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

CHHEANG Sarak¹, Paul J.J. BATES², Katherine BOUGHEY³, Gabor CSORBA⁴, Ben HAYES⁵, ITH Saveng¹, Alistair MOULD⁵, PHAUK Sophany¹ and Neil M. FUREY¹,⁶,*

¹ Centre for Biodiversity Conservation, Room 415, Department of Biology, Faculty of Science, Royal University of Phnom Penh, Confederation of Russia Boulevard, Phnom Penh, Cambodia.
² Harrison Institute, Centre for Systematics and Biodiversity Research, Bowerwood House, St Botolph's Road, Sevenoaks, Kent, TN13 3AQ, United Kingdom.
³ Bat Conservation Trust, Quadrant House, 250 Kennington Lane, London, SE11 5RD, United Kingdom.
⁴ Department of Zoology, Hungarian Natural History Museum, Baross u. 13, H-1088 Budapest, Hungary.
⁵ Integrated Solutions Asia Cooperation, #15, Street 278, Boeng Keng Kang I, Phnom Penh, Cambodia.
⁶ Fauna & Flora International, Cambodia Programme, PO Box 1380, #19, Street 360, Boeng Keng Kang I, Chamkarmon, Phnom Penh, Cambodia.

*Corresponding author. Email neil.furey@fauna-flora.org

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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 aennis. 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. aennis (which represents the first record of this species eastwards of Myanmar) is very

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 (Mondulkiri 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, Banteay 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).

In 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

Keywords
Cambodia, bat taxonomy, new records.
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 measurements 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; CM3L: maxillary toothrow length—from the front of upper canine to the back of the crown of the third molar; C’C’W: width across the upper canines—greatest width, taken across the outer borders of upper canines; M’M’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; CM1L: mandibular toothrow 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 craniodental 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. brachyotos* (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\(^L\), ML and CM\(_L\) 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,
New bat records for Cambodia

**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 aquis*: CBC02133, Phnom Kulen National Park (© B. Hayes).

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

**Fig. 7** Baculum of *Falsistrellus aquis* (v. l): CBC02158, Phnom Kulen (© N. Furey). Scale bar = 2 mm.
Table 1 Selected external measurements. Values are given as mean, SD (if n ≥5), (min–max) n. Abbreviations and definitions for measurements are explained in the text.

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

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 aenis (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 aenis* (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 (P2) often slightly displaced internally and approaching I 2 in crown area; first lower premolar (P2) in toothrow and occupying about half the crown area of second lower premolar (P4); 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
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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About the authors

CHHEANG SARAK is a Cambodian national born in Prey Veng Province. Following his studies of the taxonomy of rhinolophid bats, he graduated with an MSc from the Royal University of Phnom Penh in 2011. He currently works part time for the Centre for Biodiversity Conservation at the university and his interests include taxonomy and building conservation awareness.

PAUL BATES has spent much of the last 30 years researching the bats and small mammals of Southern and Southeast Asia. Initially studying the mammal fauna of India and Sri Lanka, in 1997 he began working in Vietnam and Cambodia which led to research and training projects throughout Southeast Asia. More recently, he has helped develop a network of Southeast Asian taxonomists working on mammals, birds and amphibians.

KATHERINE BOUGHEY is an ecologist from the UK. She gained a doctorate from the University of East Anglia focusing on distribution modelling and landscape ecology of bats, and has studied bats in the UK, the USA and Cambodia. She currently works for the Bat Conservation Trust, developing practical applications of species distribution information.

GABOR CSORBA is responsible for development of vertebrate collections in the Hungarian Natural History Museum where he has worked for almost 30 years. He travels regularly to the Old World tropics to study bat systematics and populations in protected areas and also has a special interest in the conservation biology of European mammals.

BENJAMIN HAYES has worked as a conservation biologist in Southeast Asia and Africa since 1992 and studied the biogeography of Tanzanian bats for his MSc. Much of his work involves baseline and environmental impact surveys and management planning for protected areas. He currently manages biodiversity surveys in Phnom Kulen National Park and directs alternative livelihood projects in Cambodia and Tanzania.

ITH SAVENG is a Cambodian national born in Kampong Speu Province and has worked for Fauna & Flora International (Cambodia) as a zoological curator since 2006 and as a lecturer at Royal University of Phnom Penh since 2010. He is currently undertaking a doctorate focusing on Southeast Asian bat taxonomy at the Prince Songkla University in Thailand and has special interest in systematics, ecology and biogeography.
ALISTAIR MOULD has worked for wildlife conservation and alternative livelihood projects in Cambodia since 2009. A conservation biologist by training, he has supervised research projects in Phnom Kulen National Park for the Angkor Centre for Conservation of Biodiversity and currently works for Indochine Exploration, an adventure tour company providing resources for wildlife conservation and village development projects.

PHAUK SOPHANY is originally from Sihanoukville and has worked as national coordinator for the Centre for Biodiversity Conservation at the Royal University of Phnom Penh since 2011. He studied the use of acoustic approaches for identification of Cambodian bat species for his MSc degree and has a special interest in the ecology of cave-dwelling bats and flying foxes.

NEIL FUREY has worked in Southeast Asia since 1997, spending a decade in Vietnam and completing various assignments in Cambodia, China, India, Indonesia and Myanmar. A biologist by training, he studied the ecology of Vietnamese bat populations for his doctorate and has a special interest in community ecology and systematics. Much of his work in South-east Asia focuses on strengthening conservation and research capacity.

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°12.000’N, 107°01.000’E, 295 m a.s.l.; CBC00473, male, in spirit, skull removed, collected by Va Vuthy on 2 October 2007, Seima Protected Forest, 12°13.845’N, 107°01.000’E, 308 m a.s.l.; CBC00474, CBC00476, two females, in spirit, skulls removed, collected by Vorn Vichheka on 25 May 2007, Khan Senok District, Phnom Penh, 11°33.818’N, 104°52.908’E, 68 m a.s.l.; CBC00893, male, in spirit, skull removed, collected by Phan 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 Cheang 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 Cheang 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 Cheang 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 Cheang Sarak on 30 April 2013, Bokor National Park, 11°09.210’N, 104°04.275’E, 351 m a.s.l.