Cambodian Journal of Natural History

Masked finfoots

Fire ecology in dry forests

Lessons learned from community nest guarding

Eight years of camera trap photographs

July 2012 **Vol 2012 No. 1**

Cambodian Journal of Natural History

ISSN 2226–969X

The *Cambodian Journal of Natural History* (ISSN 2226–969X) is a free journal published by the Centre for Biodiversity Conservation, Royal University of Phnom Penh. The Centre for Biodiversity Conservation is a non-profit making unit dedicated to training Cambodian biologists and to the study and conservation of Cambodian biodiversity.

Cover photo: A tiger in Phnom Tamao Wildlife Rescue Centre (© Jeremy Holden). The last known camera trap photograph of a wild Indochinese tiger in Cambodia is featured by Tom Gray *et al.*, in this issue.

Guest Editorial – To shed light on dark corners

Martin Fisher

Fauna & Flora International, Jupiter House, Station Road, Cambridge CB1 2JD, U.K.
Email martin.fisher@fauna-flora.org

So long as men can breathe, or eyes can see,
So long lives this, and this gives life to thee.

Alumni of any of my *Writing for Conservation* workshops will recognize the final two lines from Sonnet 18 by the English poet and playwright William Shakespeare. I use it to illustrate how something beautiful – in this case a poem on the immortality of the subject of the writer's admiration – can be expressed within the constraints of 14 lines arranged in three four-line verses and a final couplet, and with exactly 10 syllables in every line. This form, sometimes referred to as a Shakespearean sonnet, provides me with a convenient analogy to the challenge of writing a scientific article: how can you arrange your hypotheses, ideas, spreadsheets, statistical analyses, interpretation and speculation into a presentable, coherent form within the stricture of the formal sections of a scientific article?

Why should you do this anyway? Wouldn't it be better to complete the report for your funder and move on to the next project or to whatever else is demanding your attention? It would certainly be easier. History doesn't tell us whether Shakespeare's Sonnet 18 was written effortlessly in a few hours of inspired work or whether the 14 lines were a labour of days, weeks, or longer. There are some gifted authors who can sit down with a strong cup of coffee on a Saturday morning and – many drafts and much caffeine later – have a manuscript ready for submission to a journal by Monday morning. For most of us, however, the preparation of the first draft of an article is a lengthy and difficult affair.

But whether it takes you a weekend or a month, you eventually finish your article. We all have reason to be proud when we send the result of our toil – which started in uncomfortable field conditions and ended when we clicked the submit button – to a peer-reviewed journal. However, knowing that rejection rates are high and presuming that editors are looking for reasons to reject articles because the volume of submissions is ever increasing, anxious authors scan their inbox nervously for an e-mail from the Editor. When we finally receive a decision we find that the reviewers have severely critiqued our work and our writing and found all the errors that we couldn't see, blinded as we were by innumerable drafts and too much coffee. Nevertheless, it is my experience, both as an author and editor, that "getting published" is not particularly difficult. The majority of manuscripts are not rejected because the research is of a poor standard or the writing incomprehensible, but rather because the author has erred in his or her choice of journal.

In the *Writing for Conservation* workshops that I offer with the Conservation Leadership Programme, this is the first piece of advice that I offer: there are *c.* 150 peer-reviewed journals in the fields of ecology, conservation and natural history, and you need to research carefully the contents of a range of potentially suitable journals before you actually start to write. Every journal has its own character and preferences, and your choice of journal will influence how you tell your story. My second piece of advice is to learn how to tell that story. You are not writing about love in 14 lines of 10 syllables each, but you are nevertheless going to tell a story, and the number of words that you can use, and how you structure them, will be prescribed by the journal you choose. There are articles that do not have the now-traditional structure of Introduction – Methods – Results – Discussion. One of my favourites is the seminal paper by Hutchinson (1959), which all conservationists should read (it is even bereft of the label Introduction). But most of our articles are constrained to the required structure.

Both novice and experienced authors encounter problems correctly ordering their logic and their thoughts within this structure. Deciding whether a particular idea belongs in the Introduction or Discussion, for example, can be problematical. Ensuring that you don't slip into discursive material in the Results can be difficult (hint: if you cite any references in this section you have almost certainly slipped into the Discussion by mistake). There is no magical wand or software tool to help you plan and write your article. No matter whether you are writing with a pencil or using the latest Ultrabook, the challenge is the same.

Once you have grappled successfully with the mechanics and art – for it is both – of scientific writing, and your first article has been published, you will be both elated and relieved. I still remember my first published article (Fisher & Dixon, 1986) with fondness. But was it worth the effort? Has anybody actually read it? I can't answer that question, but Google Scholar indicates that it has been cited only 10 times: hardly indicative of a large audience. If, for the purposes of a crude calculation, we assume the mean number of articles published annually in each of the *c.* 150 peer-reviewed journals is 100, *c.* 15,000 articles are being published each year in our area of interest. I believe it was once said that the English poet, critic and philosopher, and Shakespeare expert, Samuel Taylor Coleridge, born in 1772, was the last man to have read everything published in English. But even such a hungry reader could not make a dent in the number of scientific articles now being published each year. Who is reading them? Certainly most of us are reading only a very small fraction. This leads to a dismal conclusion: after shedding blood and sweat in the field, and sweat and tears in the writing, it is unlikely that anybody other than yourself, the Editor and peer reviewers will read your article. I would like to dispel a general misconception: it is not getting published that is difficult, it is getting read.

Whether you are writing for an esteemed regional journal such as the *Cambodian Journal of Natural History* or for one aimed at a broad international readership, your problem is the same: how can you make your article stand out in the noisy crowd? All is not lost: there are several ethical, and rewarding, little tricks that you can use. Possibly the most useful pertain to those parts of an article that are often most neglected: the Title, Abstract and Keywords. We are often so engrossed in the writing of the body of an article that we pay insufficient attention to these parts, which are often cobbled together in relief once the main article has been completed. If anybody does read your article, however, they are most likely to encounter it first in the search of the scholarly databases, in which keywords play an obvious part, and they will be presented initially with the Title and Abstract. It is with these two parts that you therefore have an opportunity to stand out: to draw you audience in, to entice them to read the full article.

One useful ploy is to try to attract two audiences – specialist and more general – using the Title as bait. How easy it is to do this will depend on how well you have told your story. Most of the 15,000 articles being published each year are about particular species or places, yet also have a wider relevance. But if the title is mundane, it is unlikely to attract anybody except the dedicated specialist. With hindsight I'm sure that was one of the problems with Fisher & Dixon (1986). To put it another way: the title is uninformative and unattractive.

As an editor I encourage the writing and submission of articles. I don't want to talk myself out of a job here, but I would like to see us all publishing less rather than more. In achieving the publication of a vast number of peer-reviewed articles annually, I don't think that either the quality of our science or of our writing has improved.

This leads me to make two recommendations. Firstly, whether writing our first or our tenth article for a peer-reviewed journal, for most of us it is a tortuous experience. Make it count therefore: don't split your research into little pieces and write about each separately. You will more likely be remembered – and read, and cited – for one substantial, well-written article with a great Title and informative Abstract, than for a dozen lesser works.

Secondly, after the challenge of writing, the publication of an article can feel like an end in itself but is in fact only the beginning: don't forget this. Publication of an article in the peer-reviewed literature is not the aim of our research, even if the pressure on us to publish can seem to suggest that it is. Our task in our research is to enquire, to ask questions and test hypotheses. Ultimately, this is what we are trying to achieve with our writing: to shed light in dark corners.

References

Fisher, M. & Dixon, A.F.G. (1986) Role of photoperiod in the timing of dispersal in the green spruce aphid *Elatobium abietinum*. *Journal of Animal Ecology*, **55,** 657–667.

Hutchinson, G.E. (1959) Homage to Santa Rosalia or why are there so many kinds of animals? *The American Naturalist*, **93,** 145–159.

Editor's note:- Dr Martin Fisher is the Editor of Oryx - the International Journal of Conservation, *and sits on the International Board of the* Cambodian Journal of Natural History.

Short Communication

Species composition of ant prey of the pitcher plant *Nepenthes bokorensis* Mey (Nepenthaceae) in Phnom Bokor National Park, Cambodia

Shingo HOSOISHI[1,*], Sang-Hyun PARK[1], Seiki YAMANE[2] and Kazuo OGATA[1]

[1] Institute of Tropical Agriculture, Kyushu University, 6–10–1 Hakozaki, Higashi-ku, Fukuoka, 812–8581 Japan.

[2] Department of Earth & Environmental Sciences, Faculty of Science, Kagoshima University, Korimoto 1, Kagoshima, 890–0065 Japan.

*Corresponding author. Email hosoishi@gmail.com

Paper submitted 15 March 2012, revised manuscript accepted 26 June 2012.

To supplement their nutrient requirements, carnivorous pitcher plants attract and trap insects and other arthropods using the pitcher-like leaves after which they are named (Juniper *et al.,* 1989). Pitcher plants belonging to the genus *Nepenthes* (Nepenthaceae) are distributed from Madagascar in the East, through to southeastern Asia, northern Australia and New Caledonia in the West (McPherson, 2009). Of the approximately 140 species in the genus, most of this diversity is centred in Southeast Asia. For example, 38 species are known from Borneo, 37 species from Sumatra and Java, and 21 species from the Philippines (McPherson, 2009, 2012).

A new species, *Nepenthes bokorensis*, has recently been described from Phnom Bokor (Preah Monivong) National Park in southwestern Cambodia (Mey, 2009). The species is currently considered to be endemic to Cambodia where it is distributed between 800 and 1,080 m above sea level (a.s.l.) in nutrient-poor sandy soils in open habitats.

Numerous studies have been conducted on the prey composition of pitcher plants (e.g. Moran, 1996; Adam, 1997; Moran *et al.*, 1999; Merbach *et al.*, 2002; Bonhomme *et al.*, 2010; Rembold *et al.*, 2010). While these studies have revealed that ants (Hymenoptera: Formicidae) are the most commonly trapped prey of *Nepenthes* species, relatively little is known about which species of ants are involved. The reason for this apparent lack of information on the species composition of ants might be that the prey items are typically partially digested or because the taxonomy of the ants is inadequately understood, especially in the tropics.

To better understand the relationship between *N. bokorensis* and the surrounding ant fauna, the aim of the present study was to undertake a preliminary faunal survey of the ants in the national park. This is the first detailed report of the ant prey of the recently described *N. bokorensis*.

This study was conducted in the highlands of Phnom Bokor National Park (10°39'N, 104°03'E) in Kampot Province, Cambodia (Fig. 1) at an elevation of 900 m a.s.l. The site has sandy soils and consists of a relatively open habitat with shrubs. In mid-December 2011, sampling was performed along three transects located 0–5 m, 5–10 m, and 10–15 m from the edge of a forest area respectively. Ants that had been trapped by the young, lower pitchers of *N. bokorensis* (Fig. 2) were collected along the three transects. No upper pitchers climbing higher were found in the site. Every transect had 10 *Nepenthes* pitcher sampling points, which meant that a grand total of 30 samples were collected along all three transects.

All specimens were initially sorted to genus using an identification key (Bolton, 1994), before being identified to species level where possible using the ant reference collections held at Kyushu and Kagoshima universities. Unidentified specimens were assigned numerical codes, e.g. "sp. 1", and voucher specimens were deposited at

CITATION: Hosoishi, S., Park, S.-H., Yamane, S. & Ogata, K. (2012) Species composition of ant prey of the pitcher plant *Nepenthes bokorensis* Mey (Nepenthaceae) in Phnom Bokor National Park, Cambodia. *Cambodian Journal of Natural History*, **2012,** 3–7.

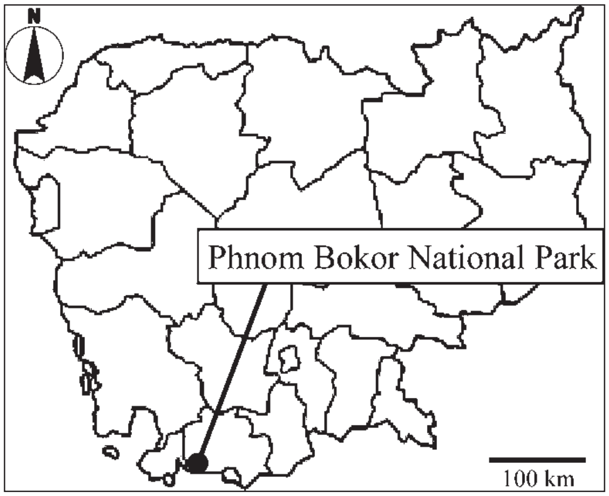


Fig. 1 Location of the study site in Cambodia.

Fig. 2 *Nepenthes bokorensis*, Phnom Bokor National Park, Cambodia, December 2011 (© S. Tagane).

Table 1 Ant prey species captured by *Nepenthes bokorensis* in the highlands of Phnom Bokor National Park. Showing the numbers of samples that contained the species (out of 10 samples taken in each transect).

	Transect (distance from forest edge)		
Family/ Species	A 0–5m	B 5–10m	C 10–15m
Dolichoderinae:			
Dolichoderus thoracicus (F. Smith)	8	2	0
Iridomyrmex sp.	0	3	6
Tapinoma sp.	2	1	2
Formicinae:			
Camponotus (Tanaemyrmex) sp.	2	4	4
Nylanderia sp.	0	1	0
Paraparatrechina sp.	2	2	0
Polyrhachis (Myrmhopla) phalerata Menozzi	4	3	0
Polyrhachis (Myrma) sp.	1	5	6
Myrmicinae:			
Cardiocondyla wroughtonii (Forel) complex	1	6	1
Pheidole sp. nr. *ochracea* Eguchi	2	1	1
Mean number of species per pitcher (± standard deviation)	2.2 ± 1.6	2.8 ± 1.7	2.0 ± 0.8
Total number of species	8	10	6

the Institute of Tropical Agriculture, Kyushu University, Japan.

A total of 10 species in nine genera and three subfamilies were collected from *N. bokorensis* pitchers in the highlands of Phnom Bokor National Park (Figs 3–12). Eight species were collected along the transect nearest to the forest edge (0–5 m), 10 along the middle transect (5–10 m), and six along the outer transect (10–15 m) (Table 1).

Ants belonging to the genus *Polyrhachis (Myrma)* were the most abundant in our samples (Figs 9–10), accounting for 40% of the ants in the 30 samples. *Dolichoderus thoracicus* (Fig. 3) and *Camponotus (Tanaemyrmex)* sp. (Fig. 6) were the second and third most abundant ant species sampled along the transects. The species richness of the prey items did not differ significantly between the three transects (Kruskal-Wallis test: *d.f.* = 2; $X^2 = 1.404$, $p = 0.49$).

Of the ants collected in this study, species belonging to the genera *Camponotus* and *Polyrhachis* had relatively large body sizes. Given the great abundance of these large ants, they may contribute markedly to the nutritional requirements of *N. bokorensis*.

The *Cardiocondyla wroughtonii* complex (Fig. 11) is generally known from open habitats and disturbed areas. This species complex is considered to have originated in tropical Africa and to have extended its range widely in tropical and subtropical areas through human activities (Wilson & Taylor, 1967). Some *Cardiocondyla* species have been reported to be stealthy invaders that employ a variety of life history strategies: polygyny, intranidal mating, budding, worker sterility, low genetic variability and possibly unicoloniality (Heinze *et al.*, 2006). Although the impacts of *C. wroughtonii* on native ant fauna appear less harmful than those of other invasive ants, such as the Argentine ant *Linepithema humile*, fire ant *Solenopsis*

Fig. 3 *Dolichoderus thoracicus*.

Fig. 4 *Iridomyrmex* sp.

Fig. 5 *Tapinoma* sp.

Fig. 6 *Camponotus (Tanaemyrmex)* sp., minor worker.

Fig. 7 *Nylanderia* sp.

Fig. 8 *Paraparatrechina* sp.

Figs 3–12 Ant species captured by the pitcher plant *Nepenthes bokorensis* in Phnom Bokor National Park, Cambodia. All scale bars are 0.5 mm in length.

invicta, and yellow crazy ant *Anoplolepis gracilipes*, close attention should be devoted to this species nonetheless.

The findings of this study suggest that *Nepenthes* pitchers play an important role in monitoring this tramp species. According Mey (2009), however, increasing tourism developments in the highland areas of Phnom Bokor National Park (e.g., a casino and hotels) threaten the populations of *N. bokorensis*. The distribution of this plant and its prey therefore needs to be monitored over a wider area, and their natural history needs to be investigated further, to aid their future conservation.

Fig. 9 *Polyrhachis (Myrmhopla) phalerata.*

Fig. 10 *Polyrhachis (Myrma)* sp.

Fig. 11 *Cardiocondyla wroughtonii* complex.

Fig. 12 *Pheidole* sp. nr. *ochracea*, major worker.

Acknowledgements

We are grateful to Mr Phourin Chang and Mr Choeung Hong Narith (Forestry Administration, Phnom Penh, Cambodia), Dr Tsuyoshi Kajisa and Dr Nobuya Mizoue (Faculty of Agriculture, Kyushu University) and Dr Tetsukazu Yahara (Faculty of Science, Kyushu University) for helping our field surveys in this study.

We also thank Dr Shuichiro Tagane and Dr Hironori Toyama (Faculty of Science, Kyushu University) for identifying the *Nepenthes* species. Thanks are also due to Mark Lorenz (Forte Inc.) for improving the English.

This work was supported in part by the Global COE program (Center of Excellence for Asian Conservation Ecology as a Basis of Human-Nature Mutualism), MEXT, Japan, and the Sumitomo Foundation (No. 113391).

References

Adam, J.H. (1997) Prey spectra of Bornean *Nepenthes* species (Nepenthaceae) in relation to their habitat. *Pertanika Journal of Tropical Agricultural Science*, **20**, 121–134.

Bolton, B. (1994) *Identification Guide to the Ant Genera of the World*. Harvard University Press, Cambridge, Massachusetts, USA.

Bonhomme, V., Gounand, I., Alaux, C., Jousselin, E., Barthélémy, D. & Gaume, L. (2010) The plant-ant *Camponotus schmitzi* helps its carnivorous host-plant *Nepenthes bicalcarata* to catch its prey. *Journal of Tropical Ecology*, **27**, 15–24.

Heinze, J., Cremer, S., Eckl, N. & Schrempf, A. (2006) Stealthy invaders: the biology of Cardiocondyla tramp ants. *Insectes Sociaux*, **53**, 1–7.

Juniper, B.E., Robins, R.J. & Joel, D. (1989) *The Carnivorous Plants*. Academic Press, London, U.K.

McPherson, S. (2009) *Pitcher Plants of the Old World*. Redfern Natural History Productions, Poole, U.K.

McPherson, S. (2012) *The New Nepenthes*. Redfern Natural History Productions, Poole, U.K.

Merbach, M.A., Merbach, D.J., Maschwitz, U., Booth, W.E., Fiala, B. & Zizka, G. (2002) Mass march of termites into the deadly trap. *Nature*, **415,** 36–37.

Mey, F.S. (2009) *Nepenthes bokorensis*, a new species of Nepenthaceae from Cambodia. *Carniflora Australis*, **7,** 6–15.

Moran, J.A. (1996) Pitcher dimorphism, prey composition and the mechanisms of prey attraction in the pitcher plant *Nepenthes rafflesiana* in Borneo. *Journal of Ecology,* **84,** 515–525.

Moran, J.A., Booth, W.E. & Charles, J.K. (1999) Aspects of pitcher morphology and spectral characteristics of six Bornean *Nepenthes* pitcher plant species: implications for prey capture. *Annals of Botany*, **83,** 521–528.

Rembold, K., Fischer, E., Wetzel, M.A. & Barthlott, W. (2010) Prey composition of the pitcher plant *Nepenthes madagascariensis*. *Journal of Tropical Ecology,* **26,** 365–372.

Wilson, E.O. & Taylor, R.W. (1967) The ants of Polynesia (Hymenoptera: Formicidae). *Pacific Insects Monographs*, **14,** 1–109.

About the Authors

SHINGO HOSOISHI studies the taxonomy, systematics, phylogeny and biogeography of Asian *Crematogaster* ants, based on morphological and molecular data and field work. Dr Hosoishi has participated in field work in Cambodia, Thailand, Malaysia, Indonesia, India and Sri Lanka.

SANG-HYUN PARK studies the community ecology of urban areas using insects, especially Formicidae (ants).

SEIKI YAMANE studies the taxonomy and biogeography of Asian ants. Dr Yamane has participated in widespread field trips in Southeast Asia.

KAZUO OGATA studies the taxonomy, systematics, phylogeny and biogeography of Asian ants.

Short Communication

Recent mammal records from the Oddar Meanchey portion of the Kulen-Promtep Wildlife Sanctuary, Northern Cambodia

Sarah EDWARDS*, James ALLISON and Sarah CHEETHAM

Frontier, 50–52 Rivington Street, London, EC2A 3QP United Kingdom. Email sarah_edwards1985@yahoo.co.uk, jamesjurgis@gmail.com, cheets.sarah@gmail.com

*Corresponding author.

Paper submitted 15 March 2012, revised manuscript accepted 26 June 2012.

Kulen-Promtep Wildlife Sanctuary, covering 4,099 km^2 and spanning the provinces of Oddar Meanchey, Siem Reap and Preah Vihear, is Cambodia's largest protected area. The sanctuary was originally designated to protect the kouprey *Bos sauveli*, currently listed by *the IUCN Red List of Threatened Species* as Critically Endangered, but this has not been reliably seen since the 1960s (Timmins *et al.*, 2008). Kulen-Promtep Wildlife Sanctuary contains a variety of habitats including lowland evergreen and deciduous dipterocarp forest as well as the second largest swamp in the country. The sanctuary is home to important bird species such as the Vulnerable sarus crane *Grus antigone* (Handschuh *et al.*, 2010) and the Endangered green peafowl *Pavo muticus* (Goes, 2009).

Despite being designated a wildlife sanctuary in 1993, relatively few published mammalian records exist for this area. Those available suggest the sanctuary houses significant species such as the fishing cat *Prionailurus viverrinus* (Rainey & Kong, 2010), Indochinese lutung *Trachpithecus germaini*, northern pig-tailed macaque *Macaca leonina*, long-tailed macaque *M. fascicularis*, pileated gibbon *Hylobates pileatus* and Bengal slow loris *Nycticebus bengalensis* (Coudrat *et al.*, 2011). This paper presents the first mammal checklist for the Oddar Meanchey portion of the sanctuary.

Frontier was established in 1989 as a non-profit conservation and development non-governmental organisation. It has been working in Cambodia since 2004, when it started biodiversity surveys in Ream National Park. Frontier has been working within the western portion of the sanctuary, in Oddar Meanchey Province, since January 2011 and is the first body to survey this area.

Frontier Cambodia conducted broad scale biodiversity surveys within the Trapeang Prasat and Anlong Veng Districts in the Oddar Meanchey portion of the sanctuary from 16 January to 25 August 2011, using camera traps, pitfall traps and Sherman traps, and by walking transects at night. Mammals were also seen opportunistically when the authors and research assistants were travelling along oxcart tracks and animal paths within the forest to survey sites.

Seven Bushnell Trophy Cam™ camera traps were placed in areas where the authors predicted large mammals would be most likely to travel, such as dry river beds, natural forest trails and oxcart tracks, which allow easier travel compared to the dense undergrowth of the forest (see Table 1 for location details). Camera traps were set to be active throughout the 24 hour cycle, at the highest sensitivity and resolution, taking three photos at a time, one second apart, with the gap between triggers set to 10 seconds. Camera traps were chained to trees approximately 1 m from ground level and set parallel to the ground or as near so as possible. Images were considered independent events if separated by at least 30 minutes. Mammals were identified using Francis (2008).

Night transects were conducted on foot along oxcart tracks and natural paths, using a spotlight to search for nocturnal mammals by their eye shine. Transects were carried out by the authors, one Environment ranger and up to three research assistants, with care being taken

CITATION: Edwards, S., Allison, J. & Cheetham, S. (2012) Recent mammal records from the Oddar Meanchey portion of the Kulen-Promtep Wildlife Sanctuary, Northern Cambodia. *Cambodian Journal of Natural History*, **2012,** 8–12.

Table 1 Locations of camera traps and species recorded.

Location	Altitude (m)	Habitat	Species recorded
14°04′07.037″N, 104°11'41.608''E	96	Dry river bed	Finlayson's squirrel, Asiatic golden cat, common palm civet, crab-eating mongoose, sun bear, lesser mouse deer
14°04′02.922″N, 104°11′47.091″E	104	Dry river bed	Northern pig-tailed macaque, Malayan porcupine, Finlayson's squirrel, common palm civet, crab-eating mongoose, sun bear, ferret badger, wild boar, lesser mouse deer
14°03′05.187″N, 104°11′29.966″E	92	Small stream	Northern pig-tailed macaque, Finlayson's squirrel, common palm civet, crab-eating mongoose, yellow-throated marten
14°04′40.246″N, 104°12′04.133″E	94	Oxcart track in forest	Malayan porcupine, leopard cat, gaur
14°03′32.782″N, 104°10′10.87″E	101	Salt lick	Malayan porcupine, Finlayson's squirrel, common palm civet, crab-eating mongoose, yellow-throated marten, lesser mouse deer
14°04′20.056″N, 104°09′09.183″E	99	Small stream	Northern pig-tailed macaque, common palm civet, wild boar, lesser mouse deer, southern red muntjac
14°03′59.240″N, 104°09'04.225''E	101	Forest path	Northern pig-tailed macaque, Malayan porcupine, southern red muntjac

to be as quiet as possible to increase chances of seeing mammals. Six transects were conducted between 1930h and 2100h and varied between 3 and 7 km in length.

A total of 15 Sherman traps (75 x 87.5 x 225 mm) were placed in a grid system (20 x 40 m) in areas most likely to capture small mammals, such as bases of trees and natural paths. Traps were baited with a mixture of sticky rice and peanuts, and checked daily in the early morning (0600h – 0645h). Within five metres of each Sherman trap, a 16 litre pitfall trap was dug into the ground with holes drilled in the bottom to allow water drainage. Pitfall traps were checked at the same time as the Sherman traps. Captured mammals were weighed, sexed, identified to species level using Francis (2008) and body measurements taken to aid identification. Hair was clipped on the flank to indicate an individual had been captured. From April to September 2011, this grid system was used in six different sites for 15 nights each: two areas at the forest edge, two areas on slash-and-burn cultivated land, and two areas of semi evergreen forest.

A total of 1,902 images were triggered during 904 operational trap nights, with 1,460 containing wild mammals (13 species) and the other 442 images containing birds, domestic animals or people. During the eight months of broad-scale biodiversity surveying, 28 mammal species were confirmed, including eight species listed as Near Threatened, Vulnerable or Endangered on the *IUCN Red List of Threatened Species* (Table 2). Eight species of small mammals were captured during a combined total of 2,700 trap nights (1,350 Sherman trap nights and 1,350 pitfall trap nights), as shown in Table 2. Night transects yielded the least success, with just three Bengal slow loris *Nyticebus bengalensis* and four common palm civets *Paradoxurus hermaphrodites* sighted on all transects combined (39 km total length).

The following section details the most significant records obtained during eight months of surveying within the area. Table 2 contains a mammal list for the survey area, but it should be noted no bat surveys were conducted. Bat surveys have the potential to significantly increase the number of mammals recorded in the area.

Bengal slow loris *Nycticebus bengalensis* (IUCN Vulnerable): Three individuals – one pair and a single animal – were seen during night transect surveys where a spotlight was used to detect eye shine. The species was

Fig. 1 Slow loris *Nycticebus bengalensis* being smoked in preparation for use in traditional medicine (© Paul Pestana).

distinguished from pygmy slow loris *N. pygmaeus* by its larger size and dark dorsal stripe (Francis, 2008). The pair of animals was seen in evergreen forest, approximately 4 km from human habitation, while the single animal was seen in the canopy on the edge of a large cultivated area containing four houses. The authors observed one dead Bengal slow loris being smoked on a farm in the forest. The people at the farm stated it was in preparation for use in traditional medicine, for curing stomach aches (Fig. 1).

Northern pig-tailed macaque *Macaca leonina* (IUCN Vulnerable): Six independent camera trap images were obtained from four locations: two small streams, one dry riverbed and a man-made track through the forest. On 7 August 2011, a female with a small baby clinging to her belly was captured on a camera trap, providing clear evidence that this species is breeding in the sanctuary. The authors also observed one adult and one juvenile animal chained up as pets outside a house at the edge of the sanctuary on the road connecting Siem Reap and Anlong Veng.

Indochinese lutung *Trachypithecus germaini* (IUCN Endangered): Four sightings of groups comprising between three and seven individuals were made throughout the year. All sightings were relatively close to areas of human habitation (1–4 km from houses). One group was seen only three metres above the ground near a salt lick, but was scared away by the authors walking through the forest. Locals in the area reported that this species often practises geophagy at the salt lick, but no evidence of such behaviour was captured on the camera trap.

Pileated gibbon *Hylobates pileatus* (IUCN Endangered): This species was commonly heard calling between 0600h and 1100h, and often two groups in the area could be identified simultaneously from the direction of the calls. Groups were often heard calling from the edges of large slash and burn areas used for rice production. A group of two females and a male was seen near to a camp where local people stayed when collecting resin from trees, within the forest, approximately 15 km from the nearest house.

Black giant squirrel *Ratufa bicolor* (IUCN Near Threatened): This species was commonly seen throughout the forest; usually single individuals, but there were occasional sightings of two or three individuals together. This species often occurred with Finlayson's squirrel *Callosciurus finlaysonii* and was seen responding to its alarm call.

Asiatic golden cat *Pardofelis temminckii* (IUCN Near Threatened): One independent record of two individuals of similar size walking down a dry river bed was captured on 9 February 2011. No further records were made (Edwards & Demski, in press).

Sun bear *Helarctos malayanus* (IUCN Vulnerable): Four independent camera trap events were captured in total. All photos showed single individuals at night (1800h – 0700h). See Edwards (2012) for more detail on sun bear surveys.

Gaur *Bos gaurus* (IUCN Vulnerable): Two independent images of gaur were recorded by camera trap, of single individuals at the same location during the night (1800h – 0700h). It is worth noting tracks were also found when checking small mammal traps on farmland where rice and vegetables were growing. Farmers reported problems from gaur coming onto the land at night and destroying crops.

Threats currently facing large mammals within Kulen-Promtep Wildlife Sanctuary were identified. The first and foremost of these being the development of a rubber plantation, with a total of 7,472 ha granted to Excel Castor Plantation Co. Ltd for agro-industrial and rubber plantation development. Work on the area started in July 2011 and has involved cutting down and clearing large areas of forest. This has already lead to large tracts of open dipterocarp habitat being removed. A second threat is the illegal logging activities the authors witnessed in the sanctuary, which have already caused small scale fragmentation and habitat degradation.

The third threat is the illegal settlement of people in the sanctuary, from which a further four sub-threats can be identified: (i) commercial hunting (ii) subsistence hunting; (iii) slash and burn agriculture for growing rice and vegetables; and (iv) the keeping of livestock such as pigs, chickens and cattle which have the potential to transmit disease. A further threat linked to human settlement is the human-wildlife conflict faced by farmers, but it is worth noting that farmers were seen practising non-lethal resolution methods in the form of manned houses throughout farmed areas, late-night drumming and the use of cloths soaked in detergent placed around farm edges to repel problem-causing wildlife.

The final main threat identified is the presence of resin collectors within the forest, who often bring oxen and domestic dogs with them, creating the potential for transmission of disease to wildlife, especially wild cattle (Neang, 2009), and predation upon local wildlife by dogs. On one occasion the authors also witnessed a fire from a resin tree that had been left unattended; such incidences have the potential to cause hugely damaging forest fires.

Obtaining records of two Endangered, four Vulnerable and two Near Threatened mammalian species in just eight months, gives a measure of the importance of the sanctuary to global conservation. However, such numbers of important species are not unusual in Cam-

Table 2 Mammals recorded from the Oddar Meanchey portion of Kulen-Promtep Wildlife Sanctuary. Status follows the *IUCN Red List of Threatened Species*. Evidence: A – Audio, CM – Claw mark, CT – Camera trap, PF – Pitfall trap, S – Sighting, SH – Sherman trap, T – Track. Relative Abundance Indices (RAI) are shown as the number of independent camera trap events or number of captures (Sherman and pitfall traps combined) per 100 trap-nights.

Common name	Scientific name	Status	Evidence	RAI
Northern tree shrew	*Tupaia belangeri*	Least Concern	S	-
Bengal slow loris	*Nycticebus bengalensis*	Vulnerable	S	-
Northern pig-tailed macaque	*Macaca leonina*	Vulnerable	CT, T	0.31
Indochinese lutung	*Trachypithecus germaini*	Endangered	S	-
Pileated gibbon	*Hylobates pileatus*	Endangered	S, A	-
Malayan porcupine	*Hystrix brachyuran*	Least Concern	CT, T	0.24
Giant black squirrel	*Ratufa bicolour*	Near Threatened	S	-
Finlayson's squirrel	*Callosciurus finlaysonii*	Least Concern	S	-
Indomalayan maxomys	*Maxomys surifer*	Least Concern	SH	2.59
Cambodian striped squirrel	*Tamiops rodolphei*	Least Concern	S	-
Indochinese ground squirrel	*Menetes berdmorei*	Least Concern	S	-
Ryukyu mouse	*Mus caroli*	Least Concern	SH	0.44
Fawn-coloured mouse	*Mus cervicolor*	Least Concern	SH	0.15
Indochinese forest rat	*Rattus andamanensis*	Least Concern	SH	0.04
House rat	*Rattus rattus*	Least Concern	SH	0.74
Southeast Asian shrew	*Crocidura fuliginosa*	Least Concern	PF	0.04
Asian house shrew	*Suncus murinus*	Least Concern	PF	0.04
Asiatic golden cat	*Pardofelis temminckii*	Near Threatened	CT	0.05
Leopard cat	*Prionailurus bengalensis*	Least Concern	CT	0.16
Common palm civet	*Paradoxurus hermaphrodites*	Least Concern	CT, S	4.41
Crab-eating mongoose	*Herpestes urva*	Least Concern	CT	4.52
Sun bear	*Helarctos malayanus*	Vulnerable	CT, CM, T	3.25
Yellow-throated marten	*Martes flavigula*	Least Concern	CT	0.21
Ferret badger	*Melogale* sp.	Data Deficient	CT	0.52
Wild boar	*Sus scrofa*	Least Concern	CT, T	1.31
Lesser mouse deer	*Tragulus kanchil*	Least Concern	CT, T	5.15
Southern red muntjac	*Muntiacus muntjac*	Least Concern	CT, T	0.84
Gaur	*Bos gaurus*	Vulnerable	CT, T	0.11

bodia: Conservation International found 15 species of large mammal, including one Endangered and five Vulnerable species, in Virachey National Park (Conservation International, 2007), whilst Elliot *et al.* (2011) found 29 large mammal species, including five Endangered, five Vulnerable and three Near Threatened species, across six Community Forest areas in Oddar Meanchey Province.

The absence of some species, such as Asian elephant *Elephas maximus*, tiger *Panthera tigris corbetti* and dhole *Cuon alpinus* from the survey area indicates the mammalian fauna is not intact within at least the Oddar Meanchey portion of Kulen-Promtep Wildlife Sanctuary, and future conservation efforts are needed to ensure the remaining mammal community continues to persist in the sanctuary despite the many threats it currently faces.

Acknowledgements

We thank all Frontier Cambodia field staff, Research Assistants and Environment officials for their help in gaining these data. Thanks to the Ministry of Environment for their kind permission to work in the area and Sy Ramony for his help in organising and gaining the necessary permits. Thanks to Aaron Sexton, Country

Coordinator for his help, humour and support throughout surveying and to Sam Lloyd for technical support and advice. Thanks also to Dr Zoe Balmforth and two anonymous reviewers for giving comments that greatly improved an earlier version of the manuscript and to Paul Pestana for kind permission to use his photograph.

References

Conservation International (2007) *Preliminary Report Virachey National Park RAP 2007.* Rapid Assessment Programme – Conservation International, Phnom Penh, Cambodia.

Coudrat, C.N.Z., Rogers, L.D. & Nekaris, K.A.I. (2011) Abundance of primates reveals Samkos Wildlife Sanctuary, Cardamom Mountains, Cambodia as a priority area for conservation. *Oryx*, **45,** 427–434.

Edwards, S. & Demski, M. (in press) New camera trap records of Asian golden cats from the Kulen-Promtep Wildlife Sanctuary, northern Cambodia. *Cat News*.

Edwards, S. (2012) First confirmed records of sun bears in Kulen-Promtep Wildlife Sanctuary, Northern Cambodia. *International Bear News*, **21,** 11–12.

Elliot, V., Lambert, F., Touch P. & Hort S. (2011) *Biodiversity Assessment of the REDD Community Forest Project in Oddar Meanchey.* Birdlife International/PACT, Phnom Penh, Cambodia.

Francis, C.M. (2008) *A Field Guide to the Mammals of South-East Asia*. New Holland Publishers, London, U.K.

Goes, F. (2009) The status and distribution of green peafowl *Pavo muticus* in Cambodia. *Cambodian Journal of Natural History*, **2009,** 7–15.

Handschuh, M., Rours, V. & Rainey, H. (2010) Clutch size of sarus crane *Grus antigone* in the Northern Plains of Cambodia. *Cambodian Journal of Natural History*, **2010,** 103–105.

Neang T. (2009) Liquid resin tapping by local people in Phnom Samkos Wildlife Sanctuary. *Cambodian Journal of Natural History*, **2009,** 16–25.

Rainey, H.J. & Kong K. (2010) A fishing cat observation from northern Cambodia. *Cat News*, **52,** 8–9.

Timmins, R.J., Hedges, S. & Duckworth, J.W. (2008) *Bos sauveli*. In *IUCN 2011 Red List of Threatened Species*. Http://www.iucnredlist.org/apps/redlist/details/2890/0 [accessed 2 February 2012].

Status of the masked finfoot in Cambodia

Berry MULLIGAN[1,*], ROURS Vann[2], SUN Visal[2], SAM Han[1,3] and Frédéric GOES[4]

[1] Fauna & Flora International, Cambodia Programme, 19, Street 360, BKK1, Chamkarmorn, PO Box 1380, Phnom Penh, Cambodia.

[2] Wildlife Conservation Society – Cambodia Program, PO Box 1620, Phnom Penh, Cambodia.

[3] Forestry Administration, #40 Preak Norodom, Daun Penh, Phnom Penh, Cambodia.

[4] Palmente, 20129 Bastelicaccia, France.

* Corresponding author. Email berry.mulligan@fauna-flora.org

Paper submitted 26 March 2012, revised manuscript accepted 23 July 2012.

មូលន័យសង្ខេប

ពព្វលទឹក (masked finfoot *Heliopais personata*) គឺជាប្រភេទបក្សីទឹកទទួលការគំរាមកំហែងជាសាកល ដែលស្ថានភាពរបស់វាចុះក្នុងបញ្ជីក្រហមនៃ IUCN ត្រូវបានតំឡើងកំរិតនៅពេលថ្មីៗនេះ ពីប្រភេទងាយរងគ្រោះទៅជាប្រភេទរងគ្រោះ។ របាយការណ៍នេះបានកត់ត្រាជាឯកសារនូវចំណេះដឹងពេលបច្ចុប្បន្ននៃប្រភេទនេះក្នុងប្រទេសកម្ពុជា ដោយពិនិត្យឡើងវិញពីកំណត់ត្រាជាប្រវត្តិសាស្រ្ត (មុនឆ្នាំ១៩៩៨) និងប្រមូលរាល់ការសង្កេតនិងភស្តុតាងនៃការបង្កាត់ពូជដែលត្រូវបានដឹងចន្លោះឆ្នាំ១៩៩៨និង២០១០។ យើងពិភាក្សាពីស្ថានភាពពព្វលទឹកក្នុងគោលបំណងកំណត់បង្ហាញអំពីទីកន្លែងសំខាន់ៗសំរាប់ការអភិរក្ស ក៏ដូចជាកង្វះខាតផ្នែកចំណេះដឹង និងតំបន់ផ្សេងៗសម្រាប់ការសិក្សានៅថ្ងៃអនាគត។ ប្រភេទនេះធ្លាប់ត្រូវបានធ្វើកំណត់ត្រាចំនួន៣១ករណីមកហើយ ក្នុងរយៈ១១ខែ តាមរយៈការសង្កេតផ្ទាល់លើបក្សីរស់នៅក្នុងព្រៃ និងបក្សីចិញ្ចឹម និងកត់ត្រាបានដោយម៉ាស៊ីនថតស្វ័យប្រវត្ត។ ពព្វលទឹកធ្លាប់ត្រូវបានប្រទះឃើញនៅក្នុងខេត្តប្រាំបី នៅតំបន់ព្រៃទំនាបតាមដងស្ទឹងនៃតំបន់ជួរភ្នំក្រវាញ តំបន់វាលរាបភាគខាងជើងនិងខាងកើត និងតំបន់ព្រៃរនាមនៃបឹងទន្លេសាប។ គេមិនអាចធ្វើការសន្និដ្ឋានពីបំលាស់ទីតាមរដូវកាលរបស់វាបានទេ ទោះបីជាមានគំរូលេចធ្លោនៃកំណត់ត្រាពីបក្សីនេះនៅតាមដងស្ទឹងពីចុងរដូវប្រាំងរហូតដល់ដើមរដូវវស្សា ដែលបង្ហាញថាបំលាស់ទីតាមរដូវកាលមួយចំនួនអាចកើតមានក៏ដោយ។ កំរិតបំលាស់ទីណាមួយដែលអាចកើតមានមិនត្រូវបានគេដឹងទេ។ ប្រភេទនេះ គឺជាប្រភេទបង្កាត់ពូជនៅរដូវវស្សាក្នុងតំបន់មួយនៅតំបន់ទំនាបភាគខាងជើងប្រទេស។ ការសិក្សាស្រាវជ្រាវបន្តទាមទារការយល់ច្បាស់ពីការគំរាមកំហែងសំខាន់ៗ ស្ថានភាពតាមរដូវកាល និងអេកូឡូស៊ីនៃការបន្តពូជ ហើយការខិតខំប្រឹងប្រែងគួររួមមានគោលដៅស្រាវជ្រាវនៅរដូវវស្សាផងដែរ។ ថ្វីបើមានការស្រាវជ្រាវខ្លះត្រូវបានដំណើរការនៅក្នុងទីជម្រកដ៏សមស្របក៏ដោយ ក៏ចំនួននៃកន្លែងដែលប្រភេទនេះត្រូវបានកត់ត្រាជាទៀងទាត់និងកង្វះខាតកំណត់ត្រាបង្ហាញពីភាពកម្រ និងការព្រួយបារម្ភនៃការអភិរក្ស។ ទោះបីជាយ៉ាងណាក៏ដោយក៏ប្រទេសកម្ពុជាអាចជាជម្រកមួយសម្រាប់ប៉ូពុយឡាស្យុងសំខាន់ជាងគេនៃពព្វលទឹកក្នុងពិភពលោកដែរ។

Abstract

The masked finfoot *Heliopais personata* is a globally threatened waterbird whose status on the *IUCN Red List of Threatened Species* has recently been elevated from Vulnerable to Endangered. This paper documents current knowledge of this species in Cambodia, reviewing historical (pre-1998) records and collating all known observations and evidence

CITATION: Mulligan, B., Rours V., Sun V., Sam H. & Goes, F. (2012) Status of the masked finfoot in Cambodia. *Cambodian Journal of Natural History*, **2012,** 13–28.

of breeding between 1998 and 2010. We discuss the status of masked finfoots with the aim of highlighting important sites for conservation as well as knowledge gaps and areas for future surveys. The species was recorded in Cambodia on 31 occasions between 1998 and 2010, through 11 months of the year, by means of direct observation of wild and captive birds and by camera-trapping. Masked finfoots have been found in lowland forested river systems in eight provinces across the Cardamom Mountains (dry season), the Northern Plains (wet season, including breeding records), the Eastern Plains (mid dry to early wet season), and the Tonle Sap swamp forest (year-round, including wet season breeding records). A pattern is emerging of the birds using rivers late in the dry season through to the early wet season, but the scale of any seasonal movements is unknown. Further research is required to better understand threats, seasonal status and breeding behaviour, and there is a need for targeted surveys during the wet season. The limited number of localities where this species is regularly recorded, and the paucity of records despite some dedicated searches in suitable habitats, indicate that this bird is genuinely scarce and of conservation concern. Cambodia, nonetheless, may host one of the most significant populations of masked finfoot in the world.

Keywords

Conservation, *Heliopais personata*, masked finfoot, status review, threats.

Introduction

The masked finfoot *Heliopais personata* is a rare waterbird with a peculiar appearance. It is the only member of the family Heliornithidae in Asia, and the only member of its genus (Bertram, 1996). This species is patchily distributed within a range extending from northern India to Vietnam, and southwards to Peninsular Malaysia and Indonesia (Sumatra) (Birdlife International, 2001) and it has been recently recorded in Malaysian Borneo (Hon, 2011). The global population is considered to be in steep decline (BirdLife International, 2011).

Enigmatic, both historically and recently, little is known of the ecology, distribution or numbers of masked finfoots throughout most of their range (Tordoff *et al.*, 2005). Neumann-Denzau *et al.* (2008) provide a detailed account of breeding in mangroves in Bangladesh. The species has been found principally along rivers in lowland forest, mangroves, freshwater swamp forest, and occasionally in lakes, marshes and forest pools (BirdLife International, 2011), but survey effort between habitats is uneven and real habitat use remains unclear. It appears to favour wetlands with emergent or dense bankside woody vegetation in areas with low levels of human activity (Timmins, 2008), although there are also a number of records from heavily disturbed areas such as park ponds, ornamental lakes and reservoirs in Peninsular Malaysia (e.g. BirdLife International, 2001; Shepherd, 2006) and Singapore (M. Tay, *in litt.*).

Masked finfoots glean insects from overhanging vegetation (BirdLife International, 2011) as well as feeding on freshwater shrimps and small fish (BirdLife International, 2001; Neumann-Denzau *et al.*, 2008). Their movements are poorly understood (BirdLife International, 2001; Tordoff *et al.*, 2005; BirdLife International 2011), but there is an emerging pattern of non-breeding season records in Peninsular Thailand, Malaysia and Indonesia and breeding season records in non-Sundaic Southeast Asia and eastern South Asia (e.g. Neumann-Denzau *et al.*, 2008), with what appear to be passage migrants observed between these regions (BirdLife International, 2011).

The ecology and distribution of the masked finfoot is so poorly known that threats are generally inferred rather than directly observed. Habitat destruction and degradation caused by reclamation of mangroves, riverside agriculture and logging in lowland riverine forest in Asia suggest a very rapidly declining population (BirdLife International, 2011). While no empirical estimates exist for the current rate of decline (BirdLife International, 2011), as a species reliant on undisturbed wetlands, habitat loss and hunting undoubtedly drove a major decline of the masked finfoot in the latter half of the twentieth century in Southeast Asia (BirdLife International, 2001).

Thomas & Poole (2003) provide only three historical records for Cambodia. The first was a specimen collected "from Cambodia" in 1861 by the explorer Henri Mouhot. Engelbach (1948) saw one bird in undisturbed mangroves and swamp at Point Samit, Koh Kong Province, in February 1944, and a Bangkok bird collector had a specimen that was collected in March 1952 in "Battambang".

Nearly 50 years passed, including a prolonged period of war and political instability, before masked finfoots were again reported in Cambodia. An increase of political stability in the early to mid 1990s allowed biological research to be carried out and the arrival of international birdwatchers to the Kingdom. Since the rediscovery of

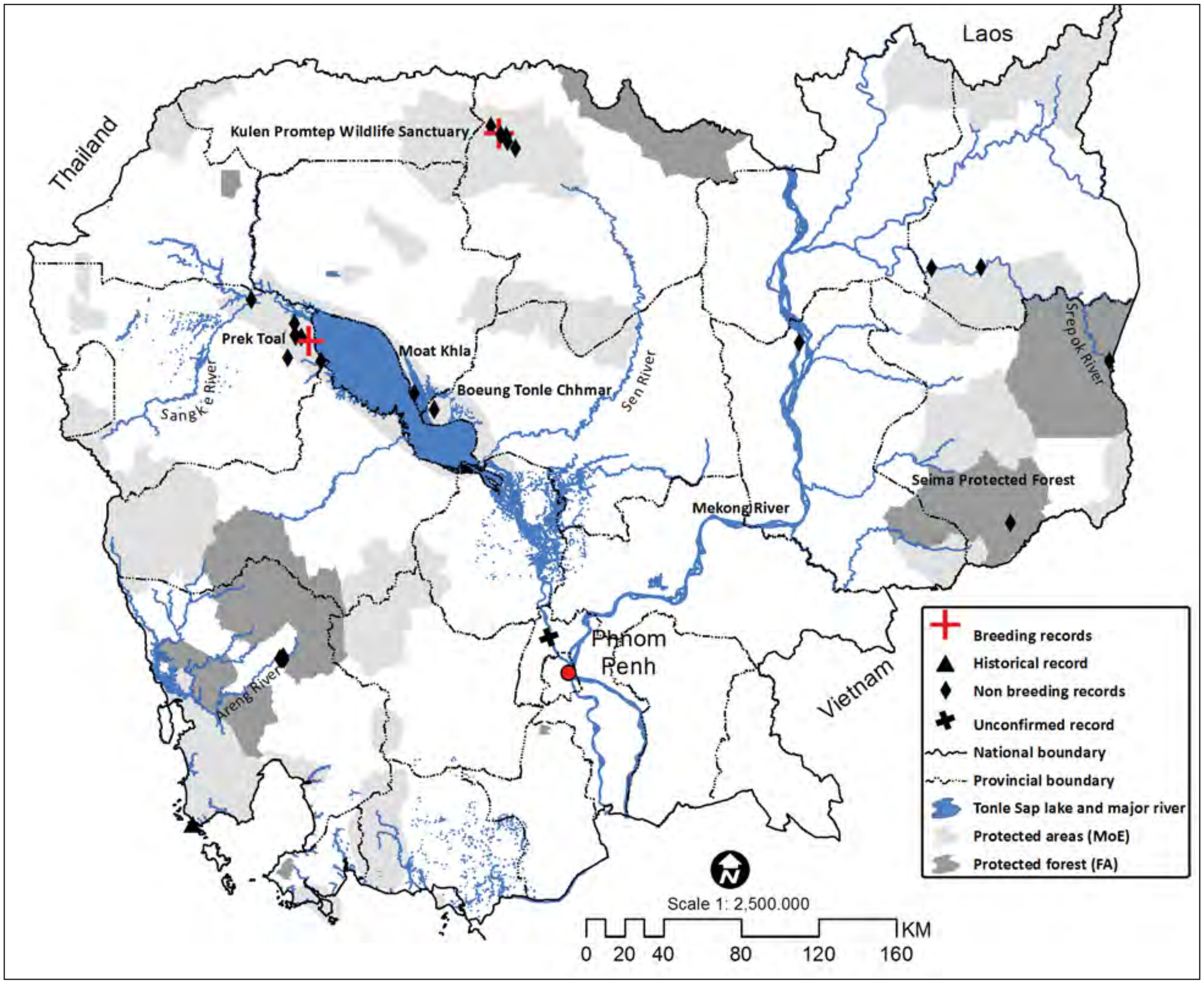


Fig. 1 Map showing the approximate locations of known historical and recent (1998–2010) masked finfoot records in Cambodia.

the masked finfoot in 1998 (Goes *et al.*, 1998; Timmins & Men, 1998), there has been a near-annual flow of records. Here we provide the first comprehensive review of known records for Cambodia, highlighting key sites for the conservation of the species. We use the available records to discuss the habitat use, distribution, behaviour and seasonal trends of, and threats to, masked finfoots in Cambodia, with the aim of identifying knowledge gaps to inform future research.

Methods

We collated all available records of masked finfoots in Cambodia for the period 1998–2010, including direct sight records of wild or captive individuals, vocalisations, camera-trap photos, and evidence of nesting. All records were from wildlife surveys or conservation activities conducted by ornithologists and field staff from non-governmental organisations (NGOs) and the Royal Government of Cambodia's Forestry Administration (FA) and Ministry of the Environment (MoE), as well as visiting ornithologists and amateur naturalists. Records were collated primarily from the grey literature (survey reports), from the 'Recent Sightings' section published in *Cambodia Bird News* between 1999 and 2005, and from an online monthly record review in 2010 (Evans & Goes, 2010a,b). Unpublished records by the authors were incorporated. We accepted records from persons generally known for their reliability in bird identification or surveys, and sought details of claims made by people we did not know (or know of only by repute), and accepted only those records with credible supporting evidence.

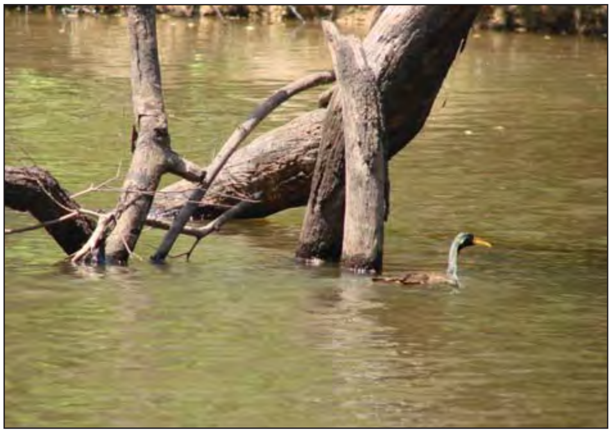


Fig. 2 Masked finfoot observed while conducting a boat-based survey on the Areng River, 28 February 2010 (© Sam H./ Cambodian Crocodile Conservation Programme).

Fig. 3 Male masked finfoot captured by a camera trap set for Siamese crocodiles, Areng River, 11 February 2008 (© Conservation International).

Fig. 4 Dead chick confiscated from villagers at Kbal Toal, 2 October 2001 (© F. Goes/ Wildlife Conservation Society).

Fig. 5 Captive male at Prek Trasok, June 2004 (© Sun V./ Wildlife Conservation Society).

Fig. 6 Nest believed to belong to the masked finfoot, discovered empty on 5 September 2009 on the Memay River, Kulen-Promtep Wildlife Sanctuary (© Rours V./ Wildlife Conservation Society).

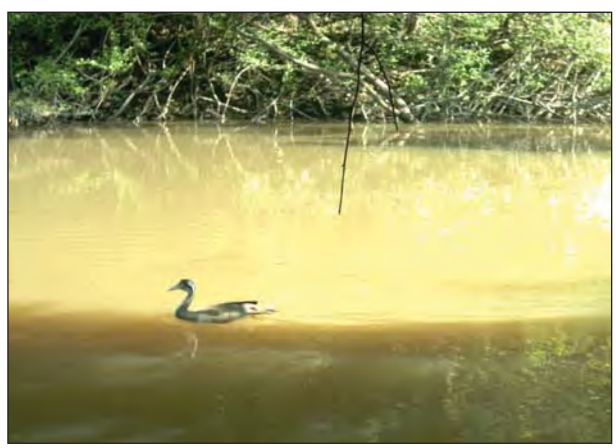


Fig. 7 Female masked finfoot on the Memay River, camera-trapped at 1430h on 24 November 2010 (© Wildlife Conservation Society).

Table 1 A compilation of known records of masked finfoot in Cambodia between 1998–2010, detailing 31 records and 1 nest record. * Photographic record; ** Approximate or estimated location; † This is an exception to our definition of a record, being listed as one record: presence at the same pool during more than 20 visits (E. Pollard, pers. comm.) strongly suggest the same individual was recorded over the 2.5 month period.

Site (Province)	Date	Record	UTM coordinates (48N)	Observer (Source)
Areng River (Koh Kong)	15 Jan. 2007	1 male seen	0343400 E, 1286700 N**	H. Nielsen (Nielsen, 2007)
	29 Jan. 2007	1 male seen*	0344243 E, 1286589 N	Sam H. (Starr & Sam, 2011)
	11 Mar. 2008	1 male*	0341912 E, 1286744 N	Camera trap (Conservation International)
	1 May 2009	1 male seen	0343491 E, 1287056 N	Sam H. (Starr & Sam, 2011)
	28 Feb. 2010	1 male seen*	0343802 E, 1287564 N	Sam H. (Starr & Sam, 2011)
Boeung Tonle Chhmar (Kampong Thom)	1 Jul. 1998	1 male seen	0421600 E, 1415400 N**	F. Goes (Goes *et al.*, 1998)
	26 May 2002	1 seen	0421600 E, 1415400 N**	Sun V. (Goes & Davidson, 2002a)
Moat Khla (Siem Reap)	10 Feb. 2000	1 probable, heard	0411500 E, 1423500 N**	F. Goes (Goes & Hong, 2002)
Sangke River (Battambang)	9 Jul. 1998	2 x 1 seen, Bap Prear	0327200 E, 1471900 N**	N. Bonheur (Goes *et al.*, 1998)
	Aug. 1998	1 seen, Bap Prear	0327200 E, 1471900 N**	F. Goes (pers. obs.)
Prek Toal (Battambang)	10 Jul. 1998	1 seen, Prek Da	0349400 E, 1459800 N**	Survey team (Goes *et al.*, 1998)
	3 Dec. 1998	1 seen, Prek Da	0349400 E, 1459800 N**	N. Bonheur (Goes, 1999)
	25–26 Jul. 2000	2 x heard, Prek Da	0349400 E, 1459800 N**	F. Goes (Goes & Hong, 2002)
	30 Sep. 2001	3 captive chicks*	0363500 E, 1439500 N**	Sun V. (Goes & Davidson, 2001)
	17 Feb. 2002	1 seen, Prek Da	0349400 E, 1459800 N**	F. Goes (Goes & Davidson, 2002a)
	16–22 Sep. 2002	2 x 2 seen, Veal Trasok	0346000 E, 1442000 N**	Rangers (Goes & Davidson, 2002b)
	23 Jan. 2003	1 seen, Prek Da	0349400 E, 1459800 N**	Rangers (Goes & Davidson, 2003)
	Late Jun. 2004	1 captive, Prek Trasok*	0363000 E, 1440500 N**	Sun V. (Goes *et al.*, 2004)
	6 Mar. 2006	1 seen, Prek Preah Daem Chheu / Day Kray Kreng	0353100 E, 1452800 N**	M. Ameels (Ameels, 2006)
	6 Mar. 2010	2 seen	0349814 E, 1453935 N	Sun V. (Evans & Goes, 2010a)
Memay River (Preah Vihear)	15–16 Jul. 2009	2 pairs seen, Antiel, 4 heard, Antiel	0458719 E, 1556433 N, to 0450813 E, 1561346 N	Rours V. (pers. obs.)
	5 Sep. 2009	1 old nest, Antiel *	0455199 E, 1557756 N	Rours V. (pers. obs.)
	5–8 Sep. 2009	2 pairs, seen, Antiel, 1 pair heard, Antiel	0454717 E, 1558534 N 0453770 E, 1559341 N	Rours V. (pers. obs.)
	20 Nov. 2010	1 female	0455728 E, 1557090 N	Camera trap (Wildlife Conservation Society)
Sen River (Preah Vihear)	17 Jul. 2009	1 pair seen, An Chheang	0463515 E, 1550425 N	Rours V. (pers. obs.)
	27 Nov. 2010	1 adult, Choam Srae*	0459322 E, 1553699 N	Camera trap (Wildlife Conservation Society)

Site (Province)	Date	Record	UTM coordinates (48N)	Observer (Source)
Srepok River (Ratanakiri)	31 May 1998	1 seen	0782000 E, 1488000 N**	R.J. Timmins (Timmins & Men, 1998)
	3 Jun. 1998	1 seen downstream of Phum Sre Angkrong	0678000 E, 1488400 N**	R.J. Timmins (Timmins & Men, 1998)
Srepok River (Mondulkiri)	20 Mar. 2004	1 seen near Vietnam border *	0770400 E, 1440000 N**	Sam H. (Starr & Sam, 2011)
Mekong River (Kratie)	24 Mar. 2007	1 seen, Koh Enchey	0610000 E, 1450000 N**	M. Bezuijen (Timmins, 2008)
Seima Protected Forest (Mondulkiri)	12 Mar. – 2 Jun. 2006†	1 seen, km 153 pond	0710177 E, 1343465 N	E. Pollard (Gray *et al.*, in prep.)
	25 Mar. 2007	1 seen, km 153 pond	0710177 E, 1343465 N	E. Pollard (Gray *et al.*, in prep.)

Where possible, additional information for every record on habitat, location, behaviour and circumstances was sought either directly from the observer or from the available published and unpublished literature.

We defined a single record as a direct observation (including sight records of wild birds, camera trap records or vocalisations) of one or more birds made at one locality within seven days. One or more captive birds were counted as one record. Where observations at a site were more than seven days apart, we considered them separate records. Although this approach could potentially result in an over- or under-representation of records, it nonetheless provides a measure by which we can discuss regularity and seasonality of national records, and minimises assumptions that would be required to estimate the number of individual seen during the 13–year review period.

Results

The period 1998–2010 yielded 31 records of individual birds, pairs and small groups (Table 1). In addition, one nest was recorded during the study period. Of these records, 21 were sightings or camera trap records of non-captive single birds. Pairs were seen on four occasions, and a brood of three captive chicks was confiscated from villagers.

Masked finfoots were recorded at 11 sites in eight provinces (see Fig. 1): one forested river in the Cardamom Mountains (n = 5), the Tonle Sap Lake swamp forest (n = 15), forested streams in the Northern Plains (n = 5), the Mekong River and its tributary the Srepok (n = 4) and at a pond in semi-evergreen forest (n = 2). The latter represents the highest national record, at approximately 385 m above sea level.

Evidence of breeding was documented from the Tonle Sap Lake and the Northern Plains. The Cambodian records were spread throughout the year, with only October lacking any record (Table 2). March (n = 7) and July (n = 6) were the months with the highest number of records, although it is important to note that observation effort varied considerably between geographic area and between dry and wet seasons. Records in different geographic regions of the Kingdom are detailed below.

Southwest

All records (n = 5) were of single birds between January and May from a 3.5–km stretch of the Areng River, in lowland evergreen forest in the Cardamom Mountains. Three of the sightings were made by staff of the Cambodian Crocodile Conservation Programme, who routinely (four times per month, every month of the year) survey the stretch of river for Siamese crocodiles *Crocodylus siamensis* (A. Starr, pers. comm.). Two of three Cambodian Crocodile Conservation Programme observations came from an area where the river was 20–30 m wide, with steep riverbanks and overhanging vegetation with fallen branches and trees emerging from the water (Fig. 2). The third was on a sandy bank where the bird left the water as the boat carrying the observers passed. The river banks were steep and relatively sparsely vegetated, offering limited cover (Starr & Sam, 2011).

A camera trap set to record Siamese crocodiles also showed an individual walking on a sandy bank (Fig. 3) on the same stretch of the Areng River.

Table 2 Temporal and geographical distribution of masked finfoot records in 11 sites: Southwest: Areng River; Tonle Sap Lake: Boeung Tonle Chhmar, Moat Khla, Sangke River and Prek Toal; North: Memay River, Sen River; North and Northeast: Srepok River (Ratanikiri and Mondulkiri), Mekong River, and Seima Protected Forest. + denotes single individual observed over 2.5 months.

Geographic Region	Jan.	Feb.	Mar.	Apr	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Southwest	2	1	1		1								5
Tonle Sap Lake	1	2	2		1	1	4	1	2			1	15
North							2		1		2		5
North and Northeast			3+	+	1+	1+							6
Total Records	3	3	7	(+)	3	2	6	1	3	0	2	1	31

Tonle Sap Lake

Masked finfoots have been recorded from four sites around the lake since 1998: Prek Toal; Boeung Tonle Chhmar; the middle Sangke River and Moat Khla. These records were from flooded forest streams or creeks lined with thick vegetation. Direct visual observations were predominately of single individuals (*n* = 9), with some pairs seen (*n* = 3).

The Prek Toal and Boeung Tonle Chhmar form two of the three core areas of the Tonle Sap UNESCO Biosphere Reserve. The Prek Toal core area has had the highest number of national records (32% of all records). This site has a near-continuous presence of birdwatchers during the dry season, and year-round patrols by a local conservation team. The records were spread throughout nine months of the year, with no discernible seasonal pattern. Prek Toal also provided evidence of breeding, based on three captive chicks in the possession of villagers in Kbal Toal, which constituted the first documented breeding of this species in Southeast Asia outside of southern Myanmar (Robson, 2002). The three chicks were confiscated from a villager who reported having captured them from a brood of five chicks swimming with an adult (Goes & Davidson, 2001; Robson, 2002). On 2 October 2001 the chicks were still small and downy (Fig. 4), indicating recent hatching.

At that time, the masked finfoot was on the list of Protected Wildlife Species and any commercial trade of live birds, eggs or meat was prohibited (Prakas #1563, Article 6). The Cambodian Forestry Law of 2002 (Article 48) required the division of species into three categories: (1) Endangered species, (2) Rare species and (3) Common species. The masked finfoot was categorised under a declaration by the Ministry of Agriculture, Forestry and Fisheries (MAFF) as a Rare Species on 25 January 2007 (Prakas #020), and it is therefore still against the law to harm, hunt, possess, transport or trade the species, although it can be captured under a MAFF permit for specific education, research and conservation activities (Article 49, Forestry Law).

North

Masked finfoots were only recently confirmed in northern Cambodia. Observers and camera-traps have recorded single individuals, pairs and a nest at different sites on two densely-vegetated streams within Kulen-Promtep Wildlife Sanctuary (*n* = 6). Birds were heard along the Memay River, a tributary of the Sen River, in July 2009. An empty masked finfoot nest (Fig. 6) was found approximately 2 metres above the water in September 2009, in a *Diospyros cambodiana* Lecomte tree (Rours V. and F. Goes, pers. obs.). An egg shell was found in the nest. Photographs of the nest and egg shell were sent to authors who have studied the breeding ecology of this species, who confirmed they matched those of the masked finfoot (Neumann-Denzau, *in litt*.). Both the upper Sen River and Memay River are highly seasonal, exhibiting large fluctuations between wet and dry season water levels, with riparian vegetation largely forming a canopy over the water. According to observations and reports by local people (Rours V., pers. obs.), the site supports a small breeding population, and birds remain in the area from June to at least late November, with the latter date testified to by a camera trap record (Fig. 7).

Northeast and East

All records were of individual birds from the late dry season (March) to the early wet season (June) from the Mekong (*n* = 1) and Srepok River (*n* = 3), and a man-made forest pool in the Seima Protected Forest (*n* = 2). At the observation site on the upper Srepok, the river was 150 m wide and its banks were covered by bamboo and open forest (Starr & Sam, 2011). The Mekong record was of a single adult bird seen along the western bank of the main channel, along the section straddling the border of Kratie and Stung Treng Provinces, which contains multiple channels and islands (M.R. Bezuijen, cited in Timmins, 2008). The sighting was made in the mid-dry season, the time of low water levels in the Mekong. Bankside vegetation comprised low secondary forest and overhanging shrubs (M.R. Bezuijen, *in litt.*). The record of a single bird in a circa 350m x 36m forest pool in two consecutive years provides the only confirmed observation away from rivers or floodplain habitats. The individual stayed at the relatively undisturbed pond, surrounded by evergreen forest and bamboo, for two and half months in 2006, spending most of its time under cover afforded by overhanging bamboo and other vegetation (E. Pollard, pers. comm.). In March 2007, an individual was recorded again at the same site. By 2008 the pool was much more disturbed (E. Pollard, pers. comm.), most probably due to re-surfacing of the adjacent RN76 road.

Discussion

Habitat and distribution

Records were obtained from scattered wetlands throughout the country. Most of the masked finfoot records in Cambodia were from forested lowland rivers or streams, in narrow (*c.* 10 m) to wide (*c.* 150 m) river channels with slow to relatively fast flowing currents. The riverbanks are usually covered with overhanging vegetation and thick undergrowth affording cover, and the species appears to favour the vicinity of fallen logs and branches with parts emerging from the water.

Wet season records from the Northern Plains were from narrow river channels or streams, both lined with thick riparian forest and riverbank vegetation that is partially submerged during the rainy season, together with the surrounding floodplains. Because the dry season is so pronounced in Laos and northern Cambodia, water levels can fall short of streamside vegetation for several months of the year (Round, 1998). The upper reaches of the Sen River and the Memay River, where the species has been observed throughout the rainy season, maintain flow during the dry season, but at very low levels (Rours V., pers. obs.). Masked finfoots are believed to be primarily associated with wetlands with (seasonally) emergent or dense bankside vegetation that is at least seasonally flooded (BirdLife International, 2001; Tordoff *et al.*, 2005; Timmins, 2008). The Northern Plains do not meet this description in the dry season.

The single record from the Mekong River was in a section with some of the most intact riverine habitats in the Lower Mekong, although even these are rapidly being degraded by human activities (Bezuijen *et al.*, 2008). Recent surveys of riverine birds north of Kratie town to Stung Treng during the dry season (e.g. Claassen, 2010; Sok *et al.*, in prep.) have not resulted in any new Mekong River records. The only other records on major rivers are from relatively undisturbed sections of the Srepok River with intact habitat, featuring dense bankside vegetation cover. The middle stretch of the Srepok River, where birds were seen in May and June 1998, supported the least disturbed riverine habitat, although bankside habitat was generally good throughout its length (Timmins & Men, 1998). This highlights the need for undisturbed stretches of river with little-degraded bankside vegetation. Long *et al.* (2000) spent little time surveying the Srepok River for waterbirds, but notably did not detect the species from many visits to seasonal forest pools in deciduous dipterocarp forests during April 2000. Extensive and repeated surveys of northeastern rivers (Sesan, Sekong and Srepok) for waterbirds during the mid-dry season between 1999–2001 (van Zalinge *et al.*, 2002) also failed to record this species.

While Tonle Sap Lake records are from densely vegetated creeks and streams, it is not possible to deduce habitat preferences within the vast mosaic of flooded forests, wet and dry scrub and grasslands. Huge areas of potentially suitable wetland habitat on the floodplain are difficult to access and survey, and the density of vegetation in flooded forest means that birds can easily flush before being detected by boat based observers (S. Mahood, *in litt.*). The species must rely on trees emerging from the floods for roosting and breeding. Large enough trees are mainly found in gallery forest lining dry season streams, rivers, ponds and the lake shore, but also scattered throughout the Prek Toal core area. Whether the habitat of the outer margin of the floodplain, with large tracts of emerging bushes, might actually better suit the species is unknown.

The Cardamom Mountains have received relatively little post-war ornithological survey effort. That which has been carried out focused primarily on evergreen hill forest (e.g. Steinheimer *et al.*, 2000; Eames *et al.*, 2002; Goes *et al.*, 2006) and deciduous forest during the dry season. Surveys on wetlands and rivers have been mainly rapid assessments and have not resulted in masked finfoot sightings (e.g. Long *et al.*, 2002; Conservation International, 2003, 2004), and there are no records elsewhere of this species in high gradient mountain streams (Birdlife

International, 2001). Tordoff *et al.* (2005) highlighted the possibility that the Cardamom Mountains may support a significant breeding population of the species, given the presence of long stretches of forested rivers in seemingly good condition. Breeding has not been confirmed, although no targeted nest searches have occurred. The short stretch of the Areng River that has provided annual records since 2007 is visited primarily during the dry-season by FA observers familiar with the species (A. Starr, pers. comm.). Community wardens monitor Siamese crocodiles every month in the same stretch, but they have not recorded the masked finfoot after the early wet season (Cambodian Crocodile Conservation Programme data).

The use of a forest pool in Mondulkiri Province indicates this species may use other wetlands in the Kingdom, provided they feature well-vegetated banks and are relatively undisturbed. Deeper permanent waterbodies, including pools and lakes, may be particularly important for the species in the late dry season when water levels drop in wetlands on the plains and smaller rivers and creeks, thereby affording less overhanging cover. The pool in Mondulkiri was formed when a logging road (now the main RN76 road) dammed a forest stream in the late 1990s (E. Pollard, pers. comm). Such use of man-made waterbodies, including reservoirs, has been documented elsewhere (e.g. Davison, 1995, cited in Birdlife International, 2001; M. Tay, *in litt.*). In this case, the pool is relatively small and retains characteristics of natural oxbow lakes found in the Cardamom Mountains (A. Starr, pers. comm.), but to date there are no additional observations from Cambodia to support the hypothesis that masked finfoots regularly use forested pools and lakes, even on passage.

A record from 1944 (Engelbach, 1948) remains the only documented occurrence of masked finfoots in mangroves in Cambodia, despite breeding and non-breeding records from coastal creeks and mangroves elsewhere (Birdlife, 2001; Neumann-Denzau *et al.,* 2008). Engelbach (1948) made three junk boat trips along the coast between February and April 1944 in the area between Kep, Point Samit and Koh Kapik, Koh Kong Province, following the coast around the Bay of Kampong Som. It is not clear the extent to which he explored mangroves and brackish creeks whilst collecting specimens and gathering ornithological records.

In the only comprehensive study of the breeding ecology of the masked finfoot, in the Bangladesh Sundarbans, Neumann-Denzau *et al.* (2008) recorded an average of one nest per 5.8 km of mangrove waterway surveyed, despite some human disturbance (boat traffic) at many nest sites. Records were from freshwater to moderately saline zones, mainly from small creeks. It is interesting to note that coastal surveys in Cambodia (Mundkur *et al.*, 1995; Edwards, 1999; Royan, 2009; Timmins & Sechrest, in prep.) and multiple visits to a good-condition mangrove at Prey Nup (Sihanoukville) in 2009 and 2010 (Overtoom, 2010) did not find any evidence of the species. Although there are no data to infer historical habitat use in mangrove and coastal waterways, survey efforts to date suggests that the species may no longer use such coastal habitat in Cambodia, or only very occasionally. Targeted surveys of small creeks with low levels of salinity in the least disturbed mangrove areas are nonetheless merited.

A large proportion of rivers that might support this species have been surveyed (Tordoff *et al.*, 2005) and one area of the Tonle Sap Lake, Prek Toal, has received high numbers of birdwatchers and researchers. While overall effort across the country can be reasonably characterised as being greater in the dry season, is important to highlight that known records are primarily from general wildlife or waterbird surveys, and few researchers were using survey methods specifically targeting masked finfoots. Exceptions are the dedicated searches on the Mekong River (e.g. Timmins, 2008), the high levels of survey effort at the turn of the century by observers familiar with masked finfoots and/or targeting riverine species in northeastern rivers (e.g. Timmins & Men, 1998; van Zalinge *et al.*, 2002), the Tonle Sap Lake (e.g. Goes & Hong, 2002) and coastal lowlands (e.g. Timmins & Sechrest, in prep.), and more recently, some limited camera trapping efforts in the Northern Plains. Most researchers who have recorded masked finfoots have done so while searching for other species, such as Siamese crocodiles or white-winged duck *Cairina scutulata*. They are aware of masked finfoots and their generally secretive habits, yet are not specifically or systematically searching for them while in the field. Detectability probably varies between habitats, for example, between riverine and dense flooded forest.

The known records thus comprise a mixture of incidental records and targeted searches. Apparent patterns inferred in this paper must therefore be treated with some caution given that targeted effort has been quite variable between sites, some relatively large areas have received little effort to date, and detectability will differ between habitats and seasons.

Seasonal status

The seasonal movements of the masked finfoot appear to be rather complex (BirdLife International, 2001) and poorly understood. In Cambodia, the historical distribution of this species cannot be accurately discerned due to the lack of records from the colonial and pre-war period.

While sightings between 1998–2010 have been relatively infrequent, patterns are emerging at different sites. In the Cardamom Mountains and the East and Northeast, masked finfoots have been recorded only during the dry season and early wet season (January to May, and March to early June respectively). Conversely, in the Northern Plains, records are restricted to the rainy season (July to November). Only the Tonle Sap Lake generated records from all seasons.

BirdLife International (2001) suggests that marshland is possibly visited only on migration. The only record in open marshland distant from forested habitat is of two birds at Basset Marshes (Kandal Province, Fig. 1) on 18 January 2004 (Goes *et al.*, 2004), but the validity of this record is subject to debate. It is treated as unconfirmed for the purpose of this study because neither observer was an experienced ornithologist and no description of the record was submitted.

Masked finfoots may be resident around the Tonle Sap Lake (BirdLife International, 2001; Timmins, 2008), with the known records offering the possibility that at least some birds remain year-round (Table 2). The possibility that this species is a primarily a breeding visitor to Indochina (BirdLife International, 2001) cannot be ruled out, however, given the extreme disparity of observation effort between the dry and wet season.

The fact that there has been an almost equal number of records during the wet and dry seasons at the Tonle Sap Lake (Table 2) might indicate that fewer birds are present during the dry season (when there is relatively high observation effort) compared with the wet season (very low observation effort, and a larger area of available wetland habitat). Perhaps the majority of this population moves elsewhere outside the breeding season. This inference is uncertain, however, because of the low total number of records for the Tonle Sap Lake. It is also possible that masked finfoots become less visible during the dry season due to local movements to parts of the floodplain that are less accessible in the dry season, and/or other behavioural changes in response to disturbance or breeding ecology. For example, fluctuations in boat traffic (which increases in the dry season) or an increase in nocturnal activity during the non-breeding season when there are no dependent young.

At the Northern Plains sites, masked finfoots have never been found or reported during the dry season, with the first birds believed to appear in June, staying until at least November. This is consistent with Round's (1998) inference that this is probably a wet season breeding visitor to southern Laos. The species also displays a pattern of repeated dry to late dry season records at the one known site in the Cardamom Mountains (across four years), and at the forest pool in Mondulkiri (across two years), which could be individuals on passage towards breeding grounds. Our method assumes that these consecutive annual records from the two sites are of different individuals, but if in fact they are the same individual visiting those sites (or becoming easier to record as water levels drop and they become more visible) this weakens the apparent pattern, and would reduce the total number of national records in the 13 year study period to 26.

Breeding

A Prek Toal fisherman explained that a local name of the masked finfoot, pronounced kompoul teuk (meaning "water peak"), originates from the bird's nesting ecology. Its nest indicates the maximum level the flood will reach that year, so that when the chicks hatch, they will easily jump out into the water (Hong, 2001). This local knowledge is consistent with studies elsewhere, indicating that the species' breeding corresponds with seasonally high water levels, around July-August in Myanmar (BirdLife International, 2001) and Bangladesh (Neumann-Denzau *et al.*, 2008).

Neumann-Denzau *et al.* (2008) found that incubation period probably exceeds three weeks, based on observations of one nest. From the indirect evidence gathered at Prek Toal in 2001 and the Northern Plains in 2009, the breeding season of masked finfoots in Cambodia can be expected to extend at least from July to September. Further observations of nests are required to firm up these estimates, and breeding sites inside Kulen-Promtep Wildlife Sanctuary currently provide the best opportunity for direct observations and studies of breeding ecology.

The masked finfoot almost certainly breeds in other areas of the vast Tonle Sap Lake floodplain, wherever sufficient and sturdy enough vegetation remains above peak flood levels and where their numbers are not suppressed by hunting pressure. Prek Toal may not provide the optimal breeding habitat compared with other areas of the floodplain, such as the Stung Sen core area, and potentially Moat Khla and Boeung Tonle Chhmar. Encounter rate of chicks at Prek Toal, which has received the greatest year-round presence of birding enthusiasts, suggests that the breeding population here is very small. The Stung Sen core area features a high density of large trees, including evergreen forest species not found anywhere else on the lake (McDonald *et al.*, 1997), and has to date received no targeted survey for masked finfoots. Given that the species is known to have nested on a *Barringtonia* sp. in Myanmar (BirdLife International, 2001) and on a *Diospyros cambodiana* in the Northern Plains (F. Goes and Rours V., pers. obs.), suitable nesting habitat at the lake could be extensive because these trees dominate the Tonle Sap floodplain forests.

The relative paucity of wet season surveys along rivers of the southern Cardamom Mountains and the Northeast prevents a reliable assessment of whether these also contain breeding sites. Forested streams and rivers with dense riverbank vegetation in the Northern Plains and Cardamoms Mountains merit targeted survey during the rainy season.

Timmins (2008) dedicated over 50 hours of survey effort in suitable habitat of the Mekong channel in Kratie Province in July-August 2006 without finding any evidence of masked finfoots. A similar survey effort during the dry season resulted in the sighting of one individual. It is not possible to ascertain whether masked finfoots used to breed on the Mekong River mainstream in Cambodia.

Behaviour

A high proportion of Cambodian records were of individual birds disturbed by observers. Responses observed by the authors, as well as those for which detailed accounts are available (E. Pollard, in Timmins, 2008; Starr & Sam, 2011), include swimming away into cover, flying away up or down river, and in one case, retreating briefly to a sandy river bank before returning to the water and swimming off. Most observations were in areas with dense bankside cover, but two records (January and March) from the Areng River document individuals walking on sandy banks. These suggest that masked finfoots are not strictly dependant on emergent or overhanging vegetation, and do occasionally stray from immediate cover, at least during the dry season when river levels are low.

Observations made from the bank of a forest pool in Mondulkiri found particularly shy and flighty behaviour, with the individual staying in the undergrowth during multiple observations of over one hour, with occasional forays of a few minutes into the open (E. Pollard, pers. comm.). On the Tonle Sap Lake observations have been generally very brief with individuals showing elusive and shy behaviour and quickly retreating to streamside vegetation (F. Goes and Sun V., pers. obs).

One case from the Srepok River in March 2004 possibly demonstrates a diversionary display, where an individual was reported flapping its wings on the surface of the water in an apparent attempt to distract the boat-based observers (M. von Kaschke, pers comm.). Neumann-Denzau *et al.* (2008) also reported one case of what appeared to be a similar distraction behaviour to lure people away from the bird's nest and eggs. A similar response to disturbance on the nest has been reported for the African finfoot *Podica senegalensis* (Skead, 1962). The Srepok observation was outside the assumed breeding period and no chicks or nest were observed, but the observers were not specifically looking for birds or nests (they were surveying Siamese crocodiles).

Five records demonstrate confiding behaviour (Bezuijen, M.R. *in litt.*; Nielsen, 2007; Starr & Sam, 2011) where boats passed within 10–25 m of individual birds swimming in the open, and they did not retreat to cover. Although the overall paucity of records is often attributed to the elusive behaviour of the species, Timmins (2008) argued that, although sometimes evidently shy, masked finfoots are not particularly difficult to detect, especially during quiet boat-based surveys. This could be particularly true during the late dry season, when birds may be forced to use areas with a sparsely vegetated or even bare zone between the water and the thick vegetation awash during the wet season. Multiple river records from Cambodia corroborate this – the five records were between January and May, with all but one from the early to mid dry season. It is worth noting, however, that these inferences are based on the records for which we could obtain detailed accounts, some of which may be the same individual bird in different years, and for five records from the study period we do not have any behavioural observations.

The timing of the observations made by the Cambodian Crocodile Conservation Programme, as well as camera-trap records from the Areng River and Northern Plains show the species to be active throughout the day. The latter recorded individuals swimming in the middle of the stream during hot hours of the day (between 1330h and 1530h). The bird that stayed for two and a half months at a pool in Mondulkiri was only seen once in the middle of the day and once in the morning, although most of the more-than 20 visits to the pool during that period were in the evening (E. Pollard, pers. comm.). It appears, nonetheless, that in absence of human disturbance, the species can be active throughout the day.

Vocalisations were heard only during the breeding season, with four records from the Tonle Sap Lake and the Northern Plains. Feeding behaviour was consistent with records elsewhere (e.g. Birdlife International, 2001), with two (separate) individuals observed actively foraging among, and under, overhanging bankside vegetation (M.R. Bezuijen, *in litt.*) and eating insects off the water's surface and gleaning from vegetation (E. Pollard, pers. comm.).

Threats

Tordoff *et al.* (2005) discuss threats to masked finfoots in the Lower Mekong Dry Forest Ecoregion, one of a set of 200 "ecoregions" identified to conserve the most outstanding and representative habitats for biodiversity globally (Olsen & Dinerstein, 2002). Lower Mekong Dry Forest Ecoregion landscapes are characterised by habitat mosaics dominated by deciduous dipterocarp forest and occur through eastern Thailand, southern and central Laos, northern and eastern Cambodia and central Vietnam (Tordoff *et al.*, 2005). As elsewhere throughout the species' range, habitat loss or degradation driven by intensification of human activities along rivers is suspected to be a key factor behind the finfoot's decline, although the lack of direct evidence and detailed ecological studies prevent proper assessment of impacts (Timmins & Men, 1998; Tordoff *et al.*, 2005). The absence of this species from some areas of apparently suitable habitat underlines how little is known of its actual habitat requirements and threats.

Capture by humans at Prek Toal was the only directly observed threat (Figs 4–5). Opportunistic harvesting of eggs, young and adults may constitute a significant threat at that site and others on the Tonle Sap Lake, as ubiquitous and continuous fishing activity increases the probability of incidental encounters or even targeted searches by locals familiar with this species. Large emergent trees are used by transient fishermen for shade and anchorage, and are the targets of macaque *Macaca* spp. poachers who criss-cross the lake during the high water months (F. Goes, pers. obs.). Adding to the potentially highly detrimental impact of nest harvesting, the habit of incubating birds to remain immobile on the nest when approached by a predator makes it easily grabbed by humans (Neumann-Denzau *et al.*, 2008).

Several authors (e.g. Timmins & Men, 1998; Tordoff *et al.*, 2005) have highlighted that the practice of placing gill nets and lines of fishing hooks along riverbank vegetation may be highly threatening to a fish-eating diving bird. Tordoff *et al.* (2005) noted that river stretches where this species has been detected in Indochina were little used by people, with low fishing activity throughout the year. The scale of the threats facing masked finfoots can be intimated only for known sites. The Antiel area on the Memay River within Kulen-Promtep Wildlife Sanctuary, for example, experiences moderate disturbance from local fisherman using gill nets, natural plant poisons and sometimes electro-fishing. Downstream, the Sen River experiences more concerted fishing pressure (H. Rainey, *in litt.*). The section of the Areng River where there are recent records also faces similar threats from nets and hooks used for small-scale fishing (Simpson, 2008).

The development of hydropower dams is a rapidly emerging threat to this species because it will cause direct habitat modifications and change the flow regime at a minimum of two sites with known masked finfoot records and habitat. A hydropower dam at the Areng River site has been approved (Moung, 2008; Simpson, 2008) and if eventually built, will flood the only known locality for the species in the Southwest. Where dams do not directly inundate riverine habitat required by masked finfoots, they may have as yet unknown impacts through modification of flow regime, turbidity, oxygen content and fish migration. The most immediate threat would likely originate from an increase in hunting pressure and disturbance from dam construction and survey teams. Two dams under construction on the Sesan River are part of a proposed hydropower cascade that will include four more dams in Vietnam and one at the confluence of the Sesan and Srepok Rivers in Cambodia (Claassen, 2010). There is a dam planned for the lower Stung Sen, although impacts on masked finfoots upstream is unknown (Rainey, H., *in litt.*) and potentially less severe than the proposed Areng or Srepok/ Sesan River developments.

Kummi & Sarkkula (2008) highlight that flow alterations in the Mekong River due to large hydropower dams and irrigation schemes would threaten sensitive ecosystems downstream, particularly the Tonle Sap Lake, its floodplain, and its gallery forest and protected areas, by changing the flood-pulse system of the lake. Their spatial analysis of three "Cumulative Impact Assessments" for the Mekong Basin, mainly concerning the impacts of hydropower dams outside of Cambodia on approximately 10–20 year timeframes, predict higher dry-season water levels and lower flood peaks on the Tonle Sap lake. An increase in dry season water level in the Tonle Sap lake would mean permanent inundation of large areas of gallery forest in the vicinity of the lakeshore, and between 13% and 42% of the Tonle Sap Biosphere Reserve core areas would be permanently inundated (Kummi & Sarkkula, 2008). This will have unknown, but most likely deleterious, impacts on masked finfoots due to changes in ecosystem productivity and vegetation cover.

Most Cambodian records are from areas with active conservation activity by the Royal Government of Cambodia and NGOs. This distribution pattern may reflect survey effort, and certainly does not imply that the habitat of the Cambodian masked finfoot population is secure. As rivers are amongst the most disturbed and most degraded ecosystems in Southeast Asia (BirdLife International 2011), and the last two bird species extirpated from the country were riverine specialists (Goes *et al.*, 2010), it should be assumed that the threat to the masked finfoots are severe. At some sites, threats are likely to be increasing, not least due to the emerging threat from hydropower projects on forested rivers throughout the Kingdom. The underlying threat to the species due to intensification of human activities along rivers (Tordoff *et al.*, 2005) will be exacerbated by larger scale infrastructure development. Of six potential hydropower projects in Cambodia surveyed by Muong (2008), for example, five were in, or would affect, protected areas.

Conclusions and further study

The masked finfoot is apparently very localised in distribution and even scarce in the sites where it has been recorded in Cambodia. If the species is indeed not difficult to detect, then the relatively extensive survey work around the Tonle Sap Lake and the rivers of Northeast Cambodia reflects low bird density rather than low detection rate. A large proportion of potential riverine and coastal habitat has received some level of survey effort for waterbirds and wildlife, but there have been few surveys specifically targeting this species, and large tracts of the Tonle Sap floodplain and rivers in Southwest Cambodia remain unsurveyed for masked finfoots. While our incomplete understanding of the birds' habitat use make it difficult to draw firm conclusions, it is clear that nowhere in Cambodia are masked finfoots encountered at high densities. The masked finfoot is scarce, and most likely present in even lower numbers during the early dry season, when most survey effort has been concentrated.

Masked finfoots appear to undertake seasonal movements in Cambodia between breeding and non-breeding areas, but whether this involves local dispersal movements by a few kilometres or long-distance migration requires further investigation. Difficulties in making accurate population estimates for this reclusive species, with scant data for the region, have been highlighted (e.g. Birdlife International, 2001). Given our wide knowledge gaps, including uncertainty regarding the masked finfoot's resident versus migrant status in Cambodia, we have not attempted a national population estimate.

Although only some parts of the Tonle Sap Lake floodplain have been surveyed well, there are no indications to suspect that large numbers of masked finfoots might remain undetected (Timmins, 2008). A local tale (Hong, 2001) nevertheless testifies of a defined place of this species in local culture, suggesting that the Tonle Sap floodplain may once have supported a larger population than it does today. Wet season surveys in suitable sites of the Tonle Sap Biosphere Reserve, specifically the Stung Sen core area, should be carried out to seek breeding populations.

In Cambodia's Northeast and East, the lack of new records is consistent with the prediction by Tordoff *et al.* (2005) that, given the population growth and human settlement along large lowland rivers, it seems very unlikely that significant numbers of birds will be able to persist on the Mekong River or lowland stretches of the Srepok catchment over the next 10 years. Tordoff *et al.* (2005) detailed priority sites in the Northeast requiring further survey. Although masked finfoots have not been recorded from the Srepok River since 2005, despite some survey effort, stretches of the Srepok River within Lomphat Wildlife Sanctuary and Mondulkiri Protected Forest may still be of significance, particularly the 34 km stretch between O'Rovei River and the Vietnamese border (T. Gray, pers. comm.).

The coverage of Cambodia's river by researchers and the known records support the notion that large breeding populations are unlikely to be found (e.g. Timmins, 2008), although further wet season surveys are merited. The only sites where relatively low survey effort has so far resulted in multiple sightings are the Areng River and the Memay River. Dedicated surveys during the rainy season in the rivers and oxbow lakes of the Cardamom Mountains and North and Northeast Cambodia would help fill knowledge gaps on the masked finfoot's seasonal distribution and breeding population in Cambodia.

Camera trapping (as has been carried out for Siamese crocodile in the Cardamom Mountains and smooth-coated otters *Lutrogale perspicillata* on the Tonle Sap Lake) may provide an additional tool to gather further information on the masked finfoot. Targeted camera trapping in Kulen-Promtep Wildlife Sanctuary has proved effective.

The records of masked finfoots in Cambodia gathered between 1998 and 2010 have confirmed at least seasonal presence of this species at multiple sites in Cambodia, and its year round presence on the Tonle Sap floodplain. Known sites, however, support very small and isolated populations, with no site hosting healthy numbers. At most, the masked finfoot is irregular in occurrence.

Engelbach (1948) wrote that this "rare and shy bird is hard to observe due to its wild nature and the difficulty of reaching the [remote] places it frequents". While this still holds true to some extent, these places are increasingly being exposed to anthropogenic impacts and pressures, including the emerging threat from hydropower development. The current picture clearly places the species as being of high conservation concern in the Kingdom, with a high risk of extinction due to escalating threats to riverine habitats. This, and the recently documented extirpation of two riverine specialists (Goes *et al.*, 2010), underscores the importance of conservation measures to protect vulnerable riverine habitats.

Myanmar is now assumed to be the masked finfoot's main stronghold, but is also the least known part of its range (BirdLife International, 2011). While Bangladesh might also be considered as a global stronghold, Cambodia nonetheless has had many of the records for mainland Southeast Asia in the last decade, suggesting it still supports a population of global conservation importance. Cambodia has also had multiple successful rare waterbird projects, which can potentially provide a basis for future conservation efforts for masked finfoots in the Kingdom.

Acknowledgements

The authors wish to thank Rob Timmins and Simon Mahood for extensive and insightful comments on the draft manuscript, as well as David Emmett (Conservation International) and Hugo Rainey (Wildlife Conservation Society Cambodia Programme) for use of photographs. In addition we thank Tom Evans, Edward Pollard, Adam Starr, Martin von Kaschke, Howie Nielsen and Hugo Rainey for their ideas and information on records, and Choun Phirom for his assistance in producing the map.

References

Ameels, M. (2006) *Cambodia, 5th March – 18th March 2006*. Unpublished birdlist.

Bertram, B.C.R. (1996) Family Heliornithidae (finfoots). In *Handbook of the Birds of the World, Volume 3* (eds. J. del Hoyo, A. Elliott & J. Sargatal), pp. 210–217. Lynx Edicions, Barcelona, Spain.

Bezuijen, M.R., Timmins, R.J. & Seng T. (2008) (eds.) *Biological Surveys of the Mekong River Between Kratie and Stung Treng Towns, Northeast Cambodia, 2006–2007*. WWF Greater Mekong – Cambodia Country Programme, Cambodia Fisheries Administration and Cambodia Forestry Administration, Phnom Penh, Cambodia.

BirdLife International (2001) *Threatened Birds of Asia: the BirdLife International Red Data Book.* BirdLife International, Cambridge, U.K.

BirdLife International (2011) Species factsheet: *Heliopais personatus*. Http://www.birdlife.org/datazone/speciesfactsheet.php?id=2801 [accessed on 3 September 2011].

Claassen, A.H. (2010) *Field Activity Report: Breeding Ecology and Conservation of Sandbar-Nesting Birds in the Mekong River Basin of Cambodia*. University of Minnesota. Minnesota, USA.

Conservation International (2003) *Mini-RAP Assessment of Silver Road Logging Concession, Cardamom Mountain Area, Cambodia*. Conservation International, Cambodia Program, Phnom Penh, Cambodia.

Conservation International (2004) *Biodiversity Survey of the Central Cardamoms Protected Forest*. Conservation International, Cambodia Program, Phnom Penh, Cambodia.

Eames, J.C., Steinheimer, F.D. & Ros B. (2002) A collection of birds from the Cardamom Mountains, Cambodia, including a new subspecies of *Arborophila cambodiana. Forktail*, **18,** 67–86.

Edwards, P. (1999) Recent waterbird surveys in Cambodia. *Forktail*, **15,** 29–42.

Engelbach, P. (1948) Liste complémentaire aux oiseaux du Cambodge. *L'Oiseau et la Revue Française d'Ornithologie*, **18,** 5–26.

Evans, T. & Goes, F. (2010a) *Cambodia Recent Bird Reports, March 2010*. Http:// www.samveasna.org [accessed on 18 March 2011].

Evans, T. & Goes, F. (2010b) *Cambodia Recent Bird Reports, November-December 2010*. Http:// www.samveasna.org [accessed on 18 March 2011].

Goes, F. (1999) (compiler) Recent sightings. *Cambodia Bird News*, **1,** 20–23.

Goes, F. (2000) (compiler) Recent sightings. *Cambodia Bird News*, **6,** 44–51.

Goes, F. & Davidson, P. (2001) (compilers) Recent sightings. *Cambodia Bird News*, **8,** 44–52.

Goes, F. & Davidson, P. (2002a) (compilers) Recent sightings. *Cambodia Bird News*, **9,** 47–59.

Goes, F. & Davidson, P. (2002b) (compilers) Recent sightings. *Cambodia Bird News*, **10,** 47–54.

Goes, F. & Davidson, P. (2003) (compilers) Recent sightings. *Cambodia Bird News*, **11,** 41–49.

Goes, F. & Hong C. (2002) *The Status and Conservation of Large Waterbirds on Tonle Sap Great Lake, 2000–2001*. Wildlife Conservation Society Cambodia Program, Phnom Penh, Cambodia.

Goes, F., Hong C., Suon M., Luon K. & Meas R. (1998) *Waterbird counting and survey at Prek Toal and Boeng Chhma/ Moat Khla. May – June 1998*. Tonle Sap Technical Coordination Unit, Ministry of Environment, Phnom Penh, Cambodia.

Goes, F., Davidson, P. & Poole, C. (2004) (compilers) Recent sightings. *Cambodia Bird News*, **12,** 47–56.

Goes, F., Rufray, X. & Oul Y. (2006) *A Naturalist Expedition to Phnom Aural and Phnom Tumpuor Cardamom Mountains, Cambodia.* Sam Veasna Center for Wildlife Conservation, Siem Reap, Cambodia.

Goes, F., Claassen, A. & Nielsen, H. (2010) Obituary to the black-bellied tern. *Cambodian Journal of Natural History*, **2010,** 5–6.

Hon, J. (2011) SOS: save our swamps for peat's sake. *Sansai*, **5,** 51–65.

Hong C. (2001) Two Tonle Sap bird tales. *Cambodia Bird News*, **8,** 41–43.

Kummu, M. & Sarkkula, J. (2008) The impact of Mekong river flow alteration on the Tonle Sap flood pulse. *Ambio*, **37,** 185–192.

Long, B., Swan, S.R. & Kry M. (2000) *Biological surveys in Northeast Mondulkiri, Cambodia.* Fauna & Flora International Indochina Programme, Hanoi, Vietnam, and the Wildlife Protection Office, Phnom Penh, Cambodia.

Long, B. Swan, S., Bora, T. & Rothmony, A. (2002) Rapid conservation assessment of the large mammals, birds, reptiles and amphibians of the Veal Veng Wetland. In *Social and Ecological Surveys of the Veal Veng Wetland, With Special Reference to the Conservation of the Siamese Crocodile* (ed. J.C. Daltry), pp. 34–47. Cambodia Programme, Fauna & Flora International, Phnom Penh, Cambodia.

McDonald, A., Pech B., Phauk V. & Leeu B. (1997) *Plant Communities of the Tonle Sap Floodplain.* Report to UNESCO, IUCN, Wetlands International and SPEC (European Commission), Phnom Penh, Cambodia.

Moung S. (2008) *The Natural and Social Environment Survey of 10 Potential Hydropower Dams in Cambodia*. Report to JICA, Phnom Penh, Cambodia.

Mundkur, T., Carr, P., Sun H. & Chhim S. (1995) *Surveys for Large Waterbirds in Cambodia. March – April 1994*. IUCN Species Survival Commission, Cambridge, U.K.

Nielsen, H. (2007) *Birdlist for the Areng Valley, January 14–19, 2007*. Unpublished birdlist and trip report.

Neumann-Denzau, G., Fahrni Mansur, E. & Mansur, R. (2008) Nests, eggs, hatchlings and behaviour of the masked finfoot *Heliopais personatus* from the Sundarbans in Bangladesh, with first nest observations. *Forktail*, **24,** 95–99.

Olsen, D.M. & Dinerstein, E. (2002) The Global 200: priority ecoregions for global conservation. *Annals of the Missouri Botanical Garden,* **89,** 199–224.

Overtoom, R. (2010) *Prey Nup Mangrove Bird Record Table, Updated 21–11–2010.* Unpublished report.

Robson, C. (2002) From the field. *Oriental Bird Club Bulletin,* **36,** 63.

Round, P.D. (1998) *Wildlife, Habitats and Priorities for Conservation in Dong Khanthung Proposed NBCA, Champasak Province, Lao PDR.* Final Report. CPAWM and Wildlife Conservation Society, Vientiane, Lao PDR.

Royan, A. (2009) Avifaunal inventory with annotated accounts for Botum-Sakor National Park, Southwest Cambodia. *Cambodian Journal of Natural History*, **2009,** 26–39.

Shepherd, C.R. (2006) Some recent behavioural observations of masked finfoot *Heliopais personata* (Gray 1849) in Selangor Darul Ehsan, Peninsular Malaysia. *BirdingASIA*, **5,** 69–71.

Simpson, B. (2008) *Siamese Crocodiles of the Areng River: Monitoring and Management.* Cambodian Crocodile Conservation Programme: Forestry Administration & Fauna & Flora International, Phnom Penh, Cambodia.

Skead, C.J. (1962) Peter's finfoot *Podzca senegalensis* (Vieillot) at the nest. *Ostrich – Journal of African Ornithology,* **33,** 31–33.

Sok K., Ryan, G., & Claassen, A.H. (in prep) Bird nest protection in the central section of the Mekong River between Kratie and Stung Treng towns.

Starr, A. & Sam H. (2011) *Masked Finfoot Sightings by the Cambodian Crocodile Conservation Programme.* Cambodian Crocodile Conservation Programme: Forestry Administration & Fauna & Flora International, Phnom Penh, Cambodia.

Steinheimer, F.D., Eames, J.C., Meas C. & Ros B. (2000) Birds. In *Cardamom Mountains Biodiversity Survey 2000* (eds J.C. Daltry & F. Momberg), pp. 87–98. Fauna & Flora International, Cambridge, U.K.

Thomas, W.W. & Poole, C.M. (2003) An annotated list of the birds of Cambodia from 1859 to 1970. *Forktail*, **9,** 103–127.

Timmins, R. (2008) Birds. In *Biological Surveys of the Mekong River Between Kratie and Stung Treng Towns, Northeast Cambodia, 2006–2007* (eds. M.R. Bezuijen, R. Timmins & Seng T.), pp. 53–80. WWF Greater Mekong – Cambodia Country Programme, Fisheries Administration and Forestry Administration, Phnom Penh, Cambodia.

Timmins, R. & Men S. (1998) *A Wildlife Survey of the Tonle San and Tonle Srepok River Basins in North-eastern Cambodia.* Fauna & Flora International, Hanoi, Vietnam, and Wildlife Protection Office, Phnom Penh, Cambodia.

Timmins, R. & Sechrest, W. (in prep.) *A Rapid Biological Survey to Assess the Conservation Significance of the Coastal Lowlands of Southwest Cambodia*. Global Wildlife Conservation, San Francisco, USA.

Tordoff, A.W., Timmins, R.J., Maxwell, A., Huy K., Lic V. & Khou E.H. (2005) (eds.) *Biological Assessment of the Lower Mekong Dry Forests Ecoregion*. WWF Indochina Programme, Phnom Penh, Cambodia.

van Zalinge, N., Poole, C., Duckworth, W. & Goes, F. (2002) Water bird counts on the Mekong, Sekong, Sesan and Srepok rivers in northeastern Cambodia in February, 1999–2001. *Cambodia Bird News*, **9,** 18–29.

About the authors

BERRY MULLIGAN has a degree in Ecology from the University of East Anglia, U.K. He first came to Cambodia in 2006 to conduct a three-month field study of large waterbirds in Mondulkiri Province, and research on the Manchurian reed-warbler *Acrocephalus tangorum* and other passerines on the Tonle Sap floodplain. Since then he has predominately worked with small NGOs in Central America, particularly on marine turtle conservation and research. He moved to Cambodia in 2010 and is the Country Manager for Fauna & Flora International Cambodia Programme.

ROURS VANN worked for Free The Bears from 2004 to 2006 as a patrol team leader and keeper at Phnom Tamao Zoo and Wildlife Rescue Centre, to protect and care for Asiatic black bears and sun bears. In 2006 he began field surveys of large waterbirds and mammals in the then Seima Biodiversity Conservation Area. Since 2007 he has worked for the Wildlife Conservation Society as a ranger

and research coordinator in Kulen-Promtep Wildlife Sanctuary where he conducts field research (camera trapping, line transects) on various species, including large ungulates, gibbons and waterbirds.

SUN VISAL has worked for the Wildlife Conservation Society since 2001 and has conducted many ornithological field surveys in Cambodia. He is responsible for the large waterbird monitoring program at Prek Toal, where he coordinates monitoring of important Globally Threatened species, especially at large breeding colonies in the core area of the Tonle Sap Biosphere Reserve. He also trains rangers of the Ministry of Environment on data collection, reporting and conservation.

SAM HAN has a BSc in Forestry from the Royal University of Agriculture and a Masters degree in Agricultural Science. He has worked with the Forestry Administration of the Ministry of Agriculture, Forestry and Fisheries since 1995, including working on the Cambodian Crocodile Conservation Programme of the Forestry Administration and Fauna & Flora International since 2001. He has worked extensively on the research and conservation of Siamese crocodiles, is a member of the IUCN-SSC Crocodile Specialist Group, and received the Disney Conservation Hero Award in 2009 for his efforts to conserve wild Siamese crocodiles. Sam Han has also conducted numerous field surveys in Cambodia on various large mammals, including Asian elephants, as well as primates and waterbirds.

FRÉDÉRIC GOES lived in Cambodia from 1994 to 2006. He has conducted numerous field surveys, provided ornithological training for Cambodian counterparts, and guided birders. He is the founding editor of the three-language periodical *Cambodia Bird News*. He was in charge of the Tonle Sap Conservation Project for the Wildlife Conservation Society from 2001 to 2004, is the co-founder and technical adviser for the NGO Osmose, and a founding member and first director of the Sam Veasna Center for Wildlife Conservation in Siem Reap. He is currently preparing an annotated checklist of birds for Cambodia.

Waterbird nest protection on the Mekong River: a preliminary evaluation, with notes on the recovery and release of white-shouldered ibis *Pseudibis davisoni* chicks

SOK Ko[1,2], Andrea H. CLAASSEN[3], Hugh L. WRIGHT[4], & Gerard E. RYAN[2,*]

[1] Forestry Administration, #40, Preah Norodom Boulevard, Phnom Penh, Cambodia.
[2] WWF-Cambodia, #21, Street 322, Sangkat Beoung Keng Kang I, Khan Chamcar Morn, Phnom Penh, Cambodia.
[3] Conservation Biology Program, University of Minnesota, St. Paul, Minnesota, 55108, USA.
[4] School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, U.K.

*Corresponding author. Email gryan@wwf.panda.org

Paper submitted 21 April 2012, revised manuscript accepted 1 July 2012.

មូលន័យសង្ខេប

នៅតាមតំបន់ដែលភាពក្រីក្រកើតមានច្រើន និងការគ្រប់គ្រងធនធានធម្មជាតិមានកម្រិត ប្រភេទសត្វជាច្រើនដូចជាប្រភេទសត្វស្លាប និងអណ្តើកត្រូវទទួលរងនូវការគំរាមកំហែងពីការលួចយកពងនិងកូនពីសំបុករបស់ពួកវា។ ដំណោះស្រាយដ៏មានសក្តានុពលមួយ គឺការផ្តល់ប្រាក់ដល់សមាជិកសហគមន៍ក្នុងតំបន់សម្រាប់ការឃាមការពារសំបុកសត្វ។ ការសិក្សានេះធ្វើការវាយតម្លៃលើកម្មវិធីមួយ នៅតាមដងទន្លេមេគង្គក្នុងប្រទេសកម្ពុជា ដែលបានផ្តល់ប្រាក់ដល់ប្រជាជនដើម្បីការពារសំបុករបស់សត្វស្លាបមានអាទិភាពខ្ពស់ បីប្រភេទ៖ ត្រយ៉ងចង្កំកស *Pseudibis davisoni* រំពេទន្លេ *Sterna aurantia* និងត្រដក់តូច *Leptoptilos javanicus* ។ នៅក្នុងរយៈពេលពីររដូវកន្លងមក កូនសត្វស្លាបចំនួន៦០ក្បាលនៃប្រភេទសត្វទាំងបីបានដុះស្លាបហើរចេញពីសំបុក ប៉ុន្តែអត្រារស់រាន មានជីវិតរបស់កូនរំពេទន្លេនិងត្រយ៉ងចង្កំកសនៅមានកម្រិតទាបនៅឡើយ។ បើទោះបីជាមានការឃាមការពារសំបុកសត្វក៏ដោយ ក៏នៅតែទទួលបរាជ័យ ដែលបណ្តាលមកពីការបំផ្លាញនិងការលួចយកពងនិងកូនរបស់សត្វស្លាបទាំងនោះ។ ការឃាយីពីសត្វរំពា ក៏ជាបញ្ហាចោទមួយចំពោះសត្វរំពេទន្លេផងដែរ។ កម្មវិធីនេះ គឺជាជោគជ័យចម្រុះមួយ ហើយការឃាមការពារសំបុកសត្វដោយនិរន្តរ ភាពយូរអង្វែងគឺនៅតែជាចំណោទបញ្ហានៅឡើយ។ យើងធ្វើការពិភាក្សាពីវិធីធ្វើឲ្យប្រសើរឡើងនូវការគង់វង្សនៃសំបុកសត្វស្លាប និង ការចូលរួមពីសហគមន៍ រួមមានទម្រង់ផ្តល់ប្រាក់ដើម្បីលើកកម្ពស់ការយកចិត្តទុកដាក់ក្នុងការឃាមការពារសំបុកសត្វ ការទាក់ទាញ ការចូលរួមពីសហគមន៍ដើម្បីកាត់បន្ថយការច្រណែនលើការផ្តល់ប្រាក់ និងវិធីការពារពីសត្វរំពា។ ដើម្បីបង្កើនប្រសិទ្ធភាព និងបង្ការ គ្រោះថ្នាក់ដោយអចេតនាដល់សត្វព្រៃនិងមនុស្ស គឺទាមទារអោយមានការចូលរួមយ៉ាងទូលំទូលាយពីសហគមន៍ និងការវាយតម្លៃ អោយបានទៀងទាត់។

Abstract

In areas where poverty is widespread and natural resource governance limited, many species are threatened by the robbery of eggs and young from nests, such as birds and turtles. A potential solution is to pay members of a local community to guard nests. This study evaluates one such programme on the Mekong River in Cambodia, which paid local

CITATION: Sok K., Claassen, A.H., Wright, H.L. & Ryan, G.E. (2012) Waterbird nest protection on the Mekong River: a preliminary evaluation, with notes on the recovery and release of white-shouldered ibis *Pseudibis davisoni* chicks. *Cambodian Journal of Natural History*, **2012,** 29–41.

people to protect the nests of three high priority species: the white-shouldered ibis *Pseudibis davisoni*, river tern *Sterna aurantia*, and lesser adjutant *Leptoptilos javanicus*. Sixty chicks of the three species fledged over two seasons, but nest survival rates remained low for the terns and ibises. Despite guarding, the main causes of nest failure were robbery from nests and vandalism. Predation was also a problem for river terns. The programme was a mixed success, and the long term sustainability of guarding nests is questionable. We discuss methods for improving nest survival and community involvement, including payment structures to improve guard diligence, community buy-in to reduce jealousy over payments, and predator exclusion devices. Comprehensive community engagement and regular evaluation may be required to improve effectiveness and prevent unintentional harm to wildlife and local people.

Keywords

Cambodia, conservation, *Leptoptilos javanicus*, lesser adjutant, nest survival, payments for environmental services, river tern, *Sterna aurantia*.

Introduction

A key approach to recovery of threatened populations is to improve recruitment, especially where the early life stages are subject to unnaturally high mortality. A wide range of conservation programmes have applied this approach, from sea turtle hatchling releases or nest protection (Ferraro & Gjertsen, 2009; National Parks Service, 2011), to nest box provision in logging sites (Lindenmayer *et al.*, 2002), and hunting and fishing restrictions on the harvest of breeding females. Here we consider guarding nests as a means to enhance hatching, chick survival, and fledging in threatened bird species in Cambodia.

Nest survival can depend on many factors, including 'natural factors' like predation and starvation, and in many places, anthropogenic influences, including passive disturbance and robbery of nests or eggs. In Europe, a number of nest protection programmes have attempted to minimise the unintentional destruction of nests through farming activities (e.g. Koks & Visser, 2001; Schifferli *et al.*, 2006). A more insidious global issue is the poaching of eggs and young, either for food or sale to the pet trade, which in particular threatens parrots, waterbirds and also turtles (Wright *et al.*, 2001; Pain *et al.*, 2006; Tomillo *et al.*, 2008; Barre *et al.*, 2010). Such nest robbery is widespread in Cambodia, occurring both opportunistically for subsistence consumption, and, for some species, commercially (Claassen, 2004; Goes, 2005, 2009; Clements *et al.*, 2009). Although legislation and patrol programmes prevent the take of some species in some areas, these measures may be ineffective. Regulations can be challenging to enforce because nest robberies happen quickly and robbers can be difficult to identify after the event. Institutions responsible for species protection in Cambodia, as in much of the developing world, are often too poorly resourced to police this type of crime (Clements *et al.*, 2010), especially outside of protected areas.

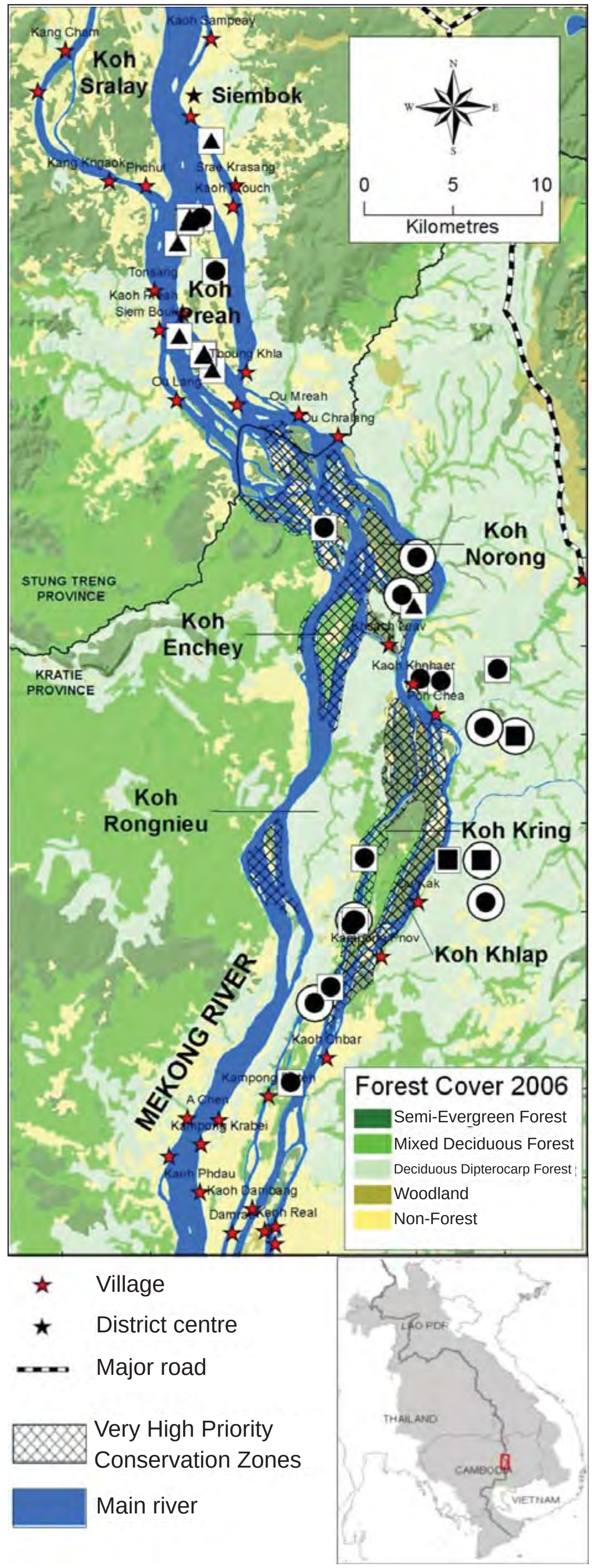
Nest protection programmes are becoming increasingly popular for exploited species in Southeast Asia, and are a component of many bird conservation programmes in Cambodia. Nest protection may be in the form of predator shields on nesting trees (Keo *et al.*, 2009), but more often involves making direct payment to individuals to discourage the harvest of eggs or chicks (Gray *et al.*, 2009) or to actively protect nests (Clements *et al.*, 2009; Wright, in press). Direct payments fall within the broader category of "Payments for Environmental Services" (PES), where environmental service providers or custodians, usually individuals or communities, can achieve financial benefits for the provision of such services. PES approaches differ from more traditional conservation interventions, such as community development or protected areas, by linking benefits directly to a desired conservation outcome (Ferraro, 2001). Direct payments are considered potentially more efficient for achieving conservation goals than indirect means of remuneration, such as ecotourism or certification schemes (Ferraro & Kiss, 2002; Milne & Nietsen, 2009). Payment for nest guarding programmes are commonly assumed to be effective, but their success is rarely evaluated thoroughly. In some sites, guarding shows a clear benefit (Clements *et al.*, in press). Recent evidence suggests that in sites where conservation action has occurred for several years, nest robbery of opportunistically exploited species may be reduced without the need for nest guarding *per se* (Wright, in press). In sites where conservation action began more recently, the threat of nest robbery may remain high and nest guarding programmes are worthy of assessment.

We applied a payment for nest guarding programme for a suite of waterbirds around a section of the Mekong River in northeastern Cambodia. Here, we discuss the initial two seasons of this programme and provide a preliminary evaluation of its impact. We evaluate the programme by first asking: what are the survival rates of nests under protection, and what are the main causes of failure? We then consider the effectiveness of guarding against two conservation aims: to halt anthropogenic nest failures, and to achieve broadly high nest survival rates. We do this based on these nest survival data, and comparable nest survival rates elsewhere. It is important to note, however, that this was not a controlled experiment. All nests were under protection, and we are therefore unable to judge the guarding effect against an untreated baseline. We also consider how local participation and effective guarding is best achieved, in the context of different nest outcomes and using a variety of payment strategies, and make recommendations for nest guarding programmes in Cambodia and elsewhere. We also detail an unexpected outcome: the successful rehabilitation and release of two white-shouldered ibis chicks that had been blown from a nest in high winds.

Methods

Study area

The project focused around a 56 km linear stretch of the mainstream Mekong River on the border area between Kratie and Stung Treng Provinces in Northeast Cambodia, known as the "Mekong Flooded Forest" (Fig. 1), described in detail by Bezuijen *et al.* (2008). The site is a mosaic landscape of islands among braided channels and wetlands. The islands are covered with a mixture of dry deciduous, mixed deciduous and semi-evergreen forest, and small areas of cultivation – which are rapidly expanding on riverbanks. Within the river channel are large seasonally emergent sandbars and rocky areas that support large stands of *Acacia-Anogeissus* flooded forest. The surrounding mainland consists of larger areas of dry deciduous, mixed deciduous and semi-evergreen forest with some habitation and cultivation.



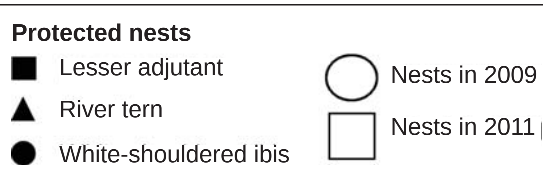


Fig. 1 The Mekong Flooded Forest project site, showing all protected nests. Inset: mainland Southeast Asia, showing location of study site, with Lower Mekong Basin shaded in grey.

Fig. 2 White-shouldered ibis (© Gordon Congdon, WWF-Cambodia).

Fig. 3 A white-shouldered ibis chick blown out of its nest is held by a guard's son (© Gordon Congdon, WWF-Cambodia).

The local human population consists of 15 official villages within the target area and a larger number scattered around the area's periphery (Fig. 1). Numerous small settlements are scattered on islands and riverbanks throughout the area. Most households rely on rice cultivation for subsistence, usually supplemented by fishing, and a range of low-intensity natural resource harvesting activities including hunting and resin gathering. In the dry season (December to May), many families from outside the study area temporarily enter and establish small camps on sandbars and islands to fish, and increasingly in 2011, to extract gold. Logging, small-scale settlement and forest conversion, egg-collection, wildlife hunting and trading, and artisanal gold extraction are all threats to waterbirds within the site, as are economic land concessions on the surrounding mainland and hydropower dam proposals that may flood the site or alter water flow. There exist several community forests and community fishery areas throughout the study site that provide some level of protection to local biodiversity. A payment for nest protection programme for the Asian giant softshell turtle *Pelochelys cantorii* is run in the area by another organization and is very similar to the programme we describe below (Sun, 2011).

Target species

Four waterbirds were targeted for nest protection: white-shouldered ibis *Pseudibis davisoni* (Fig. 2), river tern *Sterna aurantia*, lesser adjutant *Leptoptilos javanicus* and greater adjutant *L. dubius*, but no greater adjutant nests were located. The target species are all high priorities for conservation action at the site (Bezuijen *et al.*, 2008), facing considerable threat in the region. White-shouldered ibis and greater adjutants are highly threatened globally (Table 1).

Cambodia is a stronghold for the white-shouldered ibis, with around 90% of the global population (731–856

Table 1 Target species in the nest protection programme, with local conservation priority based on biological surveys of the site, global status from the *IUCN Red List of Threatened Species*, legal classification in Cambodia, status in Thailand and status in Lao PDR. Sources: 1 – Bezuijen *et al.* (2008), 2 – Birdlife International (2011), 3 – BirdLife International (2012), 4 – BirdLife International (2008b), 5 – BirdLife International (2008a), 6 – MAFF (2007), 7 – Sanguansombat (2005), 8 – Duckworth *et al.* (1999), 9 – listed under black ibis *Pseudibis papillosa*.

Species	Local Conservation priority [1]	Global status	Cambodian Law [6]	Thai Status [7]	Lao PDR Status [8]
White-shouldered ibis *Pseudibis davisoni*	Very high	Critically Endangered [2]	Endangered	Extinct in the Wild	At risk [9]
River tern *Sterna aurantia*	Very high	Near Threatened [3]	Common	Critically Endangered	At risk
Lesser adjutant *Leptoptilos javanicus*	Very high	Vulnerable [4]	Rare	Critically Endangered	At risk
Greater adjutant *Leptoptilos dubius*	Very high	Endangered [5]	Endangered	Critically Endangered	At risk

birds), of which at least 124 birds occur in the project site (Wright *et al.*, 2012). White-shouldered ibises occur in dry deciduous forest and riverine habitats, feeding at trapeangs (seasonal waterholes) and open areas including abandoned rice fields (Wright *et al.*, 2010; Wright *et al.*, in press). This species is now highly threatened by habitat conversion, and in some areas the poaching of eggs and chicks from nests (Timmins, 2008). White-shouldered ibises nest solitarily in tall trees in dry deciduous and riverine forest and, in Cambodia, breed in the dry season from December to May (Clements *et al.*, 2009; Wright, in press).

The river tern is exclusively associated with rivers and lakes (Robson, 2000). River terns are thought to be globally declining (BirdLife International, 2009) and, although widespread in South Asia, this species is highly threatened in Southeast Asia (Table 1). The project site may hold the largest breeding population in Indochina (Timmins, 2008). Evidence suggests the species is threatened in Cambodia, although national legislation lists it as "Common" (Claassen, 2004; MAFF, 2007; Timmins, 2008). River terns nest solitarily or in diffuse colonies on sandbars from January to June, and are highly threatened by robbery at nests as well as predation by rats, domestic dogs and trampling from water buffalo (Claassen, 2004; WWF, unpublished data).

The lesser adjutant has a global population of fewer than 10,000 birds (BirdLife International, 2008b), of which 2,500–4,000 occur in Cambodia (Bird *et al.*, 2006, cited by BirdLife International, 2008b). They are colonial nesters and highly vulnerable to nest robbery (BirdLife International, 2008b; Timmins, 2008; Clements *et al.*, in press). In northern Cambodia, this species is known to nest from August to February (Clements *et al.*, 2009), but around the Tonle Sap, nesting is recorded only in the dry season from January to June (Clements *et al.*, 2007).

Greater adjutants were also targeted for protection despite a lack of breeding records in the area, because the habitat was believed suitable. There was also concern that the scarcity of greater adjutant observations may have been due, at least in part, to high levels of egg collection.

While nesting requirements and habits differ among these species, their populations in the study site are faced with a similar anthropogenic threat that nest guarding attempts to directly address: robbery. Collection of eggs or chicks of these species is typically opportunistic and for household consumption, both at this site and elsewhere in Cambodia (Clements *et al.*, in press). Trade in these species has not been observed at this site.

Nest guarding programme

A nest guarding programme was carried out over the 2008–09 and 2010–11 dry seasons, from December to the following June (hereafter referred to as 2009 and 2011). A funding gap prevented protection in 2009–10. Awareness-raising work began in the mid-wet season every year (September), and involved informal and *ad hoc* meetings to disseminate information about the programme with local authorities, villagers, fishers, and settlers throughout the target site, encouraging them to report nests of target species. A number of laminated signs were also distributed strategically throughout the site (e.g. at village chiefs' houses).

Table 2 Payments for nest protectors, in US dollars, for target species in 2009 and 2011. Finder's rewards were only paid to those who found nests but did not go on to guard them. In 2011, daily rates were increased and fledgling bonuses introduced to improve the incentive to find and adequately protect nests. Fledgling bonuses were lower for river tern and lesser adjutant, which can be found in colonies, but higher for white-shouldered ibis, which nest solitarily. Finder's rewards and fledgling bonuses were highest for greater adjutant to encourage nest detection (though no nests were located).

	White-shouldered ibis		River tern		Lesser adjutant		Greater adjutant	
	2009	2011	2009	2011	2009	2011	2009	2011
Finder's reward	5	10	5	10	5	10	5	20
Daily rate	1	4	1	4	1	4	1	4
Fledgling bonus	-	15	-	8	-	8	-	20

The nest protection programme guidelines and structure are adapted from those developed and applied elsewhere in Cambodia (Clements *et al.*, 2009). Target species' nests and colonies were reported to programme staff, and the finders were either contracted to guard the nest until fledging or failure, or, if they did not want this employment, were paid a finder's reward and another member of the local community was contracted to guard. Guarding began as soon as nests were located and all located nests were guarded. Contracts were issued for single nests for white-shouldered ibis, colonies of lesser adjutants, and either colonies or single nests of river terns. Up to two nest guards were allowed on one contract to share duties and payment. Nests were checked every 3–5 days by project staff. Excluding management, the programme consisted of three employees including a counterpart from the Forestry Administration and two staff from local communities.

In 2009, a simple scheme was initiated to pay nest finders US$5, and guards US$1 per day from the date a nest or colony was reported until fledging (Table 2). Payment was entirely conditional on successful fledging. In addition to providing an incentive to protect diligently, this conditionality was imposed due to concerns that guards may either cease protection, or rob the nest themselves after receiving partial payment. Guards were not required to be permanently present at nests, but were expected to stay in their proximity during daylight hours to prevent robbery and, as far as possible, natural predation, but not cause extra disturbance to the nest.

Based on the results of 2009, the guidelines and payment scheme were updated in 2011 to encourage increased community participation in the programme and improve nest detection and survival rates. The guards' daily rate was increased to US$4, matching the local wage for a day's labour, and finder's rewards were increased to encourage nest detection (Table 2). A bonus per fledged chick was offered to encourage diligent guarding, and bonus size differed between colonially and solitarily nesting species. Nest failure now resulted in no payment only when occurring within the first 30 days of guarding. Two guards could be employed (each receiving a salary), but at least one was required to be present at the nest at all times during the day, although this was not strongly enforced.

As this programme ran during the dry season when rice farming does not occur, opportunity costs for guards were minimal. The main impact on livelihoods was reduced fishing time, although this was mitigated by the sharing of guard duties. The guards' opportunity cost of not robbing nests was also minimal, i.e., a meal, because such robbery is intended for home consumption only.

Guards recorded the key activity and status of the nests every day up to fledging. Because data were collected with minimal disturbance, hatching dates for white-shouldered ibis and lesser adjutants were not known with certainty. Data were verified by project staff who visited each nest every few days, also checking on guards and informally taking feedback from them on the guarding programme. These data were used to generate estimates of nest survival and as the basis for this evaluation.

Analysis and evaluation

Here we refer to protection days as being equivalent to 'exposure' days in the methods of Mayfield (1961) and 'risk' days in Johnson's (1979) analysis method. The calculation of daily survival rate of nests and overall nest survival used the Mayfield method (Mayfield, 1961, 1975) with the confidence interval as per that derived by Johnson (1979). Small sample sizes and the difficulty in assessing the age of some nests prevented the applica-

Table 3 Success of guarded white-shouldered ibis, lesser adjutant and river tern nests in 2009 and 2011. Data shown are per nest with the exception of values indicated with an asterisk (*) as denoting per colony. The number of river tern chicks fledging the nest (r) are those that hatched and left the nest, but ultimately fledging was not confirmed: see text for more details.

	White-shouldered ibis		Lesser adjutant		River tern	Total
	2009	2011	2009	2011	2011	
Protected nests [colonies]	6	11	9 [2]	2 [1]	18	48 [3]
Failed nests	2	5	0	0	9	16
Chicks fledging the nest	7	12	14	4	23r	60
Apparent success rate	66.6	54.6	100	100	50	
Total protection days	164.5	297	196*	32*	182	871.5
Mean protection days (± SD)	27.4 ± 21.1	27.0 ± 27.9	98.0* ± 15.6	32.0*	10.1 ± 7.3	
Daily survival rate (%)	98.8	98.3	100	100	95.1	
Overall nest survival rate (%)	43	31	100	100	32.7	
95% confidence interval in overall nest survival rate (%)	12.9 – 100	10.7 – 87.7			15.4 – 68.1	

tion of more advanced analytic methods (e.g., Dinsmore *et al.*, 2002).

Because hatching dates were not accurately known, incubation and nestling periods were pooled for white-shouldered ibises to provide an overall daily survival rate. A nesting period of 69 days was applied for calculations of white-shouldered ibis survival rate (Wright, in press). The river tern incubation period takes an estimated 22 days (Claassen, 2004), shortly after which the mobile chicks leave the nest and are exceedingly cryptic and difficult to locate. Guarding ceased at this stage and the analysis considers only the 22–day egg period. True survival to fledging and overall river tern nest survival may potentially be overestimated by not accounting for chick survival after hatching. Estimates of nest survival for lesser adjutants are based on the raw survival rates of nests in colonies because the data to calculate daily survival rates using the Mayfield method were not available. Confidence intervals were also not reported for adjutants.

All nests were protected. Without control (unguarded) conditions, the study cannot quantify the absolute success of the programme. Instead, observed survival rates were compared with those of other guarded and unguarded populations of target species elsewhere in Cambodia. Such comparisons provide a preliminary indication of success. We considered guard feedback and staff observations of guard behaviour, as well as the causes of observed failure, to judge the strengths and problems with the guarding approach.

Results

Nest survival

In 2009, two adjutant colonies, totalling nine nests, and six white-shouldered ibis nests were protected (Fig. 1, Table 3). No river tern nests were guarded, but five nests were reported to programme staff after they had been robbed. In 2011, 11 white-shouldered ibis nests, 18 river

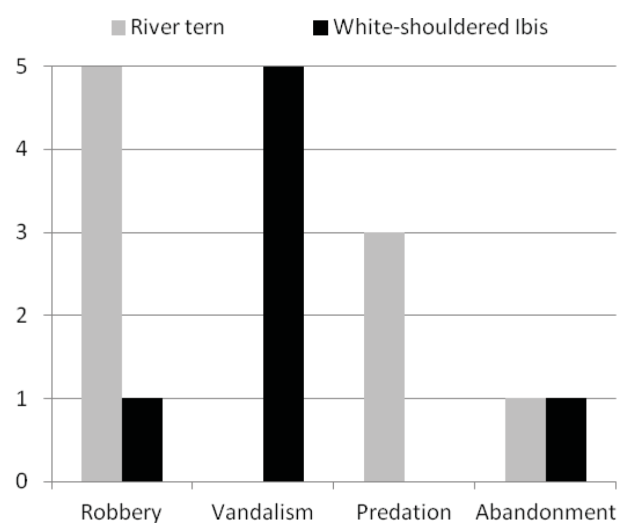


Fig. 4 The frequency of nest failure causes during the study period for river tern and white-shouldered ibis, pooled for all years.

tern nests and one lesser adjutant colony with two nests were guarded (Fig. 1, Table 3). No greater adjutant nests were located during either season. Half of all protected river tern nests survived, as did slightly more than half of white-shouldered ibis nests and all lesser adjutant nests. Nest survival, estimated using the Mayfield method, was low, at around 43% and 31% for the ibises in 2009 and 2011, and 32% for river terns in 2011, although the margins of error for these estimates were considerable (Table 3).

Causes of failure

The majority of nest failures were due to anthropogenic reasons (Fig. 4). White-shouldered ibises suffered one nest robbery, one abandoned clutch and, most alarmingly, five nests vandalised by community members from a nearby gold mining camp, reportedly jealous over the payments to guards (Fig. 4). These destructive incidents all occurred in late January to early March 2011, in the area of Koh Tnot and Koh Preal Tom near the southern end of the project site, which saw an exponential increase in artisanal gold extraction from exposed sediment at that time (G.E. Ryan, pers. obs.). The destruction was accomplished by a small party with slingshots, who approached the five nests on separate occasions from the opposite side of the guards' camps and vandalised the nests both during the day and night. Guards heard the vandals during these events, and sometimes saw them afterwards, but were powerless to act in time, being positioned on the other side and not close to the nests. Three chicks from two different nests were also blown out of nests in high winds. In 2009 a single chick was blown out, but the nest successfully fledged another chick. In 2011 two chicks were blown out, but recovered and fledged, (see below). This nest was considered successful, with protection days counted up to the time of the chicks' fall.

River terns were also highly subject to egg robbery, with six nests robbed, although eggs from one nest were recovered from thieves by the guard and successfully hatched. Robbery occurred when guards were absent from the nests, but signs of both poaching and predation were identified from tracks in the sand. As exposed ground-nesters, river terns appeared much more susceptible to predation, with three nests lost to predators believed to be domestic dog, a rat, and a great thick-knee *Esacus recurvirostris*. A single nest was also abandoned for unknown reasons, and another avian predator, thought to be a river lapwing *Vanellus duvaucelii,* subsequently pecked a hole in the unattended egg (Fig. 4).

Employment and payment of guards

In 2009, eight local community members were employed as nest guards. Due to the failure of two nests, two guards received no payment. That the eggs at one of these nests failed to hatch after an investment of 69 days was a very unfortunate outcome for the guard.

In 2011 there were 32 contracted guards: 17 for white-shouldered ibis nests, 13 for river tern, and two for lesser adjutant. White-shouldered ibis failures occurred within the first 10 days of guarding (mean = 4.8, SD = 3.6 days). Two pairs of guards successively guarded two nests each, only to have them swiftly vandalised, resulting in at least one guard being frustrated and declaring no further interest in the programme. River tern failures occurred after up to 16 protection days (mean = 7.7, SD = 4.6 days), with guards receiving no payment in these instances. Many guards were responsible for multiple nests if they were close by, especially around an important river tern colony on a large sandbar near Koh Preah. Others took up additional nests after their first, including after failures.

Only one ibis guard from 2009 participated in 2011, but given the small number of guards in 2009 and the stochastic nature of nest location, it is unclear whether guards from the first season were dissatisfied or simply did not find nests in 2011. We believe it to be the latter case because many guards from 2011 went on to protect nests in the 2012 season. Guards protecting more than one nest were 'species specialists', with none protecting more than one species. This could be due to the uneven spatial distribution of nests in different places and habitat types (Fig. 1).

White-shouldered ibis chick recovery

In March 2011, two chicks were blown from a protected nest and here we report on their successful recovery through to fledging. The chicks fell from a large dipterocarp tree and were apparently unharmed, but incapable of returning to the nest (Fig. 3). The adults were not present, although the chicks did call. The nest was unreachable, so it was not possible to physically return the chicks. After several hours, guards removed the chicks to a chicken coop at their house, fearing predators. Afterwards, adults did return to the nest tree, from where they were heard calling every evening. Three days later an attempt was made to return the chicks to an artificial nest by tying a large woven basket lined with straw in a high fork (c. 8–10 m above the ground), which the chicks were placed inside. One chick immediately glided down, but was unable to fly up again. It was recaptured and placed in the artificial nest again. The birds appeared to settle, and were left and observed from a distance. After around 30 minutes in the artificial nest, both glided to the ground. They were then returned to the chicken coop, and continued to feed on small frogs and snails caught locally. Three more days after the first artificial nest attempt, the chicks were able to fly to a small branch in the coop, so the guards returned them to the tree, but this was again unsuccessful. Fifteen days after falling it was believed the chicks were strong enough to fly properly, and they were moved to an open-roofed wire mesh cage, purpose-built around a small muddy pool near to the nest tree and within hearing range of the calling parent birds. With minimal disturbance, the guards maintained constant observation, close enough to detect predators. Three days later (18 days after their fall), the adult birds approached and the chicks flew from the cage and fed with them in the surrounding fallow paddies. The guards reported frequently seeing the four ibises feeding together in the area afterwards so the release is believed to have been successful.

Although staff and local people intervened in this case, elsewhere white-shouldered ibis chicks have been observed leaving the nest before fully capable of flight (H.L. Wright, pers. obs.), and yet continuing to be fed by adults to fledge successfully. This fledging strategy is common for many birds, even altricial species, and we would therefore urge caution before removing chicks in such cases – especially where white-shouldered ibis chicks are believed to have left the nest early and for uncertain reasons. If intervention is necessary to prevent predation, we suggest building a large, unroofed exclosure for the chicks at the site of the nest, allowing access by the adult birds to feed chicks until they are capable of flight.

Discussion

Nest survival and causes of failure

Nest survival was low for both the white-shouldered ibis and river tern, reflecting the multiple and frequent threats faced at nest sites in the Mekong Flooded Forest and surrounding mainland. Confidence intervals were large, probably due to small sample sizes, but as knowledge of nest site localities improves, larger samples of nests in the programme will increase the precision of nest survival estimates. Lesser adjutant nest survival was much higher than for ibises and terns, with no nest failures. Whether this is explained by a smaller number of nest locations resulting in lower likelihood of nest site discovery by robbers, more effective guarding, or other reasons, is not yet clear. Despite being targeted, no greater adjutant nests were located in the study area and the species may not breed at this site.

The causes of most nest failure were anthropogenic, with nest robbery and vandalism accounting for 11 of the 16 failures. This is much higher than either Kulen-Promtep Wildlife Sanctuary or Western Siem Pang where predation has been suggested as the main source of nest failure for white-shouldered ibis (Clements *et al.*, 2009; Wright, in press). Claassen (2004) reports that nest robbery accounts for almost all failures of unguarded river tern nests in the Sesan and Sekong Rivers, and here, even at guarded nests, it represented the major cause of tern nest failure. The severity of anthropogenic threats at this site, even with guards in place, demonstrates the need to address them with effective interventions. Assessing and improving this programme is an important step in developing such measures.

Predation by multiple species was also a problem for river terns in this programme, and remains a potential threat to the other species. Three white-shouldered ibis chicks were blown from nests by high winds. Although not resulting in nest failure in these cases this appears to be a re-occurring phenomenon: white-shouldered ibis, lesser adjutant, and giant ibis *Thaumatibis gigantea* nests have all been affected by weather events in other parts of Cambodia (Clements *et al.*, 2009).

Effectiveness and limitations of nest guarding

Without a control sample we could not compare nest survival at guarded with unguarded nests. Nevertheless, nest guarding effectiveness could be evaluated in relation to two aims: halting anthropogenic causes of failure and achieving broadly high survival rates (e.g. >50%). Nest survival rates for river terns and white-shouldered ibises were low, and the main sources of failure were anthropogenic, which suggests these aims were not well met: guarding was not nearly as effective as hoped. Comparison with nest guarding programmes elsewhere in Cambodia suggests white-shouldered ibis nest failure rates at this site were considerably higher than in Kulen-Promtep Wildlife Sanctuary or Western Siem Pang Important Bird Area in equivalent years (Clements *et al.*, in press; Wright, in press), although in 2011, the nest failure rate was comparable with that observed for guarded nests in Lomphat Wildlife Sanctuary (Wright, in press). Wright (in press) attributes this to a longer protection programme and broader conservation presence at both Kulen-Promtep and Western Siem Pang, than at either Lomphat or here in the Mekong Flooded Forest. Clements *et al.* (2009, in press) found few failures among guarded lesser adjutant nests, suggesting broadly similar survival rate for this species. This is the first protection scheme for the river tern, so no direct comparison is available, but the modest survival observed here (33%) is considerably higher than the 0% survival observed by Claassen (2004) for unprotected nests on the Sesan River in 2003.

White-shouldered ibises at this site nest in both flooded forest around river channels and terrestrial dry dipterocarp forest inland: a combination not observed at any other population (Sozer & van der Heijden, 1997; Clements *et al.*, 2009; Sutrisno *et al.*, 2009; Wright, in press). The ibises' use of both habitats may make it especially vulnerable to nest exploitation, as people use dry forests in the day and fishers travel along rivers both day and night. The complex combination of human activities at this site suggests broader strategies may be needed than for similar conservation programmes elsewhere (Clements *et al.*, 2009; Wright, in press), such as the potential application of 24–hour nest protection, wide outreach and awareness-raising, and improved site management and enforcement.

As knowledge of nest sites improves, the potentially increasing scale of the intervention brings into question the sustainability of such a payment scheme in the long term. Funding, staff and equipment are often at a premium in conservation programmes and investing ever more of these into nest protection may lack efficiency. There is also the concern that payments generate local expectations of prolonged employment or reward, as local people equate nests only with direct monetary value rather than as a 'common good' (Bowles, 2008). In the longer term, this may undermine efforts to protect nests when that incentive is removed. There is therefore a need to design a transition toward more socially and financially sustainable methods of improving nest survival.

Improving nest survival in the Mekong Flooded Forest

Numerous improvements can be made to the protection programme and we recommend particular attention to payment structures and community engagement to enhance the impact and fairness of the intervention. Improving the monitoring protocol by designating a control sample of nests will allow for the direct comparison of guarded and unguarded nests, permitting the robust evaluation of nest guarding in future.

Although since 2010 at least one guard was required to be present at the nest at all times, the financial incentive was perhaps too little and enforcement not strong enough to ensure guards fully protected nests, with robbery and vandalism occurring in the 2011 season. An additional incentive to encourage guard diligence is necessary, but the non-payment approach caused frustration among guards who were unable to prevent 'natural' causes of failure. Guards generally incur some outlay in fuel for travel and phone calls to programme staff, plus invest a considerable amount of time in guarding, so non-payment could be considered exploitative and create animosity towards the birds. Unhappy community members with good knowledge of where and how the birds nest could prove a great danger if unfair treatment provokes them to take destructive action. To encourage diligence without inordinately punishing guards or causing extra frustration, one solution may be to link payment to particular causes of nest failure. This could involve full payment where causes of nest failure were out of the guards hands (e.g. predation, abandonment, or high winds), but reduced or no payment in cases of robbery from the nest or clear impact of preventable human disturbance. A soft approach should be applied to the burden of proof, so that only clear cases of robbery are penalised.

The issue of jealousy and vandalism of ibis nests was the most serious limitation of the guarding programme; one that may entirely undermine this intervention if such incidents recur. That vandalism was repeated over a series of days, rather than in a single incident, suggests more calculated discontent than brief frustration. Similar unhappiness with nest protection programmes is known from elsewhere in Cambodia, resulting in non-reporting and destruction of nests, but these are often believed to be caused by perceptions of rangers as enemies and concerns over land tenure (Ashish John, pers. comm.). Providing large payments to small sections of the community may also cause discontent (Clements *et al.*, in press). As with guard unhappiness, community discontent is a major drawback, and resolving these forms of disharmony are essential to avoid actual harm to those communities involved or influenced by conservation interventions (Adams *et al.*, 2004; Milne & Nietsen, 2009). Such social impact will require continual, careful evaluation relative to the putative benefits of guarding.

Improved community engagement could have several forms, and would probably complement guarding while assisting an eventual transition away from direct payments. Establishing village committees to arbitrate disputes, and implementing land-use planning to secure tenure, have apparently proven effective for mitigating jealousies elsewhere in Cambodia (Ashish John, pers. comm.). That the vandals of five white-shouldered ibis nests were from a mining camp is of concern because they may originate outside the local area and therefore be less influenced by local social obligation. This issue requires further monitoring, and broader outreach methods will be needed if the problem persists. In the short term, alternative community-based protection of small yet important river tern and white-shouldered ibis nesting areas may be a cost-effective means to supplement nest guarding to individuals. Initially pairing this with nest guarding may help prevent visible demarcation from actually increasing the conspicuousness of nest sites and encouraging nest robbery.

Other options include directly linking a proportion of guarding payments to broader community benefits to expand the buy-in of other local people, similar to a scheme used to protect snow leopard *Uncia uncia* habitat (Mishra *et al.*, 2003). Tying benefits to the community level is common in conservation interventions (e.g., Nietsen & Rice, 2004; Milne & Nietsen, 2009), but using a combination of individual and community benefits appears rarer (Oum *et al.*, 2009). Community benefits would be small at the payment scheme's current scale, but may at least provide community goodwill and increase the accountability of would-be poachers to their communities. Benefits would increase as more nests are found and the programme expands. Such dual benefits may also ameliorate potential conflicts if a nest's guards are not from the delineated village area in which it is found.

A transition toward more comprehensive awareness raising and direct, participatory community enforcement, whereby community rangers partner with government officers in patrolling and enforcing natural resource regulations, may reduce reliance on nest protection payments in the medium to long term. This could also provide other benefits to biodiversity (but lose the beneficial directness of the payment programme: Ferraro & Kiss, 2002). In addition, this engagement may encourage the valuing of nests beyond a direct financial incentive, and complement the effect of nest guarding (Wright, in press). These alternative interventions are still likely to require external funding, but may have lower costs than direct payments for protection in the long term.

Ecotourism is often proposed as a means of sustainable funding for biodiversity protection. Elsewhere in Cambodia, rare species such as white-shouldered ibises have already brought tourism revenue into rural communities (Clements *et al.*, 2008). In the short- to medium-term, however, tourism is unlikely to provide sufficient income and incentive to protect nests. Currently, virtually no tourism activity exists in the area, although there are potential opportunities to integrate with established dolphin-watching tourism in Kratie, and other community-based ecotourism projects nearby (Ministry of Tourism, 2012).

Anti-predator devices are an established solution to reducing predation at nests (Keo *et al.*, 2009; Smith *et al.*, 2011). Fences for ground nests may be suitable for river terns, but could deter parents and attract other predators such as perching raptors or crows. Plastic baffles on trees, to stop mammalian predators from accessing nests, have proved successful at improving giant ibis nest survival in Cambodia (Keo *et al.*, 2009), and could be easily applied to white-shouldered ibis or lesser adjutant nests if such predation is identified as a threat. It would be necessary, however, to ensure that such devices do not make nests more conspicuous to potential nest robbers. The effects of high winds are much harder to deal with and there would appear to be little intervention that can mitigate this. A careful judgement call must be made when either leaving fallen chicks alone, returning them to the nest site or rearing them in captivity.

Conclusion

The immediate success of the nest guarding intervention was very limited. Anthropogenic failures were rife and the programme was some source of discontent in the community. Nonetheless, the severity of ongoing anthropogenic threats at the site suggests that direct protection, such as guarding, is still necessary at least in the short term. The nest guarding programme in the Mekong Flooded Forest is in its infancy. Working where communities do not place a conservation value on wildlife and are unfamiliar with the work of conservation NGOs creates a challenging working environment with many lessons to learn.

Alternative payment structures, protection techniques or community buy-in measures may help to address the direct and indirect shortcomings of nest guarding to achieve higher nest survival and better community engagement in the coming years. These, along with regular re-assessment, will help to ensure that payment schemes do not enhance threats to priority species or cause disharmony among local communities.

Acknowledgements

The authors would like to thank the nest guards for their participation in the programme, and Keo Bopha Rangsey and Nguon Rin for much hard work in the field. Gordon Congdon, Richard Zanre, Michelle Owen and Seng Teak provided organizational support. Tom Clements and Ashish John gave helpful discussion on issues in bird nest protection programmes elsewhere in Cambodia. Cartography in Fig. 1 by Huy Keavuth with many thanks. We also thank Tom Clements, Melissa Rodgers, and two anonymous reviewers for comments that greatly improved the manuscript.

Funding for this programme was provided by WWF-Germany and the Critical Ecosystem Partnership Fund. The Critical Ecosystem Partnership Fund is a joint initiative of l'Agence Française de Développement, Conservation International, the Global Environment Facility, the Government of Japan, the MacArthur Foundation and the World Bank. A fundamental goal is to ensure civil society is engaged in biodiversity conservation.

References

Adams, W., Aveling, R., Brockington, D., Dickson, B., Elliott, J., Hutton, J., Roe, D., Vira, B. & Wolmer, W. (2004) Biodiversity conservation and the eradication of poverty. *Science*, **306,** 1146–1148.

Barre, N., Theuerkauf, J., Verfaille, L., Primot, P. & Saoumoe, M. (2010) Exponential population increase in the endangered Oueva parakeet (*Eunymphicus uvaeensis*) after community-based protection from nest poaching. *Journal of Ornithology*, **151,** 695–701.

Bezuijen, M.R., Timmins, R. & Seng, T. (eds.) (2008) *Biological Surveys of the Mekong River Between Kratie and Stung Treng towns, Northeast Cambodia, 2006–2007*. WWF Greater Mekong – Cambodia Country Programme, Cambodia Fisheries Administration, & Cambodia Forestry Administration, Phnom Penh, Cambodia.

BirdLife International (2008a) *Leptoptilos dubius*. In *IUCN 2011 Red List of Threatened Species, Version 2011.1.* Http://www.iucnredlist.org/apps/redlist/details/106003842/0 [accessed 13 August 2011].

BirdLife International (2008b) *Leptoptilos javanicus*. In *IUCN 2011 Red List of Threatened Species, Version 2011.1.* Http://www.iucnredlist.org/apps/redlist/details/106003842/0 [accessed 13 August 2011].

BirdLife International (2012) *Sterna aurantia*. In *IUCN 2012 Red List of Threatened Species, Version 2012.1.* Http://www.iucnredlist.org/apps/redlist/details/106003259/0 [accessed 29 July 2012].

BirdLife International (2011) *Pseudibis davisoni*. In *IUCN 2011 Red List of Threatened Species, Version 2011.1.* Http://www.iucnredlist.org/apps/redlist/details/106003842/0 [accessed 25 November 2011].

Bowles, S. (2008) Policies for self-interested citizens may undermine "the moral sentiments": evidence from economic experiments. *Science*, **320,** 1605–1609.

Claassen, A.H. (2004) *Abundance, Distribution, and Reproductive Success of Sandbar Nesting Birds Below the Yali Falls Hydropower Dam on the Sesan River, Northeastern Cambodia.* WWF, Danida, Wildlife Conservation Society and BirdLife International, Phnom Penh, Cambodia.

Clements, T., O'Kelly, H. & Sun V. (2007) *Monitoring of Large Waterbirds at Prek Toal, Tonle Sap Great Lake 2001–2007.* Wildlife Conservation Society Cambodia Program, Phnom Penh, Cambodia.

Clements, T., John, A., Nielsen, K., Chea V., Ear S. & Meas P. (2008) *Case Study: Tmatboey Community-Based Ecotourism Project.* Ministry of Environment, Cambodia, and Wildlife Conservation Society, Phnom Penh, Cambodia.

Clements, T., Garrett, L., John, A., Keo O., Kongkim S., Pech B., Rours V., Tan S., Thong S. & Rainey, H. (2009) *Bird Nest Protection Programme in the Northern Plains of Cambodia.* Wildlife Conservation Society and USAID, Phnom Penh, Cambodia.

Clements, T., John, A., Nielsen, K., Dara A., Tan S. & Milner-Gulland, E.J. (2010) Payments for biodiversity conservation in the context of weak institutions: comparison of three programmes from Cambodia. *Ecological Economics*, **69,** 1283–1291.

Clements, T., Rainey, H., An D., Rours V., Tan S., Thong S., Sutherland, W.J. & Milner-Gulland, E.J. (in press) An evaluation of the effectiveness of a direct payment for biodiversity conservation: the bird nest protection program in the Northern Plains of Cambodia. *Biological Conservation*.

Dinsmore, S.J., White, G.C. & Knopf, F.L. (2002) Advanced techniques for modelling avian nest survival. *Ecology*, **83,** 3476–3488.

Duckworth, J.W., Salter, R.E. & Khounboline, K. (1999) *Wildlife in Lao PDR: 1999 Status Report*. IUCN, Vientiane, Lao PDR.

Ferraro, P.J. (2001) Global habitat protection: limitations of development interventions and a role for conservation performace payments. *Conservation Biology*, **15,** 990–1000.

Ferraro, P.J. & Gjertsen, H. (2009) A global review of incentive payments for sea turtle conservation. *Chelonian Conservation and Biology*, **8,** 48–56.

Ferraro, P.J. & Kiss, A. (2002) Direct payments to conserve biodiversity. *Science*, **298,** 1818–1819.

Goes, F. (2005) Four years of waterbird conservation activities in the Prek Toal Core Area, Tonle Sap Biosphere Reserve (2001–2004). Wildlife Conservation Society, Phnom Penh, Cambodia.

Goes, F. (2009) The status and distribution of green peafowl *Pavo munticus* in Cambodia. *Cambodian Journal of Natural History*, **2009,** 7–15.

Gray, T.N.E., Collar, N.J., Davidson, P.J.A., Dolman, P.M., Evans, T.D., Fox, H.N., Chaman, H., Ro B., Seng K.H. & van Zalinge, R. (2009) Distribution, status and conservation of the Bengal florican *Houbaropsis bengalensis* in Cambodia. *Bird Conservation International*, **19,** 1–14.

Johnson, D.H. (1979) Estimating nest success: the Mayfield method and an alternative. *The Auk*, **96,** 651–661.

Keo O., Collar, N.J. & Sutherland, W.J. (2009) Nest protectors provide a cost-effective means of increasing breeding success in giant ibis *Thaumatibis gigantea*. *Bird Conservation International*, **19,** 77–82.

Koks, B.J. & Visser, E.G. (2001) Montagu's harriers *Circus pygargus* in the Netherlands: does nest protection prevent extinction? *Ornithologischer Anzieger*, **41,** 159–166.

Lindenmayer, D.B., Macgregor, C. & Gibbons, P. (2002) Comment – economics of a nest-box program for the conservation of an endangered species: a re-appraisal. *Canadian*

Journal of Forestry Research, **32,** 2244–2247.

MAFF – Ministry of Agriculture, Forestry & Fisheries (2007) *Prakas on Classification and List of Wildlife Species. Ministry of Agriculture, Forestry and Fisheries, No. 020 PR.MAFF, 25 January 2007*. Royal Government of Cambodia, Phnom Penh, Cambodia.

Mayfield, H. (1961) Nesting success calculated from exposure. *Wilson Bulletin*, **73,** 255–261.

Mayfield, H. (1975) Suggestions for calculating nesting success. *Wilson Bulletin*, **87,** 456–466.

Milne, S. & Nietsen, E. (2009) Direct payments for biodiversity conservation in developing countries: practical insights for design and implementation. *Oryx*, **43,** 530–541.

Ministry of Tourism (2012) Mekong discovery trail. Http://www.mekongdiscoverytrail.com [accessed 21 April 2012].

Mishra, C., Allen, P., McCarthy, T., Madhusudan, M., Bayajargal, A. & Prins, H. (2003) The role of incentive programs in conserving the snow leopard. *Conservation Biology,* **17,** 1512–1520.

National Parks Service (2011) Sea turtle recovery project. Http://www.nps.gov/pais/naturescience/strp.htm [accessed 16 September 2011].

Nietsen, E. & Rice, R. (2004) Sustainable forest management and conservation incentive agreements. *International Forestry Review*, **6,** 56–60.

Oum S., Hor L., Han S., Sonn P., Simpson, B.K. & Daltry, J.C. (2009) A comparative study of incentive-based schemes for Siamese crocodile *Crocodylus siamensis* conservation in the Cardamom Mountains, Cambodia. *Cambodian Journal of Natural History,* **2009,** 40–57.

Pain, D.J., Martins, T.L.F., Bousseky, M., Diaz, S.H., Downs, C.T., Ekstrom, J.M.M., Garnett, S., Gilardi, J.D., McNiven, D., Primot, P., Rouys, S., Saomoue, M., Symes, C.T., Tamungang, S.A., Theuerkauf, J., Villafuerte, D., Verfailles, L., Widmann, P. & Widmann, I.D. (2006) Impacts of protection on nest take and nesting success of parrots in Africa, Asia and Australasia. *Animal Conservation,* **9,** 322–330.

Robson, C. (2000) *A Field Guide to the Birds of Southeast Asia*. Asia Books, Bangkok, Thailand.

Sanguansombat, W. (2005) *Thailand Red Data: Birds*. Office of Natural Resources and Environmental Policy and Planning, Bangkok, Thailand.

Schifferli, L., Spaar, R. & Koller, A. (2006) Fence and plough for lapwings: nest protection to improve nest and chick survival in Swiss farmland. *Osnabrücker Naturwissenschaftliche Mitteilungen*, **32,** 123–129.

Smith, R.K., Pullin, A.S., Stewart, G., & Sutherland, W.J. (2011) Is nest predator exclusion an effective strategy for enhancing bird populations? *Biological Conservation,* **144,** 1–10.

Sozer, R. & van der Heijden, A.J.W. (1997) An overview of the distribution, status and behavioural ecology of the white-shouldered ibis in East Kalimantan. *Kukila*, **9,** 126–140.

Sun Y. (2011) *Mekong Turtle Conservation Centre: Community Led Nest Protection and Headstarting of Cantor's Softshell Turtles.* Update prepared for the Cambodian Fisheries Administration. Conservation International, Phnom Penh, Cambodia.

Sutrisno, E., Imanuddin & Rachmady, R. (2009) Preliminary observations of the breeding biology of the critically-endangered white-shouldered ibis *Pseudibis davisoni* in East Kalimantan. *Kukila*, **14,** 32–35.

Timmins, R. (2008) Birds. In *Biological surveys of the Mekong River between Kratie and Stung Treng Towns, Northeast Cambodia, 2006–2007* (eds M.R. Bezuijen, R. Timmins & T. Seng), pp. 53–80. WWF Greater Mekong – Cambodia Country Programme, Cambodia Fisheries Administration, & Cambodia Forestry Administration, Phnom Penh, Cambodia.

Tomillo, P.S., Saba, V.S., Piedra, R., Paladino, F.V. & Spotila, J.R. (2008) Effects of illegal harvest of eggs on the population decline of leatherback turtles in Las Baulas Marine National Park, Costa Rica. *Conservation Biology,* **22,** 1216–1224.

Wright, H.L. (in press) *Synanthropic survival: low-impact agriculture and white-shouldered ibis conservation ecology*. PhD thesis, University of East Anglia, Norwich, U.K.

Wright, H.L., Buckingham, D.L. & Dolman, P.M. (2010) Dry season habitat use by Critically Endangered white-shouldered ibis in northern Cambodia. *Animal Conservation,* **13,** 71–79.

Wright, H.L., Collar, N.J., Lake, I.R., Net N., Rours V., Sok K., Sum P. & Dolman, P.M. (2012) First census of white-shouldered ibis *Pseudibis davisoni* reveals roost-site mismatch with Cambodia's protected areas. *Oryx*, **46,** 236–239.

Wright, H.L., Collar, N.J., Lake, I.R., Bou V. & Dolman, P.M. (in press) Foraging ecology of sympatric white-shouldered ibis *Pseudibis davisoni* and giant ibis *Thaumatibis gigantea* in northern Cambodia. *Forktail*.

Wright, T.F., Toft, C.A., Enkerlin-Hoeflich, E., Gonzalez-Elizondo, J., Albornoz, M., Rodriguez-Ferraro, A., Rojas-Suarez, F., Sanz, V., Trujillo, A., Bessinger, S.R., Berovides, V., Galvez, X., Brice, A.T., Joyner, K., Eberhard, J., Gilardi, J., Koenig, S.E., Stoleson, S., Martuscelli, P., Meyers, M.J., Renton, K., Rodriguez, A.M., Sosa-Asanza, A.C., Villella, F.J. & Wiley, J.W. (2001) Nest poaching in neotropical parrots. *Conservation Biology,* **15,** 710–720.

The status of large mammals in eastern Cambodia: a review of camera trapping data 1999–2007

Thomas N.E. GRAY[1,*], OU Rattanak[2], HUY Keavuth[2], PIN Chanrattana[2] and Andrew L. MAXWELL[2]

[1] WWF Greater Mekong, House 39, Unit 05, Ban Saylon, Vientiane, Lao PDR.

[2] WWF Greater Mekong Cambodia Country Program, House #21, Street 322, Sangkat Boeung Keng Kang 1, Khan Chamkamorn, Cambodia.

*Corresponding author. Email tomnegray@hotmail.com

Paper submitted 26 March 2012, revised manuscript accepted 29 June 2012.

មូលន័យសង្ខេប

ព្រៃស្ងួតតាមរដូវនៅតំបន់ភាគខាងកើតនៃប្រទេសកម្ពុជា បង្កើតបានជាតំបន់ដែលមានសារៈសំខាន់ជាសកលសម្រាប់ការអភិរក្សជីវៈចម្រុះ។ នៅចន្លោះឆ្នាំ១៩៩៩និង២០០៧ អង្គការមូលនិធិពិភពលោកសម្រាប់ធម្មជាតិ (WWF) និងសមភាគីរដ្ឋាភិបាលពីរដ្ឋបាលព្រៃឈើ និងក្រសួងបរិស្ថាន បានដាក់ពង្រាយម៉ាស៊ីនថតស្វ័យប្រវត្តនៅក្នុងព្រៃពាក់កណ្ដាលស្រោងនិងព្រៃរបោះ នៅទូទាំងភូមិភាគបូព៌ានៃប្រទេសកម្ពុជា។ ម៉ាស៊ីនថតស្វ័យប្រវត្តជាង៤០០ត្រូវបានដាក់នៅតាមទីតាំងប្រាំបួនកន្លែង។ ថនិកសត្វធំៗដែលកំពុងទទួលរងការគម្រាមកំហែងត្រូវបានកត់ត្រាពីគ្រប់ទីកន្លែង ដោយមានចំនួនសត្វសរុបក្នុងមួយកន្លែងៗចំនួនចន្លោះ១៦(ព្រៃការពារមណ្ឌលគីរីក្នុងខេត្តមណ្ឌលគីរី) និង១ (ព្រៃកប្រសព្វ ខេត្តក្រចេះ)។ កំណត់ត្រាសំខាន់ៗដែលមិនធ្លាប់បានបោះពុម្ពពីមុនមក រួមមានកំណត់ត្រាពីម៉ាស៊ីនថតស្វ័យប្រវត្តថ្មីៗបំផុតនៃខ្លា *Panthera tigris* ពីប្រទេសកម្ពុជា កំណត់ត្រាក្របីព្រៃ *Bubalus arnee* ពីឥណ្ឌូចិន រមាំង *Cervus eldii* ពីប្រាំកន្លែង និងឆ្កែព្រៃ *Cuon alpinus* ពីប្រាំពីរកន្លែង។ យើងធ្វើការពិភាក្សាអំពីស្ថានភាព និងអេកូឡូស៊ីនៃថនិកសត្វធំៗដែលកត់ត្រាបានដោយម៉ាស៊ីនថតស្វ័យប្រវត្ត នៅតំបន់ភូមិភាគខាងកើតនៃប្រទេសកម្ពុជា។ ដោយសារតែក្នុងចំណោមប្រាំបួនកន្លែង មានតែពីរកន្លែងប៉ុណ្ណោះ (ដែនជម្រកសត្វព្រៃភ្នំព្រេច និងព្រៃការពារមណ្ឌលគីរី) ដែលបច្ចុប្បន្ននេះទទួលបានការការពារមានប្រសិទ្ធភាពគួរសម វាទំនងជាថា ប្រភេទខ្លះដែលត្រូវបានកត់ត្រានៅក្នុងឯកសារនេះ បានផុតពូជពីតំបន់នេះដោយសារការបរបាញ់ ឬការរេចរឹលនៃទីជម្រក។

Abstract

The seasonally dry forests of eastern Cambodia form a globally important area for biodiversity conservation. Between 1999 and 2007, the World Wide Fund for Nature (WWF) and government counterparts from the Forestry Administration and the Ministry of the Environment undertook extensive camera trapping in semi-evergreen and deciduous dipterocarp forests throughout eastern Cambodia. More than 400 locations across nine sites were camera-trapped. Threatened large mammals were recorded from all sites, with the total number of threatened species recorded per site between 16 (Mondulkiri Protected Forest, Mondulkiri Province) and one (Prek Prasab, Kratie Province). Important records, never previously published, include the most recent tiger *Panthera tigris* camera trap records from Cambodia, the only wild water buffalo *Bubalus arnee* camera trap records from Indochina, and Eld's deer *Cervus eldii* and dhole *Cuon alpinus* from five and seven sites respectively. We discuss the implications of the camera trap records upon the status and ecology of

CITATION: Gray, T.N.E., Ou R., Huy K., Pin C. & Maxwell, A.L. (2012) The status of large mammals in eastern Cambodia: a review of camera trapping data 1999–2007. *Cambodian Journal of Natural History*, **2012,** 42–55.

selected large mammals in eastern Cambodia. Because only two of the nine camera trapping sites (Phnom Prich Wildlife Sanctuary and Mondulkiri Protected Forest) currently receive relatively effective protection, it is likely that some of the species documented in this paper have already become locally extirpated by hunting or habitat degradation.

Keywords
Camera trap, deciduous dipterocarp forest, Indochina, mammal conservation, tiger.

Introduction

The Lower Mekong Forests of eastern Cambodia are globally significant for biodiversity conservation (Tordoff *et al.*, 2005) and form part of the Indo-Burma biodiversity hotspot (Myers *et al.*, 2000). Consequently, the region has been the focus of conservation efforts since the late 1990s led by Cambodian government conservation agencies (the Ministry of Environment and the Forestry Administration, Ministry of Agriculture, Forestry and Fisheries) with technical and financial support from international NGOs, including the World Wide Fund for Nature (WWF), the Wildlife Conservation Society (WCS), and BirdLife Indochina. Surveys within protected areas have recorded a large number of globally threatened species (Long *et al.*, 2000; Timmins & Ou, 2001; Walston *et al.*, 2001; Phan *et al.*, 2010; Gray & Phan, 2011) and provided evidence that the region is globally significant for the conservation of Asian elephants *Elephas maximus* (Pollard *et al.*, 2008; Gray *et al.*, 2012), primates (Pollard *et al.*, 2007; Rawson *et al.*, 2009; Phan & Gray, 2010a), large ungulates (Maxwell *et al.*, 2007; Phan & Gray, 2010b; O'Kelly & Nut, 2010; Gray *et al.*, 2011, in press), and large waterbirds (Seng *et al.*, 2003; Wright *et al.*, 2012).

Between 1999 and 2007, WWF undertook extensive camera trapping surveys in semi-evergreen and deciduous dipterocarp forests throughout eastern Cambodia, including surveys in Virachey National Park, Phnom Prich Wildlife Sanctuary and Mondulkiri Protected Forest. These produced a vast amount of data on the distribution, status and ecology of globally threatened large mammal and bird species. Highlights included the rediscovery of hog deer *Axis porcinus* in Indochina (Maxwell *et al.*, 2007), the only convincing evidence of extant populations of wild water buffalo *Bubalus arnee* in Cambodia, and the country's last unequivocal record of the tiger *Panthera tigris*. However the majority of data from these surveys was never published or made accessible (for an exception, see Maxwell *et al.*, 2007).

In this paper we collate, for the first time, these camera trap data, corresponding to trapping from more than 400 locations across nine sites in eastern Cambodia, and give details of all globally threatened species recorded. These, and more recent, records are then used to discuss the current status of large carnivores, Asian elephants, and globally threatened large ungulates in eastern Cambodia.

Methods

Between June 1999 and November 2007, WWF Cambodia's Dry Forest Species and Srepok Wilderness Area Projects undertook camera trapping across a range of sites in the eastern Cambodian provinces of Mondulkiri, Ratanakiri, Stung Treng and Kratie both east and west of the Mekong river (Fig. 1). Objectives were largely to document the presence and absence of globally threatened large mammal species (particularly Asian elephant, Eld's deer *Cervus eldii*, hog deer, wild cattle, and large carnivores) with cameras placed at locations chosen to maximise encounters with these species and minimise the risk of camera theft. CamTrakker™ (CamTrak South, Inc., Watkinsville, GA 30677 USA) passive infra-red sensor film camera traps were used.

A minority of these data, particularly from Mondulkiri Protected Forest, was never accurately documented while the remainder, although catalogued, have never been analysed or published. In March 2010, 400–plus rolls of negatives from camera trap photographs stored in the WWF Phnom Penh office were digitally scanned by Rob Timmins. From notes on the negatives, location data and limited trapping dates were obtained for most camera trap locations. Cross-referencing of film roll numbers with those in an existing WWF database, previously developed by Huy Keavuth, enabled location and date information to be associated with most camera trap locations. The remainders were identified to site based on the researchers and rangers in the photographs.

Pin Chanrattana subsequently entered all independent encounters with wildlife species from the scanned negatives into a database recording camera trap location, species, time of day (night or day), group size, and habitat at the camera trap location (divided into three categories: 'deciduous dipterocarp forest', 'mixed-deciduous/semi-evergreen/evergreen forest' and 'other' e.g. bamboo forest, stream beds) based on examination of the photographs. Independent encounters were defined

Table 1 Sites camera-trapped by WWF between 1999 and 2007 in eastern Cambodia with approximate latitude/ longitude (to centre of the study area), number of camera trap locations, approximate dates trapped and total number of species and threatened species (i.e. IUCN-listed Vulnerable, Endangered or Critically Endangered) recorded.

Site (Province)	Approximate latitude/ longitude	Number of locations	Approx dates	Species recorded	Threatened species recorded
A. Chhlong (Kratie)	12.12ºN; 106.17ºE	17	Jul 03 to Jan 06	20	6
B. Phnom Prich Wildlife Sanctuary (Mondulkiri)	12.70ºN; 106.80ºE	168	Nov 01 to Mar 07	42	14
C. Prey Khieu (Mondulkiri/ Stung Treng)	13.45ºN; 106.42ºE	31	Nov 03 to May 06	32	11
D. Prey Long (Kratie/ Stung Treng)	13.30ºN; 105.70ºE	32	Apr 02 to Mar 06	32	12
E. Prek Prasab (Kratie)	12.55ºN; 105.86ºE	8	Jan 06 to Sep 06	8	1
F. Mondulkiri Protected Forest (Mondulkiri)	13.00ºN; 107.35ºE	48	Nov 04 to Nov 07	35	16
G. Virachey National Park (Stung Treng/ Ratanakiri)	14.20ºN; 106.80ºE	85	Jun 99 to Aug 01	36	14
H. West Seima/ Snoul (Mondulkiri/ Kratie)	12.52ºN; 106.45ºE	7	Jan 04 to Jan 06	13	4
I. Western Siem Pang (Stung Treng)	14.13ºN; 106.31ºE	7	Aug 03 to Sep 03	11	2

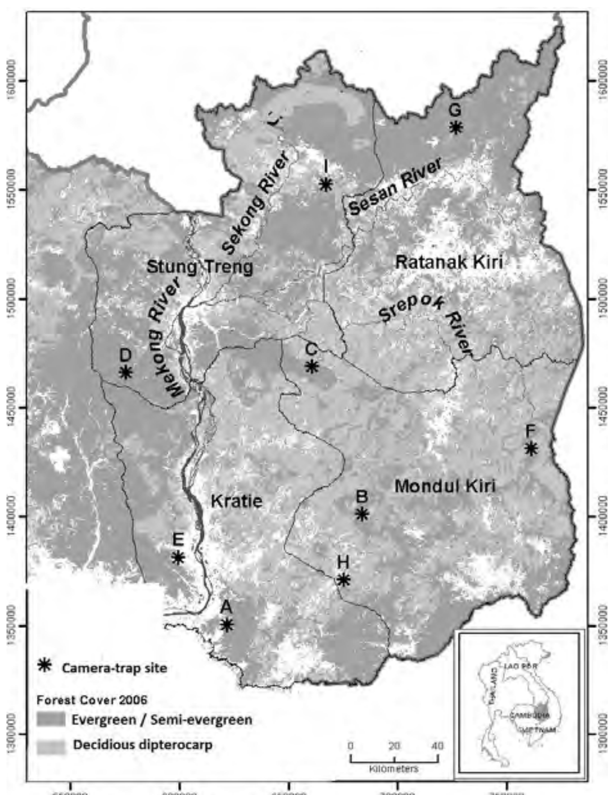


Fig. 1 Approximate locations of sites camera-trapped by WWF in eastern Cambodia 1999–2007. A Chhlong; B Phnom Prich Wildlife Sanctuary; C Prey Khieu; D Prey Long; E Prek Prasab; F Mondulkiri Protected Forest; G Virachey National Park; H West Seima/ Snoul; I Western Siem Pang.

as successive exposures of different species, successive exposures of obviously different individuals of the same species when not clearly within the same group, or successive exposures of the same species at clearly different times (i.e. night versus day). Species identification was performed by Pin Chanrattana with assistance from Tom Gray and Prum Sovanna (WWF/FA). Photographs for which identification may have been contentious (e.g. some photographs of leopard cats *Prionailurus bengalensis* which could be mistaken for fishing cats *P. viverrinus*) were sent to international experts (e.g. members of the IUCN Cat Specialist Group) for confirmation. All photographs of muntjacs were assigned to the red muntjac *Muntiacus muntjak* (but see later comment on the potential presence of large-antlered muntjacs *M. vuquangensis*) while encounters with ferret badgers *Melogale* and chevrotain *Tragulus* were assigned only to genus. Species with more than 25 encounters were classified as nocturnal (>90% of photographs at night), diurnal (>90% of photographs during the day) or cathemeral. Species for which >90% of encounters were made within deciduous dipterocarp or mixed deciduous/ semi-evergreen/ evergreen forests were assessed as being habitat specialists.

Results

The scanned camera film negatives corresponded to nine sites in the eastern Cambodian provinces of Mondulkiri, Rattanakiri, Stung Treng and Kratie between June 1999

Table 2 The number of independent encounters, % of nocturnal encounters and % of encounters in deciduous dipterocarp forests (DDF) for all species photographed on more than 25 occasions by WWF camera trapping in eastern Cambodia between 1999 and 2007.

Species		# of encounters	Nocturnal %	DDF %
Red muntjac	*Muntiacus muntjak*	658	40	55
Wild pig	*Sus scrofa*	444	45	46
Banteng	*Bos javanicus*	210	81	73
Common palm civet	*Paradoxurus hermaphroditus*	150	99	36
Siamese fireback	*Lophura diardi*	142	2	6
Red junglefowl	*Gallus gallus*	124	2	40
Pig-tailed macaque	*Macaca nemestrina*	106	0	43
East Asian porcupine	*Hystrix brachyura*	102	100	39
Gaur	*Bos gaurus*	98	63	38
Asian elephant	*Elephas maximus*	90	67	17
Large Indian civet	*Viverra zibetha*	73	96	50
Eld's deer	*Cervus eldii*	71	42	100
Leopard	*Panthera pardus*	63	49	71
Dhole	*Cuon alpinus*	57	18	71
Sambar	*Cervus unicolor*	56	88	70
Chevrotain	*Tragulus* spp.	51	51	26
Sun bear	*Ursus malayanus*	50	72	20
Green peafowl	*Pavo muticus*	50	0	85
Small Indian civet	*Viverricula indica*	47	96	96
Golden jackal	*Canis aureus*	46	80	98
Large-spotted civet	*Viverra megaspilla*	39	100	80
Leopard cat	*Prionailurus bengalensis*	30	70	58
Lesser adjutant	*Leptoptilos javanicus*	30	0	100
Jungle cat	*Felis chaus*	27	78	96

and November 2007 (Fig. 1; Table 1). Approximately three-quarters of all camera trap locations were within three protected areas: Phnom Prich Wildlife Sanctuary, Virachey National Park and Mondulkiri Protected Forest (Table 1). Camera trapping also occurred in five sites outside of protected areas, three of which were dominated by closed canopy semi-evergreen and evergreen forest i.e. Chhlong in southwestern Kratie Province, Prey Khieu in northwest Mondulkiri Province and adjacent areas of southern Stung Treng Province, and Prey Long, where camera trapping was concentrated in two distinct areas: within Siem Bok District, Stung Treng Province (25 locations) and approximately 30 km to the south in northwestern Kratie Province (seven locations) (Fig. 1; Table 1). Camera trapping also occurred at two sites dominated by deciduous dipterocarp forest: Western Siem Pang, Stung Treng Province, and in the west of Seima Protected Forest in Keo Seima District, Mondulkiri Province and adjacent areas of Snoul District, Kratie Province. The final camera trap location was from Prek Prasab District, Kratie Province on the opposite bank of the Mekong River from the provincial capital (Fig. 1).

A total of 3,017 independent animal encounters were extracted from the scanned negatives corresponding to records of 75 species. Species detected varied in size from Berdmore's squirrel *Menetes berdmorei*, blue-rumped pitta *Pitta soror*, and northern treeshrew *Tupaia belangeri* to Asian elephant and tiger. The most frequently recorded species were red muntjac and wild pig *Sus scrofa* with Siamese fireback *Lophura diardi* the most frequently recorded bird species (Table 2). A total of 28 globally threatened species were recorded (22 mammals; 6 birds) including 2 Critically Endangered and 12 Endangered species (Table 3). In addition three Near Threatened species, two mammals and one bird, were photographed (Table 3). The total number of threatened species per site

Table 3 Number of independent encounters for all Near Threatened, Vulnerable, Endangered or Critically Endangered species recorded from camera traps by WWF in eastern Cambodia between 1999 and 2007. Columns indicate presence/ absence in nine sites: A – Chhlong; B – Phnom Prich Wildlife Sanctuary; C – Prey Khieu; D – Prey Long; E – Prek Prasab; F – Mondulkiri Protected Forest; G – Virachey National Park; H – West Seima/ Snoul; I – Western Siem Pang.

Species		IUCN	# of encounters	A	B	C	D	E	F	G	H	I
Banteng	*Bos javancius*	EN	210		X	X	X		X			
Pig-tailed macaque	*Macaca nemestrina*	VU	106	X	X	X	X		X	X		
Gaur	*Bos gaurus*	VU	98	X	X	X	X		X	X		
Asian elephant	*Elephas maximus*	EN	90		X		X			X		
Eld's deer	*Cervus eldii*	EN	71		X	X			X		X	X
Leopard	*Panthera pardus*	NT	63	X	X	X			X	X		
Dhole	*Cuon alpinus*	EN	57	X	X	X	X		X	X	X	
Sambar	*Cervus unicolor*	VU	56		X	X	X		X	X		
Green peafowl	*Pavo muticus*	EN	50		X		X		X			X
Sun bear	*Helarctos malayanus*	VU	50	X	X	X	X			X		
Large-spotted civet	*Viverra megaspilla*	VU	39		X	X	X		X	X	X	
Lesser adjutant	*Leptoptilos javanicus*	VU	30		X	X			X	X	X	
Hog deer	*Hyelaphus porcinus*	EN	25					X				
Hog badger	*Arctonyx collaris*	NT	14		X	X	X		X	X		
Sarus crane	*Grus antigone*	VU	11						X			
Clouded leopard	*Neofelis nebulosa*	VU	7		X	X	X			X		
Wild water buffalo	*Bubalus arnee*	EN	7						X			
Tiger	*Panthera tigris*	EN	5						X	X		
Asian golden cat	*Catopuma temminckii*	NT	4							X		
Giant ibis	*Thaumatibis gigantea*	CR	4						X		X	X
Binturong	*Arctictis binturong*	VU	3	X	X		X					
Black-shanked douc	*Pygathrix nigripes*	EN	3			X			X			
Marbled cat	*Pardofelis marmorata*	VU	2		X					X		
Indochinese silvered langur	*Trachypithecus germaini*	EN	2			X						
Asian black bear	*Ursus thibetanus*	VU	1							X		
Black-necked stork	*Ephippiorhynchus asiaticus*	VU	1						X			
Oriental small-clawed otter	*Aonyx cinerea*	VU	1	X								
Red-headed vulture	*Sarcogyps calvus*	CR	1						X			
Smooth-coated otter	*Lutrogale perspicillata*	VU	1						X			
Sunda pangolin	*Manis javanica*	EN	1							X		
Yellow-cheeked crested gibbon	*Nomascus gabriellae*	EN	1							X		

varied between 16 (Mondulkiri Protected Forest) and one (Prek Prasab) (Table 3).

Records of selected species

Banteng *Bos javanicus* were the most frequently recorded globally threatened species photographed on 210 occasions from four of the nine survey sites. The majority of the banteng photographs (87%) were taken in Phnom Prich Wildlife Sanctuary (Fig. 2) and the adjacent Mondulkiri Protected Forest. Banteng were also recorded in Prey Long (15 encounters in eight locations; all but one from the northern Siem Bok section) and Prey Khieu (13 encounters in five locations). No banteng were photographed in Virachey National Park, Western Siem Pang, Chhlong or western Keo Seima/ Snoul. Presumed wild water buffaloes were photographed from four locations (seven encounters; one to three individuals per pho-

Fig. 2 Banteng – Phnom Prich Wildlife Sanctuary, January 2003.

Fig. 3 Asian elephant – Phnom Prich Wildlife Sanctuary, March 2005.

Fig. 4 Eld's deer – Mondulkiri Protected Forest, February 2001.

Fig. 5 Dhole – Prey Khieu, January 2006.

Fig. 6 Asian golden cat – Virachey National Park, February 2000.

Fig. 7 Clouded leopard – Virachey National Park, May 2000.

Fig. 8 Hog deer – Prek Prasab, January 2006.

Fig. 9 Wild water buffalo – Mondulkiri Protected Forest, October 2005.

Fig. 10 Tiger – Mondulkiri Protected Forest, November 2005.

tograph) between May and October 2005 in the core of the Mondulkiri Protected Forest south of Mereuch headquarters and west of the Srepok river (Fig. 9).

Asian elephants were recorded in three sites with the majority of photographs (92%) taken in Phnom Prich Wildlife Sanctuary (Fig. 3). Elephants were also photographed in four locations in western Virachey National Park (in March 2000 and January-February 2001) and two locations in the Siem Bok section of Prey Long (from February and March 2003) with groups of at least three individuals photographed in both sites. None of these encounters, or those in Phnom Prich Wildlife Sanctuary, appeared to be of domestic elephants.

Eld's deer were encountered on 71 occasions in five of the nine survey sites. In Phnom Prich Wildlife Sanctuary there were 32 encounters in seven locations in the extreme southwest of the site close to Sre Khitong village approximately 2–3 km outside the protected area boundary. Groups of up to five individuals, including small fawns and males with antlers, were photographed. Eld's deer were also photographed in two locations (10 encounters) approximately 20 km to the southwest in Snoul District, Kratie Province with up to three individuals (including fawns) per photo. In Mondulkiri Protected Forest, Eld's deer were photographed in two locations (seven encounters, one to seven individuals per photograph), both west of the Srepok river close to Mereuch head-quarters (Fig. 4). Eld's deer were also recorded in two locations in deciduous dipterocarp forest north of the main semi-evergreen block in Prey Khieu at the Mondulkiri-Stung Treng provincial border in March 2003 and December 2005 and in six locations in Western Siem Pang (18 encounters; one to two individuals per photograph) in 2003. Hog deer were photographed on 25 occasions in five camera trap locations at Prek Prasab District, Kratie, between January and March 2006 (Fig. 8; for more details see Maxwell *et al*., 2007).

Dholes *Cuon alpinus* were photographed on 57 occasions from seven survey sites; more widespread than for any other globally threatened species. Dholes were recorded in Phnom Prich Wildlife Sanctuary (38 encounters), Virachey National Park (nine encounters), twice in Prey Long (in November 2004 and January 2005) and once each in Chhlong (November 2004) and Western Siem Pang with just single individuals photographed at the latter three sites. Two dhole photographs were taken in Prey Khieu including two adults and five cubs from January 2006 (Fig. 5). Sun bears *Helarctos malayanus* were recorded in five sites with the majority of encounters in Phnom Prich Wildlife Sanctuary (44%) and Virachey National Park (30%). There were two encounters in each of Prey Khieu and Prey Long (from the Siem Bok section) and nine encounters (in three locations likely representing three individuals) from Chhoul. In contrast, the Asiatic black bear *Ursus thibetanus* was photographed just once, in northeastern Virachey National Park.

Six cat species were photographed of which leopards were the most frequently recorded with 63 encounters in five sites (Table 2). Tigers were photographed on five occasions in Virachey National Park and Mondulkiri Protected Forest (Fig. 10). In Virachey three tiger photographs were obtained in two locations 3 km apart, at O'Krung (approximately 14.32°N, 107.25°E) in the east of the National Park on 13 and 30 May 2001. The photos appear to be of the same individual based on pelage patterns. In Mondulkiri Protected Forest a tiger, or tigers, were photographed in November (Fig. 10) and December 2005 and November 2007 in Phnom Yangke (2005) and O Lumith (2007). These sites are approximately 10 km apart and are south of Mereuch and west of the Srepok river (approximately 13.00°N, 106.31°E). Due to the quality of photographs it is not possible to be certain whether all three encounters were of the same individual. Other cat species recorded were leopard cats (30 encounters recorded in all sites except Prek Prasab), jungle cats *Felis chaus* (27 encounters in five sites), clouded leopards *Neofelis nebulosa* (seven encounters in four sites; Fig. 7), Asian golden cats *Catopuma temminckii* (four encounters in Virachey National Park; Fig. 6) and marbled cats *Pardofelis marmorata* (one encounter in each of Virachey and Phnom Prich).

Six globally threatened and one Near Threatened bird species were recorded, including the Critically Endangered giant ibis from camera traps placed at trapeang in Mondulkiri Protected Forest, Western Siem Pang, and western Seima/ Snoul. Birds are not covered in detail in this paper and a more comprehensive publication, combining camera trap data with observational records from throughout Mondulkiri Province, is in preparation.

Activity patterns and habitat preferences

Of the 25 species with greater than 25 encounters, 15 displayed cathemeral activity patterns, five species were nocturnal (the four civets and East Asian porcupine *Hystrix brachyura*) and five species were diurnal; the four birds with sufficient observations and pig-tailed macaque *Macaca nemestrina* (Table 2). Based on the habitats recorded at the camera trap locations, five species were assessed as deciduous dipterocarp forest specialists (Eld's deer, lesser adjutant *Leptoptilos javanicus*, jungle cat, golden jackal *Canis aureus*, and small Indian civet *Viverricula indica*). One species, the Siamese fireback, was predominantly photographed in mixed deciduous/ semi-evergreen/ evergreen forest with three other taxa, Asian elephant, sun bear and *Tragulus* spp., with greater than 70% of encounters in these forest types (Table 2).

Discussion

This paper presents the biggest study of camera trap data from anywhere in Cambodia. A total of 28 globally threatened species were recorded, with threatened large mammal species recorded from every camera trapping site. However, of the camera trap sites only four – Virachey National Park, Phnom Prich Wildlife Sanctuary, Mondulkiri Protected Forest, and parts of western Seima/Snoul – are within Cambodia's protected area network. More worrying, only two of these protected areas (Phnom Prich Wildlife Sanctuary and Mondulkiri Protected Forest) currently receive relatively effective protection by Cambodian government conservation agencies (Ministry of the Environment and the Forestry Administration of the Ministry of Agriculture, Forestry and Fisheries) with financial and technical support from international NGOs. There is currently limited conservation activity in Virachey National Park, Western Siem Pang and within the western buffer of Seima Protected Forest (which covers many of the camera trap sites from western Seima/ Snoul), and there appears to be no conservation effort currently directed at Chhlong, Prey Khieu, Prey Long, or Prek Prasab. Consequently the state of forest cover and remaining biodiversity at these sites is unknown, but is likely to be greatly reduced since the data in this paper was collected.

Status of wild cats in eastern Cambodia

Camera trapping recorded six cat species. Of the species potentially present within the study region only the fishing cat was not recorded. The status of fishing cat in Cambodia is unclear, with few confirmed records and none east of the Mekong River (Royan, 2009; Rainey & Kong, 2010). Regular reports from local people across Cambodia seem likely to represent confusion over the Khmer name "kla dtray" (literally fish cat or fish tiger) which, though often translated as fishing cat, seems likely to be used by local people as a generic name for all small cats. The lack of fishing cat records from this, and subsequent, camera trapping (WWF/ WCS, unpublished data) suggests that if it occurs at all, the species is extremely rare in eastern Cambodia.

Among the most important of all the records documented in this paper are the five photographs of tigers. The November 2007 photograph from Mondulkiri Protected Forest represents the last confirmed, unequivocal evidence of tiger in Cambodia. Tiger records were widespread across Cambodia as recently as the 1990s, during which it was estimated that 100 to 200 tigers a year were exported from wildlife markets in Phnom Penh and Poipet. In the early 2000s, intensive targeted tiger hunting continued in and around what are now the Seima (Walston *et al.*, 2001) and Mondulkiri Protected Forests (Long *et al.*, 2000). Walston *et al.* (2001) reported a fresh tiger carcass fetching US$ 3,270 for the local hunter and suggested that this indicated that awareness of the international trade value of tigers had reached even the most remote areas of the country.

In addition to the tiger records documented in this paper, eight tiger camera trap photographs of at least three individuals were obtained in evergreen areas in the south of Seima Protected Forest between 2000 and 2003 (WCS/ FA, internal-data) and one photograph from Southwest Lumphat Wildlife Sanctuary in March 2005 (Ministry of Environment, internal data). Despite extensive subsequent targeted camera trapping in Phnom Prich Wildlife Sanctuary and Mondulkiri and Seima Protected Forests (covering >15,000 camera trap nights and >300 locations), together with >300 km of surveys by trained scat detection dog, there have been no further unambiguous tiger records from eastern Cambodia (WWF internal data; H. O'Kelly, WCS Cambodia, pers. comm.). Pugmarks with measurements appearing to support identification as tiger were recorded from Seima Protected Forest in early 2007 (WCS/ FA, internal data), Mondulkiri Protected Forest in January 2008 (WWF-internal data), Prey Khieu in Feburary 2010 (Kry & Pech, 2010), and eastern Phnom Prich Wildlife Sanctuary in October 2010 (WWF, internal data). However, if tigers remain in eastern Cambodia their numbers are clearly extremely low. Estimates of the densities of ungulate tiger prey species, while lower than the carrying capacity of the landscape, are sufficient to support a minimum of 15–30 tigers within the cores of protected areas in the Eastern Plains Landscape (i.e. Phnom Prich Wildlife Sanctuary and Mondulkri and Seima Protected Forests; O'Kelly & Nut, 2010; Gray *et al.*, 2011). This is much higher than even the most optimistic current estimates of tiger population size in the landscape. Given that sufficient prey densities exist to support a small tiger population, the species' possible extinction for eastern Cambodia is likely to have been driven by poaching for trade.

The records of Asian golden cats we documented from Virachey National Park are the only camera-trapped occurrences of this species from eastern Cambodia. Asian golden cats have not been photographed from Seima Protected Forest, although there have been two reported sightings (WCS/FA, internal data). Studies elsewhere in the species' range report encounters both more frequently (Holden, 2001; Duckworth *et al.*, 2005) and less frequently (Rao *et al.*, 2005; Mishra *et al.*, 2006) than the sympatric clouded leopard. The evidence from this paper, and subsequent camera trapping in Phnom Prich Wildlife Sanctuary and Seima Protected Forest during which clouded leopard but not Asian golden cat have been recorded, shows the former situation in eastern Cambodia.

In addition to the two records documented in this paper, the marbled cat has also been recorded from Seima Protected Forest (four camera trap records and one carcass; WCS/ FA, internal data) and on one subsequent occasion (April 2011) from Phnom Prich Wildlife Sanctuary (WWF, internal data). However, this species' postulated arboreal behaviour may make camera trap encounters less likely than for other cats, and it has been recorded from a number of protected areas in Southwest Cambodia (Starr *et al.*, 2010).

The number of encounters with marbled cat (two), Asian golden cat (four), clouded leopard (five) and jungle cat (21) in this study differ from those in Duckworth *et al.* (2005) based on Cambodia-wide camera trapping data collated between 1999 and 2002, with marbled cat (13), Asian golden cat (12), clouded leopard (four) and jungle cat (eight). The higher number of jungle cat encounters in the present study in eastern Cambodia can be parsimoniously explained through the increased representation of deciduous dipterocarp forest-dominated sites in this study. We cannot determine from these data whether our relatively low number of photographs of marbled and golden cats suggests genuine population declines or that other areas of Cambodia are most significant for these species, or was simply an artefact of camera trap placement or low sample size. Although habitat data from this study are of limited value given they refer only to habitat in the immediate surroundings of the camera trap (as interpreted from the photographs) and thus ignores the wider habitat matrix, nine of the 10 photographs of marbled and Asian golden cats and clouded leopards were in mixed delicious/ semi-evergreen/ evergreen forests. This supports previously documented habitat preferences of these species (Grassman *et al.*, 2005; Austin *et al.*, 2007). Jungle cats, which were recorded from all five deciduous dipterocarp dominated sites, showed preferences for deciduous dipterocarp forest. This matches the species' speculated habitat preferences in Indochina (Duckworth *et al.*, 2005).

Leopards were photographed in five sites. At two of these – Phnom Prich Wildlife Sanctuary and Mondulkiri Protected Forest – the species is known to still be extant, with a 2009 density estimate of just under 4 individuals per 100 km^2 in the core area of Mondulkiri Protected Forest (Gray & Prum, 2011). Large cat tracks have recently been documented from Prey Khieu (Kry & Pech, 2010), but leopards have not been camera-trapped during limited recent effort at this site (M. Grindley, PRCF, pers. comm.). There is also recent camera trap and sign evidence of leopards from Seima Protected Forest. However, the leopard is probably now very rare away from the cores of large, better managed protected areas in Cambodia. Recent reports of large cats from forest remnants across Cambodia should be collated to assess the species' current status.

Status of bears in eastern Cambodia

The camera trapping documented in this paper recorded two species of bear: sun bear and a single record of Asiatic black bear. Sun bears have subsequently been photographed on multiple occasions in Phnom Prich Wildlife Sanctuary, Mondulkiri Protected Forest and Seima Protected Forest (WWF/ WCS, internal data). Between January 2006 and March 2009, Heng (2009) surveyed nine sites across Cambodia for bear signs including Virachey National Park, Prey Long and Mondulkiri Protected Forest. Bear signs were assigned to species based on a discriminate function model developed by Steinmetz & Garshelis (2008). The number of bear signs per hectare was high at Virachey National Park (45 signs per hectare; 52% of those identifiable to species assigned to Asiatic black bear), low at Prey Long (seven signs per hectare; 25% Asiatic black bear) and intermediate in Mondulkiri Protected Forest (13 signs per hectare; 68% Asiatic black bear).

Whilst Heng (2009) clearly confirmed the importance of both Virachey and Mondulkiri Protected Forest for bear conservation, the species identifications based on signs are at odds with those obtained from camera trapping and we suggest that the vast majority of the records of bear from eastern Cambodia refer to sun bear. Asiatic black bears appear to be scarce throughout the dry forest ecoregion of mainland Southeast Asia with sun bears much more abundant at lower elevations and Asiatic black bear largely restricted to montane forest (Steinmetz, 2011). In addition to the Virachey record, the only other confirmed Asiatic black bear records from eastern Cambodia are from Seima Protected Forest where the species has been camera-trapped twice in evergreen forest at 480 and 530 m above sea level (WCS/ FA, *in litt.*). The majority of the camera trapping sites in this study, and those surveyed by Heng (2009), are below this altitude and therefore one would expect Asiatic black bear to be scarce. Many bear signs and camera trap photographs from eastern Cambodia originate from *Lagestromia*-dominated mixed deciduous forest. This habitat does not bear fruit eaten by bears but appears to support high densities of *Trigona* spp. stingless bee nests (Tom Gray, pers. obs.). Steinmetz (2011) suggested that the morphology of sun bear is better adapted to access this food resource than Asiatic black bear, perhaps also helping to explain the former species' greater abundance in eastern Cambodia.

Status of Asian elephants and ungulates in eastern Cambodia

Camera trapping produced Asian elephant records from three areas: Phnom Prich Wildlife Sanctuary, Virachey National Park and the Siem Bok section of Prey Long. The former site is still known to support the species (e.g. 73 camera trap photographs during 2011; WWF internal data) with a 2009 estimate, based on capture-mark-recapture analysis of fecal DNA, of between 101 and 175 individuals (Gray *et al.*, 2012). Phnom Prich Wildlife Sanctuary along with Seima Protected Forest, with a 2007 estimate of 101–139 individuals (Pollard *et al.*, 2008), may support the majority of the Asian elephants in Cambodia. This population also appears contiguous with that of Mondulkiri Protected Forest and Yok Don National Park, Vietnam with confirmed wet season dispersal between these protected areas (Gray *et al.*, 2012). Whether viable populations of Asian elephants persist in Prey Long or Virachey National Park is unclear.

Camera trapping recorded three species of wild cattle: banteng, gaur, and wild water buffalo. All three were photographed from Mondulkiri Protected Forest. The only other site in Asia that supports these three species is Huai Kha Khaeng Wildlife Sanctuary in Thailand. Banteng were regularly photographed in Phnom Prich Wildlife Sanctuary and Mondulkiri Protected Forest. These protected areas remain the global stronghold for the species with an estimated population, based on distance-based line transect sampling, of between 2,700 and 5,700 individuals (Gray *et al.*, in press). This represents more than 50% of the estimated global population. Banteng were also photographed from two of the evergreen/ semi-evergreen forest blocks surveyed: Prey Long and Prey Khieu. Recent camera trapping at the latter site has confirmed the species continued presence (M. Grindley, PRCF, pers. comm.). Banteng were not photographed in Virachey National Park and it is unclear whether the species occurs or occurred in this protected area.

The majority (81%) of banteng encounters were photographed at night which corroborates a more recent analysis of camera trap photographs from Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary (Phan & Gray, 2010b). While most banteng photographs came from camera traps in deciduous dipterocarp forest, banteng were also recorded from mixed deciduous and semi-evergreen forest supporting the idea that the species occurs in a variety of forest types (Gray, 2012). The lack of photographs from Virachey National Park may indicate that extensive areas of closed canopy evergreen or mountainous forest may be less suitable for the species. However, there were also few (three) gaur photographs from Virachey, and the lack of wild cattle photographs from this site could reflect low populations following hunting or simply biases in camera trap placement.

The putative identification of wild water buffalo in the core of the Mondulkiri Protected Forest represents the only recent confirmed presence of this species from Indochina (*sensu* Cambodia, Laos and Vietnam). The site is therefore of huge conservation significance for this globally Endangered species. Identification as wild, as opposed to domestic/ feral, water buffalo was made based on a combination of morphology, particularly horn shape and spread (Fig. 9), and the absence of domestic cattle in this remote area. Ranger patrol data suggests wild water buffalo occur across approximately 400 km^2 of the core area in the northeast of Mondulkiri Protected Forest on both sides of the Srepok river (WWF, internal data). Wild water buffalo in Mondulkiri Protected Forest are the subject of ongoing research by WWF to obtain additional camera trap photographs and to explore the extent to which domestic water buffalo enter the protected area.

Five species of deer were camera-trapped of which the most significant for conservation was hog deer. All hog deer photographs came from a 12 km^2 area of seasonally inundated tall grassland along the Mekong river. More details of these records are given in Maxwell *et al.* (2007). There are no recent additional hog deer records in eastern Cambodia away from this tiny site, although Bezuijen *et al.* (2008) documented possible reports from elsewhere in the central section of the Mekong. Whether hog deer persist in Prek Prasab is unclear because support for conservation efforts at this site discontinued in 2008 due to a regrettable lack of funding and political will. A recent brief visit to the area indicated considerable recent habitat conversion, largely for cassava, with little 'natural' habitat remaining (Tom Gray, pers. obs.). Without immediate conservation activity at this site, the extinction of this population – if it has not already happened – is inevitable. The only other wild hog deer population in Southeast Asia, away from Myanmar where the species' status is unclear, has recently been documented close to Botum-Sakor National Park in Southwest Cambodia where the population size is likely to be low (M. Hurley, Global Wildlife Conservation, pers. comm.).

Eld's deer were recorded from five sites: Southwest Phnom Prich Wildlife Sanctuary and adjacent areas of Snoul and western Keo Seima; Mondulkiri Protected Forest; western Siem Pang; and Prey Khieu. There have been recent (2010/ 2011) records from the former three sites with evidence of a minimum of 10–20 individuals per site (WWF/ WCS, internal data; J. Eames, BirdLife Indochina, pers. comm.). However only the Eld's deer in Mondulkiri Protected Forest are within the core of a current protected area and accurately assessing size, range and viability of all populations is difficult. There are no recent records from Prey Khieu and whether Eld's deer still occur at this site in unclear. In addition to these four sites there are a minimum of three other reported Eld's deer locations in Cambodia east of the Mekong: deciduous dipterocarp forest between Phnom Prich and

Lumphat Wildlife Sanctuaries (where footprints and local reports were recently obtained; Prum Sovanna FA/ WWF, pers. comm.); O'Yadao protected forest (Prum Sovanna FA/ WWF, pers. comm.); and in Veun Sai District, Rattanakiri (Phan Channa, WWF pers. comm.). However, given the extensive and rapid conversion of lowland deciduous dipterocarp forest across eastern Cambodia the future of these populations may be bleak. Given the majority of documented Eld's deer in eastern Cambodia occur outside protected areas (including those from Phnom Prich which largely occur outside the protected area boundary) protecting habitat for this species may be particularly difficult. A review of the current status of Eld's deer in Cambodia, identifying site-specific threats and mitigating actions, appears warranted – ideally in the form of a Species Action Plan under the auspices of the IUCN Species Survival Commission Deer Specialist Group.

The large-antlered muntjac *Muntiacus vuquangensis* is likely to occur in extreme eastern Cambodia with a number of records of trophy antlers (Desai & Lic, 1999; Tom Gray, pers. obs.). Areas of Virachey National Park and parts of Seima Protected Forest appear to be ecologically similar to the sites where the species has been recorded in Laos and Vietnam (Timmins *et al*., 2008). However, identification, even from camera trap photographs, is not easy and was not attempted during this study. Critical examination of the 45 'red muntjac' photographs from Virachey may be warranted.

Conclusions

This study provides a salutary lesson to conservation researchers regarding the importance of permanent data archiving. Much of the data associated with the camera trapping in this study (e.g. exact locations of cameras, number of camera trap nights) appear to have been lost. The high level of staff turnover within international conservation NGOs working in Cambodia and a lack of priority given to long-term data management means considerable field effort and expense can thus be wasted. Since the end of 2008, WWF have continued extensive camera trapping in the core areas of Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary. This has produced a density estimate for leopards (Gray & Prum, 2011) as well as additional information on the status and ecology of a number of the globally threatened species in the landscape (Phan & Gray, 2010b; Gray *et al*., 2010; Gray & Phan, 2011; Gray, 2012). All photographs (currently >6,000 independent encounters) and associated data, as well as those referred to in this paper, are being permanently archived and will be made available for all researchers exploring any aspects of species conservation, ecology and distribution in eastern Cambodia. For access to any of these data please contact WWF Cambodia.

Acknowledgements

The conservation activities of WWF in eastern Cambodia are under the permission of, and with the support and co-operation of, the Forestry Administration of the Ministry of Agriculture Forestry and Fisheries and the General Department for Administration of Nature Conservation and Protection of the Ministry of the Environment. We thank HE Ty Sokhun, HE Cheng Kimsun, HE Chay Samith, HE Dr Mok Mareth, Men Phymean, and Dr Keo Omaliss for support. Funding for WWF's work in eastern Cambodia includes contributions from WWF-US, WWF-Germany, United States Fish and Wildlife Service, Humanscale and Habitat Hotels. Jonathan Eames, Martha Hurley, Hannah O'Kelly, Phan Channa, Mark Grindley, Tom Evans, and Prum Sovanna provided information on status of mammals in Cambodia whilst Rob Timmins found, scanned, and organised all the photo-negatives. Two anonymous reviewers provided comments which improved the quality of the manuscript. Finally we thank the field teams which set the cameras used in this study they include (based on photo-identifications), Duong Kong, Lien Kha, Lien Nor, Sin Somoan, Sary Tre, Seng Teak, Martin van Kashike, Tony Lynham, Craig Bruce, and many others.

References

Austin, S.C., Tewes, M.E., Grassman, L.I. & Silvy, M.J. (2007) Ecology and conservation of the leopard cat and clouded leopard in Khao Yai National Park, Thailand. *Acta Zoologica Sinica*, **53,** 1–14.

Bezuijen, M.R., Timmins, R.J. & Seng T. (2008) *Biological Surveys of the Mekong River Between Kratie and Stung Treng Towns, Northeast Cambodia, 2006–2007*. WWF Greater Mekong Cambodia Country Programme, Cambodia Fisheries Administration and Cambodia Forestry Administration, Phnom Penh, Cambodia.

Desai, A.A. & Lic V. (1996) *Status and Distribution of Large Mammals in Eastern Cambodia: Results of the First Foot Surveys in Mondulkiri and Ratanakiri*. IUCN, Fauna & Flora International, Cambridge, U.K., and WWF, Gland, Switzerland.

Duckworth, J.W., Poole, C.M., Tizard, R.J., Walston, J.L. & Timmins, R.J. (2005) The jungle cat *Felis chaus* in Indochina: a threatened population of a widespread and adaptable species. *Biodiversity and Conservation*, **14,** 1263–1280.

Grassman, L.I., Tewes, M.E., Silvy, M.J. & Kreetiyutanont, K. (2005) Ecology of three sympatric felids in a mixed evergreen forest in North-Central Thailand. *Journal of Mammalogy*, **86,** 29–38.

Gray, T.N.E. (2012) Studying large mammals with imperfect detection: status and habitat preferences of wild cattle and large carnivores in eastern Cambodia. *Biotropica*, **44,** 531–536.

Gray, T.N.E., & Phan C. (2011) Habitat preferences and activity patterns of the larger mammal community in Phnom Prich Wildlife Sanctuary, Cambodia. *The Raffles Bulletin of Zoology*, **59,** 311–318.

Gray, T.N.E. & Prum S. (2011) Leopard density in a post-conflict landscape Cambodia: evidence from spatially explicit capture-mark-recapture. *Journal of Wildlife Management*, **76,** 163–169.

Gray, T.N.E., Pin C. & Pin C. (2010) Status and ecology of large-spotted civet in eastern Cambodia. *Small Carnivore Conservation,* **43,** 12–15.

Gray, T.N.E., Phan C., Pin C. & Prum S. (2011) Establishing baseline ungulate densities in Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary, Cambodia. WWF Greater Mekong Cambodia Country Program, Phnom Penh, Cambodia.

Gray, T.N.E., Vidya, T.N.C., Maxwell, A.L., Bharti, D.K., Potdar, S., Phan C. & Prum S. (2012) *Using Fecal-DNA and Capture-Mark-Recapture to Establish a Baseline Asian Elephant Population for the Eastern Plains Landscape, Cambodia.* WWF Greater Mekong Cambodia Country Program, Phnom Penh, Cambodia, and Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India.

Gray, T.N.E., Phan C., Pin C. & Prum S. (in press) Distance sampling reveals Cambodia's Eastern Plains Landscape supports largest global population of the endangered banteng *Bos javanicus*. *Oryx*.

Heng, N. (2009) *Report on Bear Research and Conservation in Cambodia.* Conservation International Indochina, Phnom Penh, Cambodia.

Holden, J. (2001) Small cats in Kerinci Seblat National Park, Sumatra, Indonesia. *Cat News,* **35,** 11–14.

Kry M. & Pech B. (2010) *Rapid Tiger, Tiger Prey and Bird Surveys in Prey Khieu Evergreen Forest, Koh Nhek, Mondulkiri.* People Resources and Conservation Foundation and Forestry Administration, Phnom Penh, Cambodia.

Long, B., Swan, S. & Kry M. (2000) *Biological surveys in Northeast Cambodia, April 2000.* Fauna & Flora International, Hanoi, Vietnam, and the Wildlife Protection Office, Phnom Penh, Cambodia.

Maxwell, A., Chea N., Duong K., Timmins, R. & Duckworth, J.W. (2007) Hog deer (*Axis porcinus*) confirmed in the wild in eastern Cambodia. *Natural History Bulletin of the Siam Society*, **54,** 227–237.

Mishra, C., Madhusudan, M.D. & Datta, A. (2006) Mammals of the high altitudes of western Arunachal Pradesh, eastern Himalaya: an assessment of threats and conservation needs. *Oryx*, **40,** 29–35.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, A.B. & Kent, J. (2000) Biodiversity hotspots for conservation priorities. *Nature*, **430,** 853–858.

O'Kelly, H. & Nut M.H. (2010) *Monitoring of Ungulate, Primate and Peafowl Populations Using Line Transect Surveys in Seima Protection Forest, Cambodia 2005–2010*. Wildlife Conservation Society Cambodia, Phnom Penh, Cambodia.

Phan C. & Gray, T.N.E. (2010a) Status and habitat of yellow-cheeked crested gibbons in Phnom Prich Wildlife Sanctuary, Mondulkiri, Cambodia. In *Conservation of Primates in Indochina* (eds T. Nadler, B.M. Rawson & Van N.T.), pp. 79–89. Frankfurt Zoological Society, Frankfurt, Germany, and Conservation International, Washington DC, USA.

Phan C. & Gray, T.N.E. (2010b) Ecology and natural history of Banteng in eastern Cambodia: evidence from camera trapping in Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary. *Cambodian Journal of Natural History,* **2010,** 118–126.

Phan C, Prum S. & Gray, T.N.E. (2010) Recent camera trap records of globally threatened species from the Eastern Plains Landscape, Cambodia. *Cambodian Journal of Natural History,* **2010,** 89–93.

Pollard, E., Clements, T., Nut M.H., Sok K. & Rawson, B. (2007) *Status and Conservation of Globally Threatened Primates in the Seima Biodiversity Conservation Area, Cambodia*. Wildlife Conservation Society, Phnom Penh, Cambodia.

Pollard, E., Eggert, L., Cheur C. & Hedges, S. (2008) *The Status and Conservation of Asian Elephant in the Seima Biodiversity Conservation Area, Cambodia*. Wildlife Conservation Society Cambodia Program, Phnom Penh, Cambodia.

Rainey, H. & Kong K. (2010) A fishing cat observation from northern Cambodia. *Cat News,* **52,** 8–9.

Rao, M., Myint, T., Zaw, T. & Htun, S. (2005) Hunting patterns in tropical forests adjoining the Hkakaborazi National Park, north Myanmar. *Oryx,* **39,** 292–301.

Rawson, B.M., Clements, T. & Meng, H. (2009) Status and conservation of yellow-cheeked crested gibbons in Seima Biodiversity Conservation Area, Mondulkiri Province, Cambodia. In *The Gibbons: New Perspectives on Small Ape Socioecology and Population Biology* (eds S. Lappan & D.M. Whitaker), pp. 387–408. Springer, New York, USA.

Rowcliffe, J.M. & Carbone, C. (2008) Surveys using camera traps: are we looking to a brighter future? *Animal Conservation,* **11,** 185–186.

Royan, A. (2009) Confirmation of the Endangered fishing cat in Botum-Sakor National Park, Cambodia. *Cat News,* **51,** 10–11.

Seng, K.H., Pech B, Poole, C.M., Tordoff, A.W., Davidson, P. & Delattre, E. (2003). *Directory of Important Bird Areas in Cambodia: Key Sites for Conservation*. Department of Forestry and Wildlife, Department of Nature Conservation and Protection, BirdLife International in Indochina and Wildlife Conservation Society, Phnom Penh, Cambodia.

Starr, A.T., Sam H. & Lun D. (2010) New records of threatened mammals from Southwest Cambodia. *Cambodian Journal of Natural History,* **2010,** 94–96.

Steinmetz, R. (2011) Ecology and distribution of sympatric Asiatic black bears and sun bears in the seasonally dry forests of Southeast Asia. In *Conservation of Asian Seasonally Dry Forests* (eds B. McShea, S.J. Davies & N. Bhumpakphan), 249–273. Springer, New York, USA.

Steinmetz, R. & Garshelis, D.L. (2008) Distinguishing Asiatic black bears and sun bears by claw marks on climbed trees. *Journal of Wildlife Management*, **72,** 814–821.

Timmins, R.J. & Ou R. (2001) *The Importance of Phnom Prich Wildlife Sanctuary and Adjacent Areas for the Conservation of Tigers and Other Key Species: A Summary.* WWF Cambodia Conservation Program, Phnom Penh, Cambodia.

Timmins, R.J., Duckworth, J.W. & Long, B. (2008) *Muntiacus vuquangensis*. In *IUCN Red List of Threatened Species. Version 2011.1.* Http://www.iucnredlist.org/details/44703/0 [accessed 1 July 2012].

Tordoff, A.W., Timmins, R.J., Maxwell, A., Huy K., Lic V. & Khou E.H. (2005) *Biological Assessment of the Lower Mekong Dry Forests Ecoregion*. WWF Greater Mekong, Phnom Penh, Cambodia.

Walston J., Davidson, P. & Men S. (2001) *A Wildlife Survey of Southern Mondulkiri Province, Cambodia*. Wildlife Conservation Society Cambodia Program, Phnom Penh, Cambodia.

Wright, H.L., Collar, N.J., Lake, I.R., Net N., Rours V., Sok K., Sum P. & Dolman, P.M. (2012) First census of white-shouldered ibis *Pseudibis davisoni* reveals roost-site mismatch with Cambodia's protected areas. *Oryx*, **46,** 236–239.

Mammal and bird diversity at a salt lick in Kulen-Promtep Wildlife Sanctuary, Northern Cambodia

Sarah EDWARDS[1,*], James ALLISON[1], Sarah CHEETHAM[1] and HOEUN Bunto[2]

[1] Frontier, 50–52 Rivington Street, London, EC2A 3QP, United Kingdom. Email sarah_edwards1985@yahoo.co.uk, jamesjurgis@gmail.com, cheets.sarah@gmail.com

[2] Ministry of Environment – Anlong Veng District, c/o #48, Sihanouk Boulevard, Phnom Penh, Cambodia.

*Corresponding author.

Paper submitted 15 March 2012, revised manuscript accepted 2 July 2012.

មូលន័យសង្ខេប

ដីប្រាបគឺជាតំបន់ខុសពីគេមានបរិវេណកំណត់ដែលសត្វអាចទៅរកស៊ីចំណី ផឹកទឹក ឬក៏ចាប់ចំណី។ ការសិក្សាពេលបច្ចុប្បន្នបង្ហាញថា ការបំពេញបន្ថែមនៃសារធាតុខនិជគឺជាមូលហេតុចំបងសំរាប់ការស្វែងរកចំណីនៅតំបន់ដីប្រាបនៃប្រភេទសត្វតិណាសី។ ម៉ាស៊ីនថតស្វ័យប្រវត្តមួយត្រូវបានដាក់នៅតំបន់ដីប្រាបមួយកន្លែងក្នុងតំបន់ការពារ នៅភូមិភាគខាងជើងនៃប្រទេសកម្ពុជា។ នានាភាពនៃប្រភេទ ភាពសំបូរធៀប និងរយៈពេលមធ្យមនៃការចំណាយពេលនៅតំបន់ដីប្រាបនោះ ត្រូវបានកត់ត្រាក្នុងរយៈពេលពីរនៃការស្រាវជ្រាវ គឺពីខែឧសភាដល់ខែមិថុនា ឆ្នាំ២០១១(សរុបចំនួន២៧យប់) និងពីខែកក្កដាដល់ខែកញ្ញា ឆ្នាំ២០១២(៥០យប់)។ ថនិកសត្វ៦ប្រភេទ និងបក្សី១២ប្រភេទត្រូវបានកត់ត្រានៅតំបន់ដីប្រាបនោះ។ ក្នុងចំណោមសត្វទាំងនោះ មានតែថនិកសត្វបួនប្រភេទទេ ដែលត្រូវបានកត់ត្រាពីមុនមកនៅតំបន់ដីប្រាប។ តាមរយៈថនិកសត្វនិងបក្សីទាំងអស់ ភាពសំបូរធៀប និងរយៈពេលមធ្យមនៃការចំណាយពេលនៅតំបន់ដីប្រាបនោះក្នុងរយៈពេលពីខែកក្កដាដល់ខែកញ្ញា(រដូវភ្លៀងខ្លាំង) គឺទាបជាងក្នុងរយៈពេលពីខែឧសភាដល់ខែមិថុនា។ ដូច្នេះវាអាចផ្តល់សេចក្តីសន្និដ្ឋានថា ប្រភេទខ្លះបានទៅតំបន់ដីប្រាបដើម្បីផឹកទឹកពីក្រហូងដីនៅទីនោះ និងមិនសូវអាស្រ័យលើតំបន់ដីប្រាបទៀតទេ នៅពេលដែលប្រភពទឹកកាន់តែច្រើនអាចងាយរកបាន។ ប៉ុន្តែ ការចំណាយពេលយូរនៅតំបន់ដីប្រាបរបស់សត្វសំពោចក្រអូប *Paradoxurus hermaphroditus* និងសត្វកាំប្រមា *Hystrix brachyura* បង្ហាញថា ការផឹកទឹកមិនមែនជាមុខងារសំខាន់នៃការទៅទីនោះរបស់សត្វទាំងនោះទេ។ ការសិក្សានេះផ្តល់សេចក្តីសន្និដ្ឋានថា ដីប្រាបមានសារៈសំខាន់ណាស់សម្រាប់ប្រភេទសត្វជាច្រើន បើទោះបីជាហេតុផលនៃការទៅកន្លែងនោះរបស់វាមិនទាន់ត្រូវបានអះអាងបញ្ជាក់នៅឡើយក៏ដោយ។

Abstract

Salt or mineral licks are spatially limited, distinct areas that animals may visit to ingest soil, drink water or hunt. Current research indicates that mineral supplementation is the main reason for such visits by herbivorous species. One camera trap with a motion sensor was placed at a salt lick in a protected area in Northern Cambodia. Species diversity, relative abundance and mean length of time spent at the salt lick were recorded over two survey periods: May to June 2011 (totalling 27 trap nights) and July to September 2012 (50 trap nights). Six species of mammals and 12 bird species were recorded at the salt lick. Of these, only four mammal species had previously been recorded at salt licks. Across all mammals and birds, relative abundance and mean time length spent at the lick were lower in July to September (the peak rainy season) than in May to June. This suggests some species visited the salt lick to drink water from the hole, and

CITATION: Edwards, S., Allison, J., Cheetham, S. & Hoeun B. (2012) Mammal and bird diversity at a salt lick in Kulen-Promtep Wildlife Sanctuary, Northern Cambodia. *Cambodian Journal of Natural History*, **2012,** 56–63.

were less dependent on this site when more water sources became available. Common palm civets *Paradoxurus hermaphroditus* and Malayan porcupines *Hystrix brachyura* spent prolonged periods of time at the salt lick, however, indicating drinking water was not the primary function of their visit. This study suggests salt licks are important for a variety of species, although their reasons for visiting this site could not be confirmed.

Keywords
Camera trap, diversity, geophagy.

Introduction

Mineral or salt licks are spatially limited sites within the home range of a wide variety of animals where they may go to ingest soil (geophagy), drink water or hunt (Klaus & Schmigd, 1998; Ping *et al.*, 2011). The function of ingesting mineral-rich soil and water at salt licks is much debated and several hypotheses for the behaviour have been proposed: a source of grit for grinding food, absorption of dietary toxins and mineral supplementation (Brightsmith, 2004a; Blake *et al.*, 2011), with many studies citing the last, in particular the provision of sodium, as the primary role (Kreulen, 1985; Moe, 1993; Abraham, 1999; Rick *et al.*, 2003; Ayotte *et al.*, 2008).

There are several costs associated with visiting salt licks, which must be compensated for by the benefits species gain at the site (Klaus *et al.*, 1998). The first of these costs is the energetic cost of seeking out and travelling to the salt lick, which is consequently associated with decreased foraging time (Klein & Thing, 1989). There is also an increased chance of predation at the site (Moe, 1993); with both natural predators and humans believed to visit salt licks in order to hunt (Matsubayashi *et al.*, 2006). Finally there is the increased risk of transmission of parasites and disease at the salt lick (Henshaw & Ayeni, 1977). Given that a variety of species visit salt licks despite such costs for predators and prey, the sites can therefore be viewed important (Blake *et al.*, 2011).

Geophagy is commonly seen in mammals and has been observed in every continent except Antarctica (Klaus & Schmidg, 1998; Brightsmith, 2004a). It has been recorded for a variety of herbivorous and omnivorous species (Klaus *et al.*, 1998) including ungulates (Weeks, 1978; Ayotte *et al.*, 2008; Tobler *et al.*, 2009; Ping *et al.*, 2011), rodents (Matsubayashi *et al.*, 2006), and primates (Ganzhorn, 1987; Haymann & Hartmann, 1991; Mahaney *et al.*, 1995; Bolton *et al.*, 1998; Krishnamani & Mahaney, 2000; Blake *et al.*, 2010). The majority of mammals known to practise geophagy are herbivores or frugivores. Carnivores are able to obtain sodium from their prey and are believed to visit salt licks in order to hunt (Matsubayashi *et al.*, 2006).

Geophagy is less well documented for birds than mammals (Brightsmith & Arambure, 2004), with examples coming from Africa, North and South America and New Guinea, from species such as parrot, pigeons, cracids and grouse (Diamond *et al.*, 1999; Somers *et al.*, 2005; Brightsmith *et al.*, 2008). Avian geophagy is perhaps best known from the number of studies focusing on parrot species, where its function is thought to be detoxification and cytoprotection (Gilandi *et al.*, 1999). Diamond *et al.* (1999) suggested compounds in soil may aid digestion by inhibiting plant secondary compounds contained in many tropical seeds and fruits and may also supply additional vitamins and minerals.

Documenting the diversity of species at salt licks gives an indication of their importance within the area, which in turn could help focus future land management decisions, and gives a chance to record more secretive species that may be difficult to record elsewhere. In this study, we used a single motion sensor camera trap placed at a salt lick to (i) record species diversity at the salt lick, and (ii) record and compare relative abundance indices (RAI) and mean time length spent at the site within and between the taxa at the salt lick over two study periods: 27 trap nights from May to June 2012 and 50 trap nights from July to September 2012 in a protected area in Northern Cambodia.

Methods

The study was conducted within the Oddar Meanchey portion of the Kulen-Promtep Wildlife Sanctuary, Northern Cambodia. The sanctuary, established in 1993, covers an area of 4,099km^{2,} spanning three provinces: Preah Vihear, Siem Reap and Oddar Meanchey. It was originally set up as a protected area for the kouprey *Bos sauvelli*, currently listed as Critically Endangered by the IUCN, although it has not been reliably seen since the 1960s (Timmins *et al.*, 2008b). The reserve is part of the Northern Plains Dry Forest Priority Corridor.

Since January 2011, Frontier's previous surveys using camera traps have shown that a variety of large mammal species are present in the Trapeang Prasat and

Anlong Veng Districts in the Oddar Meanchey portion of the sanctuary, including sun bears *Helarctos malayanus* (Edwards, 2012a), gaur *Bos gaurus*, leopard cats *Prionailurus bengalensis*, red muntjac deer *Muntiacus muntjak*, and Eurasian wild boar *Sus scrofa*. A total of 51 species of birds have also been recorded in the Trapeang Prasat and Anlong Veng District portions of the sanctuary since January 2011, comprising several families, such as the Bucerotidae represented by Oriental pied hornbill *Anthracoceros albirostris*, the Columbidae, containing emerald dove *Chalcophaps indica* and imperial green pigeon *Ducula aenea* amongst others, and the Psittacidae family containing red-breasted parakeet *Psittacula alexandri*.

A single salt lick was located within the Oddar Meanchey portion of the wildlife sanctuary (14°03′32.782″N, 104°10′10.872″E), in an area dominated by secondary semi-evergreen forest. The salt lick was shown to us by locals, who informed us that this was a place visited by various species, including Malayan porcupine *Hystrix brachyura*, to 'eat the soil'. The salt lick consisted of a bare patch of ground in which two shallow holes had been dug; these holes would fill up with water after periods of heavy rain. The total salt lick area was approximately 5 m^{2,} and was located approximately 1 km from a small camp where locals stayed while extracting resin from trees in the forest, and approximately 3 km from a small, permanent stream.

A single Bushnell Trophy Cam camera trap was placed at the salt lick from May until June 2011, totalling 27 trap nights, and then for a further 50 trap nights from July to September 2011. The total period represents the wet season in Cambodia, which peaks during July to September. The trap was set to the highest sensitivity and resolution, taking three photos at a time, one second apart with the gap between triggers set to 10 seconds. All photos were stamped with the date and time. The camera trap was chained to a tree approximately 1 m from ground level and set parallel to the ground. No baits or lures were used. The trap was checked approximately once every 10 days for battery condition and damage. Mammals were identified using Francis (2008) and birds were identified from Robson (2005).

Relative abundance indices – the number of photographs per 100 trap nights – were calculated for each species seen visiting the lick by dividing the total number of independent photos by the number of trap nights, and then multiplying by 100. Photographic events were classed as independent if there was a minimum of 30 minutes between them. The average time spent at the salt lick for each species was also calculated by summing the total time spent during each independent visit, i.e. from the time given on the first photo to the time given on the last photo, and dividing by the total number of visits.

Results

A total of 1,443 images containing animals were captured throughout the whole study, from 77 operational trap nights, comprising 838 images from May to June and 605 from July to September, giving a mean of 31.0 and 12.1 images per day, respectively. Six mammal species (three species between May and June and six species between July and September) and 12 bird species (ten in the May to June period and five in the July to September period) were captured on camera (Table 1).

Fig. 1 Malayan porcupine *Hystrix brachyura* at the salt lick (© Frontier).

Fig. 2 Common palm civet *Paradoxurus hermaphroditus* at the salt lick (© Frontier).

Table 1 Summary of species recorded visiting salt lick, feeding guild, relative abundance indices, mean length of time spent at the salt lick and references of species previously recorded at salt licks. Abbreviations for feeding guilds: CN – Carnivore, FR – Frugivore, GR – Granivore, HB – Herbivore, IN – Insectivore. Relative Abundance Index (RAI) is the number of independent photos per 100 trap nights.

Family	Species	Feeding guild	Relative Abundance Index		Mean length of time at site (minutes)		Literature recording taxa presence at salt licks
			May-Jun	Jul-Sep	May-Jun	Jul-Sep	
Mammals							
Sciuridae	Variable squirrel *Callosciurus finlaysonii*	HB	0	2	n/a	1.0	
Hystricidae	Malayan porcupine *Hystrix brachyura*	HB/ FR	15	20	17.2	14.4	Navarino (1995), Matsubayashi *et al.* (2006).
Viverridae	Common palm civet *Paradoxurus hermaphroditus*	OM	26	0	22.1	0.0	Matsubayashi *et al.* (2006).
Mustelidae	Yellow-throated marten *Martes flavigula*	CN	0	2	0.0	1.2	Matsubayashi *et al.* (2006).
Herpestidae	Crab-eating mongoose *Herpestes urva*	CN	0	2	0.0	1.3	
Tragulidae	Lesser mouse deer *Tragulus kanchil*	HB/ FR	41	44	7.4	5.6	Robichaud & Sounthala (1995), Matsubayashi *et al.* (2006), Timmins *et al.* (2008a).
Birds							
Phasianidae	Scaly-breasted partridge *Arborophila chloropus*	GR	4	0	0.5	0.0	
Cuculidae	Coral-billed ground cuckoo *Carpococcyx renauldi*	CN	0	2	0.0	1.5	Family recorded by Blake *et al.* (2011).
	Green-billed malkoha *Phaenicophaeus tristis*	IN	11	0	0.5	0.0	
Columbidae	Emerald dove *Chalcophaps indica*	FR/ IN	48	10	4.0	1.5	Family recorded by Diamond *et al.* (1999), Symes *et al.* (2005), Blake *et al.* (2011).
Strigidae	Asian barred owlet *Glaucidium cuculoides*	CN	4	0	0.5	0.0	
Tytonidae	Barn owl *Tyto alba*	CN	4	0	2.8	0.0	
Pittidae	Blue-winged pitta *Pitta moluccensis*	IN	11	2	4.4	0.5	
Picidae	Laced woodpecker *Picus vittatus*	IN	19	2	0.7	0.2	
Tamaliidae	White-browed scimitar-babbler *Pomatorhinus schisticeps*	IN	4	0	0.2	0.0	
Pycnonotidae	Puff-throated bulbul *Alophoixus pallidus*	IN/ FR/ GR	15	0	1.0	0.0	
Corvidae	Common green magpie *Cissa chinensis*	IN	7	0	0.2	0.0	Family recorded by Diamond *et al.* (1999), Symes *et al.* (2005).
Dicruridae	Greater racket-tailed drongo *Dicrurus paradiseus*	IN	0	2	0.0	0.1	

Relative abundance indices (RAI) for mammals ranged from 0 to 41 in the May to June period and 0 to 44 in the July to September period, with lesser mouse deer having the highest RAI for both periods. The average RAI for all mammal species was 13.7 for the May to June period and 11.6 in the July to September period, suggesting a trend for decreased mammal activity between the study periods. Mean time length spent at the lick for all mammals also decreased from 7.78 in the May to June period to minutes to 3.91 in July to September.

Both common palm civets *Paradoxurus hermaphrodites* (Fig. 2) and Malayan porcupines (Fig. 1) were frequently recorded at the site in groups. Civet group size ranged from two to five individuals, whilst porcupines ranged from two to four. All other mammal species were captured on camera as solitary individuals, though it is possible that group activity by these species occurred outside of the camera's field of view. Civets and porcupines were also recorded spending prolonged periods of time at the salt lick (mean length of time for civets: 11 minutes; porcupines: 15 minutes 30 seconds) in comparison to an average of 1 minute 59 seconds for birds (all species combined) and 4 minutes 29 seconds for mammals (all species combined).

Bird RAIs ranged from 0 to 48 in the May to June period and 0 to 10 in the July to September period. In both periods, the highest RAIs came from emerald doves *Chalcophaps indica*. The average RAI for all bird species showed a more pronounced decrease between study periods than in mammals, decreasing from 10.5 in the May to June period to 1.6 in July to September. In a similar pattern, the mean time spent at the salt lick by birds decreased between the study periods, with less time being spent at the salt lick in the July to September period (0.31 minutes) than May to June (1.23 minutes). Birds spent much less time in the salt lick than mammals, the highest mean length of time being 4.4 minutes by a blue-winged pitta *Pitta moluccensis*.

Discussion

This study, to the best of our knowledge, represents the first published study of large mammal and bird diversity at a salt lick within Cambodia. A total of six mammal species and 12 bird species were seen visiting the site between May and September 2011, during the Cambodian wet season. From the photos alone, however, it is not obvious what the primary function of visiting the salt lick was. Species may have been visiting the site to drink the water in the hole when it was present after heavy rains.

Six mammal species were recorded at the salt lick, with four of these having been recorded at salt licks in Asia previously (see Table 1 for references). Only variable squirrels *Callosciurus finlaysonii*, and crab-eating mongooses *Herpestes urva* have not been recorded at salt licks previously (for more details on small carnivores in the area see Edwards, 2012b). However, other species of squirrels and mongooses have been recorded at salt licks: Blake *et al.* (2011) recorded northern Amazon red squirrels *Sciurus igniventis* visiting a salt lick in Ecuador, and Weeks & Kirkpatrick (1978) recorded salt preference in fox squirrels *Sciurus niger*, Matsubayashi *et al.* (2006) recorded short-tailed mongooses *H. brachyurus* and collared mongoose *H. semitorquatus* at salt licks in Borneo.

Matsubayshi *et al.* (2006) examined the presence of large mammal species at salt licks in Borneo and noted that lesser mouse deer were among the most frequent visitors to the site. This species also showed the highest RAI and during both periods at our study site. This result would suggest that visiting salt licks is particularly important for this species and perhaps constitutes a vital component of its ecology, although the primary function cannot be suggested from these results. It is worth noting no large species such as gaur, banteng *Bos javanicus*, or wild boar were captured at the salt lick, but this might be due to its close proximity to a resin collecting camp (approximately 1 km) and associated hunting activities.

Both porcupine and common palm civet spent prolonged periods of time at the salt lick in groups. Both species were seen spending much of the time in and around the holes at the salt lick, engaged in what appears to be geophagy, digging into the soil or drinking water from the holes (Figs 1 and 2). Spending such prolonged periods of time would indicate that the salt lick represents an important resource for the two species because they are willing to spend long periods of time here even though this may be associated with a number of risks. More importantly, however, it suggests simply drinking water may not be the primary function of the visits by these two species at least.

Geophagy is less commonly observed in birds than mammals (Downs, 1982) and is less well documented (Brightsmith, 2004a). The few bird studies have tended to focus on geophagy in South America (Brightsmith, 2004a,b; Brightsmith & Aramburè, 2004; Mee *et al.*, 2005), looking mainly at the family Psitticadae. However, the following studies examined the diversity of birds at salt licks and are therefore most comparable our study: Diamond *et al.* (1999) and Symes *et al.* (2005) looked at salt licks in New Guinea, while Blake *et al.* (2011) focused on those within Ecuador. All of the birds reported by our study, to the best of our knowledge, represent new records of these species visiting salt licks. However, as there are an estimated 9,920 extant bird species worldwide (BirdLife International, 2011), with high levels of endemism, it is not particularly useful to focus on new species records at salt licks. Instead, comparisons of new family records are likely to be much more meaningful. Eight of the families that were recorded visiting the salt lick in this study represent new records, whereas the Columbidae, Cuculidae and Corvidae were recorded by at least one of the aforementioned studies.

Both the RAI and mean time length spent at the salt lick by all birds combined was lower in July to September. This suggests there may be seasonal differences in bird activity at the salt lick, because the July to September period represented the wettest part of the rainy season within the local area (pers. obs.). Blake *et al.* (2011) noted a similar salt lick use pattern in birds, with a strong negative correlation being rainfall and salt lick use. Many ungulate species also show seasonal patterns of salt lick use (Ping *et al.*, 2011). This may be triggered by a number of causes; for example, de Souza *et al.* (2002) found geophagic behaviour increased in red-handed howler monkeys *Alouatta belzebul* in the dry season, with an increase in the amount of leaves in their diet. It is also possible the animals were simply visiting the salt lick to drink water, and changes in its use may reflect the changes in water availability in the area (during the wet July to September period, there would be a greater choice of water sources elsewhere). Birds may also visit such water holes to drink or hunt the elevated number of insects here, which are in turn attracted by the increased humidity, water, mineral content or animal dung.

The relatively high RAIs seen among lesser mouse deer, common palm civets, porcupines and emerald doves would suggest that the salt lick in this study is an important resource for these species for at least part of the year. Although it is not possible to confirm the primary functions of the salt lick, animals may come for a mixture of reasons: ingesting minerals, hunting and drinking water. The relatively large amount of time spent at the salt lick by Malayan porcupines and common palm civets would suggest the site constitutes a vital part of their ecology.

Whatever the reasons for visiting the salt lick, it is clear the site is used by a number of species in the Kulen-Promtep Wildlife Sanctuary. Managers should therefore conserve salt licks for the benefit of biodiversity within the sanctuary. Another recommendation of this study is that future studies compare the biodiversity and behaviour of animals at known salt licks to ordinary water holes to gain a greater understanding of the reasons for visiting salt licks.

Acknowledgements

We thank all Frontier Cambodia field staff, Research Assistants and Environment Rangers for their help in gaining this data, and the Ministry of Environment for kind permission to work in the area and to Sy Ramony for his help in obtaining the necessary permits. Thanks to Aaron Sexton, Country Coordinator for his help, humour and support throughout surveying, also to Sam Lloyd for giving technical support and advice. Thanks also to Dr Zoe Balmforth and Dr Stuart Marsden and three anonymous reviewers for their comments on earlier versions of the manuscript which greatly improved its quality.

References

Abraham, P.W. (1999) The chemistry and mineralogy of three savannah salt licks. *Journal of Chemical Ecology,* **25,** 2215–2228.

Ayotte, J.B., Parker, K.L. & Gillingham, M.P. (2008) Use of natural licks by four species of ungulates in northern British Columbia. *Journal of Mammalogy*, **89,** 1041–1050.

BirdLife International (2011) *Birds on the IUCN Red List.* Http. www.birdlife.org/action/science/species/global_species_programme/red_list.html [Accessed 7 December 2011].

Blake, J.G., Guerra, J., Mosquerra, D., Torres, R., Loiselle, B.A. & Romo, D. (2010) Use of mineral licks by white-bellied spider monkeys (*Ateles belzebuth*) and red howler monkeys (*Alouatta seruculus*) in eastern Ecuador. *International Journal of Primatology*, **31,** 471–483.

Blake, J.G., Mosquerra, D., Guerra, J., Loiselle, B.A., Romo, D. & Swing, K. (2011) Mineral licks as biodiversity hotspots in lowland forest of eastern Ecuador. *Diversity*, **3,** 217–234.

Bolton, K.A., Campbell, V.M. & Burton, F.D. (1998) Chemical analysis of soils of Kowloon (Hong Kong) eaten by hybrid macaques. *Journal of Chemical Ecology,* **24,** 195–205.

Brightsmith, D.J. (2004a) Effects of diet, migration, and breeding on clay salt lick use by parrots in South western Peru. *Paper presented to the 2004 Symposium of the American Federation of Aviculture, Austin, Texas, USA.*

Brightsmith, D.J. (2004b) Effects of weather on avian geophagy in Tambopata, Peru. *Wilson Bulletin,* **116,** 134–145.

Brightsmith, D.J. & Aramburè, R. (2004) Avian geophagy and soil characteristics in southeastern Peru. *Biotropica,* **36,** 534–543.

Brightsmith, D.J., Taylor, J. & Phillips, T.D. (2008) The roles of soil characteristics and toxin absorption in avian geophagy. *Biotropica*, **40,** 766–774.

Diamond, J., Bishop, K.D. & Gilard, J.D. (1999) Geophagy in New Guinea birds. *Ibis,* **141,** 181–193.

Downs, C.T. (1982) Geophagy in the African olive pigeon *Columba arquatrix*. *Ostrich*, **77,** 40–44.

Edwards, S. (2012a) First confirmed records of sun bears in Kulen-Promtep Wildlife Sanctuary, Northern Cambodia, *International Bear News*, **21,** 11–12.

Edwards, S. (2012b) Small carnivore records from the Oddar Meanchay sector of Kulen-Promtep Wildlife Sanctuary, northern Cambodia. *Small Carnivore Conservation*, **46,** 22–25.

Francis, C.M. (2008) *A Field Guide to the Mammals of South-East Asia*. New Holland Publishers, London, U.K.

Ganzhorn, J.U. (1987) Soil consumption of two groups of semi-free ranging lemurs (*Lemur catta* and *Lemur fulvus*). *Ethology*, **74,** 146–154.

Gilandi, J.D., Duffey, S.S., Munn, C.A. & Tell, L.A. (1999) Biochemical functions of geophagy in parrots. detoxification of dietary toxins and cytoprotective effects. *Journal of Chemical Ecology,* **25,** 897–922.

Haymann, E.W. & Hartmann, G. (1991) Geophagy in moustached tamarins, *Saguinas mystrax* (Platyrrhini: Callitrichidae), at the Rio Blanco, Peruvian Amazon. *Primates*, **32,** 533–537.

Henshaw, J. & Ayeni, J. (1977) Some aspects of big-game utilization of mineral licks in Yankari Game Reserve, Nigeria. *East African Wildlife Journal*, **9,** 73–82.

Klaus, G. & Schmidg, T. (1998) Geophagy at natural licks and mammal ecology; a review. *Mammalia*, **62,** 482–489.

Klaus, G., Klaus-Hugi, C. & Schmid, B. (1998) Geophagy by large mammals at natural licks in the rain forest of the Dzanga National Park, Central African Republic. *Journal of Tropical Biology*, **14,** 829–839.

Klein, D.R. & Thing, H. (1989) Chemical elements in mineral licks associated with muskoxen feces in Jameson Land, Northeast Greenland. *Canadian Journal of Zoology*, **67,** 1092–1095.

Kreulen, D.A. (1985) Lick use by large herbivores: a review of benefits and banes of soil consumption. *Mammal*, **15,** 117–123.

Krishnamani, R. & Mahaney, W.C. (2000) Geophagy among primates: adaptive significance and ecological consequences. *Animal Behaviour*, **59,** 899–915.

Mahaney, W.C., Aufreiter, A. & Hancock, R.G.V. (1995) Mountain gorilla geophagy: a possible seasonal behaviour for dealing with the effects of dietary changes. *International Journal of Primatology*, **16,** 475–488.

Matsubayashi, H., Lagan, P., Majalap, N., Tangan, J., Abd Sukor, J.M. & Kitayama, K. (2006) Importance of natural licks for the mammals in Bornean inland tropical rainforests. *Ecological Research*, **22,** 742–748.

Mee, A., Denny, R., Fairclough, K., Pullan, D.M. & Boyd-Wallis, W. (2005) Observations of parrots at a geophagy site in Boliva. *Biota Neotropica*, **5,** 1–5

Moe, S.R. (1993) Mineral content and wildlife use of soil licks in southwestern Nepal. *Canadian Journal of Zoology*, **71,** 933–936.

Navarino, W. (2005) *Population Monitoring and Study of Daily Activities of Malayan Tapir (*Tapirus indicus*)*. Rufford Small Grants Reports Http://www.ruffordsmallgrants.org/files/Novarino_Repot.pdf [accessed 1 July 2012].

Ping, X., Li, C., Jiang, Z., Liu, W. & Zhu, H. (2011) Sexual difference in seasonal patterns of salt lick use by Chinese sika deer, *Cervus nippon*. *Mammalian Biology*, **76,** 196–200.

Rick, A.A., Scott, C.P., Katherine, M.T., Jenna, J. & Brad, P. (2003) Calcium as a limiting resource to insectivorous bats: can water holes provide a supplemental mineral source? *Journal of Zoology*, **260,** 189–194.

Robichaud, W. & Sounthala, B. (1995) *A Preliminary Wildlife and Habitat Survey of Phou Dendin National Biodiversity Conservation Area, Phongsali.* Cedar Grove Ornithological Research Station, S. Pasadena, USA. Http://www.directoryofngos.org/project_publications/PHOU%20DENEDIN%201995.pdf on 7/12/11 [accessed 1 July 2012].

Robson, C. (2005) *New Holland Field Guide to the Birds of South-East Asia*. New Holland Publishers, London, U.K.

de Souza, L.L., Ferrari, S.F., Da Costa, M.L. & Kern, D.C. (2002) Geophagy as a correlate of folivory in red-handed howler monkeys (*Alouatta belzebul*) from eastern Brazilian Amazonia. *Journal of Chemical Ecology,* **28,** 1613–1621.

Symes, C.T., Hughes, J.C., Mack, A.L. & Marsden, S.J. (2005) Geophagy in birds of Crater Mountain Wildlife Management Area, Papua New Guinea. *Journal of Zoology*, **268,** 87–91.

Timmins, R.J., Duckworth, J.W. & Gilardi, J.D. (2008a) *Tragulus kanchil*. In *IUCN 2011 Red List of Threatened Species*. Http://www.iucnredlist.org/details/136297/0 [accessed 2 February 2012].

Timmins, R.J., Hedges, S. & Duckworth, J.W. (2008b) *Bos sauveli*. In *IUCN 2011 Red List of Threatened Species*. Http://www.iucnredlist.org/details/2890/0 [accessed 2 February 2012].

Tobler, M.W., Carillo-Percastegui, S.E. & Powell, G. (2009) Habitat use, activity patterns and use of five mineral licks by five species of ungulate in south-eastern Peru. *Journal of Tropical Ecology,* **25,** 261–270.

Weeks, H. (1978) Characteristics of mineral licks and behaviour of visiting white-tailed deer in southern Indiana. *American Midland Naturalist*, **100,** 384–395.

Weeks Jr, H.P. & Kirkpatrick, C.M. (1978) Salt preferences and sodium drive phenology in fox squirrels and woodchucks. *Journal of Mammalogy*, **59,** 531–542.

About the Authors

SARAH EDWARDS was the Principle Investigator for Frontier Cambodia from November 2010 to November 2011, and holds an MSc in Animal Behaviour which she gained in 2009 from Manchester Metropolitan University. Sarah's main research interest is large mammals and she has previously worked in Namibia studying brown hyena ecology and Cape ground squirrel behaviour. Sarah is currently studying for her PhD, focusing on human-wildlife conflict issues on Namibian farmlands.

JAMES ALLISON was an Assistant Research Officer for Frontier Cambodia for six months in 2011. He completed his BSc (Hons) in Zoology at the University of Edinburgh in 2009. His main interests lie in ornithology and he has had much experience of studying birds throughout Southeast Asia. He is currently the Assistant Ecologist of the Alderney Wildlife Trust where he is conducting research on seabird productivity.

SARAH CHEETHAM was an Assistant Research Officer for Frontier Cambodia for six months in 2011. She completed her BSc (Hons) in Geography and Kings College London University in 2009. After her wildlife conservation experience in Southeast Asia she has developed an interest in the study of amphibians and how they are affected by differences in disturbance. She has recently accepted the position of Principal Investigator in Costa Rica for Frontier where she is conducting survey work monitoring a variety of species looking at the affects of global warming.

HOEUN BUNTO is a Cambodian national whom has lived within the Anlong Veng District all his life. Bunto has been an Ministry of Environment forest official for five years in the Kulen Promtep Wildlife Sanctuary and has worked with Frontier on the Cambodia Forest programme since January 2011. He has extensive knowledge of, and keen interest in the local area and its wildlife.

Fire ecology of the dry dipterocarp forests of South West Cambodia

Timothy F. WOOD

3C #17EZ Sothearos Bvd, Tonle Bassac, Phnom Penh. Email nitchaga@gmail.com

Paper submitted 19 September 2011, revised manuscript accepted 24 June 2012.

មូលន័យសង្ខេប

ភ្លើងឆេះព្រៃកើតមានតែនៅក្នុងព្រៃខ្លុងត្បែងស្ងួតនៃប្រទេសកម្ពុជា។ វាផ្តល់មុខងាររក្សាស្ថិរភាពដែលទប់ស្កាត់កុំអោយព្រៃខ្លុងត្បែងស្ងួតក្លាយទៅជាព្រៃក្រាស់ ទប់ស្កាត់កំណព្រៃពាក់កណ្តាលស្រោង និងទប់ស្កាត់ការកើនឡើងនៃសំណល់រុក្ខជាតិងាប់ៗ។ ប៉ុន្តែភ្លើងឆេះព្រៃប្រចាំឆ្នាំអាចបណ្តាលអោយមានផលប៉ះពាល់បរិស្ថានរយៈពេលវែង ជាពិសេសពេលដែលភ្លើងឆេះព្រៃរាលដាលចូលទៅក្នុងព្រៃពណ៌បៃតងពេញមួយឆ្នាំដែលងាយឆេះដោយភ្លើងឆេះព្រៃ ឬនៅពេលលក្ខខណ្ឌដីត្រូវបានរេចរឹល។ ដើម្បីកំណត់ថា តើភ្លើងឆេះព្រៃមានឥទ្ធិពលអវិជ្ជមានទៅលើព្រៃខ្លុងត្បែងស្ងួតឬទេនោះ ទំហំដើមឈើ(បន្ទាត់ផ្ចិតដើមនៅកំពស់១៣៧សមពីដី និងកំពស់ដើម) ភាពសំបូរបែបនៃរុក្ខជាតិ ចំនួនប្រភេទ នានាភាពនៃប្រភេទ សមាសភាពឬស្សីព្រិចនិងស្មៅផ្សេងទៀត និងកំរាស់សំណល់រុក្ខជាតិងាប់ត្រូវបានសិក្សានៅក្នុងឡូត៍គំរូចំនួនបីដែលត្រូវបានដុតដើម្បីធ្វើពិសោធន៍ក្នុងរយៈពេលខុសៗគ្នា។ ការសិក្សានេះបង្ហាញថាភ្លើងឆេះព្រៃជះឥទ្ធិពលទៅលើជំរើសកូនរុក្ខជាតិ និងការលូតលាស់ឡើងវិញទៅជារុក្ខជាតិធំពេញវ័យ និងបណ្តាលអោយមានការថយចុះនៃភាពសំបូរបែប ចំនួនប្រភេទ និងនានាភាពនៃដើមឈើពេញវ័យ។ ភ្លើងឆេះព្រៃក៏មានឥទ្ធិពលដ៏សំខាន់ទៅលើដង់ស៊ីតេ ចំនួនប្រភេទ និងនានាភាពនៃប្រភេទរបស់រុក្ខជាតិដែលមានកំពស់ទាបជាង២០០សម និងមានបន្ទាត់ផ្ចិតកំពស់ទ្រូងតិចជាង៣សម ។ ជាទូទៅ ភាពសំបូរបែប ចំនួនប្រភេទ និងផ្ទៃមុខកាត់នៃដើមឈើ គឺទាបជាងនៅក្នុងតំបន់ដែលទើបនឹងដុតថ្មីៗ ប៉ុន្តែវាហាក់ដូចជាដុះលូតលាស់ឡើងវិញយ៉ាងឆាប់រហ័ស។ កំរាស់សំណល់រុក្ខជាតិងាប់កើនឡើងយ៉ាងរហ័សបំផុត នៅក្នុងកន្លែងដែលមិនមានភ្លើងឆេះព្រៃ។ ការសិក្សានេះផ្តល់ជាភស្តុតាងថា ការដុតព្រៃជាទៀងទាត់មានសារៈសំខាន់ក្នុងការរក្សាកំរិតស្ថិរភាពនៃព្រៃខ្លុងត្បែងស្ងួត និងក្នុងការទប់ស្កាត់ភ្លើងឆេះព្រៃខ្លាំងក្លា ដែលអាចធ្វើអោយបាត់បង់ស្ថិរភាព និងបំផ្លាញព្រៃទាំងនោះ។

Abstract

Fire is endemic in the dry dipterocarp forests of Cambodia. It provides a stabilizing function that prevents dry dipterocarp forests from turning into denser, semi-deciduous formations and prevents an accumulation of fuel. However, annual fires may cause long-term environmental impacts, particularly when fires spread into the fire-sensitive evergreen forests or when soil conditions become degraded. To determine whether the dry dipterocarp forests of Cambodia are negatively impacted by fire, the sizes of trees (diameter at breast height and height), vegetation abundance, species richness and diversity, the composition of pygmy bamboos and other grasses, and fuel levels were examined in three plots with different time-since-burn periods. This study shows that fires affect the recruitment of seedlings and regrowth into adult trees, and cause a decrease in abundance, species richness and diversity of adult trees. Fires also have a significant effect upon the density, species richness and diversity of vegetation less than 200 cm in height or with a diameter at breast height of less than 3 cm. Abundance, species richness and basal area were generally lower in the most recently burnt areas, but appeared to recover quickly. Fuel levels accumulate rapidly to extreme levels in the

CITATION: Wood, T.F (2012) Fire ecology of the dry dipterocarp forests of South West Cambodia. *Cambodian Journal of Natural History*, **2012,** 64–74.

absence of fire. This study provides evidence that regular burning is essential for maintaining a level of stability in DDF and to prevent extreme fires that could destabilise and damage the forests.

Keywords

Cardamom Mountains, South East Asia, time since burn.

Introduction

Tropical forests are among the world's most threatened ecosystems because they are being modified through human activities into agricultural land or into other, less productive ecosystems (Khurana & Singh, 2001; Saha & Howe, 2003). The use of fire by humans is widespread (Parr & Chown, 2003) as a tool to manage and shape forests and landscapes. In the past, fires were caused by lightning strikes, but now fires are almost exclusively caused by humans and are increasing in frequency (Stott, 2000; Goldammer & de Ronde, 2004).

Fire is a key ecological process in many of the earth's biomes and plays an important role in maintaining stability in many ecosystems (Mutch, 1970; Bond & Midgley, 1995; Roberts, 2000; Marod *et al.*, 2002; Parr & Chown, 2003; Goldammer & de Ronde, 2004; Shlisky *et al.*, 2007). Fires are more prevalent in the tropics than in other parts of the world (Crutzen & Andreae, 1990). Fire can stabilise ecosystems, and some species have evolved adaptive traits to co-exist with fire. However, fire can also have devastating impacts and can damage or destroy fire-sensitive tropical ecosystems, such as rainforests, resulting in a loss of biodiversity.

Dry dipterocarp forests (DDFs) are unique to Southeast Asia (Martin, 1973) and develop in response to certain soil and bioclimatic conditions (Blasco, 1983). Fire combines with soil and climate to determine the structure of the environment: Soil type and rainfall can limit the establishment and growth of seedlings, while the fires can prevent the seedlings from becoming adults (Higgins *et al.*, 2000). The DDFs of Southeast Asia are dependant on fire for stability (Blasco, 1983), preventing their transition to more evergreen forest types (Goldammer, 1996). They possess evolutionary traits that allow them to persist in annual burning cycles and even depend on them. Adaptive traits include thick bark, post-burn resprouting, below ground biomass, flammability, seeds that germinate in response to fire, the heights of reproductive individuals and drought resistance. However, they cannot survive high intensity fires (Stott, 1990), which can destabilise the ecosystem and cause widespread damage.

DDFs are widespread throughout Thailand, Cambodia, Laos and Vietnam at elevations below 900 m and represent the commonest vegetation type in Cambodia (Blasco, 1983; Goldammer, 1996). Stott *et al.* (1990) suggests that current formations originated from ancient DDF communities in Cambodia, Vietnam, Thailand, Myanmar, and Manipur State in India, and have been spread through fire and human activity. It is clear that the current distribution of DDF is strongly correlated with human activities (Blasco, 1983; Slik *et al.*, 2002).

Fig. 1 Dry dipterocarp forest, with mixed deciduous and evergreen forest in riparian areas, in Phnom Samkos Wildlife Sanctuary (© Tim Wood/ Fauna & Flora International).

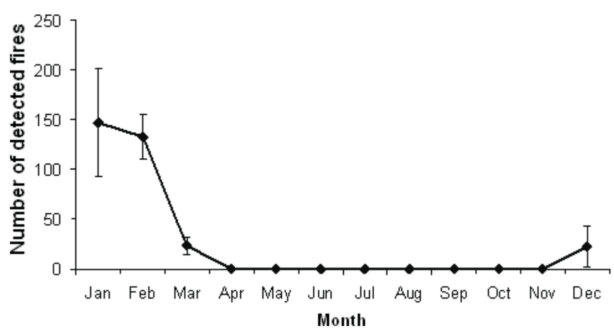


Fig. 2 Mean monthly detected fires 2004–2007 in Phnom Samkos Wildlife Sanctuary. Source: NASA/ University of Maryland (2007).

DDF environments can be described as a coexistence between trees and grasses (Higgins *et al.*, 2000). The ground layer is comprised of various grasses and pygmy bamboos. In Cambodia the most abundant of these tree species are *Dipterocarpus tuberculatus* Roxb., *Shorea obtusa* Wall. ex Blume, and *S. siamensis* Miq., *D. obusifolius* Teijsm. (Blasco, 1983; Cole, 1986; Stott, 1986) while the ground layer is composed of the pygmy bamboos *Vietnamosasa ciliata* (A. Camus) Nguyen, *V. pusilla* (A. Chevalier & A. Camus) Nguyen, *Drepanostachyum falcatum* (Nees) Keng and grasses *Imperata cylindrica* Beauv and *Themeda triandra* (Stott, 1986, 1988, 1990; Hacker *et al.*, 1996). The pygmy bamboos are the most abundant form of vegetation on the ground layer (Stott, 2000), but they can be replaced by *I. cylindrica* in fire-degraded sites (Martin, 1973). These pygmy bamboos species represent about 90% of the ground cover biomass (Stott, 2000) and they also provide the majority of the fuel for the annual fires (Stott, 1988).

Fires occur annually in the dry season and in Cambodia they burn from December to March, but commencement times vary (Goldammer, 1996). These fires are mostly unnatural fires, having been lit by humans for a variety of reasons. Typical reasons given are hunting, swidden agriculture, pest-removal, promoting grass growth for cattle, burning stubble, collecting honey and accidental burning from discarded cigarette butts or unattended cooking fires (Wharton, 1966; Stott, 1988; Crutzen & Andreae, 1990; Savet, 1999; Laris, 2002; Maxwell, 2004).

The fuel level in DDF ranges from 5–10 tonnes per hectare and some areas are even burnt twice in one season (Goldammer, 1996). If these fires are lit early in the dry season, they are generally less intense and patchier than if the burning was carried out during the mid-dry season (Stott, 1989; Goldammer, 1996). If a regular burning pattern is followed, and the forest is burnt annually, the level of fuel does not have an opportunity to build up (Stott, 1988). Evidence indicates that historical fires from lightning in Cambodia would have burned the forests much later in the year than currently occurs (Maxwell, 2004).

Major widespread changes in tropical forests have been linked with extreme drought periods associated with El Nino-Southern Oscillation (ENSO) cycle events coupled with fire events (Murphy & Lugo, 1986; Goldammer, 1999, 2006; Roberts, 2000, 2001). Fires propagate from the DDF into mixed deciduous and evergreen forest areas, replacing fire-sensitive species with species that possess adaptive traits to survive the annual burning cycle. The evergreen forests are, through fire and ENSO climatic events, gradually being replaced by dryer forest types, including DDF (Blasco *et al.*, 1996). This allows the extent of the DDF to expand into the more humid and evergreen vegetation types.

The aim of this study is to examine the ecological effects that fire has on the DDF of Cambodia, to determine whether the DDFs in Cambodia are negatively impacted by fire, and identify what characteristics (height and diameter at breast height, DBH) allow individual plants to survive. This is the first study of its kind in Cambodia to investigate the effects that fire has on DDF.

Methods

Study area

The study area was in South West Cambodia within the Phnom Samkos Wildlife Sanctuary (Fig. 1). The wildlife sanctuary covers 3,338 km² with elevations of between 150 m and 1,717 m, with Phnom Samkos being the highest peak (FFI, 2004). The locations of the research areas are described in Table 1. The vegetation types within the wildlife sanctuary include DDF, lowland dry evergreen forests, gallery forest, bamboo forest, lower and upper hill evergreen forest, and lower and upper mountain evergreen forest with some marshes and grasslands (FFI, 2004).

Climatic data gathered from the nearest weather observation centre in Pursat Town (some 100 km away from the study site) shows that temperatures range between 25 and 30 °C with very little seasonal variation and the average yearly rainfall is 1,178 mm, but other parts of the wildlife sanctuary can receive up to 5,000 mm rain per year (FFI, 2004).

Fires occur annually in the wildlife sanctuary. Fig. 2 shows the temporal distribution of the fires in Phnom Samkos Wildlife Sanctuary. The fire season starts in December and concludes in April, with January and February consistently having peak fire frequencies.

Research design

Using historical fire data obtained from NASA/University of Maryland (2007) and vegetation distribution maps for Cambodia (JICA, 2005), an analysis was undertaken using ArcGIS 9.1 to identify potential sites that displayed differing fire histories within the DDF communities. An initial field visit was made to the area to inspect these sites for suitability. As landmines are relatively abundant in Phnom Samkos Wildlife Sanctuary, a Ministry of Environment ranger assisted in locating safe access routes to the areas. Three suitable areas were identified to represent a chronological ordination of fire events and their effects from fire (Table 1; Figs 4–6). They shared a similar aspect, slope and altitude. It was difficult to find areas that had been fire-free for some considerable length of

Table 1 Description of the research areas. *t* = time-since-burn.

Plot	Latitude	Longitude	Canopy cover (%) and structure	Altitude (m)	Fire history
t+2 months	12.322	103.066	40%. 2 layers: 6–8 m and 18–20 m	316	Late dry season, February 2007
t+4 months	12.321	103.065	45%. 2 layers: 6–8 m and 18–20 m	302	Early dry season, December 2006
t+14 months	12.293	103.096	50%. 2 layers: 10 m and 18–22 m	254	Late dry season, February 2006

time, as most areas are burnt annually, or at least every 2–3 years (Stott, 1988).

As the research was intended to examine the impact that fire has on the ecology, and diversity of DDFs the following variables were assessed:

- Vegetation abundance, species richness, basal areas and diversity in the three sampling areas with different time-since-burn periods;
- Diameter at breast height (DBH) measured at 1.5 m above the ground, and heights of individuals in the three sampling areas with different time-since-burn periods;
- Cover of bamboos and other grasses in the three plots with different time-since-burn periods;
- Fuel levels in the three plots with different time-since-burn periods.

Three 20 m x 20 m plots were established in each research area. A total of nine plots were used for this research. Every plot was not less than 100 m from another plot. Random subplots of 1 m x 0.5 m were used to measure fuel and the cover of bamboos and other grasses.

Data collection and analysis

The heights of trees, seedling, vines and sedge shrubs were measured. Trees exceeding 3 cm DBH were measured, noting the species, height and DBH class. If the plant's scientific name was unknown, the vernacular name was recorded and then checked against Dy Phon (2000). The heights and species of bamboos and other grasses were recorded with each sub plot.

Fuel levels and fuel heights were recorded in the same subplots according to procedures outlined by McCarthy *et al.* (1999).

To compare the stand structures, stem diameters were grouped into five categories according to DBH in cm: <3, ≥3 and <10, ≥ 10 and <20, ≥20 and < 30, and ≥ 30. Trees were also grouped into seven categories according to height in cm: <50, ≥50 and <100, ≥100 and <200, ≥ 200 and <500, ≥500 and <1000, ≥1000 and <2000, ≥2000). The Shannon Index of Diversity was used to measure levels of diversity for plants.

Statistical procedures were used to test the hypothesis that fire has a substantial impact on the ecology, and diversity of DDF and this impact is strongly correlated to the time since the last burn. Significance was tested using a one-way ANOVA (SPSS 15.0 for Windows). When a significant difference was found, a post hoc analysis using Tukey's Honestly Significant Difference (HSF) procedure was used to determine which sites differed significantly from one another. Those variables that failed the homogeneity of variance test were measured using a Kruskal-Wallis test. When a significant difference was found after running the Kruskal-Wallis test, a post hoc analysis using Dunnett's TC procedure was used to determine which sites differed significantly from one another. Fuel hazard was determined using the methods described by McCarthy *et al.* (1999) using the "overall fuel hazard calculated" (Tran, 2004) in a Microsoft Excel environment.

Results

Forest composition

Only within the <3 cm DBH class was there significant variation between the plots in terms of number of individual plants (ANOVA p = 0.002) (Table 2). There were significantly fewer individuals at t+2 months (Fig. 4) than at t+4 months and t+14 months (Fig. 6) (Tukey's HST p = 0.02). The majority of these plants were small (i.e. smaller DBH classes). Across all DBH classes, the greatest number of individuals was recorded at t+14 months (mean = 850.3/ 0.1 ha), while t+2 months had the fewest (mean = 73.3/ 0.1 ha).

Number of species also varied within the <3 cm DBH class (ANOVA p = 0.02), with significantly fewer species at t+2 months than t+4 months (Tukey's HST p = 0.001). Species richness was also lower among the larger DBH classes than the smaller DBH classes. The number of individuals and number of species within each DBH class appeared to have a positive correlation. Across all size classes, the species richness was significantly lower at

Table 2 Mean number of individuals, number of species, basal area and Shannon Index of trees in different DBH classes in the three study areas. Plot t denotes time since burn. Standard errors of the mean (±SE) are shown. For explanation of probability values (*p*) see text (NS = not significant).

DBH Class	Plot	Mean no. of individuals/ 0.1 ha	Mean no. of species/ 0.1 ha	Mean basal area (m^2/ ha)	Mean Shannon Index
<3 cm	t+2 months	53.3 (16.0)	11.0 (1.5)	n/a	2.2 (0.43)
	t+4 months	445.7 (32.6)	26.3 (4.4)	n/a	2.2 (0.42)
	t+14 months	828.0 (171.4)	26.7 (2.8)	n/a	2.1 (0.8)
	p value	< 0.01	< 0.05	n/a	NS
≥ 3 cm & <10 cm	t+2 months	6.7 (2.6)	3.3 (1.5)	0.3 (0.1)	0.7 (0.4)
	t+4 months	7.7 (3.5)	3.3 (1.2)	0.3 (0.1)	1.0 (0.5)
	t+14 months	10.7 (7.7)	4.0 (1.2)	0.3 (0.2)	0.9 (0.3)
	p value	NS	NS	NS	NS
≥ 10 cm & <20 cm	t+2 months	9.3 (1.2)	5.0 (1.5)	1.4 (0.2)	1.4 (0.3)
	t+4 months	3.3 (1.5)	1.7 (0.3)	0.6 (0.3)	0.4 (0.2)
	t+14 months	5.3 (2.2)	2.3 (0.7)	1.1 (0.4)	0.7 (0.4)
	p value	NS	NS	NS	NS
≥ 20 cm & <30 cm	t+2 months	1.7 (0.3)	1.0 (0.0)	0.8 (0.2)	0.0 (0.0)
	t+4 months	2.3 (1.3)	1.7 (0.7)	0.9 (0.5)	0.2 (0.2)
	t+14 months	4.3 (0.9)	2.7 (0.3)	2.4 (0.5)	0.7 (0.1)
	p value	NS	NS	NS	NS
≥ 30 cm	t+2 months	2.3 (0.9)	2.0 (0.6)	2.9 (0.9)	0.6 (0.3)
	t+4 months	3.3 (0.9)	2.0 (0.0)	4.5 (0.6)	0.7 (0.0)
	t+14 months	2.0 (0.6)	1.0 (0.0)	2.4 (0.8)	0.0 (0.0)
	p value	NS	NS	NS	NS
All classes combined	t+2 months	73.33 (21.04)	5.35 (1.50)	2.24 (0.31)	21.66 (8.50)
	t+4 months	462.33 (39.83)	6.28 (1.58)	2.22 (0.42)	30.33 (6.70)
	t+14 months	850.33 (182.68)	6.11 (1.89)	2.08 (0.07)	30.00 (2.60)

t+2 months (mean = 21.66) than t+4 months (mean=30.33) and t+14 months (mean = 30.00). Basal area, on the other hand, did not vary significantly.

Within different height classes, there was significant variation in the number of individuals in the <50 cm class (ANOVA $p = 0.009$), the 50–100 cm class (ANOVA $p = 0.017$) and the ≥2,000 cm classes (Kruskal-Wallis $p = 0.03$) (Table 3). In the <50 cm class, there were highly significantly fewer individuals at t+2 months than at t+14 months (Tukey's HST $p = 0.008$). Similarly, in the 50–100 cm class, there were significant fewer individuals at t+2 months than t+14 months (Tukey's HST $p = 0.14$). In the ≥2000 cm height class, the number of individuals was significantly lower at t+2 months than t+14 months (mean = 3.0/ 0.1 ha) (Dunnett's TC $p = 0.032$). In size classes below 500 cm, there was greater deviation between the plots than the larger size classes.

The number of species also varied significantly within the <50 cm height class (ANOVA $p = 0.019$), 50–100 cm class (ANOVA $p = 0.006$), 100–200 cm class (ANOVA $p = 0.02$), and >2,000 cm class (Kruskal-Wallis $p = 0.03$) (Table 3). In the <50 cm class, significantly fewer species were found at t+2 months than t+4 months (Tukey's HST p =0.02) and at t+14 months (Tukey's HST $p = 0.047$). Similarly, in the 50–100 cm height class, fewer species were recorded at t+2 months than at t+4 months (Tukey's HST $p = 0.028$) and at t+14 months (Tukey's HST $p = 0.006$). In the 100–200 cm height class, significantly fewer species were found at t+2 months than t+14 months (Tukey's HST $p = 0.017$). In the >2,000 cm height class, on the other hand, Dunnett's TC procedure found no significant differences.

Both the number of species and number of individuals were greater among the smaller plants (lower height

Table 3 Mean number of individuals, number of species and Shannon Index of trees in different height classes in the three study areas. Plot t denotes time since burn. Standard errors of the mean (±SE) are shown. For explanation of probability values (*p*) see text (NS = not significant).

Height Class	Plot	Mean no. of individuals/ 0.1 ha	Mean no. of species/ 0.1 ha	Mean Shannon Index
<50 cm	t+2 months	51.0 (18.7)	10.7 (1.2)	1.8 (0.2)
	t+4 months	331.3 (24.1)	24.7 (4.3)	2.2 (0.3)
	t+14 months	571.0 (131.4)	22.0 (0.6)	1.9 (0.1)
	p value	< 0.01	< 0.05	NS
≥ 50 cm & <100 cm	t+2 months	0.7 (0.3)	0.7 (0.3)	0.0 (0.0)
	t+4 months	86.3 (19.1)	12.3 (2.7)	1.5 (0.5)
	t+14 months	151.3 (40.2)	17.3 (3.0)	1.9 (0.2)
	p value	< 0.05	< 0.01	< 0.05
≥ 100 cm & <200 cm	t+2 months	4.0 (1.0)	2.7 (0.9)	0.8 (0.4)
	t+4 months	16.3 (4.5)	6.3 (1.9)	1.3 (0.2)
	t+14 months	53.0 (19.3)	10.7 (1.3)	1.7 (0.1)
	p value	NS	< 0.05	NS
≥ 200 cm & <500 cm	t+2 months	6.0 (3.1)	2.3 (1.3)	0.5 (0.5)
	t+4 months	5.7 (3.0)	2.3 (1.2)	0.6 (0.3)
	t+14 months	15.0 (9.0)	5.3 (1.5)	1.2 (0.2)
	p value	NS	NS	NS
≥ 500 cm & < 1000 cm	t+2 months	4.0 (0.6)	3.3 (0.7)	1.1 (0.3)
	t+4 months	7.7 (3.5)	4.3 (1.2)	1.3 (0.2)
	t+14 months	3.3 (2.0)	1.7 (0.9)	0.6 (0.2)
	p value	NS	NS	NS
≥ 1000 cm & <2000 cm	t+2 months	4.0 (0.9)	3.3 (0.9)	1.0 (0.3)
	t+4 months	16.3 (2.0)	1.3 (0.7)	0.4 (0.2)
	t+14 months	53.0 (2.4)	2.7 (0.7)	0.9 (0.2)
	p value	NS	NS	NS
>2000 cm	t+2 months	0.3 (0.3)	0.3 (0.3)	0.0 (0.0)
	t+4 months	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	t+14 months	3.0 (0.0)	2.0 (0.0)	0.6 (0.0)
	p value	< 0.05	< 0.05	< 0.05

Table 4 Mean heights of bamboos and other grasses, bamboo composition and fuel in the three study areas. Plot t denotes time since burn. Standard errors of the mean (±SE) are shown. For explanation of probability values (*p*) see text (NS = not significant).

Plot	Mean height of bamboo (cm)	Mean height of other grasses (cm)	Mean relative composition of bamboo (%)	Mean fuel cover (%)	Mean fuel height (cm)	Mean fuel mass (tonnes/ ha)	Fuel level classification
t+2 months	54.3 (6.6)	24.3 (3.0)	52.3 (5.6)	9.5 (11.7)	4.5 (2.2)	1.5 (0.8)	Medium
t+4 months	100.7 (21.9)	45.3 (92.8)	68.0 (9.5)	28.2 (13.1)	7.3 (1.5)	2.5 (0.5)	Medium
t+14 months	198.0 (51.2)	32.3 (16.2)	92.7 (5.5)	85.0 (12.5)	30.0 (8.7)	10.7 (3.5)	Extreme
p value	NS	< 0.05	< 0.05	NS	< 0.05	< 0.05	

Fig. 3 Basal sprouting from *Dipterocarpus obusifolius* tree after fire (© Tim Wood/Fauna & Flora International).

Fig. 4 Study plot two months after burning (© Tim Wood/ Fauna & Flora International).

Fig. 5 Study plot four months after burning (© Tim Wood/ Fauna & Flora International).

Fig. 6 Study plot 14 months after burning (© Tim Wood/ Fauna & Flora International).

classes) than in larger height classes. The decrease in the number of species with increased height class appears to be a uniform trend.

Diversity

There was little overall change in species diversity, as measured using the Shannon Index, within the plots across all classes, but there was significant variation in the 50–100 cm height class (ANOVA $p = 0.011$) and the ≥2,000 cm height class (Kruskal-Wallis $p = 0.018$). Multiple comparisons were made to determine differences in the plots in the height class 50–100 cm (Table 3), which found the Shannon Index to be significantly lower at t+2 months than t+4 months (Tukey's HST $p = 0.032$) and at t+14 months (Tukey's HST $p = 0.011$). In the ≥2,000 cm height class, on the other hand, no significant differences were found between the plots after multiple comparisons were made.

In the lower height classes, the Shannon Index showed diversity was lower at t+2 months and t+4 months than at t+14 months. However, in the smaller DBH classes, diversity was higher at t+4 months than at t+2 months and t+14 months. Among the height classes (Table 3), there was a general decline in Shannon Index score with increased height, but this trend was not apparent in the DBH classes (Table 2).

Bamboos and other grasses

There was significant variation in bamboo height (ANOVA $p = 0.05$) and the relative abundance of bamboo (ANOVA $p = 0.019$), but not the height of other grasses (Kruskal-Wallis $p = 0.253$) (Table 4). The bamboos were significantly taller by t+14 months than at t+2 months (Tukey's HST $p = 0.046$) and more abundant at t+14 months than t+2 months (Tukey's HST $p = 0.016$).

Fuel

There was significant variation in the height of fuel (ANOVA $p = 0.027$), and the fuel per hectare (ANOVA $p = 0.041$) (Table 4). Fuel height, fuel cover and fuel per hectare appeared to be correlated with bamboo height and the relative composition of bamboo. The height of fuel in t+2 months (mean = 4.5 mm) was significantly less than t+14 months (mean = 85.0 mm) (Tukey's HST $p = 0.033$). Similarly, fuel per hectare was significantly less at t+2 months than in t+14 months (Tukey's HST $p = 0.049$).

Calculations for overall fuel hazards show that the t+14 months sampling area had an overall fuel hazard rating of 'extreme', with 20 tonnes of fine fuel in each hectare. The t+4 months and t+2 months sites had an overall fuel hazard rating of 'medium', with eight tonnes and two tonnes in each hectare respectively (Table 5).

Discussion

Abundance

This study has shown fires have a significant effect on the numbers of shrubs, trees and seedlings, with significantly fewer individuals within the DBH class of <3 cm and the height classes of <100 cm in the t+2 months site than the t+14 months site. These findings corroborate both Marod *et al.* (1999) and Sutthivanish (1989). Significant effects were also found in vegetation up to 500 cm in height; with both the t+2 months and the t+4 months sites having consistently fewer trees of less than 500 cm in height. Trees taller than 500 cm, on the other hand, appeared better able to survive fires.

Stott (1986) presented the temperature profiles of fires in dipterocarp forests, which showed the temperature drops considerably when the fire reaches a height of 0.5 metres for typical litter fires and 1 metre for a typical groundcover fire. Given this, it is reasonable to conclude that typical fires will have a greater negative effect on individuals <1,000 cm in height and especially individuals <500 cm in height. The t+14 months site had the greatest abundance of plant species within these lower classes, having had a longer period in which to recover. In the t+4 months site, the ≥50 cm height class that suffers high mortality in the fire had been replaced by resprouters (Fig. 3), while the t+2 months site was still relatively bare (Fig. 4). The significant differences detected in the ≥2,000 cm height class are possibly related to edaphic factors rather than fire.

There was a noticeable lack of new dipterocarp seedlings present throughout all the sites. Only two new *Shorea obtusa* seedlings were found in the sites, both in the t+14 months site. The rest of the seedlings were resprouters. This suggests that the forest regenerates quickly, but this is done by resprouting and not by recruiting.

Species richness

Overall species richness was lowest at the t+2 months site, but quickly recovered in the older sites. Fire limits the recruitment of seedlings and regrowth into adults: this was particularly evident in the <50 cm height class for the t+4 months site. Species richness was highest amongst the understorey classes, while the canopy is dominated almost exclusively by dipterocarp species. The decrease of species with height appears to follow a

Table 5 Overall fuel hazard levels in study areas with different time-since-burn periods.

Time since burn	t+2 months		t+4 months		t+14 months	
Fuel type	Assessed Rating	Equivalent Fuel Load (t/ha)	Assessed Rating	Equivalent Fuel Load (t/ha)	Assessed Rating	Equivalent Fuel Load (t/ha)
Surface fine fuel	Low	2	Low	2	High	10
Elevated fine fuel	Low	0	High	2	Very High	6
Bark fine fuel	Low	0	Low	0	Low	0
Near surface fine fuel	No	0	Yes	4	Yes	4
Overall fine fuel hazard	Medium	2	M	8	Extreme	20

uniform trend. While fire does increase species richness; this is confined to particular segments, or partitions of the forest structure.

The species richness of the 10–20 cm DBH class stands out. One possible reason for this high level of species richness could be that the site was located near an ecotone between evergreen forest and DDF.

Diversity

Significant differences were found in the Shannon Indices for two height classes: 50 to <100 cm and ≥2000 cm. The Shannon Index was higher in the t+2 months sampling areas (2.24) than t+4 months (2.22) and t+14 months (2.08).

Basal area

Basal area was surprisingly low at all sites. In a comparison of basal areas of DDF in Thailand undertaken by Lamotte *et al.* (1988), basal area was shown to range from 7.91 to 23.7 m^2/ ha. By contrast, the sites examined in Cambodia had much lower basal areas. It is not known if these are due to edaphic conditions, or due to fire history and fuel levels.

Bamboos and grasses

The pygmy bamboos *Vietnamosasa* spp. and *Drepanostachum* spp. dominated the ground layer, increasing in abundance and height as the time-since-fire increased. This confirmed Stott's (2000) study in which pygmy bamboos made up to 90% of the ground cover. There was a significant increase in bamboo height and abundance between t+2 months and t+14 months, replacing other grasses. Apart from providing an excess amount of fuel, the pygmy bamboo shades out seedlings and dipterocarp tree fruits can become caught in the leaves and stalks of the pygmy bamboo and thus fail to reach the ground. Marod *et al.* (1999) observed that such shading out the forest floor also affects seedling growth, but the area where the pygmy bamboo was highest and most abundant seemed to have little effect on seedling density. It is expected, however, that different species of pygmy bamboo react to fire exclusion in different ways. Some species of pygmy bamboo do not grow as high (Hacker *et al.*, 1996). The invasive nature of the pygmy bamboos may allow it to progress into the evergreen forest areas, and, as an excellent source of fuel, it brings fire along with it.

Fuel levels

When fires are absent from the DDF, the fuel level accumulated rapidly, as predicted by Stott (1990). In this study, the fuel accumulates to 20 tonnes/ha, which has a fuel hazard rating of 'extreme'. The difference between t+2 months and t+14 months was particularly significant, because there was an intervening wet season and therefore an accumulation of fuel. This is reflected in the difference in fuel height, bamboo height and differences in tonnes of fuel per hectare. The level of fuel, coupled with the height of the fuel and bamboo, will provide what Stott (1986) refers to as both an extreme ground cover fire and extreme litter burns. The temperature of these fires may then reach 700–900 ^{o}C and flame heights may exceed 3 m. Van Wilgen *et al.* (1990) state that 2,500 kWm^{-1} are required to produce a 'topkill' of trees up to a height of 2 m.

The potential intensity of the fire and its consequences are troubling. These extreme events will cause the zone of influence to reach much higher intensities, causing catastrophic losses of trees that have already escaped the fire zone. Moreover, such extreme fires may be a destabilising factor, as they would cause significant changes to the forest composition, soil and soil micro-organisms, resulting in a less dense and less diverse formation. How these extreme fire events affect the ability of dipterocarp to resprout is unknown.

Conclusion

Fire is a key ecological process in many of the earth's biomes. The use of fire by humans to alter ecosystems is widespread (Parr & Chown, 2003) and fire has been used as a tool to manage and shape forests and landscapes. Fires can also damage the forests and cause a loss of biodiversity, and they are seen by some as a threatening process which must be mitigated.

Some species will react to perturbations in different ways, as one species may possess the necessary evolutionary traits required for surviving fires, while another may be lacking and perish. There are also those ecosystems that require a certain amount of instability, such as fires, for long-term survival (Gowdy, 1997). The dominant species in the DDFs of Cambodia possess evolutionary traits to allow them to persist in the annual burning cycle and even to depend on it. Following a fire, the DDF ecosystem recovers quickly to pre-fire levels only to suffer the same fate the following dry season.

The fires in DDF communities appear to be stabilised temporally by fire, and spatially by edaphic conditions. DDF are not fragile ecosystems and demonstrate a degree of elasticity, as DDF species have evolved evolutionary traits over thousands of years to survive fire, climate and poor soils. Fires prevent the DDF from transforming into a less deciduous forest type or from accumulating fuel to dangerously high levels that will cause extreme perturbations. It is also true that fire has the ability to invade and transform other forest types. Fire transforms the mixed-deciduous and evergreen formations into DDF, resulting in a less productive ecosystem and loss of biodiversity. With an increasing human population living among the DDF in Cambodia, this transformation is a not just a possibility, it is inevitable.

Fire in the DDF was shown to affect the recruitment of seedlings and regrowth into adults, causing a loss of abundance, species richness and diversity among the larger tree classes. Fires have a significant effect on density, species richness and diversity in vegetation in the understorey, especially among plants of less than 200 cm in height or with a DBH of less than 3 cm. Fuel levels were shown to accumulate rapidly in the absence to fire, raising fuel levels to 'extreme' levels of 20 tonnes per hectare.

Management options in Cambodia are limited. There is an unfortunate lack of research and lack of resources that are required to address this issue. The fundamental questions that arise from this study are how often should the DDF be burnt and when should they be burnt? Until these questions are answered, management interventions may be redundant.

Acknowledgements

From the Ministry of Environment, I would like to thank His Excellency, Mr Chay Samith, Director General of GDANCP for granting permission to conduct this research; Mr Thorn Kimhong, Cluster Manager of the Cardamom Mountains Cluster for granting access to Phnom Samkos Wildlife Sanctuary and allowing me to stay at the Ranger Station; Mr Ung Sam Oeun for organising the research permits; Mr Khou Eanghourt, Head of Ecology and Botany at GDANCP for his assistance in species identification; Mr Tan Khun Ratana for his assistance with the fieldwork and Ministry of Environment Ranger Mr Boy Joy for assisting with initial site selection.

From Kasetsart University in Bangkok, I would like to thank Mr Somsakdi Tabtimthong and Miss Nicharee Phusorn from the International Affairs Division and Dr Yongyut Trisurat, Assistant Professor from the Department of Forest Biology, Faculty of Forestry for their hospitality and for allowing me access to the University and its resources.

I would also like to thank Mr David Bradfield, Mr Chun Run, Mrs Jenny Wood, Miss Pok Samnang, Mr Vong Thavy, Dr David Pavlacky, Dr Manda Page, and Miss Ke Socheata for their help and assistance during my research and the preparation of this manuscript. Finally, I would like to thank the anonymous reviewers for their valuable comments and suggestions to improve the manuscript.

References

Blasco, F. (1983) The transition from open forest to savanna in continental Southeast Asia. In *Ecosystems of the World, Volume 13, Tropical Savannas* (ed. F. Bourliere), pp. 167–182. Elsevier Scientific Publishing, New York, USA.

Blasco, F., Bellan, M.F. & Aizpuru M. (1996) A vegetation map of tropical continental Asia at scale 1:5 million. *Journal of Vegetation Science,* **7,** 623–634.

Bond, W.J. & Midgley J.J. (1995) Kill thy neighbour: an individualistic argument for the evolution of flammability. *Oikos,* **73,** 79–85.

Cole, M.M. (1986) *The Savannas: Biogeography and Geobotany*. Academic Press, London, U.K.

Crutzen, P.J. & Andreae, M.O. (1990) Biomass burning in the tropics – impact on atmospheric chemistry and biogeochemical cycles. *Science,* **250,** 1669–1678.

Dy Phon, P. (2000) *Dictionnaire des Plantes Utilisées au Cambodge*. Imprimerie Olympic, Phnom Penh, Cambodia.

FFI – Fauna & Flora International (2004) *Cardamom Mountains Wildlife Sanctuaries Project (CMWSP) Project Briefing*. Fauna & Flora International, Phnom Penh, Cambodia.

Goldammer, J. (2006) History of equatorial vegetation fires and fire research in Southeast Asia before the 1997–98 episode: a reconstruction of creeping environmental changes. *Mitigation and Adaptation Strategies for Global Change,* **12,** 13–32.

Goldammer, J.G. (1996) Fire in dipterocarp forests. In *Dipterocarp Forest Ecosystems: Towards Sustainable Management* (eds D.H.-F. Schöne & A. Schulte), pp. 155–185. World Scientific, Singapore.

Goldammer, J.G. (1999) Ecology – forests on fire. *Science,* **284,** 1782–1783.

Goldammer, J.G., & de Ronde, C. (2004) *Wildland Fire Management Handbook for Sub-Sahara Africa*. Global Fire Monitoring Centre and Oneworldbooks, Cape Town, South Africa.

Gowdy, J.M. (1997) The value of biodiversity: markets, society, and ecosystems. *Land Economics,* **73,** 25–41.

Hacker, J.B., Simon, B.K. & Phengvichith, V. (1996) The pek savannas of the Lao People's Democratic Rebublic – ecology and floristics. *Genetic resources communication,* **23,** 1–38.

Higgins, S.I., Bond, W.J. & Trollope, W.S.W. (2000) Fire, resprouting and variability: a recipe for grass-tree coexistence in savanna. *Journal of Ecology,* **88,** 213–229.

JICA – Japan International Cooperation Agency (2005) *Cambodia Reconnaissance Survey Digital Data.* Ministry of Public Works and Transportation, Phnom Penh, Cambodia, and Japan International Cooperation Agency, Tokyo, Japan.

Khurana, E. & Singh, J.S. (2001) Ecology of seed and seedling growth for conservation and restoration of tropical dry forest: a review. *Environmental Conservation,* **28,** 39–52.

Lamotte, S., Gajaseni, J. & Malaisse, F. (1988) Structure diversity in three forest types of north-eastern Thailand (Sakaerat Reserve, Pak Tong Chai). *Biotechnology, Agronomy, Society and Environment,* **2,** 192–202.

Laris, P. (2002) Burning the seasonal mosaic: preventative burning strategies in the wooded savanna of southern Mali. *Human Ecology,* **30,** 155–186.

Marod, D., Kutintara, U., Yarwudhi, C., Tanaka, H. & Nakashisuka, T. (1999) Structural dynamics of a natural mixed deciduous forest in western Thailand. *Journal of Vegetation Science,* **10,** 777–786.

Marod, D., Kutintara, U., Tanaka, H. & Nakashizuka, T. (2002) The effects of drought and fire on seed and seedling dynamics in a tropical seasonal forest in Thailand. *Plant Ecology,* **161,** 41–57.

Martin, M. (1973) Notes on the vegetation of the Cardamom Mountains, Cambodia. *Gardens' Bulletin, Singapore,* **26,** 213–222.

Maxwell, A.L. (2004) Fire regimes in north-eastern Cambodian monsoonal forests, with a 9300–year sediment charcoal record. *Journal of Biogeography,* **31,** 225–239.

McCarthy, G.J., Tolhurst, K.G. & Chatto, K. (1999) *Overall Fuel Hazard Guide.* Fire Management Research Report No.47. Department of Natural Resources and Environment, Melbourne, Australia.

Murphy, P.G. & Lugo, A.E. (1986) Ecology of tropical dry forest. *Annual Review of Ecology and Systematics,* **17,** 67–88.

Mutch, R.W. (1970) Wildland fires and ecosystems--a hypothesis. *Ecology,* **51,** 1046–1051.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. & Kent. J. (2000) Biodiversity hotspots for conservation priorities. *Nature,* **403,** 853–858.

NASA – National Aeronautics and Space Administration/ University of Maryland (2007) *MODIS Active Fire Detections Data Set.* MODIS Rapid Response Project, University of Maryland, College Park, USA. Http://maps.geog.umd.edu [accessed 1 July 2012].

Parr, C.L. & Chown, S.L. (2003) Burning issues for conservation: a critique of faunal fire research in Southern Africa. *Austral Ecology,* **28,** 384–395.

RCG – Royal Government of Cambodia (2006) *Commune Data Source*. Royal Government of Cambodia, Phnom Penh, Camboda.

Roberts, S.J. (2000) Tropical fire ecology. *Progress in Physical Geography,* **24,** 281–288.

Roberts, S.J. (2001) Tropical fire ecology. *Progress in Physical Geography,* **25,** 286–291.

Saha, S. & Howe, H.F. (2003) Species composition and fire in a dry deciduous forest. *Ecology,* **84,** 3118–3123.

Savet, E. (1999) Forest and land fire prevention in Cambodia. *International Forest Fire News,* **20,** 2–5.

Shlisky, A., Waught, J., Gonzalez, M., Manta, M., Santoso, H., Alvarado, E., Ainuddin Nuruddin, A., Rodriguez-Trejo, D.A., Swaty, R., Schmidt, D., Kaufmann, M., Myers, R., Alencar, A., Kearns, F., Johnson, D., Smith, J., Zollner, D. & Fulks, W. (2007) *Fire, Ecosystems and People: Threats and Strategies for Global Biodiversity Conservation.* The Nature Conservancy, Arlington, USA.

Slik, J.W.F., Verburg, R.W. & Kessler, P.J.A. (2002) Effects of fire and selective logging on the tree species composition of lowland dipterocarp forest in East Kalimantan, Indonesia. *Biodiversity and Conservation*, **11,** 85–98.

Stott, P. (1986) The spatial pattern of dry season fires in the savanna forests of Thailand. *Journal of Biogeography,* **13,** 345–358.

Stott, P. (1988) The forest as phoenix – towards a biogeography of fire in mainland South East-Asia. *Geographical Journal,* **154,** 337–350.

Stott, P. (1989) Lessons from an ancient land: Kakadu National Park, Northern Territory, Australia. *Plants Today,* **2,** 121–125.

Stott, P. (1990) Stability and stress in the savanna forests of mainland South-East Asia. *Journal of Biogeography,* **17,** 373–383.

Stott, P. (2000) Combustion in tropical biomass fires: a critical review. *Progress in Physical Geography,* **24,** 355–377.

Stott, P., Goldammer, J.G. & Werner, W.L. (1990) The role of fire in the tropical lowland deciduous forest of Asia. In *Fire in the Tropical Biota: Ecosystem Processes and Global Challenges* (ed. J.G. Goldammer) pp. 32–44. Springer-Verlag, Berlin, Germany.

Sutthivanish, S. (1989) *Effects of fire frequency on vegetation in dry dipterocarp forest at Sakaerat, Changwat Nakhonratchasima.* MSc thesis, Faculty of Forestry. Kasetsart University, Bangkok, Thailand. (In Thai, abstract in English).

Tran C. (2004) *Overall Fuel Hazard Calculator*. Griffith University, Brisbane, Australia.

Van Wilgen, B.W., Andreae, M.O., Goldammer, J.G. & Lindesay, L.J. (1990) Fire management in southern Africa. In *Fire in the Tropical Biota: Ecosystem Processes and Global Challenges* (ed. J.G. Goldammer), pp. 199–203. Springer-Verlag, Berlin, Germany.

Wharton, C. (1966) Man, fire and wild cattle in north Cambodia. *Proceedings of the 5th Annual Tall Timbers Fire Ecology Conference,* **5,** 22–65.

A rapid survey of Odonata on Bokor Plateau, Preah Monivong National Park, Cambodia

Oleg E. KOSTERIN

Institute of Cytology & Genetics of Siberian Branch of Russian Academy of Sciences, Acad. Lavrentyev ave. 10, Novosibirsk, 63090, Russia; and Nobosibirsk State University, Pirogova str. 2, Novosibirsk, 630090, Russia. Email kosterin@bionet.nsc.ru

Paper submitted 28 March 2012, revised manuscript accepted 26 June 2012.

មូលន័យសង្ខេប

ខ្ពង់រាបភ្នំបូកគោ ដែលស្ថិតនៅតំបន់ឆ្នេរនៃប្រទេសកម្ពុជា ទ្រទ្រង់ល្បាយព្រៃពណ៌បៃតងពេញមួយឆ្នាំនៃតំបន់ដីទួលខ្ពស់ៗនិងតំបន់ដីសើម រាប់បញ្ចូលទាំងតំបន់ដីជាំផុះស្លែ ដែលស្ថិតនៅរយៈកំពស់ប្រហែល១,០០០ម។ ទោះបីជាស្ថិតនៅក្នុងឧទ្យានជាតិព្រះមុនីវង្សក៏ដោយ ក៏ការកសាងរមណីយដ្ឋាននៅលើខ្ពង់រាបនាពេលថ្មីៗនេះបានបំផ្លាញតំបន់ដីសើមភាគច្រើនដែរ មុនពេលដែលជីវៈចម្រុះរបស់វាត្រូវបានសិក្សាពេញលេញ។ លទ្ធផលនៃការស្រាវជ្រាវខ្លីៗបីលើក មុនការបាត់បង់តំបន់ដីសើមនៅទីនោះត្រូវបានបង្ហាញនៅពេលនេះ។ ក្នុងរយៈពេល៦ថ្ងៃ កន្ទុំរុយ៤៥ប្រភេទត្រូវបានធ្វើកំណត់ត្រានៅលើខ្ពង់រាបភ្នំបូកគោ (1 Calopterygidae, 1 Euphaeidae, 2 Chlorocyphidae, 2 Lestidae, 11 Coenagrionidae, 1 Platycnemididae, 1 Protoneuridae, 1 Aeshnidae, 2 Corduliidae and 23 Libellulidae) ដែលរួមមានកន្ទុំរុយ១០ ប្រភេទរស់នៅតាមតំបន់ទឹកហូរ និង៣៥ប្រភេទទៀតរស់នៅតាមតំបន់ទឹកនឹង។ ក្នុងរយៈពេលដូចគ្នា មានតែកន្ទុំរុយបួនប្រភេទទេ គឺ *Aciagrion tillyardi, Idyonyx?thailandica, Lyriothemis elegantissima* and *Orthetrumum pruinosum neglectum* ដែលមិនត្រូវបានកត់ត្រានៅរយៈកំពស់ទាបជាង។ ប្រភេទ *Aciagron tillyardi* ទំនងជាបន្តពូជនៅក្នុងទីជម្រកតំបន់ដីជាំផុះស្លែនៅលើខ្ពង់រាប ប៉ុន្តែគ្មានប្រភេទដែលពិតជារស់នៅទីនោះត្រូវបានប្រទះឃើញទេ។ កន្ទុំរុយមិនទាន់ពេញវ័យជាច្រើននៃប្រភេទ *Ceriagrion olivaceum, Neurothemis intermedia, Potamarcha congener* និង *Tholymis tillarga* ត្រូវបានប្រទះឃើញនៅលើតំបន់ខ្ពង់រាបនាខែធ្នូ និងប្រភេទ *Pantala flavescens* នាខែមេសា និងមួយចំនួនរហូតដល់ខែសីហា ដែលភាគច្រើនប្រហែលជាបានហើរមកពីរយៈកំពស់ទាបជាងដើម្បីស្វែងរកចំណី។ គ្មានប្រភេទកម្រ ឬប្រភេទដែលរស់នៅតែក្នុងតំបន់នេះត្រូវបានប្រទះឃើញទេ ប៉ុន្តែ នេះអាចបណ្តាលមកពីការសិក្សាមានរយៈពេលខ្លីពេក។

Abstract

Bokor Plateau, in the coastal area of Cambodia, supports a mixture of upper hill evergreen forest and wetlands, including *Sphagnum* peat-moss bogs, at approximately 1,000 m elevation. Despite being within Preah Monivong National Park, the recent construction of a resort on the plateau has destroyed most of its accessible wetlands before their biodiversity was fully investigated. The findings of three rapid surveys, which preceded the loss of the wetlands, are presented here. During six days in total, 45 species of Odonata (dragonflies and damselflies) were recorded on Bokor Plateau (1 Calopterygidae, 1 Euphaeidae, 2 Chlorocyphidae, 2 Lestidae, 11 Coenagrionidae, 1 Platycnemididae, 1 Protoneuridae,

CITATION: Kosterin, O.E. (2012) A rapid survey of Odonata on Bokor Plateau, Preah Monivong National Park, Cambodia. *Cambodian Journal of Natural History*, **2012,** 75–86.

1 Aeshnidae, 2 Corduliidae and 23 Libellulidae), comprising 10 lotic and 35 lentic species. Only four species, *Aciagrion tillyardi, Idyonyx ?thailandica, Lyriothemis elegantissima* and *Orthetrumum pruinosum neglectum*, were not recorded at lower elevations during the same period. *Aciagron tillyardi* appeared to breed in peat-moss habitats on the plateau, but no obligate peat-moss species were found. Numerous non-breeding individuals of the common species *Ceriagrion olivaceum, Neurothemis intermedia, Potamarcha congener* and *Tholymis tillarga* were found on the plateau in December, and *Pantala flavescens* in April and to a lesser extent in August, most of which had probably dispersed from lower elevations to forage. No very rare or localised endemic species were detected, but this may be explained by the short survey period.

Keywords

Damselflies, dragonflies, Elephant Mountains, protected area, wetlands.

Introduction

Bokor Plateau is the south-easternmost part of the Cardamom Mountains region, within a range known as the Damrei or Elephant Mountains. The plateau reaches up to 1,081 m a.s.l. and, along its southwestern margin, sinks abruptly towards the sea, just 6 km away. It is a moist and foggy plateau throughout the year, clad in upper hill evergreen forest (Fig. 1). This has been described as "a distinctive dwarf forest 5–10 meters in height [...] on the acid and skeletal soils on the sandstone plateau... dominated by *Dacrydium elatum*, with another conifer, *Podocarpus (Dacrycarpus) imbricatus*, also commonly present. Other important associates in this dwarf forest are a variety of Fagaceae and Myrtaceae, *Vaccinium viscifolium*, and *Schima crenata*" (World Wildlife Fund, 2007).

Due to its relatively cool climate, Bokor served as a resort for French colonists and is famous for the ruins of impressive buildings which occupied the highest part of the plateau, called 'Bokor Hill Station' or the 'Station climatique du Bokor'. After the fall of the Khmer Rouge regime (one of the last resistance enclaves was on Bokor), this area attracted many tourists. Preah Monivong National Park was declared in 1993 to protect its unique environment, which harboured a rich flora and fauna, including tigers and elephants.

In 2008, however, the Sokimex Group was granted a lease to 'redevelop' Bokor Hill Station. The extensive construction work (Figs 2–4) aims to establish a resort comprising 3,000 houses plus a number of large buildings (Fig. 2), including a casino (Fig. 4). The first customers arrived in 2012. The construction work has already destroyed a large area of the low upland hill coppice, although a sufficient area of the coppice remains, if not to harbour large mammals then at least to accommodate plant and insect communities. According to the constructors' plans, however, no room is to be left for natural open areas and wetlands, represented by 'veals' (savannah-like areas on acidic sandy soil) and *Sphagnum* mires. Until recently, these open areas harboured *Nepenthes bokorensis* Mey, a carnivorous plant species endemic to the plateau (Mey, 2010), and maybe other unknown endemics. Given that one of the main purposes of a national park is to conserve biodiversity, it is disappointing that these small yet important habitats were allowed to be destroyed.

The wildlife of Cambodia was poorly investigated until recently. This was especially true for Odonata. When I first visited this country in 2006, only 53 species were definitely recorded for Cambodia, chiefly by Martin (1904) and Asahina (1967) (for a short overview see Kosterin, 2010, 2011). Of these, only three species were reported by Asahina (1967) for Bokor: *Aciagrion occidentale* Laidlaw, 1919 (probably a misidentified *A. borneense* Ris, 1911), *Ischnura senegalensis* (Rambur, 1842) and *Neurothemis intermedia* (Rambur, 1842). In recent years, Cambodian Odonata have been studied more actively (Kosterin & Vikhrev, 2006; Benstead, 2006; Roland & Roland, 2010; Kosterin, 2010, 2011, 2012; Roland *et al.*, 2011; Day, 2011; Kosterin & Holden, 2011) and the number of named species recorded in Cambodia has increased to 125.

I have made three trips to survey the Odonata of the Cardamom Mountains, in April 2010 (Kosterin, 2010), November-December 2011 (Kosterin, 2011) and August 2011 (Kosterin, 2012). On my first visit, I spent just two hours on Bokor Plateau, and on the second I spent three days and made a good examination of diverse habitats. On my third visit, for two days, I witnessed the best of the wetlands being destroyed (Figs 5–8). The data I collected during a total of six days on Bokor are therefore very incomplete, but worth presenting here. All in all, we have a sad situation when a unique nature monument is lost before it has been fully studied.

Methods

Odonata were surveyed on foot during the daytime on 23 April 2010, 8–10 December 2010 and 18–19 August

2011. The locations examined were along and close to the road from Bokor Palace through the pagoda to the Popokvil Waterfall. In previous reports (Kosterin, 2011, 2012), I ascribed names to some of the ponds and bogs, mostly after Odonata. Coordinates and elevations were retrieved from GoogleEarth.

1. Rangers' Pond: an artificial pond at the rangers' station, partly with stone banks and some grassy seepages nearby, from 10°37′33″N, 104°01′29″E to 10°37′34″N, 104°01′37″E, 1,030 m. Studied on 23 April 2010 and 9 December 2010.
2. Neglectum Brook: a small stream with brown water and a sandstone bed near the constructor's hostel, mostly hidden in coppice, with an open roadside section. 10°37′52″N, 104°01′21″E, 1,034 m. Studied on 23 April 2010 and 8–10 December 2010.
3. Old Road: a section of the original road, with some *Sphagnum* mats at roadside holes and small pools. 10°37′53″N, 104°01′18″E to 10°37′58″N, 104°01′26″E, 1,030–1,034 m. Studied on 8–10 December 2010.
4. Praemorsus Pond: a small, 2–metre deep and rather cold roadside pond with grassy banks, 2.9 km Northeast of Bokor Palace. 10°38′44″N, 104°02′21″E, 926 m. Studied on 9–10 December 2010. On 18 August 2011, the pond was still present, but its banks had been destroyed by extensive road improvements.
5. Minutissima Pit: very shallow pools over a sandy, bulldozered ground near Praemorsus Pond, with many flowering *Utricularia minutissima* Wahl. when visited, 2.9 km Northeast of Bokor Palace, 10°38′46″N, 104°02′24″E, 923 m. Studied on 18 August 2011.
6. Bokorensis Mire (Fig. 7): a large, 0.4 x 0.5 km, *Sphagnum* bog covered mostly with Cyperaceae, Juncaceae, Poaceae grasses, with very abundant club mosses, scattered shrubs, including *Vaccimium* spp., and numerous individuals of the pitcher plant *Nepenthes bokorensis*. Water levels range from 50 cm deep, with floating *Sphagnum* and submerged Juncaceae, through shallow pools with *Sphagnum*, to rather dry places with bracken. 3.0–3.7 km Northeast of Bokor Palace. 10°38′47″N, 104°02′11″E to 10°39′02″N, 104°02′24″E, 923 m. Studied on 9–10 December 2010 and 18–19 August 2011. In the latter two days, an excavator was seen digging a ditch to dry this bog out (Fig. 8).
7. Roadside pools, with open water and grassy banks, at Bokorensis Mire. From 10°38′52″N, 104°02′22″E to 10°39′02″N, 104°02′24″E, 923 m. Studied on 9 December 2010.
8. Odorata Road: an old sandy road through a veal between Bokorensis Mire and Limbata Ponds, seeping with shallow water. When visited, this site had many flowering *Utricularia odorata*. 3.6 km Northeast of Bokor Palace, 10°39′03″N, 104°02′14″E to 10°39′13″N, 104°02′26″E, 921–927 m. Studied on 18–19 August 2011.
9. Lyriothemis Pools: a chain of shallow "black" stagnant pools, connected via a tiny brook, in a rather tall forest at the Popokvil River right bank. 10°39′14″N, 104°02′15″E, 928 m. Studied on 18–19 August 2011.
10. Aciagrion Swamplet: a natural, knee-deep small swamp densely overgrown with a tussock sedge (*Carex* sp.) in the same forest near the Popokvil River bank. 10°39′17″N, 104°02′13″E, 922 m. Studied on 19 August 2011.
11. Idionyx Reach (Fig. 9): on the Popokvil River upstream of the upper bridge where there are several huts on the left bank, with a sandy bed and varying depth (from very low to about a knee-deep) and speed. The water here is dark red to black due to humic acids, and carries a thick, brownish foam. 3.6–3.9 km Northeast of Bokor Palace 10°39′12″N, 104°02′12″E to 10°39′19″N, 104°02′21″E, 925–932 m. Studied on 19 August 2011.
12. Limbata Ponds (Fig. 5): two large, but shallow (to 0.5 m) ponds, with sparse emerging grass (mostly large Cyperaceae), formed by a small brook flowing to the nearby Popokvil River near the upper bridge. 3.7 km Northeast of Bokor Palace. 10°39′04″N, 104°02′35″E, to 10°39′06″N, 104°02′39″E, 920m. Studied on 10 December 2010. On 18–19 August 2011, I witnessed heavy goods vehicles discharging soil over the ponds (Fig. 6).
13. The Popokvil River at an open area by the upper bridge, 3.9 km Northeast of Bokor Palace. 10°39′06″N, 104°02′43″E, 920 m. Studied on 18–19 August 2011.
14. The Popokvil River between the two bridges, adjacent to wide new roads through the forests, in some places seeping with water, and with an open area covered in bracken at the lower bridge. 3.9–4.9 km Northeast of Bokor Palace, 10°39′06″N, 104°02′43″E to 10°39′30″N, 104°03′09″E, 916–926 m. Studied on 18–19 August 2011.
15. The Popokvil River between the lower bridge and the waterfall (Fig. 10): powerful rapids above a rocky bed with low trees on the banks and in the water, and a slow side tributary with stony bed. 4.9 km Northeast of Bokor Palace. 10°39′30″N, 104°03′04″E to 10°39′30″N, 104°03′06″E, 912–918 m. Studied on 9 December 2010 and 18–19 August 2011. By August 2011, the foundation of a large building had been constructed just above the waterfall.
16. The Popokvil River downstream of the waterfall: a broad rocky valley descending through the tall primary forest at quite an angle. 4.9 km Northeast of Bokor Palace. 10°39′32″N, 104°03′04″E, to 10°39′34″N, 104°03′04″E, 912–918 m. Studied on 9 December 2010.

Photos of Odonata in their natural environments were taken with an Olympus Camedia C8080 digital camera, without restricting the individual's freedom or making any attempts to otherwise influence their behaviour.

Results

In the following text, 'April', 'December' and 'August' denote 23 April 2010, 8–10 December 2010 and 18–19 August 2011, respectively. Species marked as being 'on dispersal' were non-breeding individuals in December that were not associated with water bodies. It is possible that some of the other species observed on the plateau were also in their dispersal phase and do not breed here.

Calopterygidae

1. *Vestalis gracilis* (Rambur, 1842)

Common around bushes and low tree branches on the banks of the Popokvil River, plus three individuals were

Fig. 1 Upper hill evergreen forest at Bokor Hill Station, still relatively undisturbed on 8 December 2010 (© O. Kosterin).

Fig. 2 Model of the town under construction on Bokor Plateau, in a new pavilion near the pagoda (© O. Kosterin).

Fig. 3 Construction on the Bokor Plateau. 'Improvement' of a road to the Popokvil Waterfalls (© O. Kosterin).

Fig. 4 The new casino under construction, on 18 August 2011 (© O. Kosterin).

Fig. 5 Limbata Ponds, still intact on 10 December 2010 (© O. Kosterin).

Fig. 6 Limbata Ponds being filled in with soil on 18 August 2011 (© O. Kosterin).

Fig. 7 Bokorensis Mire, a large *Sphagnum* bog, still intact on 9 December 2010 (© O. Kosterin).

Fig. 8 Bokorensis Mire being drained on 18 August 2011 (note white flowers of an *Arundina* orchid) (© O. Kosterin).

Fig. 9 The Popokvil River: showing the Idionyx Reach on 19 August 2011 (© O. Kosterin).

Fig. 10 The Popokvil River: showing the rapids above the waterfall on 19 August 2011 (© O. Kosterin).

Fig. 11 The Popokvil Waterfall on 19 August 2011 (© O. Kosterin).

Fig. 12 A teneral female *Vestalis gracilis* at the rapids above the Popokvil Waterfall, 18 August 2011 (© O. Kosterin).

Fig. 13 A perching male of *Lestes praemorsus decipiens* at Praemorsus Pond, 9 December 2010 (© O. Kosterin).

Fig. 14 A copula of *Aciagrion tillyardi* at Aciagrion Swamplet, 19 August 2011 (© O. Kosterin).

found at Neglectum Brook in April, but not in December and August. Individuals congregate, with up to several tens on a bank. In August they were immature with clear wings, two teneral individuals (Fig. 12) being encountered. In April they were mature, with the wingtips having a dark brown enfumation.

Euphaeidae

2. *Euphaea masoni* Selys, 1879

Found just upstream (two males, one female, 19 August 2011) and downstream (one male, 9 December 2010) of the Popokvil Waterfall. These individuals were slightly larger than those found at low elevations in Koh Kong Province (Kosterin, 2011). The male collected downstream of the waterfall was an aberration with clear wings without wingspots, but with slight, diffuse and uneven shades of dark pigmentation (Fig. 69 in Kosterin, 2011).

Chlorocyphidae

3. *Aristocyhpa fenestrella* (Rambur, 1842)

Several males perched on rocks around pools of the Popokvil River, downstream of the waterfall on 9 December 2010.

4. *Heliocypha biforata biforata* (Selys, 1859)

One male found at the same location as above, but on bushy vegetation, as expected for this species. Unexpectedly, a teneral male was found at the Lyriothemis Pools in forest shade, obviously having dispersed from a nearby calm section of the Popokvil River. Even more unexpected was a female of the Chlorocyphidae family in grass at the walls of the Bokor Palace, a place unfit for representatives of this family, on 8 December 2010.

Lestidae

5. *Lestes concinnus* Hagen in Selys, 1862

In December, this species was common in sedges in small roadside bogs in open areas at Bokor Hill Station (five individuals observed on 8 December 2010) and Bokorensis Mire (11 individuals observed during two hours of walking on 9–10 December 2010), not recorded in August.

6. *Lestes praemorsus decipiens* Kirby, 1893 (Fig. 8)

In December, males were present around the Praemorsus Pond and Limbata Ponds (several individuals observed at each), where they perched on emerging vegetation. In August they were recorded at shallow, slightly disturbed water bodies such as Minutissima Pit. Three teneral males were found at Limbata Ponds on 10 December 2010 and a teneral female at the Popokvil River near the upper bridge on 18 August 2011.

Coenagrionidae

7. *Aciagrion borneense* Ris, 1911

(Asahina, 1967, as *Aciagrion occidentale* Laidlaw, 1919: 1 male, Bokor, 2.XII.1964). Common in December, occurring mostly among coppices during dispersal, but also recorded in sedges on the banks of Praemorsus Pond and at pools of Bokorensis Mire, which might serve as breeding places. Only one female recorded on Odorata Road in August (18 August 2011).

8. *Aciagrion tillyardi* Laidlaw, 1919 (Fig. 14)

In December, very numerous at the Praemorsus Pond and Limbata Ponds (three males were observed at the former on 18 August, even though it had already been destroyed), and on the shaded banks of the Popokvil River upstream of the waterfall. However, no individuals were found on the banks of the main river. In August this species was even more numerous, extending to any stagnant water bodies, both moderately disturbed (e.g. Minutissima Pit and Odorata Road), and undisturbed (e.g. Aciagrion Swamplet). Copulae and tandems were observed at Praemorsus Pond in December and Aciagrion Swamp in August. A teneral male made its maiden flight from a roadside hole filled with wet *Sphagnum* at Old Road on 8 December 2011. Teneral males and females were found at an open place with boulders and bracken just upstream of the Popokvil Waterfall.

The ground colour of mature individuals was saturated blue to greenish blue. This corresponds to information on specimens from Assam, where the species was described (see discussion in Kosterin, 2012) – not violet, as in Hong Kong (Wilson, 2000) or North Thailand (Dennis Farrell, pers. comm.).

9. *Agriocnemis nana* (Laidlaw, 1914)

An immature (red stage) female recorded at Odorata Road on 18 August 2011.

10. *Agriocnemis pygmaea* (Rambur, 1842)

Common in grass near Rangers' Pond in December. Present, but unexpectedly scarce, in pools of Bokorensis Mire.

11. *Archibasis viola* Lieftink, 1948

A shade-preferring species. On 18–19 August 2011, a mature male hovered above the running water of a shady Idionyx Reach (a typical habitat for this species), one found flying above Lyriothemis Pools in forest shade, and one at Aciagrion Swamplet. A teneral male found in unexpected habitat, at a small pool at Bokorensis Mire on 9 December 2010.

12. *Ceriagrion calamineum* Lieftink, 1951

Scarce mature males were found in breeding places in Bokorensis Mire (one on 9 December 2010) and Limbata Ponds (three on 10 December 2010). None found in August.

13. *Ceriagrion cerinorubellum* (Brauer, 1865)

A male found at a tiny brook at the ranger's station on 23 April 2010, at Minutissima Pit on 18 August 2011, and five teneral individuals on Bokorensis Mire were disturbed during two hours of walking on 9–10 December 2010.

14. *Ceriagrion olivaceum* Laidlaw, 1914

On dispersal. Very numerous individuals of both sexes, showing no interest in water bodies or each other, were observed in December in all open places, whether dry or wet (but seemed less frequent on Bokorensis Mire). These individuals had probably migrated from lower elevations beneath the plateau escarpment.

15. *Ischnura senegalensis* (Rambur, 1842)

(Asahina, 1967: 1 male, Bokor, 4.XII.1964). Common at the Rangers' Pond. In December, this was the only odonate at the black pools where brooks had been crossed by new roads, and also at Neglectum Brook. Present in roadside pools at Bokorensis Mire, and plentiful at the Limbata Ponds.

16. *Pseudagrion australasiae* Selys, 1876

In December, males perched on emergent vegetation at Praemorsus Pond (only one male observed) and Limbata Ponds (many), and one was recorded at a roadside pool in Bokorensis Mire. A few males and tandems were found perching on sticks emerging from water of the Popokvil River (open reach at the upper bridge), both in December and August.

17. *Pseudagrion pruinosum* (Burmeister, 1839)

Males and tandems were common above the water of the Popokvil River – frequent along open reaches and infrequent in shaded ones – but only in August. This species was more abundant than other *Pseudagrion* spp. in August, but scarce in December: the same pattern was also observed at lower elevations in Koh Kong Province.

Platycnemididae

18. *Copera vittata* (Selys, 1863)

Found in its typical habitat at small black pools in the shade of coppices (a female on 9 December 2010 at the brook forming Praemorsus Pond) or forest (tandems, males and immature 'ghost forms' at the Lyriothemis Pools on 18–19 August 2011), at the Popokvil River above the waterfall (a male and immature individual, 18 August 2011) and on shady moist cliffs downstream ('ghost' immature, 9 December 2010).

Protoneuridae

19. *Prodasineura autumnalis* (Fraser, 1922)

A male observed hovering over the water of Popokvil River between the bridges, a typical habitat for this species, on 19 August 2011.

Aeshnidae

20. *Anax guttatus* (Burmeister, 1839)

Ranging males were observed over Rangers' Pond (23 April 2010), above Odorata Road (18 August 2010) and above the road between the bridges at the Popokvil River (19 August 2011). A female oviposited into winding submerged vegetation (Fig. 15) in the shallow open reach of this river at the upper bridge.

From neighbouring Thailand, two similar species of *Anax* have been recorded (Yeh, 1999), *A. indicus* Lieftink, 1942 and *A. panybeus* Hagen, 1867. The males observed in Bokor were not examined, but the above-mentioned female was examined in the hand and its key characters can also be seen in Fig. 15. Unlike *A. panybeus,* its has no black T-shaped spot or any other black mark on the frons. Unlike *A. indicus*, the lateral light spots on abdominal segments were small and not fused into lateral bands on segments 6–8 (but the author of the latter species, Lieftink, 1942, reported this character only for males). In Thailand, A. *indicus* is restricted to the North (Yeh, 1999; Day *et al.*, 2011), so it is not expected to occur in southern Cambodia.

Corduliidae *sensu lato*

21. *Idionyx ?thailandica* (Hämäläinen, 1985) (Fig. 16)

A teneral female commenced its maiden flight from a shaded bank of Idionyx Reach of the Popokvil River on 19 August 2011, and landed on the leaves of bushes and palm fronds. Females in this genus, which is rich in similar species, allow for only tentative identification, but I collected a male of *I. ?thailandica* in a jungle brook in Kep, 33 km East-Southeast from Bokor.

22. *Hemicordulia* sp.

This undescribed Indochinese species is very close to *Hemicordulia tenera* Lieftink, 1930, and has also been found in the Loei and Chiang Mai Provinces of Thailand (Kosterin, 2011, 2012). It is to be described elsewhere.

Two males were observed on 19 August 2011 patrolling half-shaded reaches (including Idionyx Reach, Fig.

Fig. 15 Female *Anax guttatus* laying eggs in submerged vegetation in the Popokvil River, 19 August 2011 (© O. Kosterin).

Fig. 16 Teneral female *Idionyx ?thailandica* on a bank on the Idionyx Reach, 19 August 2011 (© O. Kosterin).

Fig. 17 Perching male *Lyriothemis elegantissima* at Aciagrion Swamplet, 19 August 2011 (© O. Kosterin).

Fig. 18 Female *Neurothemis fulvia* on a road by the Popokvil River, 19 August 2011 (© O. Kosterin).

9) with slow to moderate currents, and sandy beds of the Popokvil River from 1000h. At 1300h – 1320h on 18 August 2011, during overcast weather between rains, about five patrolling males appeared over the shallowest pools with sandy bottoms and over the water flowing over the Odorata Road crossing a large veal, with a sedgy small brook nearly. This looked like some unusual outburst, for they were absent from this point both before, during 1150h – 1210h, and after 1530h, as well as on the next day at 0848h, 1100h and 1530h, in spite of the weather varying from short sun through overcast to drizzling rain.

At 1020h on 19 August 2011, a patrolling male appeared above Lyriothemis Swamplet, which was filled with a tussock sedge that left no open water. In Decem-

Fig. 19 Male *Orthetrum pruinosum neglectum* at Neglectum Brook, 8 December 2010 (© O. Kosterin).

ber, there was just one sighting of this species flying for a while above the Praemorsus Pond (9 December 2010).

Libellulidae

23. *Brachythemis contaminata* (Fabricius, 1793)

In December, several individuals were found at roadside pools in Bokorensis Mire, many at the Limbata Ponds nearby, and one at the open reach of the Popokvil River by the lower bridge.

24. *Crocothemis servilia* (Drury, 1770)

One territorial male of this common species was observed at Rangers' Pond on 23 April 2010 and one at the Limbata Ponds on 18 August 2011.

25. *Diplacodes nebulosa* (Fabricius, 1793)

A male and female were found in grassy seepages at Rangers' Pond in April. This species was common in Bokorensis Mire and occurred at the Limbata Ponds in December.

26. *Diplacodes trivialis* (Rambur, 1842)

Common at open places in coppice, tending to rocks, in December, probably on dispersal. This species also occurred in wetlands, e.g. Bokorensis Mire and Limbata Ponds, where it could probably breed.

27. *Indothemis limbata* (Selys, 1891)

About 10 reproductive males were perched on emergent vegetation at Limbata Ponds on 10 December 2010, and moved to surrounding grass when disturbed. Two females were observed nearby.

28. *Lyriothemis elegantissima* Selys, 1883 (Fig. 17)

Found in August in small forest pools and tiny brooks with black water and a bed of leaf litter (a typical habitat of the species) at Lyriothemis Pools and Aciagrion Swamp. At both sites, two males were observed perching on bush branches at 2–3 m above the ground or flying above the pools and chasing each other. At the former site, a female was seen ovipositing into mud at the edge of a pool.

29. *Nannophya pygmaea* Rambur, 1842

This species is more or less connected with grassy bogs. One male was found in grass at the Limbata Ponds on 10 December 2010. In August this species was common around shallow waters in open areas, e.g. Minutissima Pit and Odorata Road.

30. *Neurothemis fluctuans* (Fabricius, 1793)

Surprisingly few individuals of this elsewhere very common species were found. One male was recorded at Neglectum Brook on 23 April 2010 and one at Minutissima Pit on 18 August 2011.

31. *Neurothemis fulvia* (Drury, 1773) (Fig. 18)

Only one female (of this usually common species) was recorded on a roadside between the bridges across the Popokvil River.

32. *Neurothemis intermedia atalanta* Ris, 1919

(Asahina, 1967, as *N. intermedia degeneer* Selys (?): 1 female, Bokor, 2.XII.1964). On dispersal. Numerous immature (males still yellowish) individuals were observed in coppices in December.

33. *Neurothemis tullia tullia* (Drury, 1773)

Several individuals recorded at grassy seepages at Rangers' Pond, together with *D. nebulosa* (these species often occur together).

34. *Orthetrum chrysis* (Selys, 1891)

In December, several males kept to the open Popokvil River reach at the upper bridge. On 10 December 2010, an ovipositing female, guarded by a male, was observed. A male was seen at engraved sandstone rocks at Neglectum Brook on 23 April 2010 (but not in December or August), and another at the forest edge at Lyriothemis Pools.

35. *Orthetrum glaucum* (Brauer, 1865)

Two matching males patrolled along, and perched on stones near, a tiny temporary brook in a ditch along the newly widened road by Praemorsus Pond. Small streams are the typical habitat of this species, but this was among the smallest ones.

36. *Orthetrum pruinosum neglectum* (Rambur, 1842) (Fig. 19)

This species occurred and bred in the same locations as *O. chrysis,* but was less abundant. A male was recorded on the small Neglectum Brook on 8 December 2010, where one *O. chrysis* was also recorded. Another male, which captured a female into copula, was observed on 9 December 2010 on the Popokvil River at the upper bridge.

37. *Orthetrum sabina* (Drury, 1770)

Elsewhere this is a common species, but only a few individuals were encountered in August. Most were away from water, but this species was also observed in the Limbata Ponds site.

38. *Pantala flavescens* (Fabricius, 1798)

Large swarms containing several dozens of individuals were observed at the lee sides of French Ruins on 23 April 2010. Small swarms of young, light-coloured individuals were recorded here and there in August, but only a few individuals were registered above the Popokvil River (plus one dead female in a pool at Rangers' Pond) during three observation days in December (although the species was extremely abundant near sea level in Kep at this time). These individuals may have been on dispersal, or may breed in the many shallow pools on the plateau.

39. *Potamarcha congener* (Rambur, 1842)

On dispersal. Recorded only in December when numerous immature individuals (mostly females), indifferent to water, perched on bush branches behind the wind. At least one in view from almost every point in the coppices.

40. *Rhyothemis variegata* (Linnaeus, 1763)

One gynochromic female joined a large swarm of *Pantala flavescens* on 23 April 2010.

41. *Tholymis tillarga* (Fabricius, 1798)

On dispersal. Observed only in December, but in abundance, represented mostly (seemingly excusively) by females, which occurred everywhere at openings in the coppice. They were often observed flying even in daytime (e.g. above the Praemorsus Pond), even though the species is mostly crepuscular and more active in the evening. Not found in April and August.

42. *Tramea transmarina euryale* Selys, 1878

A male ranged over the road to Popokvil Waterfall on 9 December 2010.

43. *Trithemis aurora* (Burmeister, 1839)

Common at Rangers' Pond in April, and the Limbata Ponds and open reaches of the Popokvil River. In August, this species was also seen at Minutissima Pit and other shallow pools.

44. *Trithemis festiva* (Rambur, 1842)

Several males perched on stones at the Popokvil River at the upper bridge in December, and one was recorded here in August.

45. *Trithemis pallidinervis* (Kirby, 1889)

Recorded at Rangers' Pond (23 April 2010) and Limbata Ponds (10 December 2010), with one perching male at each.

In addition, there was an uncertain sighting of a gomphid at Neglectum Brook on 23 April 2010 and of a libellulid, most probably *Macrodiplax cora* (Brauer, 1867), at the Limbata Ponds on 10 December 2010. While ascending the Plateau on 8 December 2010 under the canopy on the tall forest on its southwestern slope, I recorded many individuals of *Lestes elatus* Hagen in Selys, 1862 and an individual of *Gynacantha* sp. They were not included into the main list because they represented a very briefly visited biotope that was quite different from top surface of the plateau.

Discussion

No doubt the list of 45 species is incomplete, and at least twice as many species would be expected on the Bokor Plateau in its natural state. However, Bokor Hill Station has now lost its veals and unique wetlands. This paper therefore summarises the scanty data I managed to collect shortly before the best natural habitats were lost.

In the future, the Popokvil River may retain some interesting lotic species, but will inevitably be polluted by the town being constructed there. The developers plan to make large artificial ponds in the town, which will support a handful of common and widespread lentic species (as the pond at the rangers' station already does). The Bokor Plateau is large and still hides interesting habitats, although none of them as easily accessible as Bokor Hill Station. They are worth being investigated.

Although the upper hill evergreen low forest of the Bokor Plateau is very distinct from the lowland tall forest in many respects, including its short height, low density and tree species composition, the overwhelming majority of Odonata species on Bokor appeared unexpectedly common. For instance, Libellulidae comprised almost half (22) of the species list. The list contains one undescribed species of *Hemicordulia* which, however, enjoys quite a substantial range in Thailand and Cambodia (Kosterin, 2011). It is noteworthy that only four of the species recorded on Bokor have not been found during similar times of year below 300 m a.s.l. in Koh Kong Province (Kosterin, 2010, 2011, 2012): *Aciagrion tillyardi, Idionyx ?thailandica, Lyriothemis elegantissima* and *Orthetrumum pruinosum*. Of these, however, *I. thailandica* was found at c. 100m a.s.l. in Kep, Kep Province (Kosterin, 2012), and *O. pruinosum* is quite common at low elevations in Thailand (Hämäläinen & Pinratana, 1999). The range of *Aciagrion tillyardi* extends to Assam, continental Thailand and South China (Guanxi, Guandong, Hong Kong) (Wilson, 2000), and *L. elegantissima* ranges through South China (including Taiwan) and has been found on one occasion in Central Thailand (Hämäläinen & Pinratana, 1999; Tsuda, 2000). The last two species may be supposed to be somewhat more 'northern' than the rest of the list, and hence have been found in Cambodia only on an elevated and cool plateau.

In spite of the presence of many small streams and the large Popokvil River, of 42 species recorded, only 10 species may be considered as obligatory lotic, namely *Vestalis gracilis, Euphaea masoni, Aristocyhpa fenestrella, Heliocypha biforata, Archibasis viola, Pseudagrion pruinosum, Prodasineura autumnalis, Idionyx ?thailandica, Hemicordulia* sp. and *Orthetrum glaucum*. Lentic species are generally more numerous and widespread than lotic species. The lack of representatives of the very diverse and mostly lotic family Gomphidae, except for one unidentified sighting, was disappointing. I expected to find some Odonata species specialised on *Sphagnum* peat-moss bogs, which were a remarkable feature of Bokor Plateau. So far, only *Aciagrion tillyardi* may be roughly considered as a peat-moss species. Although common in most lentic water bodies in the plateau, it was recorded emerging from a small, almost waterless pool covered with *Sphagnum*. This species has not been registered from elsewhere in Cambodia. In Hong Kong, it has also been found in "a hilly wet marsh area" and is said to accompany *Nannophya pygmaea* in Guangxi, Guandong and Hong Kong (Wilson, 2000), as is the situation on Bokor Plateau. In Koh Kong Province, *N. pygmaea* was observed on grassy swampy areas, but also extended to small, clear rivulets on the edges of forest (Kosterin, 2011, 2012).

It was interesting to observe that Bokor Plateau accumulates amazingly numerous individuals of certain common lowland species, such as *Ceriagrion olivaceum*, *Potamarcha congener* and *Tholymis tillarga* in December and *Pantala flavescens* in April and August (but not in December, when it was numerous at low elevations along with the aforementioned three species). It is likely that these dragonflies, with the possible exception of *P. flavescens*, breed at lower elevations, probably beneath the southern cliffs of Bokor Plateau where suitable lentic breeding places are abundant (but the breeding habitat of *C. olivaceum* is unknown: for discussion see Kosterin, 2011). Hence, they appear to have vertical seasonal migrations.

The rather unique peat-moss bogs occupy a restricted area on the Bokor Plateau and appear isolated from analogous communities elsewhere, being surrounded by upper hill evergreen forest. It is therefore surprising that the survey found common species here, rather than localised species with small or disjunctive ranges. No doubt this mismatch is a bias of too brief a survey, and the most interesting species that should exist in such habitats remain to be revealed. Localised and disjunctive species in such families as the Platystictidae, Gomphidae, Chlorogomphidae and Corduliidae tend to be seasonal, rare and elusive. Seasonal changes are scarcely expressed on the plateau, while the misty weather is generally unfavourable round the year for adult odonates to be active. This makes it impossible to predict where or when putative species of the aforementioned families, if any, would be found. To fully survey the Odonata of Bokor Plateau is therefore a difficult task that demands a lot of time. Unfortunately, construction work on the plateau means that time has now run out.

Acknowledgements

The work was supported by grants nos 61, 64 and 72 of the International Dragonfly Fund (IDF). I am grateful to my companions who visited Bokor – Natalya Priydak in April 2010, Nikita Vikhrev in December 2010 and François Sochom Mey and Alastair Robinson in August 2010 – to François and Alastair also for identification of some plant species, and to Hanns-Jürgen Roland for his help and efforts in summarising the old and recent records of Odonata in Cambodia. I am indebted to the four anonymous referees for valuable comments and improving the text.

References

Asahina, S. (1967). The Odonata of Cambodia chiefly taken by the Osaka City University expedition in 1964–1965. *Nature and Life in South-East Asia*, **5,** 209–215.

Benstead, P. (2006) Casual observations of Odonata recorded in Cambodia in 2005 and 2006. *Malangpo*, **21,** 218–220.

Day, L. (2011) Odonata seen in Tatai, Koh Kong Province, Cambodia. *International Dragonfly Fund Report*, **42,** 1–6.

Day, L., Farrell, D., Guenther, A., Hamalainen, M., Klimsa, E., Korshunov, A., Kosterin, O., Makbun N., Pelegrin, A., Roeder, U., Ruangrong, R. & Vikhrev, N. (2012) New provincial records of Odonata from Thailand mostly based on photographs. *Agrion*, **16,** 16–24.

Hämäläinen, M. & Pinratana, A. (1999) *Atlas of the Dragonflies of Thailand: Distribution Maps by Provinces*. Brothers of St. Gabriel in Thailand, Bangkok, Thailand.

Kosterin, O.E. (2010) A glance at the Odonata of the Cambodian coastal regions: end of dry season in 2010. *International Dragonfly Fund Report*, **29,** 1–75.

Kosterin, O.E. (2011) Odonata of the Cambodian coastal regions revisited: beginning of dry season in 2010. *International Dragonfly Fund Report*, **40,** 1–108.

Kosterin, O.E. (2012) Odonata of the Cambodian coastal regions in late rainy season of 2011. *International Dragonfly Fund Report*, 45, 102.

Kosterin, O.E. & Holden, J. (2011) Some photographic records of Odonata in Cambodia. *International Dragonfly Fund Report*, **42,** 1–6.

Kosterin, O.E. & Vikhrev, N.E. (2006) Odonata seen during three days in a populated lowland part of Cambodia. *Malangpo*, **21,** 212–217.

Martin, R. (1904) Liste des Névroptères de l'Indo-Chine. In *Mission Pavie Indo-Chine 1879–1895. Études diverses. III. Recherses sur l'Historie Naturelle de l'Indo-Chine Orientale* (A. Pavie), pp. 204–221. Emest Leroux, Paris, France.

Mey, F.S. (2010) Introduction to the pitcher plants (*Nepenthes*) of Cambodia. *Cambodian Journal of Natural History*, **2010,** 106–117.

Roland, H.-J. & Roland, U. (2010) New records of Odonata on a birding trip to Cambodia 12th-26th February 2010. *Agrion,* **14,** 30–33.

Roland, H.-J., Sacher, T. & Roland, U. (2011) New records of Odonata for Cambodia – results from a trip to various places of the country November 14th – December 1st 2010. *International Dragonfly Fund Report*, **35,** 1–22.

Tsuda, S. (2000) *A Distributional List of World Odonata*. Shigeru Tsuda, Osaka, Japan.

Wilson, K.D.P. (2000) *Aciagrion tillyardi* (Odonata: Zygoptera), a damselfly new to Hong Kong. *Porcupine*, **21,** 9–10.

World Wildlife Fund (2007) Cardamom Mountains Rainforests. In (ed. C.J. Cutler) *Encyclopedia of Earth*. Environmental Information Coalition, National Council for Science and the Environment, Washington, DC. Http://caaltd.org/Rainforest/Cambodia/CaramonMountains.aspx [accessed 1 July 2012].

Yeh, W.C. (1999) Notes on three aeshnid species from Thailand. *Malangpo*, **16,** 144–145.

About the author

OLEG ENGELSOVICH KOSTERIN was born in Omsk, but entered Novosibirsk State University and since then has been living in Novosibisrk (both cities in West Siberia, Russia). Since finishing university, he has worked at the Institute of Cytology and Genetics of the Siberian Branch of the Russian Academy of Sciences. His main occupation is plant genetics, with research interests also including molecular genetics, phylogeography, faunogenesis in North Asia, speciation and evolutionary theory. In parallel, he is an active odonatologist, mostly focusing on the dragonfly fauna of Siberia and, in the last seven years, Southeast Asia. He has produced a number of publications and described new subspecies of butterflies and co-authored two books on the butterflies in the Asian part of Russia. At present he is attempting to investigate the still scarcely-known Odonata fauna of Cambodia.

Recent literature from Cambodia

This section summarizes recent scientific publications concerning Cambodian biodiversity and natural resources. The complete abstracts of most articles are freely available online (and can be found using Google Scholar or other Internet search engines), but not necessarily the whole article. Authors are usually willing to provide free reprints or electronic copies of their papers on request and their email addresses, where known, are included in the summaries below.

If you or your organisation have recently published a technical paper or report that you would like to be listed in the next issue, please send an electronic copy, summary or Internet link to Editor.CJNH@gmail.com

New species and taxonomic reviews

Blanco, S., Alvarez-Blanco, I., Cejudo-Figueiras, C. & Becares, E. (2012) Contribution to the diatom flora of Cambodia: five new recent freshwater taxa. *Journal of Systematics and Evolution,* **50,** 256–266.

Cambodia's aquatic ecosystems are very diverse, but their algae are poorly understood. Several unknown diatoms were found in artificial lakes around the Angkor and Banteay Srei temples in 2010, five of which are described here as new to science: *Pinnularia cambodiana, P. shivae, Gomphonema angkoricum, G. paradaphnoides* and *Frustulia lacus-templi*. The ecological and environmental implications of these findings are briefly discussed. Author: sblal@unileon.es

Geissler, P., Hartmann, T. & Neang T. (2012) A new species of the genus *Lygosoma* Hardwicke & Gray, 1827 (Squamata: Scincidae) from northeastern Cambodia, with an updated identification key to the genus *Lygosoma* in mainland Southeast Asia. *Zootaxa,* **3190,** 56–68.

A new species of lizard, *Lygosoma veunsaiensis* sp. nov., is described from northeastern Cambodia based on a single voucher specimen from the Veun Sai Proposed Protected Forest, Veun Sai District, Ratanakiri Province. A key to the Southeast Asian mainland species of *Lygosoma* is provided. Author: pgeissler84@yahoo.de

Kosterin, O.E. (2012) Odonata of the Cambodian coastal regions in late rainy season of 2011. *International Dragonfly Fund Report,* **45,** 1–102.

A survey of dragonflies and damselflies in coastal Southwest Cambodia identified 87 species, of which 15 were new records for Cambodia: *Aciagrion hisopa, Anax immaculifrons, Burmagomphus divaricatus, Gomphidictinus perakensis, Merogomphus parvus, Nepogomphus walli, Idionyx thailandica, Macromia cupricincta, M. septim, Macromidia rapida, Agrionoptera insignis, Lyriothemis elegantissima, Onychothemis testacea, Orthetrum luzonicum* and *O. testaceum*. The national list of Odonata now stands at 125 named species. Authot: kosterin@bionet.nsc.ru

Morino, H. (2012) A new species of *Kamaka* (Amphipoda: Kamakidae) from Lake Tonle Sap, Cambodia. *Zootaxa,* **3297,** 64–68.

Kamaka tonlensis sp. nov. is a small freshwater crustacean from the Tonle Sap Lake. Author: morino631@gmail.com

Neang T., Grismer, L.L. & Daltry, J.C. (2012) A new species of kukri snake (Colubridae: *Oligodon* Fitzinger, 1826) from the Phnom Samkos Wildlife Sanctuary, Cardamom Mountains, southwest Cambodia. *Zootaxa,* **3388,** 41–55.

A new species of kukri snake *Oligodon kampucheaensis* sp. nov. is described from a single specimen from Phnom Samkos Wildlife Sanctuary. This discovery increases the number of known kukri snakes in Cambodia to 10 species. Author: nthymoeffi@gmail.com

Park, K.-T. & Bae, Y.-S. (2012) A new *Synersaga* species from Cambodia (Lepidoptera, Lecithoceridae), with a world catalogue of the genus. *ZooKeys*, **187,** 1–7.

A new species of moth, *Synersaga mondulkiriensis* sp. nov., is described from the Seima Protection Forest. The species was discovered during an entomological survey by the Environmental Ministry of South Korea. Author: keitpark22@gmail.com; Online: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3345899/

Soh, W.-K. & Parnell, J. (2011) Three new species of *Syzygium* (Myrtaceae) from Indochina. *Kew Bulletin,* **66,** 557–564.

Descriptions, illustrations, a distribution map and conservation assessments are provided for three new species of flowing plants in the genus *Syzygium*. They include *Syzygium bokorense* sp. nov. from Phnom Bokor. Author: sohw@tcd.ie

Zhou, L.-W. & Zhang, W.-M. (2012) A new species of *Fulvifomes* (Hymenochaetaceae) from Cambodia. *Mycotaxon,* **119,** 175–179.

A new fungus, *Fulvifomes cambodiensis* sp. nov., is described and illustrated from Preah Vihear Province. Author: liwei_zhou1982@163.com

Biodiversity inventories and monitoring

Elliot, V., Lambert, F., Touch P. & Hort S. (2011) *Biodiversity Assessment of the REDD Community Forest Project in Oddar*

Meanchey. Birdlife International and PACT, Phnom Penh, Cambodia.

Interviews and field surveys were carried out in six community forests in a proposed REDD project site to determine their significance for birds and mammals. In total, 174 bird species and 26 mammals were recorded, but many of the identifications are tentative (the interviewees were found to be very poor at naming birds). The authors highlighted the apparent importance of these areas for banteng *Bos javanicus* and green peafowl *Pavo muticus* in particular, and observed a number of threats, including the highly invasive neotropical shrub *Lantana camara*. Recommendations include annual monitoring of birds and mammals in the project area. Author: vittoria_elliott@yahoo.co.uk; Online: http://www.pactworld.org/galleries/resource-center/Oddar%20Meanchey%20Biodiversity%20Assessment%202011.pdf

Seak, S., Schmidt-Vogt, D. & Thapa, G.B. (2011) A comparison between biodiversity monitoring systems to improve natural resource management in Tonle Sap Biosphere Reserve, Cambodia. *International Journal of Biodiversity Science, Ecosystem Services & Management*, **7,** 258–272.

This paper examines and compares three systems for monitoring biodiversity and biological resources in the Great Lake: (1) state-managed monitoring, (2) NGO-managed monitoring and (3) community-based monitoring. Data were generated using informant interviews, focus group discussions and direct observation, and the three types of monitoring were assessed with respect to perceived cost, methodological rigour, ease of use, compatibility with existing day-to-day activities of the local stakeholders and efficiency of intervention. Author: schmidt@ait.ac.th

Species ecology and status

Clements, T. Gilbert, M. Rainey, H.J., Cuthbert, R., Eames, J.C., Pech B. & Seng T. (2012) Vultures in Cambodia: population, threats and conservation. *Bird Conservation International, FirstView*, 1–18, doi: http://dx.doi.org/10.1017/S0959270912000093

Vultures have declined by 90–99% in the Indian Subcontinent due to poisoning by veterinary use of the drug diclofenac. Cambodia supports among the last populations of white-rumped vulture *Gyps bengalensis*, slender-billed vulture *G. tenuirostris* and red-headed vulture *Sarcogyps calvus* because diclofenac is not widely used. Population sizes of each species are estimated at 50–200+ individuals, ranging across approximately 300 km by 250 km, including adjacent areas of Laos and Vietnam. The principal causes of vulture mortality were poisoning (73%) – probably an unintended consequence of local hunting and fishing – and hunting or capture for traditional medicine (15%). Cambodian vultures are now heavily dependent on domestic ungulate carcasses because wild ungulate populations have been severely depleted. Limiting the use of poisons and providing supplementary food ('vulture restaurants') are necessary to conserve these birds. Author: tclements@wcs.org

Edwards, S. (2012) First confirmed records of sun bears in Kulen-Promtep Wildlife Sanctuary, Northern Cambodia. *International Bear News*, **21,** 11–12.

Camera traps obtained four images of Malayan sun bears *Helarctos malayanus* during 392 trap nights in this protected area. Author: sarah_edwards1985@yahoo.co.uk; Online: http://www.bearbiology.com/fileadmin/tpl/Downloads/IBN_Newsletters/IBN_Low_February_2012.pdf

Edwards, S. (2012) Small carnivore records from the Oddar Meanchey portion of the Kulen-Promtep Wildlife Sanctuary, northern Cambodia. *Small Carnivore Conservation*, **46,** 22–25.

A camera trapping survey from January to August 2011 captured images of four carnivores: the common palm civet *Paradoxurus hermaphroditus*, yellow-throated marten *Martes flavigula*, an unidentified ferret badger *Melogale* sp. and crab-eating mongoose *Herpestes urva*. Author: sarah_edwards1985@yahoo.co.uk; Online: http://smallcarnivoreconservation.org/home/wp-content/uploads/2012/07/Edwards_SCC46.pdf

Gilbert, M., Chea S., Joyner, P.H., Thomson, R.L. & Poole, C. (2012) Characterizing the trade of wild birds for merit release in Phnom Penh, Cambodia and associated risks to health and ecology. *Biological Conservation*, **153,** 10–26.

In many parts of East and South Asia, a large commercial trade has resulted from the demand for captive wild animals for religious or 'merit' release. This study describes the sale of birds for merit release in Phnom Penh. Birds were available throughout the year with an estimated annual turnover of 688,675 individuals, including significant numbers of the Near Threatened Asian golden weaver *Ploceus hypoxanthus*. A total of 57 species were observed on sale, all native to Cambodia. Zoonotic viruses and bacteria were detected in many of the birds sold for merit release (e.g. tests of 414 birds revealed that about 10% were infected with avian flu virus), posing a threat to humans as well as the wild bird populations. Author: mgilbert@wcs.org

Gray, T.N.E., Vidya, T.N.C., Maxwell, A.L., Bharti, D.K., Potdar, S., Phan C. & Prum S. (2011) *Using Fecal-DNA and Capture-Mark-Recapture to Establish a Baseline Asian Elephant Population for the Eastern Plains Landscape, Cambodia*. WWF Greater Mekong Cambodia Country Program, Phnom Penh, Cambodia, and Jawaharlal Nehru Centre for

Advanced Scientific Research, Bangalore, India.

A study in Seima Protected Forest in 2006 that used faecal-DNA samples and capture-mark-recapture analysis estimated the Asian elephant *Elephas maximus* population to number between 101 and 139 individuals. Using similar methods, Phnom Prich Wildlife Sanctuary was estimated to contain between 101 and 175 individuals, while Mondulkiri Protected Forest holds a minimum of 21 individuals. At least some elephants use both protected areas, highlighting the importance of landscape scale management across protected area boundaries. WWF proposes to repeat this study every few years to monitor the elephant population. Author: tomnegray@hotmail.com

Gray, T.N.E. (2012) Studying large mammals with imperfect detection: status and habitat preferences of wild cattle and large carnivores in Eastern Cambodia. *Biotropica*, **44,** 531–536.

Studying large mammal species in tropical forests is a notoriously difficult. This study used occupancy models from >3,500 camera-trap nights to examine the status and habitat use of banteng *Bos javanicus*, gaur *B. gaurus*, dhole *Cuon alpinus* and leopards *Panthera pardus* in Mondulkiri Protected Forest. The findings underscore the importance of mixed deciduous and semi-evergreen forest for wild cattle in eastern Cambodia. Author: tomnegray@hotmail.com

Hill, J. (2012) Review of local knowledge and uses for primates in the Veun Sai – Siem Pang Conservation Area, Northeastern Cambodia. *Canopy – Journal of the MSc in Primate Conservation,* **12,** 9–10.

Six species of primates inhabit this area, of which the pygmy slow loris *Nycticebus pygmaeus* is the most frequently traded. Interviews conducted in several villages revealed a trade chain from indigenous people through traders in "Chinese Village" to Vietnamese buyers in Ban Lung. While the lorises are traded for traditional medicine, macaques and northern yellow-cheeked gibbons are caught mainly for the pet trade. The authors calls for stronger law enforcement and the development of alternative income sources for local people. Author: jurhill@umail.iu.edu; Online: http://www.social-sciences.brookes.ac.uk/journals/canopy/canopy_v12_i1.pdf

Holden, J. & Mey, F.S. (2012) Discovery of a new population of *Nepenthes holdenii*. In *New* Nepenthes*, Volume One* (ed. S. McPherson), pp. 144–149. Redfern Natural History Productions, Poole, U.K.

Until recently, the endemic pitcher plant *Nepenthes holdenii* was known only from very small populations on two peaks in the Cardamom Mountains. This chapter reports the discovery of a new, larger population in Phnom Samkos Wildlife Sanctuary. Author: jeremyxholden@gmail.com

Holden, J. & Mey, F.S. (2012) *Nepenthes* carpet phenomenon in the Cardamom Mountains. In *New* Nepenthes*, Volume One* (ed. S. McPherson), pp. 150–161. Redfern Natural History Productions, U.K.

An illustrated report of an unidentified pitcher plant growing in unusually dense swathes in an undisturbed site in Phnom Samkos Wildlife Sanctuary. Author: jeremyxholden@gmail.com

Ihlow, F., Geissler, P., Sovath S., Handschuh, M. & Böhme, W. (2012) Observations on the feeding ecology of *Indotestudo elongata* (Blyth, 1853) in the wild in Cambodia and Vietnam. *Herpetology Notes*, **5,** 5–7.

Radiotagged elongated tortoises in the Kulen-Promtep Wildlife Sanctuary in northern Cambodia were observed feeding on the common land snail *Quantula striata* as well as carrion, mushrooms and earthworms. A scat from an elongated tortoise in Cat Tien, Vietnam, contained the remains of two ricefield crabs *Somanniathelphusa* sp. Author: nc-ihlowfl@netcologne.de

Ivanova, S., Herbreteau, V., Blasdell, K., Chaval, Y., Buchy, P., Guillard, B. & Morand, S. (2012) *Leptospira* and rodents in Cambodia: environmental determinants of infection. *The American Journal of Tropical Medicine and Hygiene,* **86,** 1032–1038.

Infection of rodents and shrews by *Leptospira* bacteria were studied in Veal Renh and Kaev Seima in forests, non-flooded lands, lowland rain-fed paddy fields and houses during the wet and the dry seasons. A total of 649 small mammals were trapped, representing 12 rodent species and one shrew. Of the 642 animals tested, 71 were carriers of *Leptospira* spp. Infection rates were found to be higher around rain-fed paddy fields, especially during the rainy season. Rates of infection tended to be lower among species that inhabit houses (the rat *Rattus exulans* and shrew *Suncus murinus*) than among species associated with forests. Author: serge.morand@univ-montp2.fr

Miyazawa, Y., Tateishi, M., Kajisa, T., Ma V., Heng S., Kumagai, T. & Mizoue, N. (2012) Transpiration by trees under seasonal water logging and drought in monsoon central Cambodia. *Paper presented to the European Geosciences Union General Assembly, 22–27 April, 2012, Vienna, Austria.*

Water flow was monitored in two native tree species (*Dipterocarpus obtusifolius* and *Shorea roxburghii*) and two exotic trees (*Acacia auriculiformis* and *Eucalyptus camaldulensis*). In the dry season, transpiration of water from the leaves did not appear hindered by soil drought. In the rainy season, on the other hand, there was evidence that the leaf water demand exceeded the supply, perhaps due to roots becoming waterlogged. Author: miyazawa@jamstec.go.jp

Moody, J.E, An D., Coudrat C.N.Z., Evans, T., Gray, T., Maltby, M., Men S., Nut M.H., O'Kelly, H., Pech B., Phan C., Pollard, E., Rainey, H.J., Rawson, B.M., Rours V., Song C., Tan S. & Thong S. (2011) Summary of the conservation status, taxonomic assignment and distribution of the Indochinese silvered langur *Trachypithecus germaini (sensu lato)* in Cambodia. *Asian Primates Journal,* **2,** 21–28.

Previously confused with the Sundaic silvered langur *Trachypithecus cristatus* of Peninsular Malaysia and Indonesia, the Indochinese silvered langur or lutung *T. germaini* occurs in Cambodia, southeastern Thailand, southern and central Laos, and southern and central Vietnam. The authors call for more attention to conserve the Endangered Indochinese lutung in Cambodia, especially within existing protected areas. Author: moody@wcs.org; Online: http://www.primate-sg.org/PDF/APJ2%281%29Article5.pdf

Milocco, C., Kamyingkird, K., Desquesnes, M., Jittapalapong, S., Herbreteau, V., Chaval, Y., Douangboupha B. & Morand, S. (2012) Molecular demonstration of *Trypanosoma evansi* and *Trypanosoma lewisi* DNA in wild rodents from Cambodia, Lao PDR and Thailand. *Transboundary and Emerging Diseases*, doi: 10.1111/j.1865–1682.2012.01314.x

Between November 2007 and June 2009, 94 wild rodents were tested using direct microscopic blood examination, 633 tested using the card agglutination test for trypanosome parasites and 145 using a polymerase chain reaction analysis with two sets of primers. In addition to *Trypanosoma lewisi*, *T. evansi* was detected in rodents from Thailand (*Rattus tanezumi*) and Cambodia (*R. tanezumi, Niviventer fulvescens* and *Maxomys surifer*). Human infections by *T. evansi* and *T. lewisi* have been reported in India and Thailand. The authors recommend studying the urban and rural circulation of these protozoan parasites in rodents to evaluate human exposure and infection risk. Author: fvetspj@yahoo.com

Tingay, R.E., Nicoll, M.A.C, Whitfield, D.P., Sun V. & McLeod, D.R.A. (2010) Ecology and conservation of the grey-headed fish-eagle (*Ichthyophaga ichthyaetus*) at Prek Toal, Tonle Sap Lake, Cambodia. *The Ornis Mongolica*, **1,** 26–29.

Grey-headed fish-eagles occur at an unusually high density in Prek Toal, part of the seasonally flooded swamp forest surrounding the Great Lake. A five-year study revealed the Near Threatened fish-eagles nest in relatively tall trees with an open canopy and close to permanent water, and hunt water snakes as well as fish. The two main threats to the birds are the unsustainable mass harvesting of water snakes (an estimated 6.9 million snakes are removed from the swamp forest every year for human consumption, food for thousands of crocodile farms around the lake, and for medicinal trade); and the development of large hydropower dams in the upstream reaches of the Mekong River. Author: dimlylit100@hotmail.com; Online: http://xa.yimg.com/kq/groups/25556199/475255978/name/Ornis+Mongolica+Volume+1–24–04–2012.pdf#page=26

Wright, H.L., Collar, N.J., Lake, I.R., Net N., Rours V., Sok K., Sum P. & Dolman, P.M. (2012) First census of white-shouldered ibis *Pseudibis davisoni* reveals roost-site mismatch with Cambodia's protected areas. *Oryx*, **46,** 236–239.

The first census of Critically Endangered white-shouldered ibises *Pseudibis davisoni* across Cambodia in 2009–2010 used simultaneous counts at multiple roost sites, and found at least 523 individuals. This suggests the global population could number between 731 and 856 individuals, more than previously estimated. However, the largest sub-populations are imminently threatened by development and three-quarters of the birds counted in Cambodia were outside protected areas. Author: hugh.wright@uea.ac.uk

Coasts, wetlands and aquatic resources

Marschke, M. (2012) *Life, Fish and Mangroves: Resource Governance in Coastal Cambodia*. University of Ottawa, Canada.

Following six households and one village-based institution in coastal Cambodia from 1998 to 2010, this book explores the opportunities and constraints facing villagers in their management of resources. Government and business interests in community-based management and resource exploitation result in a complex and highly unstable situation. In spite of considerable effort, resource governance in rural communities remains fragile, and coastal livelihoods in Cambodia therefore remain precarious. Author: melissa.marschke@uottawa.ca; Online: https://www.ruor.uottawa.ca/fr/bitstream/handle/10393/20676/Life_fish_and_mangroves.pdf?sequence=3

Meshkova, L.V. (2012) *Geomorphology and channel network patterns of the Mekong River in Cambodia*. PhD thesis, Geography and Environment, University of Southampton, U.K.

This study used both ground surveys and remote sensing data to describe the Mekong River in detail. The multichannel pattern of the river contains primary channels, secondary channels, cross-channels and blind channels, divided by major and seasonally-inundated islands. The riverbed includes outcrops of Mesozoic bedrock and fixed sand bars. The presence of river terraces and palaeochannel deposits show that the river incised during the Last Glacial Maximum, but has remained within the same course seen today for at least the past 70,000 years. Vegetation plays an important role in determining channel dynamics in this mixed bedrock-alluvial system. Online: Http://eprints.soton.ac.uk/id/eprint/339991

Phan K., Sthiannopkao, S., Heng S., Phan C., Huoy L, Wong, M.H. & Kim K.-W. (2012) Arsenic contamination in the food chain and its risk assessment of populations residing in the Mekong River Basin of Cambodia. *Journal of Hazardous Materials*, doi: 10.1016/j.jhazmat.2012.07.005

This study examined the arsenic content of paddy soil, rice, vegetables and fish in Kandal, Kratie and Kampong Cham Provinces to estimate how much inorganic arsenic is ingested by local people. The results show people in Kandal are at significant risk from arsenic poisoning, with an estimated average daily consumption of 0.089–8.386 μg per kg of body weight – a figure high enough to increase the risk of lung cancer. Author: suthisuthi@gmail.com; kwkim@gist.ac.kr

Forests and forest resources

Motzke, I., Wanger, T.C., Zanre, E., Tsharntke, T. & Barkmann, J. (2012) Socio-economic context of forest biodiversity use along a town-forest gradient in Cambodia. *The Raffles Bulletin of Zoology, Supplement No. 25*, 37–53.

This study focused on four villages between Siem Reap and the forest of Phnom Kulen National Park. Analysis of 149 structured interviews showed that with increased distance from Siem Reap, there were fewer small businesses and more forest-related activities and slash-and-burn agriculture. Local residents were heavily dependent on forest resources, especially fuel wood. To prevent the continuing degradation of forests, there needs to be stronger law enforcement, greater community engagement in sustainable forest management, and protection of forests from harvesters from outside the local communities. Author: iris.motzke@agr.uni-goettingen.de

Nathan, I. & Boon, T.E. (2012) Constraints and options in local forest management in Cambodia: is decentralization a solution? *Journal of Sustainable Forestry*, **31,** 396–420.

There is an urgent need to protect the livelihoods of the forest-dependent rural poor and, at the same time, sustain valuable forest resources. International scholars and development practitioners increasingly recommend the decentralisation of power in favour of granting authority over forest management to commune councils. This article argues that in Cambodia, a transfer of power and authority to accountable local institutions is unlikely to work unless the communities gain access to substantial benefits from the forests, and they are able to deal with strong external and internal actors and conflicting interests. This article calls for increased focus on the role of the government in helping decentralised forest management to succeed. Author: in@life.ku.dk

Ratner, B.D. (2011) *Common-pool Resources, Livelihoods, and Resilience Critical Challenges for Governance in Cambodia*. IFPRI Discussion Paper No. 01149. International Food Policy Research Institute, Washington DC, USA.

This paper examines policy choices and governance challenges facing Cambodia's forests and fisheries, and outlines policy needs for institutional development to improve livelihoods and environmental sustainability. The core argument is that (1) community-based management of natural resources requires more effective protection from other types of private- and public-sector investment; and (2) success depends on governance reforms to improve stakeholder representation, mechanisms of accountability, and institutional capacity. Strengthening the management of forests and fisheries is not simply a matter of removing state interference and letting local communities get by as they see fit. Author: b.ratner@cgiar.org; Online: www.ifpri.org/sites/default/files/publications/ifpridp01149.pdf

Tsuyoshi, K, Sakiko, K., Shintaro, S., Nobuya, M. & Shigejiro, Y. (2012) Vegetation recovery and local use of natural resource on community forestry in Cambodia. *Abstracts of the Asia Sustainable Local Resource Management Workshop 2012, Fukuoka, Japan.*

By 2009, 391 community forestry sites were registered across Cambodia. Using Geographical Information System analysis, plot-based studies and interviews, this paper reveals that the vegetation inside community forests has tended to improve while forests under other management regimes (forest concession, economic land concession) have deteriorated. Author: kajisa@agr.kyushu-u.ac.jp

Payments for conservation services, including carbon

Arias, M.E., Cochrane, T.A., Lawrence, K.S., Killeen, T.J. & Farrell, T.A. (2011) Paying the forest for electricity: a modelling framework to market forest conservation as payment for ecosystem services benefiting hydropower generation. *Environmental Conservation*, **38,** 473–484.

Forest cover can reduce soil erosion and thereby contribute to the economic life span of a hydropower dam. The cost of forest conservation is a sensible investment in hydropower and can be financed via a payment for ecosystem services (PES) scheme. This study attempts to estimate payments for forest conservation by modelling land-use change, watershed erosion, reservoir sedimentation, power generation, and PES scheme design. When the framework was applied to a proposed dam in Cambodia ("Pursat 1"), the authors estimated the net present value of forest conservation was US$ 4.7 million when using average annual climate values over 100 years, or US$ 6.4 million when considering droughts every eight years. This value can be remunerated with annual payments of US$ 4.26 or US$ 5.78 per hectare, respectively, covering forest protection costs estimated at US$ 0.9 per hectare per year. This represents a rational option that would allow for conservation and development of hydropower watersheds susceptible to erosion and sedimentation. Author: tom.cochrane@canterbury.ac.nz

Milne, S. & Adams, B. (2012) Market masquerades: uncovering the politics of community-level payments for environmental services in Cambodia. *Development and Change*, **43,** 133–158.

Payments for Environmental Services (PES) schemes are increasingly being implemented at community level in developing countries, especially in the context of Reduced Emissions from Deforestation and forest Degradation (REDD). There are, however, concerns about the impact they could have on resident communities that depend on natural resources. This article explores community-level PES in Cambodia, focussing on contracts for 'avoided deforestation' and biodiversity conservation with five communities. The practice of engaging of communities as single homogeneous entities, the simplification of land-use and resource rights, and the assumption that contracts are voluntary or reflect community choice work to silence certain voices and claims, while privileging others. Community-level PES may therefore be "a powerful intervention masquerading as a market". Author: sarah.milne@anu.edu.au

Pasgaard, M. (2012) The challenge of assessing social dimensions of avoided deforestation: examples from Cambodia. *Environmental Impact Assessment Review*. Http://dx.doi.org/10.1016/j.eiar.2012.06.002 First published online 23 June 2012.

In developing countries, Reduced Emissions from Deforestation and forest Degradation (REDD) has been promoted as a win-win strategy to reduce greenhouse gas emissions and mitigate climate change. To be successful in reducing emissions while also providing social and environmental benefits, REDD+ must overcome challenges of insecure forest tenure and inequity in the distribution of benefits. This paper considers how to assess the social dimensions of REDD+ using examples from Cambodia. Author: mase@life.ku.dk

Samreth V., Chheng K., Monda, Y., Kiyono, Y., Toriyama, J., Saito, S., Saito, H. & Ito, E. (2012) Tree biomass carbon stock estimation using permanent sampling plot data in different types of seasonal forests in Cambodia. *Japan Agricultural Research Quarterly*, **46,** 187–192.

Using 100 permanent sampling plots established by the Forestry Administration, the nationwide forest tree biomass carbon stock in 1998 was estimated to be 158.8±7.3 Mg C per hectare for evergreen and semi-evergreen forests, and 55.2±6.9 Mg C per hectare for deciduous forests. A second census in 2000–2001 recorded 163.8±7.8 Mg C and 56.2±6.7 Mg C per hectare in evergreen/ semi-evergreen and deciduous forests respectively. Using forest cover data for 2006 and field data for 2000–2001, the national forest carbon stock was estimated to be approximately 824 Tg C for evergreen forests and 264 Tg C for deciduous forests (1,088 Tg C in total). The paper contains recommendations on how to monitor carbon stocks and improve the accuracy of these estimates. Author: kiono@ffpri.affrc.go.jp

Sasaki, N. & Chheng K. (2012) Managing concession forests for carbon benefits in Cambodia. In *Proceedings of the International Conference on Balancing Economic Growth and Environmental Sustainability, Bangkok, Thailand, 20 February 2012*. pp. 315–326.

Models have been developed for setting Reference Emission Levels and Project Emission Levels for REDD+ projects in concession forests, taking emissions under conventional logging as the Reference Emission Level and those under reduced impact logging as the Project Emission Level. In Cambodia, the Reference Emission Level under the conventional 25 year cutting cycle was estimated at 23.1 Tg CO_2 per year. The authors recommend a 50 year cycle, which would give an annual emission of 0.4 Tg CO_2 under reduced impact logging or -3.3 Tg CO_2 with "liberation treatment". Annual carbon credits from managing 3.4 million hectares of concession forests in Cambodia were thus estimated to be between 15.9 and 18.5 Tg CO_2 depending on treatment, which could be worth $79.5–92.5 million from sales of carbon credits alone. Author: nop.kankyo@ai.u-hyogo.ac.jp; Online: http://gis.gms-eoc.org/GMS2020_WS-MATERIALS/2.2.8%20Nophea%20Sasaki_Concessions_Forests_for_carbon.pdf

Climate change

Bezuijen, M.R., Morgan, C. & Mather, R.J. (2012) *A Rapid Vulnerability Assessment of Coastal Habitats and Selected Species to Climate Risks in Chanthaburi and Trat (Thailand), Koh Kong and Kampot (Cambodia) and Kien Gian, Ben Tre, Soc Trang and Can Gio (Vietnam)*. IUCN, Gland, Switzerland.

This report finds that climate change could have serious implications for the management of natural resources, local livelihoods and the coastal economy in Indochina, especially in conjunction with existing threats. Some of the habitats and species at risk include *Melaleuca* forests, seagrass beds, the 'royal turtle' and sarus crane. Fish stocks are also anticipated to decline. A series of recommendations are presented for the three countries to mitigate or adapt to the predicted changes and pressures. For Cambodia, the authors emphasise the importance of retaining large and intact areas of natural habitats. Author: bezuijen@dodo.com.au; Online: Http://www.iucn.org/building-coastal-resilience

Ty T.V., Sunada, K., Ichikawa, Y. & Oishi, S. (2012) Scenario-based impact assessment of land use/cover and climate changes on water resources and demand: a case study in the Srepok River Basin, Vietnam-Cambodia. *Water Resources Management*, **26,** 1387–1407.

Future rainfall in the Srepok River Basin was predicted using the output from a high-resolution Regional Climate Model, while land use and land cover change were quantified using GIS-based logistic regression, and the future human population was projected from historical data. The analysis revealed that rainfall will increase, but changes in land use and land cover will conspire to reduce the future availability of freshwater. Author: tvty@ctu.edu.vn

Capacity building

Furey, N. (2012) Building a new generation of conservationists: Cambodia's recent history left unique challenges. *Bats*, **30,** 2–4.

An account of the University Capacity Building Project, established by Fauna & Flora International and the Royal University of Phnom Penh in 2005, which runs a Masters of Science in Biodiversity Conservation course, manages biological reference collections, publishes the *Cambodian Journal of Natural History*, and continues to mentor and support budding Cambodian scientists. This article gives special attention to the project's contribution to date to the understanding and conservation of bats in Cambodia, including the discovery of four species new to science and a further 15 that had not been recorded in the kingdom previously. Author: n.furey.ffi@gmail.com

Other livelihoods initiatives

Bunthoeun, P., Saoleng, L. & Chetra, S. (2011) Biodigesters development to ensure sustainable agriculture and mitigate greenhouse gas emissions in Cambodia. In *SAADC 2011 Strategies and Challenges for Sustainable Animal Agriculture-Crop Systems, Volume III. Proceedings of the 3rd International Conference on Sustainable Animal Agriculture for Developing Countries, 26–29 July, 2011 2011*, pp. 706–710. Suranaree University of Technology, Thailand.

By the end of 2010, the National Biodigester Program Cambodia, established by the Ministry of Agriculture, Forestry and Fisheries and the Netherlands Development, had supported the construction of 10,146 biodigesters. Monthly savings on energy (cooking and lighting) costs were estimated to be US$ 14.39 per month per household. Monthly fuel wood consumption fell from 195 kg to 13.3 kg and the biodigester saved 1.5 hours per day through reducing cooking time and time to collect firewood. The bio-slurry is highly valued organic fertilizer, saving each family US$ 52 per year on chemical fertilizer. Each biodigester reduces household greenhouse gas emissions by 5.94 tonnes of CO_2 per year on average. The authors conclude that biodigesters have the potential to alleviate rural poverty, achieve sustainable agriculture, increase the quality of living of the rural population, help protect forest from deforestation and significantly mitigate greenhouse gas emissions. Author: saoleng@nbp.org.kh

Miscellaneous

Reimer, J.K. & Walter, P. (2012) How do you know it when you see it? Community-based ecotourism in the Cardamom Mountains of southwestern Cambodia. *Tourism Management*, doi: 10.1016/j.tourman.2012.04.002

In this case study of a community-based project in southwestern Cambodia, Honey's (2008) analytical framework for "authentic ecotourism" was applied to examine its social dimensions. Qualitative research methods included interviews, focus groups and analysis of project documents. The findings highlighted the challenges in community-based ecotourism in addressing often contradictory concerns of environmental conservation, local livelihoods, and cultural preservation, and the importance of local context to management of ecotourism. The authors identified gender as an additional category that should be considered when analysing community-based ecotourism and sustainable development. Author: reimer.jk@gmail.com; pierre.walter@ubc.ca

The Recent Literature section was compiled by JENNY C. DALTRY, with additional contributions from Tom Clements, Neil Furey, Tom Gray, Jeremy Holden, Oleg Kosterin and François Mey. All Internet addresses were correct at the time of publication. Please send contributions (published or grey literature, including project technical reports and conference abstracts not more than 18 months old) by email to: Editor.CJNH@gmail.com

Instructions for Authors

Purpose and Scope

The *Cambodian Journal of Natural History* is a free journal that is published biannually by the Centre for Biodiversity Conservation at the Royal University of Phnom Penh. The Centre for Biodiversity Conservation is a non-profit making unit, dedicated to training Cambodian biologists and the study and conservation of Cambodia's biodiversity.

The *Cambodian Journal of Natural History* publishes original work by:

- Cambodian or foreign scientists on any aspect of Cambodian natural history, including fauna, flora, habitats, management policy and use of natural resources.
- Cambodian scientists on studies of natural history in any part of the world.

The Journal especially welcomes material that enhances understanding of conservation needs and has the potential to improve conservation management in Cambodia.

The primary language of the Journal is English. Authors are, however, encouraged to provide a Khmer translation of their abstract.

Readership

The Journal's readers include conservation professionals, academics, government departments, non-governmental organizations, students and interested members of the public, both in Cambodia and overseas. In addition to printed copies, the Journal is freely available online.

Papers and Short Communications

Full Papers (2,000–7,000 words) and Short Communications (300–2,000 words) are invited on topics relevant to the Journal's focus, including:

- Research on the status, ecology or behaviour of wild species.
- Research on the status or ecology of habitats.
- Checklists of species, whether nationally or for a specific area.
- Discoveries of new species records or range extensions.
- Reviews of conservation policy and legislation in Cambodia.
- Conservation management plans for species, habitats or areas.
- The nature and results of conservation initiatives, including case studies.
- Research on the sustainable use of wild species.
- Abstracts of student theses (Short Communications only).

The Journal does not normally accept formal descriptions of new species, new subspecies or other new taxa. If you wish to submit original taxonomic descriptions, please contact the editors in advance.

How to Submit a Manuscript

Manuscripts should be submitted by email to the Editors at **Editor.CJNH@gmail.com** In the covering email, the Lead (Corresponding) Author must confirm that:

- The submitted manuscript has not been published elsewhere,
- All of the authors have read the submitted manuscript and agreed to its submission, and
- All research was conducted with the necessary approval and permit from the appropriate authorities.

If you have any questions before or after submitting a manuscript, you are welcome to contact the Editors at any time.

Review and Editing

All contributors are strongly advised to ensure that their spelling and grammar is checked by a native English speaker before the manuscript is submitted to the Journal. The Editorial Team reserves the right to reject manuscripts that need extensive editing for spelling and grammar.

All manuscripts will be subject to rigorous peer review by a minimum of two qualified reviewers. Authors are welcome to suggest appropriate reviewers.

Proofs will be sent to authors as a portable document format (PDF) file attached to an email note. Acrobat Reader can be downloaded free of charge from <www.adobe.com> to view the PDF files. Corrected proofs should be returned to the Editor within three working days of receipt. Minor corrections can be communicated by email.

The Editorial Team welcomes contributions to the journal, as follows:

News

Concise reports (<300 words) on news of general interest to the study and management of Cambodia's biodiversity. News items may include, for example:

- Announcements of new initiatives; for example, the launch of new projects, conferences or funding opportunities.
- Summaries of important news from an authoritative published source; for example, a new research technique, or a recent development in conservation.

Letters to the Editors

Informative contributions (<650 words), usually in response to material published in the Journal.

Recent Literature

Copies or links to recent (<18 months) scientific publications concerning Cambodian biodiversity and the management of natural resources. These may include journal papers, project technical reports, conference posters and student theses.

Preparation of Manuscripts

Authors should consult examples in this issue for general style.

Contributions should be in English, with UK English spelling (if in doubt, Microsoft Word and similar software should be set to check spelling and grammar for 'English (UK)' language). Lines should be double-spaced.

Submissions can be in 'doc', 'docx', 'rtf' or 'wpd' format, preferably as a single file attached to one covering email. The order of the sections of the manuscript should be: cover page, main text, references, short biography of each author, tables, figures and plates (photographs).

The cover page should contain the title and full mailing address and email address of the Lead Author and the addresses of all co-authors. All pages should be numbered consecutively.

Title: A succinct description of the work, in no more than 20 words.

Abstract: (Full papers only). This should describe, in no more than 250 words, the aims, methods, major findings and conclusions. The abstract should be informative and intelligible without reference to the text, and should not contain any references or undefined abbreviations. Cambodian authors are strongly encouraged to submit a Khmer translation of the English abstract.

Keywords: (Full papers only). Up to eight pertinent words, in alphabetical order. There is no need to repeat words that are already in the title.

References: These should be cited in the text in the form of Stuart & Emmett (2006) or (Lay, 2000). For three or more authors, use the first author's surname followed by *et al.*; for example, Rab *et al.* (2006) or (Khou *et al.*, 2005). Multiple references should be in chronological order, for example, Holloway & Browne (2004); Kry & Chea (2004); Phan (2005); Farrow (2006).

The reference list should be presented in alphabetical order. Cambodian, Vietnamese and other authors who typically write their family name first are presented in the form <surname> <initials> without a comma (thus, Sin Sisamouth becomes Sin S.). Western author names are presented in the form <surname> <comma> <initials> (thus Charles Robert Darwin becomes Darwin, C.R.).

The titles of articles and journals should be written in full.

The following are examples of house style:

Papers:

Berzins, B. (1973) Some rotifers from Cambodia. *Hydrobiologia*, **41,** 453–459.

Neang T. (2009) Liquid resin tapping by local people in Phnom Samkos Wildlife Sanctuary, Cambodia. *Cambodian Journal of Natural History*, **2009,** 16–25.

Tanaka, S. & Ohtaka, A. (2010) Freshwater Cladocera (Crustacea, Branchiopoda) in Lake Tonle Sap and its adjacent waters in Cambodia. *Limnology*, **11,** 171–178.

Books and chapters:

Khou E.H. (2010) *A Field Guide to the Rattans of Cambodia.* WWF Greater Mekong Cambodia Country Programme, Phnom Penh, Cambodia.

MacArthur, R.H. & Wilson, E.O. (1967) *The Theory of Island Biogeography*. Princeton University Press, Princeton, USA.

Rawson, B. (2010) The status of Cambodia's primates. In *Conservation of Primates in Indochina* (eds T Nadler, B. Rawson & Van N.T.), pp. 17–25. Frankfurt Zoological Society, Frankfurt, Germany, and Conservation International, Hanoi, Vietnam.

Reports:

Lic V., Sun H., Hing C. & Dioli, M. (1995) *A brief field visit to Mondolkiri Province to collect data on kouprey (*Bos sauveli*), rare wildlife and for field training.* Unpublished report to Canada Fund and IUCN, Phnom Penh, Cambodia.

Theses:

Yeang D. (2010) *Tenure rights and benefit sharing arrangements for REDD: a case study of two REDD pilot projects in Cambodia*. MSc thesis, Wageningen University, Wageningen, The Netherlands.

Websites:

IUCN (2010) 2*010 IUCN Red List of Threatened Species.* Http://www.redlist.org [accessed 1 December 2010].

About the Author(s): This section is optional for Full Papers and Short Communications. It should describe the main research interests of every author (<150 words each), apart from what is obvious from the subject of the manuscript and the authors' affiliations.

Tables, figures and plates: These should be self-explanatory, each on a separate page and with an appropriate caption. Figures, including maps, should ideally be in black and white. Plates (photographs) should be included only if they are of good quality and form part of evidence that is integral to the study (e.g. a camera trap photograph of a rare species).

Appendices: Long tables and other supporting materials, such as questionnaires, should be placed in Appendices.

Species names: The first time a species is mentioned, its scientific name should follow without intervening punctuation: e.g., Asian elephant *Elephas maximus*. English names should be in lower case throughout except where they incorporate a proper name (e.g., Asian flycatcher, Swinhoe's minivet, long-billed vulture).

Abbreviations: Full expansion should be given at first mention in the text.

Units of measurement: Use metric units for measurements of area, mass, height, etc.

Publisher: Centre for Biodiversity Conservation, Room 415, Main Campus, Faculty of Science, Royal University of Phnom Penh, Confederation of Russian Boulevard, Phnom Penh, Cambodia.

The journal online. All issues of this journal can be freely downloaded from:

http://www.fauna-flora.org/publications/cambodian-journal-of-natural-history/

Authors are permitted to post their papers on their personal and institutional webpages on condition that access is free and no changes are made to the content.

Cambodian Journal of Natural History

The preparation and printing of this volume was generously supported by:

Royal University of Phnom Penh – Centre for Biodiversity Conservation

RUPP is Cambodia's oldest university, with over 9,000 students and over 400 teachers. The Department of Biology founded the Centre for Biodiversity Conservation to provide training and support for national scientists. The Centre delivers a Masters of Science curriculum in Biodiversity Conservation and has established a library, classrooms, herbarium and zoological reference collection for use by students and scholars of Cambodian natural science.

Website: http://www.rupp.edu.kh/master/biodiversity_conservation/centerbc.php

Fauna & Flora International

FFI protects threatened species and ecosystems worldwide, choosing solutions that are sustainable, are based on sound science and take account of human needs. Operating in more than 40 developing countries worldwide, FFI saves species from extinction and habitats from destruction, while improving the livelihoods of local people. Founded in 1903, FFI is the world's longest established international conservation body. FFI has been active in Cambodia since 1996.

Website: www.fauna-flora.org

John D. and Catherine T. MacArthur Foundation

The MacArthur Foundation supports creative people and effective institutions committed to building a more just, verdant, and peaceful world. This journal has been co-sponsored by the MacArthur Foundation as part of grant no. 09–92411–000–GSS: *Creating Cambodia's New Generation of Conservation Scientists.*

Website: www.macfound.org

The Editors are also grateful to Neang Thy, Phauk Sophany, Jeremy Holden and Roger Ingle for their kind assistance with the production of this issue.

The Cambodian Journal of Natural History does not charge subscription fees. The journal depends upon the generosity of its partner organisations and sponsors to be published and distributed free of charge to readers throughout Cambodia and worldwide.

If you or your organisation are interested in supporting the Cambodian Journal of Natural History or the Centre for Biodiversity Conservation, kindly contact the editors (Editor.CJNH@gmail.com) or the staff of the Centre for Biodiversity Conservation (biodiversity.conservation@gmail.com). The names and logos of all supporters will be published in the journal.

Cambodian Journal of Natural History

Volume 2012, Number 1

Contents

CBC

មជ្ឈមណ្ឌលអភិរក្សជីវៈចំរុះ

Centre for Biodiversity Conservation