

# Further new country records of four bat species (Chiroptera) from Cambodia and a call for information

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## មូលនិយសរង្វេប

យោងតាមឯកសារវិទ្យាសាស្ត្រ មានសត្វប្រចៀវចំនួន៦៦ប្រភេទហើយត្រូវបានកត់ត្រា នៅក្នុងបញ្ជីសត្វប្រចៀវកម្ពុជា។ តាមការវិភាគរូបសាស្ត្រលើសំណាកដែលប្រមូលបានពីឆ្នាំ២០០៧ដល់ឆ្នាំ២០១៣ យើងរកឃើញប្រចៀវប្រភេទបន្ថែមទៀត ដែលជាកំណត់ត្រាថ្មីសម្រាប់កម្ពុជា រួមមាន*Cynopterus horsfieldii*, *Coelops frithii*, *Rhinolophus pearsonii* និង *Falsistrellus affinis*។ ពីរប្រភេទខាងដើមត្រូវបានគេទាយទុកជាមុនថាមាននៅក្នុងប្រទេសកម្ពុជា។ កំណត់ត្រាប្រភេទទាំងបួនត្រូវបានធ្វើឡើងតាមរយៈការស្រាវជ្រាវថ្មីៗនៅតាមតំបន់ជាច្រើនក្នុងប្រទេសកម្ពុជា ដោយប្រើឧបករណ៍អន្ទាក់មង (mist net) និងអន្ទាក់រាំង (harp trap)។ ក្នុងចំណោមប្រភេទទាំងបួន មិនមានប្រភេទណាមួយត្រូវបានចាត់ទុកជាប្រភេទរងគ្រោះសកលទេ ទោះបីជា*F. affinis* (ជាសំណាកដំបូងបង្អស់ក្នុងតំបន់ភាគខាងកើតនៃប្រទេសកម្ពុជា) ជាប្រភេទកម្រនិងគួរទទួលបានការយកចិត្តទុកដាក់បន្ថែមក៏ដោយ។ បច្ចុប្បន្ន កម្ពុជាមានសត្វប្រចៀវចំនួន៧០ប្រភេទហើយដែលបានត្រូវចុះក្នុងបញ្ជីរបស់ខ្លួន ហើយចំនួននេះនឹងកើនឡើងជាប្រាកដក្នុងការស្រាវជ្រាវនាពេលអនាគត។ ដើម្បីលើកកម្ពស់ការស្រាវជ្រាវនិងអភិរក្ស យើងសូមអំពាវនាវស្វែងរកល្អាងសត្វប្រចៀវជាសាធារណៈនៅក្នុងប្រទេសកម្ពុជា។

## Abstract

Sixty-six bat species were confirmed in the scientific literature for Cambodia. Through a morphological review of specimens collected from 2007 to 2013, we document the occurrence of four additional species: *Cynopterus horsfieldii*, *Coelops frithii*, *Rhinolophus pearsonii* and *Falsistrellus affinis*. The first two species were previously predicted for Cambodia, and all four were recorded during recent surveys using harp traps and mist nets in sites around the country. None of the newly recorded species are presently regarded as being of global conservation concern, although *F. affinis* (which represents the first record of this species eastwards of Myanmar) is very

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rarely encountered and deserves further attention. The national list for Cambodia now contains 70 bat species, and future field surveys will undoubtedly reveal additional taxa. To assist such research, and allied conservation efforts, we conclude by appealing for public information on significant bat roosts throughout the country.

## Keywords

Cambodia, bat taxonomy, new records.

## Introduction

Thirteen years on from being described as “one of the least explored countries” in terms of its bat fauna (Kock, 2000), the number of taxa documented for Cambodia has more than doubled with 66 species confirmed in the peer-reviewed literature by Furey *et al.* (2012). Additional bat species were reported for Cambodia by Simmons (2005) and Francis (2008) without details. The purpose of this note is to further this growth in knowledge by confirming two such species and documenting the occurrence of two other previously unreported species by means of a morphological review of recently collected specimens. All four species were encountered during an ongoing series of nationwide field surveys to determine the composition, biogeography and status of Cambodian bats and identify priorities for conservation action. Notes on the distribution of each species are provided and current knowledge of Cambodia’s bats is briefly reviewed.

## Methods

### Study Areas

From May 2007 to May 2013, specimens were collected during field studies by the authors and associates in several parts of Cambodia, as summarised below (Fig. 1). Four-bank harp traps and mist nets of varying sizes were employed in the surveys and sampling locations focused largely on water bodies and flyways in forest areas, such as trails, watercourses and natural linear breaks in the vegetation. Specimens from these studies were deposited in the Centre for Biodiversity Conservation (CBC, Zoological Collection, Royal University of Phnom Penh) (Appendix 1).

In late May 2007, Vorn Vichheka sampled bats in a plantation near the Teuk Thla pagoda in Khan Sensok District, Phnom Penh municipality.

In July and October 2007, bat surveys were conducted in the Seima Protected Forest by Va Vuthy and Gabor Csorba. Seima Protected Forest is in the

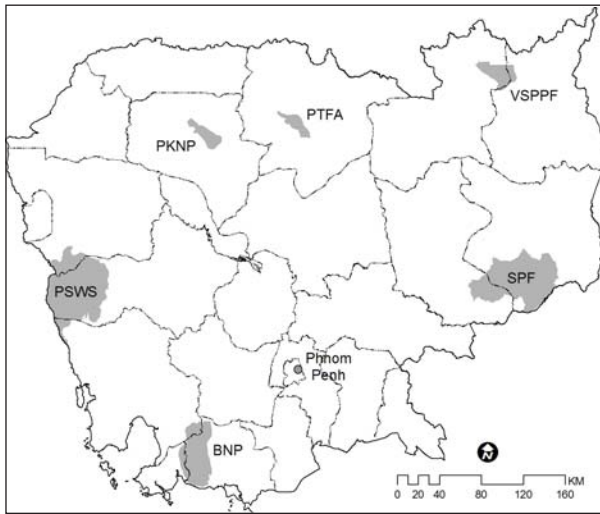
low-lying Eastern Plains of Cambodia (Monduliri Province) and covers an area of 292,690 ha. The site is characterised by a complex mosaic of forest types varying from fully deciduous to almost fully evergreen, with large areas of open grassland and numerous water sources (O’Kelly *et al.*, 2012).

In October and November 2009, Ith Saveng, Gabor Csorba and Neil Furey undertook a brief survey in the Phnom Tbeng Forest Area in the northern Cambodian plains (Preah Vihear Province). Phnom Tbeng is an isolated escarpment southwest of Tbeng Meanchey Town that rises to *circa* 580 m above sea level (a.s.l.) and supports semi-evergreen forest on the escarpment face and dry dipterocarp forest on the plateau. The site is in a region more generally dominated by dry dipterocarp forest and grasslands, interspersed with patches of semi-evergreen forest (Walston & Bates, 2001).

In November 2009 and December 2010, field surveys were undertaken by Ith Saveng and Neil Furey on the Dalai and Samkos mountains in Phnom Samkos Wildlife Sanctuary. The wildlife sanctuary covers 332,566 ha in the Pursat, Battambang and Koh Kong provinces of Southwest Cambodia and has an elevation range of 100–1,717 m.a.s.l., including large areas of lowland evergreen forest, dry dipterocarp forest and hill evergreen forest (Daltry & Momberg, 2000).

From April to July 2010, Phauk Sophany and Phen Sarith undertook bat surveys in the Kbal Spean region of Phnom Kulen National Park in Siem Reap Province. Bat surveys were also carried out in the national park from February to April 2013 by Alistair Mould, Ben Hayes and Katherine Boughey. Phnom Kulen National Park covers 37,350 ha and includes lowland areas and sandstone hills which culminate in two plateaus reaching 450 m a.s.l. Habitats include evergreen and semi-evergreen forest on hillsides and plateaus, while lowland areas include small degraded areas of dry dipterocarp forest (Neou *et al.*, 2008).

In May 2010, a single night of mist-netting was undertaken by Neil Furey and several MSc students



**Fig. 1** Location of bat survey areas in Cambodia. BNP—Bokor National Park, PKNP—Phnom Kulen National Park, PSWS—Phnom Samkos Wildlife Sanctuary, PTFA—Phnom Tbeng Forest Area, SPF—Seima Protected Forest, VSPPF—Veun Sai Proposed Protected Forest.

in a small grove of woodland fringing an artificial lake in front of the Faculty of Science within the grounds of the Royal University of Phnom Penh.

In August 2010, studies were undertaken in the Veun Sai Proposed Protected Forest by Ith Saveng, Neil Furey and Tamas Gorfol. The proposed protected forest covers approximately 55,000 ha in Veun Sai District, Ratanakiri Province, and Siem Pang District, Steung Treng Province, in Northeast Cambodia. Habitats include lowland evergreen and semi-evergreen forest between 100 and 400 m a.s.l., with more northerly areas mountainous and southern parts characterized by grasslands (Ben Rawson, pers. comm.).

From October 2012 to May 2013, bats were surveyed in Bokor National Park by Chheang Sarak, Ith Saveng and Neil Furey. The national park is located in the coastal province of Kampot and covers 140,000 ha. The site centres on a sandstone massif, with an extensive plateau at *circa* 1,000 m.a.s.l. Habitats include large areas of semi-evergreen and evergreen forest, while the plateau is dominated by dwarf evergreen forest with small areas of grassland (Seng *et al.*, 2003).

#### Morphological assessment

Age and reproductive status were assessed following Anthony (1988) and Racey (1988). External measure-

ments were taken from alcohol-preserved specimens to the nearest 0.1 mm, while craniodental and bacula measurements were taken to the nearest 0.01 mm using digital callipers under a stereo microscope. Measurements reported herein include only those taken from non-juveniles, as indicated by the presence of fully ossified metacarpal-phalangeal joints.

Definitions for external measurements were as follows: FA: forearm length—from the extremity of the elbow to the extremity of the carpus with the wings folded; HB: head and body length—from the tip of the snout to the anal opening; T: tail length—from the anal opening to the tip of the tail; E: ear length—from the lower border of the external auditory meatus to the tip of the pinna, excluding any hair; TIB: tibia length—from the knee joint to the ankle; HF: hindfoot—from the tip of the longest digit, excluding the claw, to the extremity of the heel, behind the os calcis. Illustrations of these measurements are provided by Bates & Harrison (1997).

All specimens had their skulls extracted for examination. Definitions for craniodental measurements were as follows: GTL: greatest length of skull—greatest antero-posterior length of the skull, taken from the most projecting point at each extremity regardless of what structure forms these points; CBL: condylobasal length—from the exoccipital condyle to the anterior rim of the alveolus of the first upper incisor; CCL: condylo-canine length—from the exoccipital condyle to the most anterior part of the canine; ZYW: zygomatic width—the greatest width of the skull across the zygomatic arches; MAW: mastoid width—the greatest distance across the mastoid region; CM<sup>3</sup>L: maxillary tooththrow length—from the front of upper canine to the back of the crown of the third molar; C<sup>1</sup>C<sup>1</sup>W: width across the upper canines—greatest width, taken across the outer borders of upper canines; M<sup>3</sup>M<sup>3</sup>W: width across the upper molars—greatest width, taken across the outer crowns of the last upper molars; ML: mandible length—from the anterior rim of the alveolus of the first lower incisor to the most posterior part of the condyle; CM<sub>3</sub>L: mandibular tooththrow length—from the front of the lower canine to the back of the crown of the third lower molar; CPH: least height of the coronoid process—from the tip of the coronoid process to the apex of the indentation on the inferior surface of the ramus adjacent to the angular process.

Species sequence and nomenclature follow Simmons (2005). A full list of the specimens examined is given in Appendix 1.

## Systematic Description

### *Cynopterus horsfieldii* Gray, 1843 (Fig. 2)

Material examined: two males from Seima Protected Forest, three females from Phnom Penh, one male and one female from Phnom Tbeng Forest Area, one male and one female from Phnom Samkos Wildlife Sanctuary, one female from Veun Sai Proposed Protected Forest and one male from Phnom Kulen National Park (Fig. 1, Appendix 1).

The above specimens were referred to *C. horsfieldii* on the basis of the following characters: dorsal hair of varying shades of grey-brown; ventral hair lighter; darker collar, varying from reddish brown, brown to grey in males, somewhat paler in females; ears and wing bones edged in white; external and cranio-dental measurements (Table 1 & 2) according with published ranges (Kingston *et al.*, 2006; Francis, 2008), though generally close to lower limit; cheek teeth broad, sometimes squarish in occlusal view; presence of variably developed central cusps or ridges on the lower posterior premolar ( $P_4$ ) and first lower molar ( $M_1$ ) (Fig. 6).

In Seima, two bats were caught in semi-evergreen forest areas surrounded by grassland. In Phnom Penh, three bats were captured in woodland, including one at 1830 h. On Phnom Tbeng, two bats were encountered in disturbed semi-evergreen forest next to grasslands at 1900 h and 1930 h. In Phnom Samkos, two bats were captured in hill evergreen forest at 1900 and 2030 h. In Veun Sai, one bat was caught in a dry river basin in a semi-evergreen forest area at 2010 h. In Phnom Kulen, one bat was caught over a stream in semi-evergreen forest. All were captured in mist nets.

*Cynopterus horsfieldii* has been infrequently recorded in Laos, South Vietnam and West Thailand, and also occurs in Peninsular Thailand, West Malaysia, Borneo, Java, Sumatra and adjacent islands (Simmons, 2005; Thomas *et al.*, 2013). One record from the Kompong Thom region in Cambodia (Klein, 1970) was apparently rejected by Kock (2000), but accepted by Hendrichsen *et al.* (2001a), Matveev (2005) and Simmons (2005). *Cynopterus horsfieldii* was listed for Cambodia by Francis (2008), but not included in range maps. It would appear from our records that the species actually occurs at low to high elevations throughout the country. Other species in the genus *Cynopterus* known to occur in Cambodia include *C. sphinx* and *C. brachyotis* (Kingsada *et al.*, 2011).

### *Rhinolophus pearsonii* Horsfield, 1851 (Fig. 3)

Material examined: four males and five females from Bokor National Park (Fig. 1, Appendix 1).

Possessing a wide-based sella with a characteristic middle constriction, the nine specimens were readily identified as members of the *pearsonii*-group which presently comprises four similar species: *R. pearsonii*, *R. yunanensis*, *R. chiewkweeae* and *R. thailandensis*. *Rhinolophus chiewkweeae* could be excluded because it is known only from the Sundaic subregion south of the Isthmus of Kra, in Peninsular Malaysia (Yoshiyuki & Lim, 2005), while *R. thailandensis* was excluded due to its larger size in almost all respects (Wu *et al.*, 2009). Because *R. pearsonii* and *R. yunanensis* are strikingly similar and differ primarily in size, species identification was based on the mensural ranges provided by Csorba *et al.* (2003). Some measurements from our specimens (FA, ZYW, MAW) were within the known areas of overlap between the two species (Table 1 and 2), but skull length (*sensu* Csorba *et al.*, 2003),  $CM^3L$ ,  $ML$  and  $CM_3L$  measurements for individual specimens were almost exclusively below the lower limit for *R. yunanensis* and within the range for *R. pearsonii*. Therefore the specimens were identified as the latter species.

Four of the above bats were caught in harp traps in evergreen forest from 1800–1900 h and another was caught in a harp trap overnight. The remaining four were caught in mist nets in evergreen forest at 1830 h. Time-expanded (x10) echolocation calls with a frequency of maximum energy of 53.6 kHz were recorded from a single individual (CBC02161, a juvenile female) held motionless in the hand. *Rhinolophus pearsonii* occurs from North India eastwards through Nepal, Bhutan to South China and southwards through Myanmar, Thailand, Vietnam and Laos (Csorba *et al.*, 2003; Yoshiyuki & Lim, 2005). The above bats represent the first records for *R. pearsonii* from Cambodia, whereas *R. yunanensis* was recorded from the Cardamom Mountains of Cambodia by Ith *et al.* (2011).

### *Coelops frithii* Blyth, 1848 (Fig. 4)

Material examined: two females from Phnom Kulen National Park (Fig. 1, Appendix 1).

The two individuals exhibit the features diagnostic of the genus and *C. frithii* described by Tate (1941) and Bates & Harrison (1997), including a rudimentary tail; short and broadly rounded ears with a large antitragal lobe; anterior leaf divided into two halves by a deep median notch and emphasized by two elongated,



**Fig. 2** *Cynopterus horsfieldii*: CBC01126, Veun Sai Proposed Protected Forest (© N. Furey).



**Fig. 3** *Rhinolophus pearsonii*: CBC02161, Bokor National Park (© N. Furey).



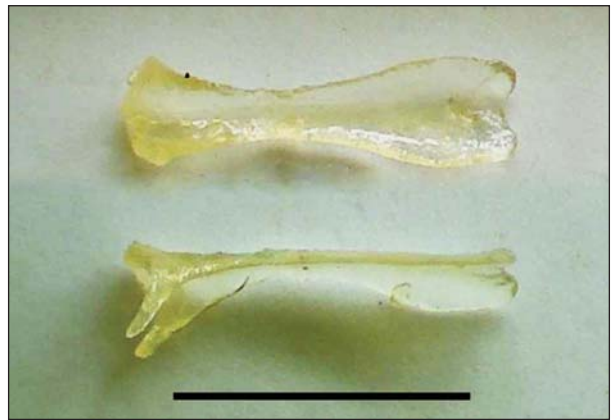
**Fig. 4** *Coelops frithii*: CBC02138, Phnom Kulen National Park (© T. Yon).



**Fig. 5** *Falsistrellus affinis*: CBC02133, Phnom Kulen National Park (© B. Hayes).



**Fig. 6** Right lower tooththrows of *Cynopterus horsfieldii* (top: CBC00453, Phnom Tbeng; below: CBC01046, Phnom Penh) (© N. Furey).



**Fig. 7** Baculum of *Falsistrellus affinis* (v, l): CBC02158, Phnom Kulen (© N. Furey). Scale bar = 2 mm.

**Table 1** Selected external measurements. Values are given as mean, SD (if  $n \geq 5$ ), (min–max)  $n$ . Abbreviations and definitions for measurements are explained in the text.

Species	FA	HB	T	E	TIB	HF
<i>Cynopterus horsfieldii</i>	69.5, 2.1 (66.5–72.2) 11	83.8, 5.0 (75.0–90.4) 11	13.4, 1.9 (10.9–17.5) 11	18.9, 0.8 (17.8–20.0) 11	27.0, 0.8 (25.8–28.2) 11	14.5, 0.6 (12.9–15.2) 11
<i>Rhinolophus pearsonii</i>	52.6, 0.7 (51.5–53.6) 8	52.6, 1.4 (50.0–54.0) 8	19.2, 1.6 (18.0–22.2) 8	26.4, 1.0 (24.6–28.0) 8	26.3, 0.9 (24.8–27.6) 8	10.6, 0.6 (9.8–11.6) 8
<i>Coelops frithii</i>	– (38.8, 38.8) 2	– (34.7, 35.5) 2	– –	– (7.5, 7.7) 2	– (15.4, 15.7) 2	– (13.5, 13.9) 2
<i>Falsistrellus affinis</i>	36.5, 0.8 (35.7–37.9) 7	45.3, 1.6 (43.3–47.2) 7	34.6, 2.6 (30.5–39.3) 7	14.1, 0.2 (13.8–14.3) 7	13.9, 0.4 (13.4–14.6) 7	6.6, 0.7 (5.7–7.4) 7

narrow and forwardly projecting lappets (as opposed to the wide, rounded lappets of *C. robinsoni*); intermediate leaf with a moderate median process; posterior leaf not divided by vertical septa, but pocketed posteriorly and possessing a median eminence. At 38.8 mm (Table 1), the forearm lengths (FA) of both animals fall within the known ranges for *C. frithii* (Bates & Harrison, 1997) and exceed those of *C. robinsoni* (Francis, 2008). Similar to some Vietnamese specimens (Hendrichsen *et al.*, 2001b; N. Furey, unpublished data), the two individuals from Phnom Kulen are slightly smaller in some cranial measurements (Table 2) than those measured by Bates & Harrison (1997), although cranial and dental features closely match descriptions for *C. frithii* in both the latter publication and Corbet & Hill (1992).

The above bats were caught at 1845 h and 1950 h in harp traps set at two cave entrances surrounded by scrubland and semi-evergreen forest respectively. As currently recognised, *C. frithii* is a widespread species, occurring from Bangladesh and Northeast India eastwards to South China and Taiwan, and southwards through Myanmar, Thailand, Laos and Vietnam as far as western Malaysia, Sumatra, Java and Bali (Simmons, 2005). Despite its extensive distribution, the species is seldom recorded in field surveys and consequently appears scarce throughout its range (Francis, 2008). However, the lack of records could be partly explained by its use of high echolocation frequencies (Ho *et al.*, 2013) and capacity for highly manoeuvrable flight (Furey, 2009), which may allow the species to detect and elude even harp traps. The above individuals confirm Francis's (2008) prediction that the species occurs in Cambodia.

### *Falsistrellus affinis* (Dobson, 1871) (Fig. 5)

Material examined: six males and one female from Phnom Kulen National Park (Fig. 1, Appendix 1).

The seven individuals from Phnom Kulen closely resemble two specimens from Mon State, Myanmar, which Bates *et al.* (2005) referred to *Pipistrellus affinis* (placed in *Falsistrellus* by Simmons, 2005) in the following regards: collectively overlapping in all external mensural characters (Table 1); dorsal hairs long and dark brown, individual scattered hairs with pale tips lending a slightly grizzled appearance; ventral hairs dark brown at base with lighter tips that vary among individuals from grey-brown, yellow-brown to white; hairs on lower abdomen and near the anus uniformly of the latter colours; braincase low; rostrum broad with median and lateral depressions; zygoma robust with weak to moderately developed postorbital processes; collectively overlapping or nearly so in all craniodental measurements (Table 2); first upper incisor ( $I^2$ ) bicuspid; first upper premolar ( $P^2$ ) often slightly displaced internally and approaching  $I^2$  in crown area; first lower premolar ( $P_2$ ) in tooththrow and occupying about half the crown area of second lower premolar ( $P_4$ ); lower molars myotodont; baculum short (length 2.5–2.7 mm,  $n = 6$ ), proximally widened and ventrally deeply fluted, narrowing in mid-extent and broadening distally in spatulate form with a slightly concave tip—virtually identical (albeit shorter) in several specimens to that of HZM.2.35125 from Myanmar (depicted in Fig. 1G of Bates *et al.*, 2005), whereas some specimens differ slightly in being straighter in lateral view with a more distinct tip concavity (Fig. 7).

Aside from a single male individual caught at 1915 h in a harp trap set in evergreen forest, the

**Table 2** Selected craniodental measurements. Values are given as mean, SD (if  $n \geq 5$ ), (min–max)  $n$ . Abbreviations and definitions for measurements are explained in the text.

Species	GTL	CBL	CCL	ZYW	MAW	CM <sup>3</sup> L	C <sup>1</sup> C <sup>1</sup> W	M <sup>3</sup> M <sup>3</sup> W	ML	CM <sub>3</sub> L	CPH
<i>Cynopterus horsfieldii</i>	31.12, 1.00 (29.17–33.18) 11	29.13, 1.49 (25.42–31.10) 11	28.58, 1.43 (25.00–30.33) 11	18.95, 1.30 (15.70–20.25) 11	12.64, 0.49 (12.03–13.40) 11	10.56, 0.37 (10.06–11.18) 11	6.46, 0.37 (5.73–6.78) 11	9.07, 0.31 (8.60–9.69) 11	23.69, 0.95 (22.24–25.11) 11	11.66, 0.39 (11.26–12.32) 11	11.94, 1.02 (9.89–13.23) 11
<i>Rhinolophus pearsonii</i>	25.30, 0.24 (24.90–25.63) 8	22.28, 0.21 (22.05–22.60) 8	21.67, 0.22 (21.30–22.02) 8	12.33, 0.27 (11.93–12.77) 8	11.14, 0.15 (10.85–11.31) 8	9.87, 0.11 (9.73–10.04) 8	6.28, 0.16 (6.09–6.56) 8	9.18, 0.33 (8.45–9.48) 8	17.07, 0.08 (16.94–17.15) 8	10.61, 0.16 (10.36–10.82) 8	3.70, 0.09 (3.56–3.81) 8
<i>Coelops frithii</i>	– (16.22, 16.64) 2	– (14.47, 14.72) 2	– (14.06, 14.37) 2	– (6.67, 6.78) 2	– (6.98, 6.99) 2	– (5.87, 5.94) 2	– (3.13, 3.14) 2	– (5.29, 5.37) 2	– (9.42, 9.76) 2	– (6.09, 6.17) 2	– (2.20, 2.23) 2
<i>Falsistrellus affinis</i>	14.51, 0.21 (14.32–14.90) 7	13.41, 0.23 (13.11–13.64) 7	13.09, 0.30 (12.67–13.45) 7	9.22, 0.19 (8.95–9.42) 7	8.04, 0.16 (7.86–8.24) 7	5.04, 0.10 (4.92–5.18) 7	4.63, 0.12 (4.49–4.80) 7	6.21, 0.14 (5.98–6.43) 7	10.39, 0.14 (10.19–10.54) 7	5.53, 0.12 (5.41–5.71) 7	3.03, 0.07 (2.93–3.13) 7

individuals were caught at a southwest-facing cave entrance mostly in harp traps (two in mist nets) from 1850–1900 h in an area of semi-evergreen forest with rocky outcrops and boulders. According to Simmons (2005), *F. affinis* occurs in Northeast Myanmar, Yunnan (China), India, Nepal and Sri Lanka. Like the specimens from Mon State in Myanmar (Bates *et al.*, 2005), however, the Phnom Kulen specimens also differ from Indian specimens, which are larger, have darker underparts and a differently shaped baculum and may represent a different taxon (Hill & Harrison, 1987; Bates & Harrison, 1997). As the holotype of *F. affinis* from Kachin State in Northeast Myanmar does not have a baculum, detailed morphological and molecular comparisons with the type or topotype material are required to determine whether this is the case, and if so, which form the name *F. affinis* actually belongs to. Pending resolution of these taxonomic and nomenclatural questions, we tentatively identify the Phnom Kulen specimens as *F. affinis*, and they represent the first records east of Myanmar of a very rarely encountered and poorly known species.

## DISCUSSION

Our confirmation of four additional bat species for Cambodia increases the total number of bats presently confirmed in this country to 70. Notwithstanding the recent spate of new records and species new to science from Cambodia (e.g. Ith *et al.*, 2011; Csorba, 2011; Csorba *et al.*, 2011; Furey *et al.*, 2012), future surveys will inevitably reveal additional taxa because

numerous species are known from neighbouring territories that have yet to be found in Cambodia.

While none of the newly recorded species are currently regarded as being of global conservation concern (IUCN, 2013), the species we identify as *F. affinis* is evidently very rare and deserving of conservation attention. In Cambodia it is currently known only from a single cave roost in Phnom Kulen National Park.

In a broader context, more information is needed to adequately determine conservation priorities for Cambodia's bats, though it is evident that several of the known roosts of *Pteropus lylei* and *Chaerephon plicatus* are of outstanding national importance by virtue of their large size. To improve existing knowledge and allied conservation efforts, we appeal to the general public for information on significant bat roosts throughout the country.

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## References

- Anthony, E.L.P. (1988) Age determination in bats. In *Ecological and Behavioral Methods for the Study of Bats* (ed. T.H. Kunz), pp. 47–58. Smithsonian Institution Press, Washington, D.C., USA.
- Bates, P.J.J. & Harrison, D.L. (1997) *Bats of the Indian Subcontinent*. Harrison Zoological Museum, Kent, UK.
- Bates, P.J.J., Tin Nwe, Si Si Hla Bu, Khin Mie Mie, Khin Maung Swe, Nyo Nyo, Aye Aye Khaing, Nu Nu Aye, Yin Yin Toke, Naing Naing Aung, Mar Mar Thi & Mackie, I. (2005) A review of the genera *Myotis*, *Ia*, *Pipistrellus*, *Hypsugo*, and *Arielulus* (Chiroptera: Vespertilionidae) from Myanmar (Burma), including three species new to the country. *Acta Chiropterologica*, **7**, 205–306.
- Corbet, G.B. & Hill, J.E. (1992) *The Mammals of the Indomalayan Region*. Natural History Museum and Oxford University Press, Oxford, UK.
- Csorba, G., Ujhelyi, P. & Thomas, N. (2003) *Horseshoe Bats of the World (Chiroptera: Rhinolophidae)*. Alana Ecology Ltd, UK.
- Csorba, G. (2011) A new species of *Glischropus* from the Indochinese Subregion (Mammalia: Chiroptera: Vespertilionidae). *Zootaxa*, **2925**, 41–48.
- Csorba, G., Son N.T., Ith S. & Furey, N.M. (2011) Revealing cryptic bat diversity: three new *Murina* and redescription of *M. tubinaris* from Southeast Asia. *Journal of Mammalogy*, **92**, 891–904.
- Daltry, J.C. & Momberg, F. (eds.) (2000) *Cardamom Mountains Biodiversity Survey 2000*. Fauna & Flora International, Cambridge, UK.
- Francis, C.M. (2008) *A Guide to the Mammals of Southeast Asia*. Princeton University Press, Princeton, New Jersey, USA.
- Furey, N.M. (2009) *Bat assemblages in Vietnamese karst: diversity, reproduction, echolocation and ecomorphology*. PhD thesis, Aberdeen University, UK.
- Furey, N.M., Phauk S., Phen S., Chheang S., Ith S., Bates, P.J.J. & Csorba, G. (2012) New country records for five bat species (Chiroptera) from Cambodia. *Cambodian Journal of Natural History*, **2012**, 141–149.
- Hendrichsen, D.K., Bates, P.J.J. & Hayes, B. (2001a) Recent records of bats (Chiroptera) from Cambodia. *Acta Chiropterologica*, **31**, 21–32.
- Hendrichsen, D.K., Bates, P.J.J., Hayes, B. & Walston, J.L. (2001b) Recent records of bats (Mammalia: Chiroptera) from Vietnam with seven species new to the country. *Myotis*, **39**, 35–122.
- Hill, J.E. & Harrison, D.L. (1987) The baculum in the Vespertilioninae (Chiroptera: Vespertilionidae) with a systematic review, a synopsis of *Pipistrellus* and *Eptesicus*, and the descriptions of a new genus and subgenus. *Bulletin of the British Natural History Museum (Zoological)*, **52**, 225–305.
- Ho, Y.-Y., Fang, Y.-P., Chou, C.-H., Cheng, H.-C. & Chang, H.-W. (2013) High duty cycle to low duty cycle: echolocation behaviour of the hipposiderid bat *Coelops frithii*. *PLOS ONE*, **8**, e62938. doi:10.1371/journal.pone.0062938
- Ith S., Csorba, G., Bates, P.J.J. & Furey, N.M. (2011) Confirmation of seven bat species for Cambodia. *Cambodian Journal of Natural History*, **2011**, 93–103.
- IUCN (2013) *IUCN Red List of Threatened Species. Version 2012.1*. <http://www.iucnredlist.org> [accessed 08 August 2013].
- Kingsada, P., Douangboubpha, B., Ith S., Furey, N., Soisook, P., Bumrungsri, S., Satasook, C., Vu D.T., Csorba, G., Harrison, D., Pearch, M., Bates, P. & Thomas, N. (2011) A checklist of bats from Cambodia, including the first record of the intermediate horseshoe bat *Rhinolophus affinis* (Chiroptera: Rhinolophidae), with additional information from Thailand and Vietnam. *Cambodian Journal of Natural History*, **2011**, 49–59.
- Kingston, T., Liat, L.B. & Akbar, Z. (2006) *Bats of Krau Wildlife Reserve*. Penerbit Universiti Kebangsaan Malaysia, Bangi, Malaysia.
- Klein, J.M. (1970) Faune de Nycteribiidae du Cambodge (Dipt. Pupipara). *Bulletin de la Société Entomologique de France*, **75**, 48–55.



- Kock, D. (2000) On some bats (Chiroptera) from southern Cambodia with a preliminary checklist. *Zeitschrift für Säugetierkunde*, **65**, 199–208.
- Matveev, V. (2005) Checklist of Cambodian bats (Chiroptera), with new records and remarks on taxonomy. *Russian Journal of Theriology*, **4**, 43–62.
- Neou B., Khou E. & Touch S. (2008) *Preliminary Study of the Kulen National Park for Development of a Botanical Garden*. Ministry of Environment, Royal Government of Cambodia.
- O’Kelly, H.J., Evans, T.D., Stokes, E.J., Clements, T.J., Dara A., Gately, M., Nut M., Pollard, E., Men S. & Walston, J. (2012) Identifying conservation successes, failures and future opportunities: assessing recovery potential of wild ungulates and tigers in eastern Cambodia. *PLOS ONE*, **7**, e40482. doi:10.1371/journal.pone.0040482
- Phauk S., Phen S. & Furey, N.M. (2013) Cambodian bat echolocation: a first description of assemblage call parameters and assessment of their utility for species identification. *Cambodian Journal of Natural History*, **2013**, 16–26.
- Racey, P. A. (1988) Reproductive assessment in bats. In *Ecological and Behavioural Methods for the Study of Bats* (ed. T.H. Kunz), pp. 31–45. Smithsonian Institution Press, Washington, D.C., USA.
- Simmons, N.B. (2005) Order Chiroptera. In *Mammal Species of the World: a Taxonomic and Geographic Reference, Third Edition* (eds D.E. Wilson & D.M. Reeder), pp. 312–529. Johns Hopkins University Press, Baltimore, USA.
- Seng K.H., Pech B., Poole C., Tordoff A., 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, Cambodia, BirdLife International in Indochina and the Wildlife Conservation Society Cambodia Program, Phnom Penh, Cambodia.
- Tate, G.H.H. (1941) Results of the Archbold Expeditions, no. 36: remarks on some old world leaf-nosed bats. *American Museum Novitates*, **1140**, 1–11.
- Thomas, N.M., Duckworth, J.W., Douangboubpha, B., Williams, M. & Francis, C. (2013) A checklist of bats (Mammalia: Chiroptera) from Lao PDR. *Acta Chiropterologica*, **15**, 193–260.
- Walston, J. & Bates, P.J.J. (2001) The discovery of Wroughton’s free-tailed bat *Otomops wroughtoni* (Chiroptera: Molossidae) in Cambodia. *Acta Chiropterologica*, **3**, 249–252.
- Wu, Y., Harada, M. & Motokawa, M. (2009) Taxonomy of *Rhinolophus yunanensis* Dobson, 1872 (Chiroptera: Rhinolophidae) with a description of a new species from Thailand. *Acta Chiropterologica*, **11**, 237–246.
- Yoshiyuki, M. & Lim, B.L. (2005) A new horseshoe bat, *Rhinolophus chiewkweeae* (Chiroptera: Rhinolophidae), from Malaysia. *Bulletin of the National Science Museum of Tokyo*, **31A**, 29–36.

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## Appendix 1

*Cynopterus horsfieldii*: CBC00453, CBC00455, male and female, in spirit, skulls removed, collected by Neil Furey on 29 October 2009, Phnom Tbeng Forest Area (Preah Vihear), 13°45.845'N, 104°51.553'E, 360 m a.s.l.; CBC00454, female, in spirit, skull removed, collected by Ith Saveng on 20 November 2009, Mount Dalai, Phnom Samkos Wildlife Sanctuary, 12°26.674'N, 103°04.582'E, 1,033 m a.s.l.; CBC00472, male, in spirit, skull removed, collected by Va Vuthy on 24 July 2007, Seima Protected Forest, 12°11.000'N, 107°01.000'E, 308 m a.s.l.; CBC00473, male, in spirit, skull removed, collected by Va Vuthy on 2 October 2007, Seima Protected Forest, 12°12.000'N, 107°01.000'E, 295 m a.s.l.; CBC00474, CBC00476, two females, in spirit, skulls removed, collected by Vorn Vichheka on 25 May 2007, Khan Sensok District, Phnom Penh, 11°33.818'N, 104°52.908'E, 68 m a.s.l.; CBC00893, male, in spirit, skull removed, collected by Phen Sarith and Phauk Sophany on 21 April 2010, Phnom Kulen National Park, 12°46.714'N, 103°28.042'E, 205 m a.s.l.; CBC01046, female, in spirit, skull removed, collected by Neil Furey on 19 May 2010, Royal University of Phnom Penh, 11°34.065'N, 104°53.395'E, 15 m a.s.l.; CBC01126, female, in spirit, skull removed, collected by Neil Furey on 16 August 2010, Veun Sai Proposed Protected Forest, 14°00.833'N, 103°01.334'E; CBC01206, male, in spirit, skull removed, collected by Neil Furey on 13 December 2010, Mount Samkos, Phnom Samkos Wildlife Sanctuary, 12°09.615'N, 103°00.191'E, 1,281 m a.s.l.

*Coelops frithii*: CBC02137, female, in spirit, skull removed, collected by Alistair Mould and Katherine Boughey on 28 February 2013, Phnom Kulen National Park, 13°32.136'N,

104°08.924'E, 373 m a.s.l.; CBC02138, female, in spirit, skull removed, collected by Alistair Mould on 28 March 2013, Phnom Kulen National Park, 13°32.543'N, 104°07.753'E, 359 m a.s.l.

*Rhinolophus pearsonii*: CBC02006, female, in spirit, skull removed, collected by Cheang Sarak on 30 October 2012, Bokor National Park, 10°50.526'N, 104°04.789'E, 409 m a.s.l.; CBC02016, CBC02018, two females, in spirit, skulls removed, collected by Ith Saveng and Chheang Sarak on 4 December 2012, Bokor National Park, 10°41.174'N, 104°03.033'E, 819 m a.s.l.; CBC02020, CBC02022, CBC02023, CBC02024, one female and three males, in spirit, skulls removed, collected by Ith Saveng and Chheang Sarak on 6 December 2012, Bokor National Park, 10°40.861'N, 104°02.759'E, 792 m a.s.l.; CBC02122, male, in spirit, skull removed, collected by Chheang Sarak on 15 February 2013, Bokor National Park, 10°43.431'N, 103°55.834'E, 393 m a.s.l.; CBC02161, juvenile female, in spirit, skull removed, collected by Neil Furey and Chheang Sarak on 30 April 2013, Bokor National Park, 11°09.210'N, 104°04.275'E, 351 m a.s.l.

*Falsistrellus affinis*: CBC00917, male, in spirit, skull removed, collected by Phen Sarith and Phauk Sophany on 21 April 2010, Phnom Kulen National Park, 12°46.714'N, 103°28.042'E, 205 m a.s.l. (= *Hypsugo* sp. A. in Phauk *et al.*, 2013); CBC02133, CBC02136, two males, in spirit, skulls removed, collected by Alistair Mould and Katherine Boughey on 26 February 2013, Phnom Kulen National Park, 13°30.699'N, 104°07.375'E, 359 m a.s.l.; CBC02153, CBC02156, CBC02157, CBC02158, one female and three males, in spirit, skulls removed, collected by Alistair Mould and Ben Hayes on 21 April 2013, Phnom Kulen National Park, 13°30.699'N, 104°07.375'E, 359 m a.s.l.