characteristic birds including the largest global population of the Critically Endangered white-shouldered ibis *Pseudibis davisoni* (Wright *et al.*, 2012). However, large mammals (>50 kg) are either absent, in the case of tigers and probably leopards, or occur at greatly reduced densities, in the case of banteng, gaur and Eld's deer *Rucervus eldii* (BLCP, 2012). Given the documented significance of large mammals for ecosystem functioning, particularly in savannah forests (Ripple *et al.*, 2015), this defaunation raises a conservation issue above and beyond that presented by the loss of rare and culturally iconic species. It may also be impacting important habitats for significant bird populations at the site. As a consequence, development of a rewilding strategy for WSPWS has been identified as a conservation need by site managers. This study identifies possible species for rewilding efforts in WSPWS with a particular emphasis on species restoration, considers these in terms of desirability and reflects on aspects of the feasibility for recovery and rewilding in the landscape.

Methods

Study area

The study considered options for rewilding within the contiguous Siem Pang and Siem Pang Khang Lech wildlife sanctuaries (hereafter referred to as Western Siem Pang Wildlife Sanctuary [WSPWS] for convenience). WSPWS forms part of a network of protected areas in Laos, Cambodia and Vietnam which collectively encompass a protected land area of 11,217 km² (UNEP-WCMC & IUCN, 2017). WSPWS is located within the Western Siem Pang Important Bird Area (centred on 14°17'N, 106°27'E), Stung Treng Province, northern Cambodia (Fig. 1). The site is dominated by DDF, semi-evergreen forest, and riverine forest (Fig. 1), all of which occurs at low elevations (<350 m asl). The Sekong River runs approximately north to south through the site, is ca. 100–200 m wide and has a braided channel in the northern portion of the site which is dotted with small sand bars and rocky outcrops. Three smaller rivers, the O'Khampa, Stoeng Molu, and Stoeng Tin Hieng, are also present and are only partly navigable during the wet season.

WSPWS was identified as an Important Bird Area (IBA) in 2003, following the discovery of five Critically Endangered bird species at the site (Seng *et al.*, 2003).

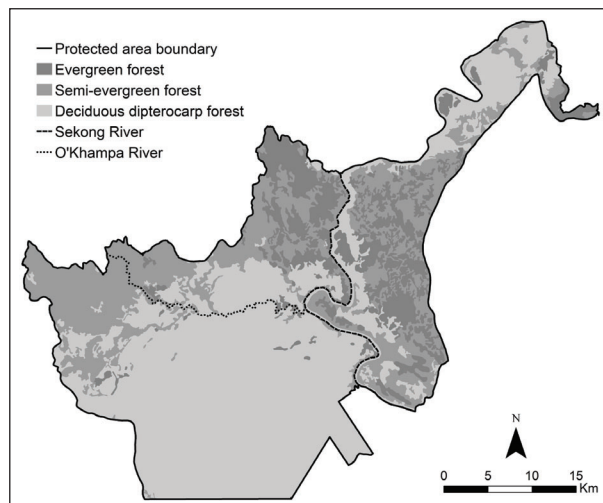


Fig. 1 Protected area boundaries, major rivers, and habitat types in Western Siem Pang Wildlife Sanctuary.

Subsequent surveys have revealed nesting populations of all five Critically Endangered birds, which includes Southeast Asia's largest populations of slender-billed vulture *Gyps tenuirostris*, white-rumped vulture *G. bengalensis*, and red-headed vulture *Sarcogyps calvus*. Additionally, approximately 35% of the global population of the white-shouldered ibis *P. davisoni* and 20% of the Critically Endangered giant ibis *Thaumatibis gigantea* occur at the site (Ty *et al.*, 2016; Wright *et al.*, 2012). Despite a significant population of Eld's deer (ca. 50–100 individuals), the landscape supports few mammals larger than wild pigs *Sus scrofa*, with Asian elephants extirpated in Siem Pang Kang Lech Wildlife Sanctuary (recent records only exist for Siem Pang Wildlife Sanctuary) and very low numbers of banteng and gaur (Loveridge *et al.*, 2018). The largest extant carnivore in the DDF landscape may now be the Asiatic golden jackal *Canis aureus*, although the mainland clouded leopard *Neofelis nebulosa* has been recorded in Siem Pang Wildlife Sanctuary (Loveridge *et al.*, 2018).

Assessing rewilding feasibility

Using recent reviews of the biodiversity of WSPWS (BLCP, 2012; Loveridge *et al.*, 2018), we identified all bird and mammal species considered globally threatened (i.e. Critically Endangered, Endangered, or Vulnerable) or Near Threatened by the IUCN that occur at the site or likely occurred prior to extirpation in the late 20th or early 21st century. These were considered as candidates for rewilding within the landscape and included species with no confirmed records (e.g., oriental small-clawed

otter *Aonyx cinereus*) that were listed in BLCF (2012) and likely occurred historically in the landscape given their habitat preferences and known range in Southeast Asia (Table 1). Due to the lack of comprehensive data on reptiles in BLCF (2012), we independently identified eight globally threatened or Near Threatened reptile species (crocodiles and chelonians only) which had been confirmed in the site since 2005 or which were also likely to have occurred historically (Table 1).

After excluding vagrants and non-resident visitors (three bird species), we classified each candidate species as locally extant or locally extinct. Mammal species were considered locally extinct if no confirmed records were listed for WSPWS in Loveridge *et al.* (2018) and birds and reptiles were considered locally extinct if no post-2010 records existed for the landscape. For locally extinct species, it was considered that any rewilding effort would comprise reintroduction under the *IUCN Guidelines for Reintroductions and other Conservation Translocations*, and for extant species, that this would consist of population reinforcement (IUCN SSC, 2013). Following consultations with site managers, one species of ecological significance (domestic water buffalo) was included in our analysis, whereas eight globally Near Threatened bird species with known and robust populations in the landscape were omitted from analysis.

Conservation rewilding can have various motivations and the relative importance of these is dependent upon the values of the organisations and individuals involved in a rewilding effort (Moro *et al.*, 2015). The main motivations for rewilding within WSPWS were to i) Restore ecological functionality to the DDF ecosystem, ii) Support conservation of globally threatened species, iii) Demonstrate the feasibility of rewilding in Asian dry forests, and iv) Promote the conservation value of the ecosystem and its biodiversity as an economic asset. Given these motivations, we assessed the suitability and 'value' of rewilding each candidate species in WSPWS by scoring these against three criteria: i) Global conservation status, ii) Ecosystem service role, and iii) Charisma. Charisma was included because of the potential role of the rewilding project to promote and showcase conservation in DDF, charismatic species being more likely to engage stakeholders, particularly government agencies (Colléony *et al.*, 2017). It was also considered that charismatic species could increase the economic value of WSPWS by providing opportunities for high-end ecotourism (Hausmann *et al.*, 2017). Further, because conservation translocations require sources of animals, we also scored each species according to the possibility of sourcing sufficient numbers of individuals from within Cambodia. We arbitrarily decided that the three criteria would be weighted

equally and higher scores represent species performing well against the motivations for rewilding (Table 2).

We assumed that rewilding species that possess a higher IUCN threat status would make a greater contribution to global species conservation. For mammals and birds, we scored species based on their published IUCN Red List status in January 2019. Critically Endangered species received a score of 4, Endangered species a score of 3, Vulnerable species a score of 2, and Near Threatened species a score of 1. Status assessments for chelonians were drawn from Rhodin *et al.* (2018) as these are updated assessments based on IUCN Red List criteria of the global conservation status of turtles and tortoises. Following relevant literature, we also assumed that large ungulate and apex carnivore species perform the most important ecosystem service roles in the DDF ecosystem (Davic, 2003; Ripple *et al.*, 2014; Ripple *et al.*, 2015). Consequently, we gave a score of 4 to species with a maximum body weight >100 kg or species which were apex carnivores, a score of 3 to species with a maximum body weight of 50–100 kg, a score of 2 to small to medium carnivores, frugivores and piscivores, and a score of 1 to all other species.

All conservation projects need to be practical and reintroduction or reinforcement efforts obviously require a source of appropriate animals. IUCN Species Survival Commission guidelines for conservation reintroductions recommend that founders for reintroductions 'should show characteristics (genetic, morphological, physiological, and behavioural) that are appropriate with the original populations' (IUCN SSC, 2013). While a number of studies have shown that reintroduction success is generally but not exclusively higher when wild (as opposed to captive) individuals are used (Fisher & Lindenmayer, 2000), we only considered captive populations as possible animal sources for rewilding efforts in WSPWS. This was because wild capture of sufficient individuals for rewilding efforts could impact the viability of source populations and would require considerable technical and financial resources. In the absence of clear understanding of the size of remnant populations of many of the globally threatened species assessed in our study, this was not felt to be justified. Consequently, each taxon was scored based on opportunities for sourcing individuals from appropriately managed captive populations in Cambodia. While animals could potentially be sourced from captive populations outside Cambodia, this possibility was excluded in our analysis because i) it was not possible to obtain complete data for collections held outside the country, and ii) there are substantial political, legal and practical barriers to transferring animals from neighbouring countries into Cambodia.

Table 1 Candidate species scores for rewilding in Western Siem Pang Wildlife Sanctuary (maximum score = 20). Two points were given to species which have been successfully reintroduced in Asia (Past Reintro) and two points were deducted for species associated with human wildlife conflict (HWC). The type column indicates whether a species rewilding project would be a reintroduction (ReinT), reinforcement (ReinF), or ecological replacement (EcoRe).

Species	Type	Threat	Ecosystem servicing	Sourcing	Charisma	Past Reintro	HWC	Total
Asian elephant <i>Elephas maximus</i>	ReinF	3	4	2	4		Yes	11
Gaur <i>Bos gaurus</i>	ReinF	2	4	2	2	Yes	Yes	10
Banteng <i>Bos javanicus</i>	ReinF	3	4	2	3	Yes		14
Domestic water buffalo <i>Bubalus bubalis</i>	EcoRe	0	4	4	1	Yes		11
Wild water buffalo <i>Bubalus arnee</i>	ReinT	3	4	1	4	Yes		12
Eld's deer <i>Rucervus eldii</i>	ReinF	3	3	3	3	Yes		14
Sambar <i>Rusa unicolor</i>	ReinF	2	3	3	2	Yes		12
Chinese serow <i>Capricornis milneedwardsii</i>	ReinF	1	2	3	1			7
Asiatic black bear <i>Ursus thibetanus</i>	ReinT	2	3	3	4			12
Sun bear <i>Helarctos malayanus</i>	ReinF	2	3	4	4			13
Tiger <i>Panthera tigris</i>	ReinT	3	4	1	4	Yes	Yes	12
Leopard <i>Panthera pardus</i>	ReinT	2	4	2	4	Yes	Yes	12
Dhole <i>Cuon alpinus</i>	ReinF	3	4	2	3			12
Mainland clouded leopard <i>Neofelis nebulosa</i>	ReinF	2	3	2	2			9
Fishing cat <i>Prionailurus viverrinus</i>	ReinT	2	2	2	4			10
Marbled cat <i>Pardofelis marmorata</i>	ReinT	1	2	1	3			7
Asiatic golden cat <i>Catopuma temminckii</i>	ReinF	1	2	1	1			5
Large spotted civet <i>Viverra zibetha</i>	ReinF	3	2	1	3			9
Greater hog badger <i>Arctonyx collaris</i>	ReinF	2	2	1	1			6
Hairy nosed otter <i>Lutra sumatrana</i>	ReinT	3	2	2	4			11
Smooth-coated otter <i>Lutrogale perspicillata</i>	ReinF	2	2	3	3			10
Eurasian otter <i>Lutra lutra</i>	ReinT	1	2	1	1			5
Asian small-clawed otter <i>Aonyx cinereus</i>	ReinT	2	2	2	3			9
Binturong <i>Arctictis binturong</i>	ReinT	2	2	2	3	Yes		11
Pygmy slow loris <i>Nycticebus pygmaeus</i>	ReinF	2	1	3	2			8
Annam gibbon <i>Nomascus annamensis</i>	ReinF	3	2	1	3	Yes		11
Red-shanked douc <i>Pygathrix nemaeus</i>	ReinF	3	2	1	3			9
Indochinese lutung <i>Trachypithecus germaini</i>	ReinF	3	2	3	3	Yes		13
Northern pig-tailed macaque <i>Macaca leonina</i>	ReinF	2	2	3	1		Yes	6
Black giant squirrel <i>Ratufa bicolor</i>	ReinF	1	1	2	3			7
Sunda pangolin <i>Manis javanica</i>	ReinF	4	1	3	2	Yes		12
White-winged duck <i>Asarcornis scutulata</i>	ReinF	3	2	1	2	Yes		10
Red-headed vulture <i>Sarcogyps calvus</i>	ReinF	4	3	1	3			11

Table 1 Continued.

Species	Type	Threat	Ecosystem servicing	Sourcing	Charisma	Past Reintro	HWC	Total
White-rumped vulture <i>Gyps bengalensis</i>	ReinF	4	3	1	3			11
Slender-billed vulture <i>Gyps tenuirostris</i>	ReinF	4	3	1	3			11
Indian spotted eagle <i>Clanga hastata</i>	ReinF	2	3	1	1			7
Green peafowl <i>Pavo muticus</i>	ReinF	3	1	2	3	Yes	Yes	9
Sarus crane <i>Antigone antigone</i>	ReinF	2	1	2	3	Yes		10
Giant ibis <i>Thaumatibis gigantea</i>	ReinF	4	2	3	4			13
White-shouldered ibis <i>Pseudibis davisoni</i>	ReinF	4	2	3	3			12
Asian woolly-neck <i>Ciconia episcopus</i>	ReinF	2	1	4	2			9
Greater adjutant <i>Leptoptilos dubius</i>	ReinF	3	2	2	3			10
Lesser adjutant <i>Leptoptilos javanicus</i>	ReinF	2	1	4	2			9
Great slaty woodpecker <i>Mulleripicus pulverulentus</i>	ReinF	2	1	1	2			6
Siamese crocodile <i>Crocodylus siamensis</i>	ReinT	4	4	4	3	Yes	Yes	15
Elongated tortoise <i>Indotestudo elongata</i>	ReinF	4	1	4	1			10
Asian giant softshell turtle <i>Pelochelys cantorii</i>	ReinF	4	1	3	2			10
Yellow-headed temple turtle <i>Heosemys annandalii</i>	ReinT	4	1	3	1			9
Southeast Asian box turtle <i>Cuora amboinensis</i>	ReinF	3	1	4	1			9
Giant Asian pond turtle <i>Heosemys grandis</i>	ReinF	3	1	2	2			8
Southeast Asian softshell turtle <i>Amyda ornata</i>	ReinT	2	1	3	1			7
Mekong snail-eating turtle <i>Malayemys subtrijuga</i>	ReinF	1	1	1	1			4

Table 2 Summary of criteria used for assessing species desirability for rewilding in Western Siem Pang Wildlife Sanctuary.

Criteria	Score			
	4	3	2	1
IUCN Threat Status	Critically Endangered	Endangered	Vulnerable	Near Threatened
Ecosystem Servicing	>100 kg / top carnivores	50-100 kg	Carnivores, frugivores, piscivores	Other
Sourcing (individuals in managed conservation breeding facilities in Cambodia)	>50	11–49	1–10	0
Charisma (ranking in MacDonald <i>et al.</i> , 2017)	1–50	51–150	151–500	>501
Other	0.3 (±0.2)	5.8 (±1.8)	0.9 (±0.3)	2 (±0.4)

Appropriately managed captive populations of globally threatened and Near Threatened species exist at two facilities in Cambodia: the Phnom Tamao Wildlife Rescue Centre (PTWRC) and the Angkor Centre for Conservation of Biodiversity (ACCB). The PTWRC is located outside Phnom Penh and is managed by the Cambodian government with technical and financial support from international conservation organisations, primarily Wildlife Alliance. The vast majority of animals in PTWRC originate from the illegal wildlife trade and the facility has been used to source individuals for ongoing reintroduction efforts including reintroduction of pileated gibbons *Hylobates pileatus* into forests surrounding the Angkor Wat temples (Le Roux *et al.*, 2019). The ACCB is located outside Siem Reap and is managed by Münster Zoo (Allwetterzoo). It principally hosts collections of large waterbirds and reptiles. The goals of the ACCB include species conservation and population restoration with an emphasis on *ex situ* breeding efforts for threatened species.

We obtained the number of each candidate species in the collections of PTWRC and ACCB. Species with >50 individuals in PTWRC or with ongoing *ex situ* breeding efforts at ACCB were given a score of 4, whereas species with between 11–49 individuals in PTWRC and ACCB were given a score of 3. Species with 1–10 individuals in PTWRC and ACCB were given a score of 2, whereas all other species were given a score of 1. As there were no pragmatic options for sourcing individuals of kouprey, Javan rhinoceros *Rhinoceros sondaicus*, and Sumatran rhinoceros *Dicerorhinus sumatrensis*, these were given a score of 0.

We scored the charisma of each candidate mammal species using MacDonald *et al.* (2017) who modelled the appeal of all terrestrial mammals (4,320 species) based on interview surveys conducted globally. Candidate species included in the top 50 most appealing species were given a score of 4, whereas those ranked between 51–150 were given a score of 3. Candidates ranked between 151–500 were given a score of 2, whereas the remainder received a score of 1. In the absence of similar models for birds and reptiles, the lead author allocated each species a charisma score based on his personal judgement (Table 1).

Two additional factors that may influence the ease and desirability of a rewilding project were also considered: practicality and risk. On practicality, two additional points were given to a species if we were able to find information confirming that reintroduction or population reinforcement efforts had been undertaken in Asia which resulted in the breeding of translocated individuals in the wild. We acknowledge that while this does not necessarily indicate successful reintroduction, it does

at least demonstrate that such a project is practically and technically feasible. On risk, two points were deducted from the score for a species if it was deemed through literature review and our field experience to pose a risk to human populations or livelihoods as a result of human wildlife conflict.

Results

We assessed a total of 56 taxa (34 mammals, 14 birds, and eight reptile species) for rewilding desirability in WSPWS (Table 1, Fig. 2). These species represented 21 reintroductions, 34 population reinforcements, and one ecological replacement (domestic water buffalo). Thirteen species assessed (five birds, four reptiles and four mammals) were listed by the IUCN as Critically Endangered and 15 were listed as Endangered (11 mammals, two birds and two reptiles).

Twelve species received the highest score for ecosystem service functioning: four apex predators (Siamese crocodile *Crocodylus siamensis*, leopard, tiger, and dhole *Cuon alpinus*), and eight herbivores weighing >100kg (Asian elephant, four wild cattle species, domestic water buffalo, and two rhinoceros species). Eight of our candidate species were modelled by MacDonald *et al.* (2017) as among the top 50 most charismatic mammals on the planet: Asian elephant (ranked 1st), wild water buffalo (2nd), tiger (6th), sun bear *Helarctos malayanus* (13th), Asiatic black bear *Ursus thibetanus* (12th), leopard (17th), hairy-nosed otter *Lutra sumatrana* (34th), and fishing cat *Prionailurus viverrinus* (39th). We also gave the highest score to giant ibis, this being the national bird of Cambodia, and an icon for ecotourism and community outreach activities in the country. Seven species received the highest score for ease of sourcing within Cambodia. These were Siamese crocodile and sun bear, with more than 50 individuals at PTWRC, and Asian woolly-neck *Ciconia episcopus*, lesser adjutant *Leptoptilos javanicus*, elongated tortoise *Indotestudo elongata*, and Southeast Asian box turtle *Cuora amboinensis*, due to established captive breeding efforts at ACCB. The ubiquitous domestic water buffalo was also given a score of four points. Finally, we found evidence that 17 of our taxa had been subject to ongoing ‘successful’ reintroduction or translocation projects in Asia, whereas seven taxa had points deducted for potentially being a cause of human wildlife conflict (Table 1).

None of our candidate species scored the theoretical maximum of 20 points. Indeed, only 14 species scored >12 points, equivalent to >65% of the score for a perfectly desirable candidate for rewilding (Fig. 3). The highest rated taxon, with 15 points or 75%, was the Siamese



Fig. 2 Selected candidate species for rewilding in Western Siem Pang Wildlife Sanctuary. Clockwise from top-left: elongated tortoise *Indotestudo elongata*, Eld's deer *Rucervus eldii* (© J.C. Eames), Siamese crocodile *Crocodylus siamensis* (© J. Holden / Wildlife Alliance), and white-winged duck *Asarcornis scutulata* (© J.C. Eames).

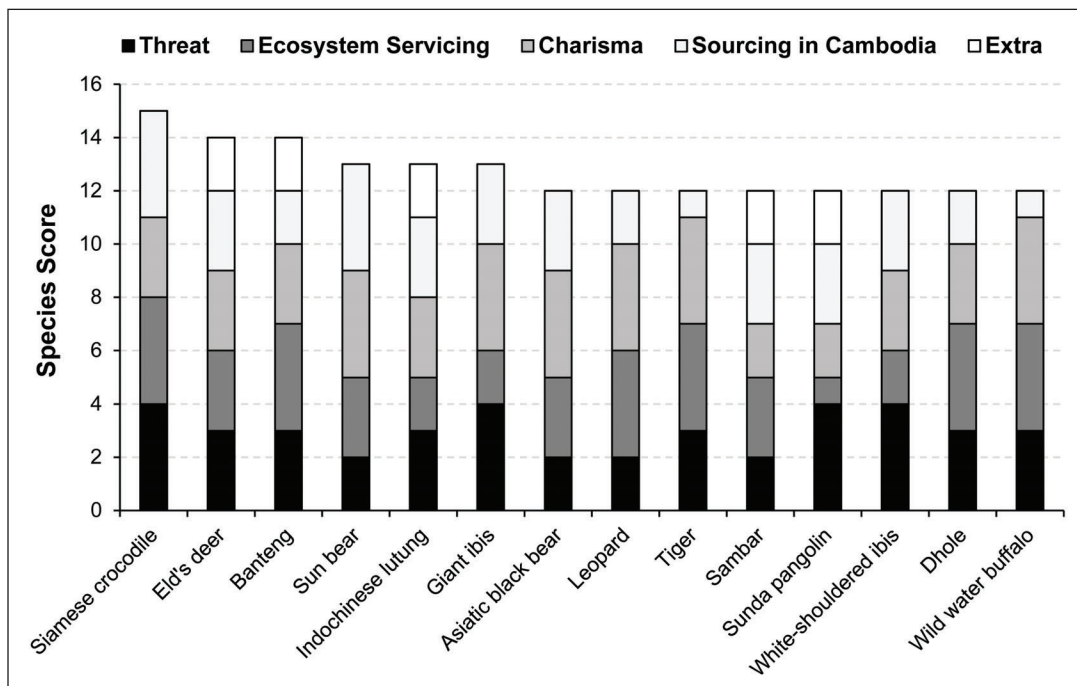


Fig. 3 Highest-ranked species for rewilding in Western Siem Pang Wildlife Sanctuary based on the sum score for four equally-weighted criteria. Extra points were given to species which have been successfully reintroduced in Asia in the past.

crocodile. This was closely followed by banteng and Eld's deer, both of which scored 14 points. The highest-ranking birds were giant and white-shouldered ibis with 13 and 12 points, respectively. The species that were ranked lowest and so the least desirable for rewilding based on our approach were the Mekong snail-eating turtle *Malayemys subtrijuga* with four points, followed by Asiatic golden cat *Catopuma temminckii* and Eurasian otter *Lutra lutra* with five points.

Discussion

We formulated a framework for identifying suitable species for rewilding projects (once appropriate feasibility studies are completed) and applied this to WSPWS, a globally significant area for conservation in northeast Cambodia. Uncritical application of the term 'rewilding' to conservation restoration projects has recently been criticized (Hayward *et al.*, 2019) and du Toit & Pettorelli (2019) attempted to define the key aspects of rewilding. Based on these principles, our conservation vision for WSPWS has characteristics of both restoration and rewilding (du Toit & Pettorelli, 2019). However, we prefer to use the term rewilding because we believe this demonstrates the novelty of our approach within an Indochinese context where there is limited history of restoration. Pragmatically, use of the term rewilding also has considerable additional value for promotion and fund-raising.

We assessed the 'desirability' of rewilding 56 taxa listed as globally threatened or Near Threatened in the *IUCN Red List*. These species would constitute 21 reintroductions (i.e. species known to be extirpated from WSPWS), 34 population reinforcements (i.e. species with extant populations in WSPWS), and one ecological replacement (domestic water buffalo). However, because the current status of a number of taxa (e.g., marbled cat *Pardofelis marmorata*) is unknown in WSPWS, it is unclear whether a rewilding project would constitute a reintroduction or a reinforcement. The criteria we used for assessing desirability for rewilding and their relative weighting were influenced by the site-specific goals of the managers of WSPWS and as such, our scoring system is largely subjective in the sense that it is site-specific and driven by local experts. Despite these caveats, we feel that our results identify species which should be seriously considered for rewilding the landscape and for which thriving populations in WSPWS would provide important ecosystem services. They would also be of high global conservation value and constitute flagships for rewilding in tropical Asia and conservation of dry and semi-evergreen forests in Cambodia.

However, robust feasibility and risk assessments need to be conducted prior to any rewilding actions for all of the species considered. This is particularly true given that we deliberately did not address one of the most critical aspects of any conservation translocation: threat mitigation. IUCN guidelines state that reintroductions and population reinforcements are not advised if threats have not been mitigated (IUCN SSC, 2013). Thus, any feasibility plan for rewilding in WSPWS would need to explicitly identify threats to the target taxa and state measures required to mitigate or avoid impacts on reintroduced or supplemented populations. Evidence that threats identified were sufficiently reduced would also be needed prior to any animal releases. Only then could any of the species we assessed as desirable for rewilding be considered suitable. Currently, threats to most of the species we analysed in WSPWS are extensive and increasing due to a combination of insufficient law enforcement, infrastructure development, and growing human populations. Effective threat mitigation would therefore likely be the most difficult and expensive aspect of any rewilding effort in WSPWS. In the following sections, we discuss several of the top-ranked species in from our analysis and identify some of the threats and mitigation efforts which would need to be undertaken prior to any rewilding effort.

The Siamese crocodile was jointly ranked as the most desirable species for rewilding in WSPWS. The species is Critically Endangered with an estimated population of <400 wild individuals remaining across 35 localities in Cambodia (Bezuijen *et al.*, 2012). More than 75% of the occupied waterways and 90% of the population are in the Cardamom Rainforest Landscape, southwest Cambodia (Han *et al.*, 2015). Given its global conservation status, establishment of a new population in northeast Cambodia, where the species was likely extirpated in the early 2000s, would be of clear conservation value. Population reinforcement efforts for Siamese crocodile are ongoing in Cambodia using individuals from captive populations at the PTWRC and crocodiles head-started from harvested wild nests. Between 2011 and 2017, 81 such crocodiles were released into the Cardamom Mountains (Eam *et al.* 2017; J. Frechette, pers. comm.). The apparent success of these efforts and availability of individuals for rewilding in WSPWS were factors that contributed to the high score of the species in our assessment.

While hunting for skins and capture to stock legal commercial crocodile farms were major drivers of the historic decline of Siamese crocodile, the greatest threats to populations in Cambodia are now habitat loss and degradation and incidental capture and drowning in

fishing gear (Bezuijen *et al.*, 2012). Due to the habitat loss and hydrological changes caused by hydropower development, this has also been identified as a threat across Southeast Asia (Bezuijen *et al.*, 2012). Reintroduction of Siamese crocodile to WSPWS would require identification of stretches of largely undisturbed and near-pristine riverine habitat and active law enforcement to reduce human disturbance and illegal fishing in such sites. The existence of and potential for future hydropower developments within the Sekong River would also need assessment. Siamese crocodiles are widely believed to pose minimal threat to humans and communities that have co-existed with the species for generations continue washing, bathing and swimming in the same waterbodies with little hesitation (Han *et al.*, 2015). However, Cambodians living in areas where crocodiles have been absent for several decades or more tend to be fearful of them (Han *et al.*, 2015). As most residents in WSPWS would have never observed crocodiles, the social implications of returning a large and 'ferocious' carnivore to the landscape would need to be considered and mitigated. While local informants have reported that Siamese crocodile still occurs in WSPWS (present authors, pers. obs.), we believe this reflects an example of collective memory rather than the current situation. In the only village in WSPWS (Kampourk), a Buddhist temple flies a flag depicting a crocodile (present authors, pers. obs.). This could present an intriguing opportunity to engage local religious leaders to promote community support for reintroduction of the species.

Our analysis identified Eld's deer and banteng among the most desirable species for a rewilding project comprising population reinforcement in WSPWS. Eld's deer is endemic to the dry forests of Southeast Asia and surrounds and wild populations of the *siamensis* subspecies are now restricted to the DDF in northern and eastern Cambodia and two sites in Laos (Gray *et al.*, 2015). These populations are small (likely considerably fewer than 100 individuals), fragmented, and suffer from high levels of anthropogenic mortality (primarily hunting and killing by domestic dogs). WSPWS may support one of the largest remaining populations of the *siamensis* subspecies globally, with a minimum estimate of 39 adults in April 2018 (Eames, 2018a). Historically, the species would have been abundant throughout the dry forests and as presumably the most naturally abundant deer would have provided significant ecosystem services through herbivory, wallowing (by males during the rut), trampling, and as prey for large carnivores. Managed populations of Eld's deer in Hainan exceed 50 individuals per km², densities which seem likely to be close to the natural carrying capacity of forests in Cambodia, and which are similar to the densities of functional equivalents in

similar South Asian habitats (Jathanna *et al.*, 2003; Zeng *et al.*, 2005; Gray *et al.*, 2015). Given the global conservation status of the species, the significance of the population in WSPWS, and its potential ecosystem service role, Eld's deer would clearly be a good candidate for rewilding in WSPWS provided the impact of hunting can be mitigated.

Twenty-four Eld's deer (presumably *siamensis*) are currently in captivity at PTWRC. However, as this population originated from only two individuals and has not been subjected to conservation management, it is potentially vulnerable to inbreeding depression. There are also ca. 75 individuals of the *siamensis* subspecies in captivity in Thailand. However, it may be difficult to source these for rewilding efforts in Cambodia due to political and/or institutional constraints (N. Marx, pers. comm.). Thai conservationists have already reintroduced the *thamin* subspecies in western Thailand (Bhumpakphan *et al.*, 2003). Capture of wild individuals from relict and declining populations in Cambodia such as the one at Ang Trapeang Thmor in Banteay Meanchey Province would be logistically difficult, expensive and politically challenging. Prior to initiating a rewilding project for Eld's deer in WSPWS, we recommend an assessment of sourcing options and viability of the population in WSPWS to determine the conservation value, in terms of reducing extinction probability and increasing the population, of supplementation using a range of realistic numbers. The most significant threats to Eld's deer in WSPWS are predation of fawns by domestic dogs, hunting for meat and trophy antlers with guns, and mortality in snares set for all ungulates (Gray *et al.*, 2015). A clear strategy for dealing with these threats would need implementation prior to any translocation. This would need to ensure significantly improved levels of law enforcement patrolling and protected area management, potentially within a fenced portion of WSPWS, together with a programme for community education and domestic dog control, which would ultimately include lethal control.

Banteng scored as highly as Eld's deer, being a globally Endangered large ungulate with presumably significant ecosystem service roles which has been successfully reintroduced into national parks in Thailand (Chaiyarat *et al.*, 2017). Though banteng require a mixture of open deciduous dipterocarp and more evergreen forest types (Gray, 2012), the species is characteristic of the dry forests of the Lower Mekong and faces threats similar to Eld's deer (Gardner *et al.*, 2016). However, numbers of banteng in WSPWS are extremely low with only a small number of camera-trap photographs (one male, one female, and one calf) from April 2013 reported by Loveridge

et al. (2018), possibly the last banteng in the landscape. Sourcing banteng would also be more problematic than Eld's deer with currently only two bulls held at PTWRC. While translocation of wild animals was not considered in this study, a recently-identified banteng population numbering 30–50 animals in a 1,000 ha forest enclave in Kampong Speu Province could be considered for translocation if conventional conservation measures *in situ* fail (N. Marx, pers. comm). The threat mitigation needs in WSPWS would be similar to those for Eld's deer and it may be possible to source banteng from Thailand where expertise in their translocation also exists.

Other candidate species which scored 12 or more points included the two bear species, one primate (Indo-chinese lutung *Trachypithecus germaini*), three top-carnivores (leopard, tiger, and dhole), two ungulates (sambar *Rusa unicolor* and wild water buffalo), Sunda pangolin *Manis javanica* and the two Critically Endangered ibises (giant and white-shouldered ibis). There are significant captive populations of sun bears (80) and Asiatic black bears (38) at the Free the Bears facility in PTWRC that originate from confiscations from the wildlife trade. Wildlife Alliance has reintroduced rehabilitated sun bears in the southern Cardamom Rainforest Landscape and therefore has the institutional expertise to undertake such a project. However, adequate mitigation of snaring to prevent re-capture of released animals remains an obstacle to success. For example, the initial release of two radio-collared bears Cardamom Rainforest Landscape was aborted after both individuals were caught in snares. Rehabilitated in captivity, one was subsequently released and lived for almost a year before being predated by another wild sun bear (N. Marx, pers. comm.).

Twenty-five Indo-chinese lutungs are currently held in PTWRC but these likely represent the nominate form. *Trachypithecus germaini margarita*, which is increasingly regarded as a separate species, is the form likely to occur in WSPWS (Moody *et al.*, 2011). Habitat monitoring at WSPWS also reveals that riverine forest, the habitat apparently preferred by the species, is the most threatened forest type in the landscape due to preferential clearance for agriculture (BirdLife Cambodia, unpublished data). The Critically Endangered Sunda pangolin is notoriously difficult to breed in captivity, but live individuals are often confiscated from the illegal wildlife trade and Wildlife Alliance have released radio-tagged individuals into the Cardamom Rainforest Landscape (N. Marx, pers. comm.). In July 2019, a Sunda pangolin confiscated at WSPWS was released in the wildlife sanctuary (present authors, pers. obs.).

As Asia's most recognizable and charismatic mammal and the top carnivore across its historical range, tiger

was not surprisingly identified as desirable for rewilding in WSPWS. Indeed, there are active, albeit potentially controversial, plans to reintroduce tigers to Cambodia, with the dry forests of the Eastern Plains Landscape and the rainforests of the Cardamom Mountains identified as prime reintroduction sites (Gray *et al.*, 2017d). Given the ecological similarity of WSPWS to the Eastern Plains Landscape, there is no fundamental reason why the 11,217 km² protected area complex which it forms part of would not also be suitable for tiger reintroduction. However, constraints identified by Gray *et al.* (2017d) and Miquelle *et al.* (2018) would apply, including insufficient ungulate prey, poor law enforcement and protected area management and limited community support and engagement. In contrast to Siamese crocodiles, well-documented cases of livestock and human fatalities caused by tigers exist across their global range (Inskip *et al.*, 2013). The lack of an unambiguously acceptable source for tigers also reduces their feasibility for reintroduction in WSPWS. The high ranking of tiger in our assessment highlights both the strength and weaknesses of our approach. The species is being considered for transformational rewilding projects in Cambodia, but the barriers to success, most notably threat mitigation, are substantial.

Sourcing wild water buffalo would be close to impossible, but domestic water buffalo represents an ecological analogue which also scored highly (11 points). Historically, wild water buffalo played an important role in maintaining habitat diversity, particularly around waterholes, in DDF throughout Southeast Asia (Wharton, 1968). Following extensive declines in numbers of wild ungulates and Asian elephants, the wallowing and grazing of domestic water buffalo *Bubalus bubalis* played a similar role in maintaining the ecological integrity of forest pools (Wright *et al.*, 2013). However, buffalo ownership in many DDF areas is decreasing due to agricultural modernisation. In WSPWS for example, 80% of buffalo herd owners have reported a desire to replace their buffaloes with hand-tractors within the next few years (BirdLife Cambodia, unpublished data). Wright *et al.* (2013) hypothesised that a future absence of domestic water buffalo from the site would increase sedimentation and vegetation at waterholes and thereby reduce their suitability for white-shouldered ibis. This is because domestic water buffalo live almost as feral animals in WSPWS, being rounded up only once per year (present authors, pers. obs.). However, recent experiments in WSPWS failed to find convincing evidence that small herds of domestic water buffalo significantly impact waterhole structure (Eames *et al.*, 2018b). Nevertheless, the release of forest-adapted and drought-resistant domestic water buffaloes into WSPWS would likely have important ecological benefits and help to replicate historic

grazing and wallowing patterns within the dry forest. This approach would be similar to many of the trophic rewilding projects being initiated in Eurasia (Pereira & Navarro, 2015), with the added benefit of providing additional biomass for the Critically Endangered vulture population at the site. As gun-hunting for trophy horns is likely to have caused the extirpation of wild water buffalo from Cambodia (present authors, pers. obs.), any rewilding of domestic water buffalo would need to be coupled with improved law enforcement patrols on the ground. Indeed, since the construction of a border road along the northern border of WSPWS which separates Laos and Cambodia, poaching of domestic water buffalo by Lao hunters has increased (present authors, pers. obs.).

The highest-ranked bird species, largely as a result of their Critically Endangered status and high charisma scores, were the giant and white-shouldered ibises, both of which breed in WSPWS. The ACCB is currently establishing insurance *ex situ* captive populations of both. However, threats to the ibises are poorly understood and until these are clarified and evidence shows that they have been mitigated, we do not recommend them for rewilding and believe that the focus should remain on establishing viable *ex situ* populations. The white-winged duck *Asarcornis scutulata* has been released in protected areas in Thailand, including Huai Kha Khaeng Wildlife Sanctuary (authors, pers. obs.) and is therefore a potential candidate for reintroduction. Many of the mitigating actions required for reintroducing Siamese crocodiles (see above) would also benefit this species. However, the flightless period during moulting renders these ducks particularly susceptible to hunting. A lack of sourcing options (no captive individuals exist in Cambodia) and limited information on the ecosystem service roles of the species resulted in it receiving a score of 10. Hornbills (Bucerotidae) play an important ecosystem service role in Asian forests through seed dispersal (Corlett, 2017) and the oriental pied hornbill *Anthracoceros albirostris* has been successfully reintroduced to Singapore (Cremades *et al.*, 2011). Two possible hornbills for rewilding in WSPWS, great hornbill *Buceros bicornis* and wreathed hornbill *Rhyticeros undulatus*, both of which are now considered globally Vulnerable, scored 10 and 9 points respectively. These have been released in the Cardamom Rainforest Landscape by Wildlife Alliance using animals confiscated from the illegal wildlife trade (Gray *et al.*, 2017c).

Aside from the Siamese crocodile, few reptiles ranked highly in our assessments because these mostly scored poorly in the two most subjective criteria: ecosystem service values and charisma. Opportunities for rewilding nevertheless exist, most notably in the case of elon-

gated tortoise and Asian giant softshell turtle *Pelochelys cantorii*, two species categorized as Critically Endangered (Rhodin *et al.*, 2018). Monitored releases of both species, particularly individuals from the captive population of elongated tortoises at ACCB, is possible. However, other protected landscapes which are currently better protected, such as the JW Concession inside Botum Sakor National Park (Gray *et al.*, 2019), may provide better prospects for release in the near future given the ongoing and trade-driven threats to almost all Asian chelonians (Rhodin *et al.*, 2018).

Given our stated goals for rewilding in WSPWS combined with the results of our analysis, we recommend that initial rewilding efforts in the landscape focus on a subset of the mammals and reptiles identified. Species-specific feasibility studies should be conducted prior to any rewilding efforts however and there are likely to be significant hurdles associated with mitigating threats and improving protected area management across WSPWS. Having considered the present analysis, Rising Phoenix Co. Ltd., a social enterprise established to support conservation of WSPWS through partnership with government and development of a long-term financing strategy, has begun implementing the following measures. First, a commitment has been made to expand enforcement to reduce levels of gun-hunting and snaring via training, professionalization of management protocols, and increased numbers of enforcement rangers. Second, Rising Phoenix anticipates fencing of at least part of the protected area boundary to regulate human access and prevent the entry of domestic dogs. Allied to this, a PhD student from the University of Queensland is presently undertaking research on the distribution and habitat preferences of Eld's deer and the extent of predation by domestic dogs. Taken together, these will provide a comprehensive foundation for restoration of the species in WSPWS.

Gray *et al.* (2017a) argued that rewilding projects and reintroduction of iconic species in Cambodia, particularly tigers, could catalyse political and financial support for landscape-scale conservation. However iconic and charismatic species would be critical for this to occur and few taxa match the appeal of tigers or Asian elephants. Given the likely role of large grazers such as water buffaloes in structuring ecosystems, we recommend that rewilding in WSPWS begin with serious efforts to create large feral domestic water buffalo herds inside the protected area. If suitable riverine stretches can be found and targeted enforcement achieved, the conditions required for Siamese crocodile release could be achieved. Most of the other species that ranked highly in our analysis would require more detailed planning and feasibility studies

to mitigate threats and determine sourcing options and conservation benefits of such projects (e.g., Eld's deer). Despite a number of challenges, we believe that rewilding will become an increasingly important conservation tool in Southeast Asia and our assessment represents the first attempt to identify appropriate candidates for rewilding efforts in the region's forests.

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