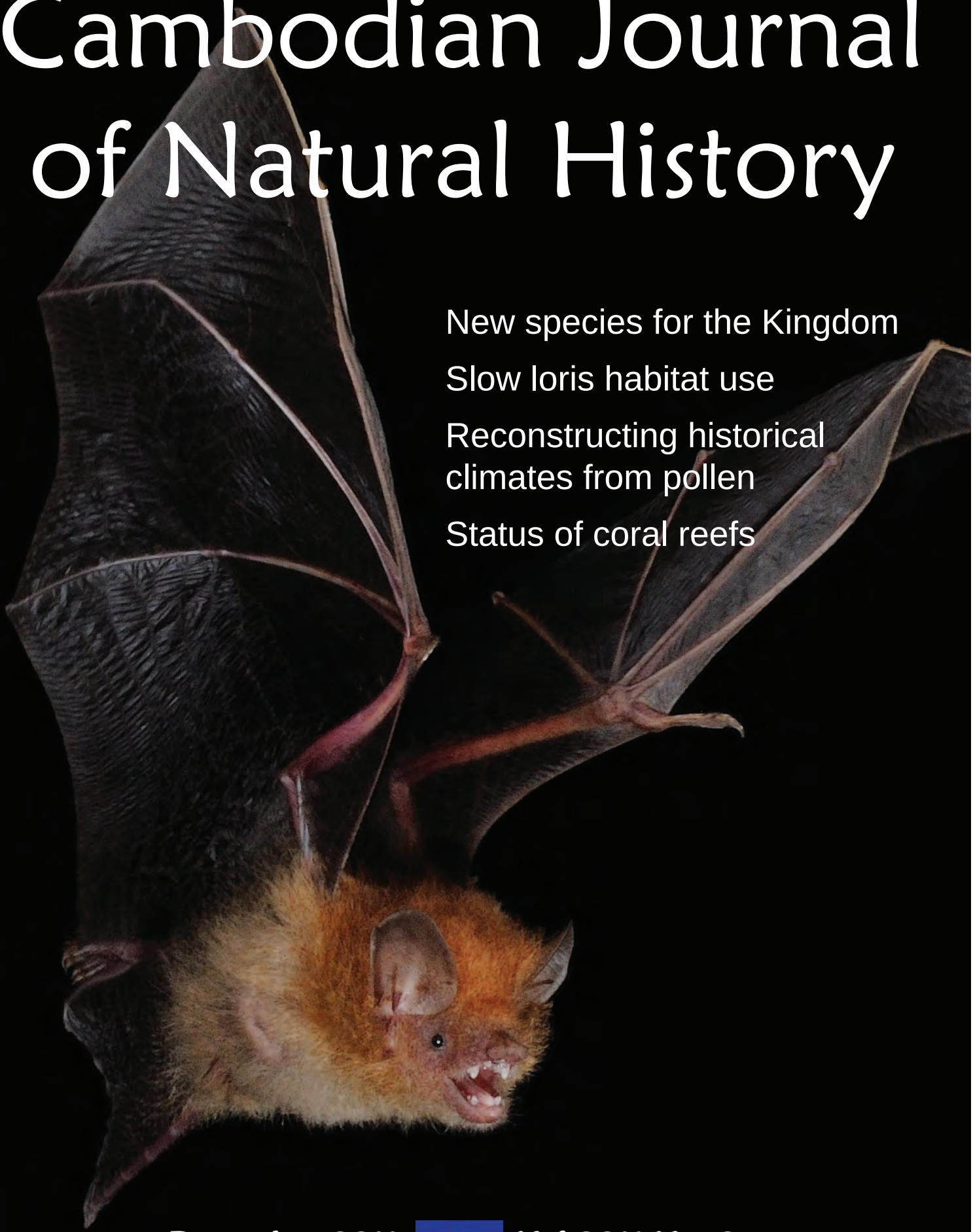
Cambodian Journal of Natural History



New species for the Kingdom

Slow loris habitat use

Reconstructing historical climates from pollen

Status of coral reefs

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Cover photo: A round-eared tube-nosed bat *Murina cyclotis* photographed in Vietnam (© Randall D. Babb). The recent discovery of this species in Cambodia, plus another six bats, is described by Ith Saveng *et al.* in this issue.

Editorial - Finders, keepers

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In the first issue of the *Cambodian Journal of Natural History*, I remarked on the astonishing growth in the number of species recorded in Cambodia (Daltry, 2008). Between 1998 and 2008, the number of published, known mammals leapt from 100 to 146, birds from 410 to 552, reptiles from 82 to 165, amphibians from 28 to 63, and fish from around 215 to 474 species.

The rate of discoveries shows few signs of slowing down. On the contrary, the national vertebrate checklist has already risen to at least 162 mammals, 577 birds (F. Goes, pers. comm.), 176 reptiles, 66 amphibians and 571 fishes. It is especially heartening to see increasing attention being paid to what are often unfairly called the 'lower taxa', including ferns (Hwang *et al*., 2011), pitcher plants (Mey, 2010), rotifers (Meas & Sanoamuang, 2010), dragonflies and damselflies (Roland *et al*., 2010; Kosterin, 2011). At least 25 animals and plants discovered between 2009 and mid-2011 were not only new records for Cambodia, but new to science. These ranged from a mosquito (Schaefer & Renner, 2011) to a new gibbon (Van *et al*., 2010).

Knowing what species are present, and where they occur, is fundamental to modern biodiversity management, including economic use and conservation (Bates, 2010). At the Royal University of Phnom Penh, the Centre for Biodiversity Conservation (CBC) is developing an important role in this regard by training and supporting Cambodian scientists (Rath, 2009), managing a working zoological reference collection (which currently holds more than 4,000 small animal specimens), assisting the university herbarium (with approximately 12,000 plant specimens), hosting and facilitating fieldwork by visiting international scientists, and fostering cooperation and information exchange between government agencies, scholars and environmental NGOs.

As the CBC's flagship publication, the *Cambodian Journal of Natural History* explicitly aims to helps scientists to document and share discoveries. This particular issue might be subtitled a "*New Records Special*" because most of the peer-reviewed papers are devoted to species newly found in Cambodia. Thomas Gray presents the country's first records of two bird subspecies (pp. 79-80), Neang Thy and his colleagues reveal another lizard and a snake (pp. 86-92), Ith Saveng *et al.* report on seven new bats (pp. 93-103), while Alexander Monastyrskyii's team raise the national list of butterflies from 30 to at least 255 species (pp. 122-130)! Meanwhile, the papers led by Kathe Jensen (pp. 81-85) and Jan-Willem van Bochove (pp. 114-121) focus on Cambodia's poorly-known marine environment and reveal a variety of corals, crustaceans and associated species. It is worth pointing out that seven of the 19 authors are Cambodians, which reflects the rising national capacity to identify and describe species accurately.

There are undoubtedly many more taxa awaiting discovery, including species that are commercially useful, nationally endemic or globally threatened. Despite impressive recent advances, this country still lags far behind many of its neighbours in the completeness of its national species checklists. Even the diminutive, heavily urbanised Singapore has documented more than 300 butterflies (Khew, 2011), for example, and Cambodia's revised checklist of 217 pteridophytes (ferns) remains woefully short of the 620 species in Thailand and 714 in Vietnam (Hwang *et al*., 2011). Moreover, due to their greater investment into biological research, neighbouring countries continue to describe species new to science at an even swifter rate than Cambodia (Thompson, 2011).

Further baseline inventories are therefore warranted and should continue across all taxonomic groups in Cambodia. At the same time, however, there is a real danger that many of these new-found species could rapidly disappear due to habitat loss, over-exploitation, climate change, alien invasive species and other man-made problems. It seems as though the more we find, the more we stand to lose.

Finders, keepers is an English saying based on an old Roman law, which means whoever finds something is entitled to be its custodian. As more species are revealed, the scientific community gains an even greater responsibility to ensure Cambodia's rich biodiversity is wisely managed and conserved. The Kingdom therefore

urgently needs even more environmental scientists to go beyond baseline inventories and checklists towards developing a better understanding of the status and ecological needs of species and habitats, analysing threats and their underlying causes, educating decision-makers and stakeholders, and informing, devising and testing more effective management actions. At the very least, it is important to ensure that legislation designed to protect species - such as the national Endangered Freshwater Species, established under Fisheries Law - keeps pace with current knowledge of resident species and their status.

Discovering new species is very exciting and important, but it is only the start. It will take even more hard work to ensure that the species we find today will still be here tomorrow.

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Short Communication

First documentation of southern Annamite races of black-throated laughingthrush *Dryonastes chinensis germaini* and black-throated sunbird *Aethopyga saturata johnsi* from Cambodia

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Lower montane (above approximately 600 m above sea level, a.s.l.) areas of South and Southeast Mondulkiri Province form an extremity of the Annamite Range Moist Forests Ecoregion (Baltzer *et al*., 2001). Their evergreen and semi-evergreen forests support a distinctive flora and fauna with a number of species more strongly associated with the Annamite Mountains and central highlands of Vietnam than the rest of Cambodia (unpublished data). For example, within Cambodia, at least 14 species of bird have been recorded only from the Sen Monorom Plateau and adjacent areas of Seima Protected Forest, including two species (white-cheeked laughingthrush *Dryonastes vassali* and the Near-Threatened black-headed parrotbill *Paradoxrnis margaritae*) from the Da Lat Plateau Endemic Bird Area (Statersfield *et al*., 1998). In this short communication, I present putative observations of the South Annamese subspecies of black-throated sunbird *Aethopyga saturata johnsi* (Robinson & Kloss, 1919) and black-throated laughingthrush *D. chinensis germaini* (Oustalet, 1890) from the Sen Monorom Plateau. These represent the first sightings in Cambodia of these subspecies, which were previously believed to be endemic to Vietnam.

Observations were made in the valley of O'Ramis, an area of degraded semi-evergreen forest approximately 6 km south of Sen Monorom town at an altitude of approximately 650 m a.s.l. I have been visiting this site semi-regularly over the past three years and recorded a number of species rarely observed in Cambodia, including black-browed fulvetta *Alcippe grotei*, white-throated fantail *Rhipidura albicollis*, orange-headed thrush *Zoothera citrina* and, on 15 January 2011, at least 11 pale-capped pigeons *Columba punicea* – the largest recorded flock of this globally Vulnerable species in Cambodia.

On 10 August 2011, I observed two black-throated laughingthrushes foraging in the valley bottom. They were distinguished from the superficially similar white-cheeked laughingthrushes by their plain all-dark tail lacking the distinctive tri-coloured markings of the latter species. Both individuals showed distinctive cinnamon backs and underparts strongly contrasting with their white cheeks and grey caps. These matched the description and illustrations of *D. c. germaini* in Collar & Robson (2007) and Robson (2008). Further examination of photographs at www.orientalbirdimages.org of the nominate *D. c. chinensis*, which occurs in southern and central Laos and in Vietnam from south to central Annam (Collar & Robson 2007), and of a captive individual in Vientiane, Laos, in October 2011, supported this identification. No individuals showed any of the cinnamon tones observed in the Mondulkiri birds. Black-throated laughingthrushes are rarely recorded in Cambodia, with fewer than 10 records from southern Mondulkiri (Seima Protected Forest, O'Ramis and Dak Dam), Ratanakiri (Banlung) and Kompong Cham (Memot) (Goes, in prep.). Collar & Robson (2007) list *D. c. germaini* as occurring in South Vietnam (southern Annam, Cochinchina) and adjacent East Cambodia. However, the evidence for this statement is unclear, with none of the previous Cambodian records having been assigned to subspecies (Goes, in prep.).

Also on 10 August 2011, I observed a single male black-throated sunbird loosely associating with a mixed species flock. This individual showed an orangey, light red upper breast below its iridescent black-throat, contrasting with the bright crimson back and the paler belly. This matches both the description and illustrations of *A. s. johnsi* in Robson (2008) and photographs of this subspecies at www.orientialbirdimages.org and The Internet

Bird Collection (http://ibc.lynxeds.com/). However, I was unable to obtain images or observe museum specimens of *A. s. ochra*, which is listed as occurring in southern Laos and central Vietnam (Cheke & Mann, 2008), and thus sub-specific identification as *A. s. johnsi*, though biogeographically likely, is unproven.

Black-throated sunbirds are common in Cambodia in hill evergreen and semi-evergreen forest above approximately 700 m a.s.l. in the Cardamom and Elephant Mountains of the Southwest where the endemic subspecies *A. s. cambodiana* (described from Bokor) occurs (Robinson & Kloss, 1919; Goes, in prep.). In eastern Cambodia, records are restricted to the Sen Monorom Plateau, where the species is frequently recorded above approximately 500 m a.s.l. (pers. obs.), but racial identity has previously been undocumented (Cheke & Mann, 2008; Goes, in prep.).

The records of these subspecies provide further evidence for the importance of southern Mondulkiri for overall biodiversity within Cambodia. Documenting the presence of *D. c. germaini* and, putatively, *A. s. johnsi*, within Mondulkiri highlights the biogeographical connections between eastern Cambodia and the Annamite mountain range. Further exploration of poorly surveyed semi-evergreen and evergreen forest remnants throughout the Sen Monorom Plateau, including those on Phnom Nam Lyr - at 1,050 m a.s.l., the highest point in Mondulkiri Province - are likely to reveal additional records of animals and plants that are currently believed to be endemic to Vietnam.

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Short Communication

First record of the rare porcellanid crab *Pseudoporcellanella manoliensis* Sankarankutty, 1961 (Crustacea: Anomura) in the coastal waters of Cambodia

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The marine and coastal biodiversity of Cambodia is poorly documented. A short status report on commercial species was published by Touch (1997). Cambodia's *Biodiversity Status Report* (Smith, 2001) devoted fewer than five of its 240 pages to marine and coastal biodiversity, and marine invertebrates were not considered at all. Some scientific publications from the French colonial period exist (e.g. Morlet, 1889; Crosse & Fischer, 1892) and during the 1980s, Soviet fisheries scientists conducted surveys of commercial species in Cambodian waters (summarized in Touch, 1996). Since 2000 the present authors have surveyed the marine and coastal biodiversity in the province of Sihanoukville. Preliminary findings have been published as four posters (marine crabs, marine bivalves, marine gastropods and marine fishes of Cambodia) and an illustrated field guide (Ing *et al.*, 2006), of which only a few copies are available. Lists of species identified before 2003 have been published as Annexes in Cambodia's national report under the UNEP-supported project *Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand* (Ing, 2007).

During our surveys we have come across some species that, based on current knowledge, must be considered rare. One such species is the small porcellanid crab *Pseudoporcellanella manoliensis* Sankarankutty, 1961, originally described from the coast of India and later found in Singapore (Johnson, 1967), Peninsular Malaysia, the Gulf of Thailand and South China Sea (Ng & Nakasone, 1994). The natural habitat for *P. manoliensis* is sea pens, a group of octocorals found on soft substrates. In Singapore, this species is specifically associated with sea pens of the genus *Scytalium* (Johnson, 1967). In the present paper we describe new records of *P. manoliensis* from Cambodian waters and discuss its global distribution and rarity.

Marine and coastal fisheries in Cambodia are multi-gear and multi-species. Most vessels are small, with <30 horsepower engines, and operate close to shore, usually leaving port in late afternoon and returning the following morning (Khy, 2005; Ing, 2007). To survey and document the marine and coastal biodiversity of Cambodia we employed a number of different sampling methods. The specimens recorded herein were collected from baskets of "trash fish" (by-catch of low-value, small size organisms to be processed as fish meal) at two fish landing sites in Sihanoukville Province: Tomnup Rolok (Fig. 1) and Steung Hav. We also went out with a trawler a couple of times, and with clam and cockle fishers in Prey Nub (Table 1), but no *P. manoliensis* were found even though several species of sea pen were collected.

The trash fish at the two landing sites were derived exclusively from trawling. Several types of trawl nets with different mesh sizes are used, but most have a mesh size of 4-5 cm. Trawling is prohibited in waters less than 20 m deep, but illegal trawling in shallower water is common. Trash fish are transferred from trawlers to smaller boats, rinsed at the shore, weighed and transported to the fish meal factory. Some sorting may take place prior to weighing, and our team picked out specimens for photographing at this stage. The survey team consisted of two or three persons, each sorting through

Table 1 Dates and number of persons (p) in team for marine biodiversity survey in Sihanoukville Province, Cambodia. * Days with less than 20 kg trash fish available. ** Other survey methods include intertidal sampling, snorkelling, buying at market stalls and aquaculture facilities. Bold font indicates days when *Pseudoporcellanella manoliensis* were collected.

Month	Tomnup Rolok	Steung Hav	Shellfish dredging	Trawling	Other**
July 2000	10 Jul (3 p)	11 Jul (3 p)	8 Jul (3 p)	9 Jul (3 p)	12 Jul (3 p)
February 2001	5 Feb (3 p)	3 Feb (3 p)	-	2 Feb (3 p)	1 Feb (3 p) 4 Feb (3 p)
September 2001	30 Sep*	29 Sep (3 p)	-	-	-
January 2002	26 Jan.*	-	25 Jan (3 p)	-	24 Jan (3 p) 26 Jan (3 p)
September 2002	7 Sep (2 p)	-	-	-	4 Sep (3 p) 5 Sep (2 p)
January 2004	21 Jan (2 p) 23 Jan *	22 Jan * **26 Jan (2 p)**	20 Jan (2 p) 27 Jan (2 p)	-	-
January 2005	13 Jan (2 p) 16 Jan (2 p) **17 Jan (2 p)**	**15 Jan (2 p)**	19 Jan (2 p)	-	-
August 2005	17 Aug (2 p)	18 Aug*	-	-	-
June 2006	13 Jun (2 p) 17 Jun (2 p)	16 Jun (2 p)	-	-	14 Jun (2 p)

Table 2 Collection data and sizes of *Pseudoporcellanella manoliensis* in Cambodian waters.

Locality	Date	Specimens	Carapace length, width (mm)
Steung Hav	26 Jan 2004	1 male	22.1, 12.7
Steung Hav	15 Jan 2005	1 male	17.1, 9.4
Steung Hav	15 Jan 2005	1 female	21.1, 11.9
Tomnup Rolok	17 Jan 2005	1 ovigerous female	19.4*, 11.6

*tip of rostrum broken off.

two or three baskets of 20 kg per day. As a conservative estimate, 100 kg were surveyed per collecting day. On five occasions very little trash fish was available (Table 1), and these samples were excluded from the total amount of trash fish surveyed.

Specimens were photographed and preserved in 96% ethanol. Carapace length (CL) and width were measured with vernier callipers. A voucher specimen was deposited in the Zoological Museum of the University of Copenhagen (ZMUC), where no registration numbers are used for non-type material. The remaining specimens will be deposited in Cambodia when appropriate museum facilities become available.

Fig. 1 "Trash fish" from one basket spread for sorting at the Tomnup Rolok fish landing site on 16 January 2005 (© K. Jensen).

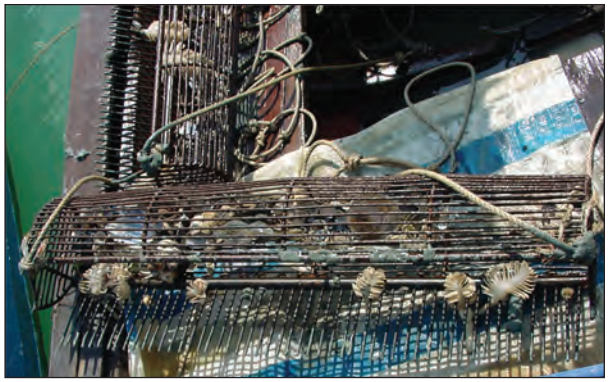

Fig. 2 Shellfish dredge containing by-catch dominated by the sea pen *Pteroeides* on 24 January 2002 (© K. Jensen).

Fig. 3 *Pseudoporcellanella manoliensis* from Cambodian waters. Dorsal view of male collected in Steung Hav on 26 January 2004 (© K. Jensen).

Fig. 4 Ventral view of the same male *Pseudoporcellanella manoliensis* as in Fig. 3 (© K. Jensen).

In nine collecting trips over a six-year period, comprising 21 days sorting through a grand total of about 1,600 kg of trash fish at the two sites (Table 1), only four specimens of *P. manoliensis* were found: two males and one female at Steung Hav and one ovigerous female at Tomnup Rolok (Table 2). All specimens were found in January: the first in 2004 (Figs 3 and 4) and the rest in 2005. Steung Hav was not visited in January 2002, but we surveyed landing sites in both Steung Hav and Tomnup Rolok in early February 2001 without seeing any *P. manoliensis*. In total, we sampled 11 days in January and February, including seven days at Tomnup Rolok and four at Steung Hav (Table 1).

The maximum size of the present specimens (CL 22.1 mm) is slightly larger than previously described specimens (maximum CL 16.9 mm in Johnson, 1967, and 19.6 mm in Ng & Nakasone, 1994). None of the Cambodian specimens were attached to sea pens or other living substrates, but sea pens were found in most of the trash fish baskets. The ovigerous female (Fig. 5) had 442 (eggs had to be partially removed for counting and the abdominal limbs were somewhat damaged in the process). The eggs were almost spherical, with a diameter of 90-110 μm, and bright orange in the recently dead specimen (Fig. 5).

In marine organisms, rarity is not a well-defined concept (Chapman, 1999; Mendoza *et al*., 2010). Few specimens may be collected if their habitats are difficult to access (e.g. deep sea species) or if the species has special and unknown habitat requirements or a very small geographic range. Three criteria have been proposed for defining rarity in marine invertebrates: (1) low abundance, (2) small geographic range, and (3) specialized habitat (Chapman, 1999). Based on published records, including the present specimens, *P. manoliensis* appears to fulfil at least two of these criteria. Since its original description in 1961, fewer than 20 specimens have been recorded in the scientific literature, and a maximum of three specimens has been collected at one time from the same location (Ng & Nakasone, 1994; present study). Thus the low abundance criterion is fulfilled. The species is considered Vulnerable in the *Singapore Red Data Book* (Davison *et al*., 2008) and very rare in Thai waters (Wisespongpand *et al*., 2008).

The Cambodian specimens were collected in January, and eight out of 12 previously collected specimens were also collected in January or late December (Ng & Nakasone, 1994). This may be because their habitats are fished only during winter months, but sea pens were common

Fig. 5 Ventral view of ovigerous female *Pseudoporcellanella manoliensis* collected in Tomnup Rolok on 17 January 2005 (© K. Jensen).

Fig. 6 Sea pens collected during this survey in Cambodia: (**a**) The commonest species of *Pteroeides* (length 11.5 cm); (**b**) Unidentified (length 10.5 cm); (**c**) Another species of *Pteroeides* (length 22 cm); (**d**) Unidentified (length 13 cm); and (**e**) Probably a species of *Virgularia* (length 23 cm and 15.5 cm). Specimens a-c were collected on 20 January 2004 from shellfish dredges; d was collected on 23 January 2004 from trash fish at Tomnup Rolok; and specimens e were collected on 25 January 2001 from shellfish dredges (© K. Jensen).

in all our surveys. During the dry season (November to April), large trawlers can operate further offshore (Khy, 2005), which may be where the habitat of *P. manoliensis* is found. The small size of *P. manoliensis* may mean that specimens are not retained by most fishing gear, but other crabs of similar size, e.g. *Leucosia* spp., *Myra* spp. and *Arcania* spp. were common in most of our collections.

The commonest sea pens in our collections from Cambodian coastal waters were species of the genus *Pteroeides* (Figs 2, 6a and 6c), which are hosts for the tiny porcellanid crab *Porcellanella triloba* White, 1852. This species was found in about 30% of the *Pteroeides* specimens collected by shellfish dredges in the present study, often one pair per sea pen. *Pteroeides* species are armed with numerous strong spines and the majority captured in fishing nets are therefore discarded at sea. In Singapore *Pseudoporcellanella manoliensis* is associated specifically with *Scytalium* (Johnson, 1967), a genus of sea pens containing only three species, all distributed only in the tropical Indo-West Pacific region (Williams, 2011). None of the *P. manoliensis* found in the present study were found in association with sea pens, and most of the sea pens found during our study remain unidentified (Fig. 6). However, we assume that in Cambodian waters *P. manoliensis* is also associated with sea pens (though probably not the common *Pteroeides* spp.), and thus the criterion of specialized habitat is also fulfilled. Both *Pteroeides* and *Scytalium* occur in soft sediments associated with coral reefs (Williams, 2011).

Pseudoporcellanella manoliensis is the only species in its genus, and does not seem to be closely related to other genera of porcellanid crabs (Ng & Nakasone, 1994). A total of 49 species of porcellanids have been described from the South China Sea (Komai, 2000). Nothing is known about the life history of *P. manoliensis*, and although several ovigerous females have been collected previously (Ng & Nakasone, 1994), the present observation is the first estimate of fecundity. In other porcellanid crabs the number of eggs varies from fewer than 100 to slightly over 1,000 (Ahmed & Mustaquim, 1974). Thus, *P. manoliensis* seems to be within the normal range for the group. Duration of larval development, number of larval stages, growth rate and age at sexual maturity are all unknown.

Except for the holotype - a juvenile specimen collected in the Gulf of Mannar, India (Sankarankutty, 1961) - and two specimens collected off the west coast of Peninsular Malaysia (Ng & Nakasone, 1994), all other specimens have been collected in the Gulf of Thailand and western part of the South China Sea. In fact, nine out of 16 specimens were collected in the north-eastern part of the Gulf of Thailand: five in Chon Buri, Thailand, and four in Sihanoukville, Cambodia (Ng & Nakasone, 1994; present study). Thus the Gulf of Thailand may be the species' main distribution area. In Cambodia coral reefs, seagrass beds and mangrove forests have been identified as habitats vulnerable to human impacts (Ing, 2007), and steps have been taken towards their conservation and management (FiA, 2006). It is recommended that research should be undertaken to identify the specific habitats of *P. manoliensis* and assess how these should be managed.

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First records of two reptile species (Gekkonidae: *Hemidactylus garnotii* Dumeríl & Bibron, 1836; Viperidae: *Ovophis convictus* Stoliczka, 1870) from Cambodia

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មូលន័យសង្ខេប

យើងរាយការណ៍ពីល្មូនពីរប្រភេទ ដែលទើបបានធ្វើកំណត់ត្រាជាលើកដំបូងសំរាប់ប្រទេសកម្ពុជា នៅក្នុងរយៈពេលនៃការស្រាវជ្រាវនៅក្នុងធម្មជាតិក្នុងឆ្នាំ ២០១០។ ប្រភេទទាំងពីរនោះគឺ *Hemidactylus garnotii* Dumeril & Bibron, 1838 ដែលបានរកឃើញពីព្រៃស្នើសុំការពារក្នុងស្រុក វឺនសៃ នៅភាគល្អាននៃប្រទេសកម្ពុជា និងប្រភេទ *Ovophis convictus* Stoliczka, 1870 ពីដែនជម្រកសត្វព្រៃភ្នំសំកុស នៅភាគនិរតីនៃប្រទេសកម្ពុជា។ ការកំណត់ត្រា *H. garnotii* ជាការបំពេញចន្លោះនៃរបាយពីមុនមក ក្នុងភាគខាងត្បូងនៃជ្រោយឥណ្ឌូចិន និងការកំណត់ត្រា *O. convictus* អាចតំណាងអោយប្រភេទនេះនៅភាគខាងជើងដាច់ពីគេ ដែលពីមុនមកត្រូវបានគេស្គាល់តែនៅជ្រោយម៉ាឡេស៊ី។ ការកើនឡើងនៃចំនួនប្រភេទល្មូន ដែលត្រូវបានកត់ត្រាទុកជាឯកសារក្នុងតំបន់ទាំងពីរនេះ ឆ្លុះបញ្ចាំងនូវភាពផ្លែកៗនៃប្រភេទល្មូនប្រទេសកម្ពុជានៅក្នុងព្រៃធម្មជាតិ ដែលបានទទួលការសិក្សាតិចតួចនៅឡើយ ហើយដែលចាំបាច់ត្រូវធ្វើការស្រាវជ្រាវបន្តទៀត។

Abstract

We report two reptile species, both new records for Cambodia, which were encountered during field surveys in 2010: *Hemidactylus garnotii* Dumeríl & Bibron, 1836, from the Veun Sai Proposed Protected Forest in Northeast Cambodia, and *Ovophis convictus* Stoliczka, 1870, from Phnom Samkos Wildlife Sanctuary in Southwest Cambodia. These records bridge a previous distribution gap in the southern part of the Indochinese range of *H. garnotii* and represent a possible northern disjunct population of *O. convictus*, previously known only from Peninsular Malaysia. The growing number of reptile species documented in the two areas reflects the highly diverse yet poorly studied nature of Cambodian reptiles, which warrant further research.

Keywords

Cardamom Mountains, Veun Sai, natural history, distribution, mountain pitviper, Garnot's house gecko.

Introduction

Knowledge of Southeast Asian reptiles has grown substantially in recent years due to resurgence in field investigations (Thompson, 2008; Das, 2010). However, a recent review for Cambodia revealed its biodiversity, including reptiles, to be poorly studied (Daltry, 2008). Nevertheless,

the results of post-conflict fieldwork in the country have led to a rapid increase of reptile records, chiefly from the Cardamom Mountains (Daltry & Wüster, 2002; Stuart & Emmett, 2006; David *et al.*, 2008; Grismer *et al.*, 2008; Grismer *et al.*, 2010; Wood *et al.*, 2010; Neang *et al.*, 2010, 2011; Malhotra *et al.*, 2011a), lowland areas of Siem Reap (Hartmann *et al.*, 2009, 2010, 2011), and from mountainous areas in the Northeast (Stuart *et al.*, 2006, 2010; Malhotra *et al.*, 2011a).

In 2010, herpetological surveys were undertaken in the Veun Sai Proposed Protected Forest in northeastern Cambodia and in the Phnom Samkos Wildlife Sanctuary in the country's Southwest. During the surveys, two reptile species were found which had not been recorded in Cambodia previously. In this paper, we provide morphological evidence of their identity and briefly remark on their natural history and biogeography.

Methods

Study sites

The 56,900 ha Veun Sai Proposed Protected Forest is in the Veun Sai and Siem Pang districts of Ratanakiri and Stung Treng provinces (respectively), Northeast Cambodia (Fig. 1). The site includes dry dipterocarp and semi-evergreen forest below 100 m a.s.l. (above sea level) through to evergreen forest at 500 m a.s.l. The study area is characterized by disturbed semi-evergreen forest dominated by *Lagerstroemia* spp., *Dipterocarpus* spp. and other short trees that are sometimes intermixed with bamboo. Surveys were undertaken in the vicinity of the lowland stream O'Kapin (14°06'42.5"N, 106°41'26.9"E) at 98 m a.s.l. in the Siem Pang District. Evidence of past disturbances were apparent in the area, which were attributed

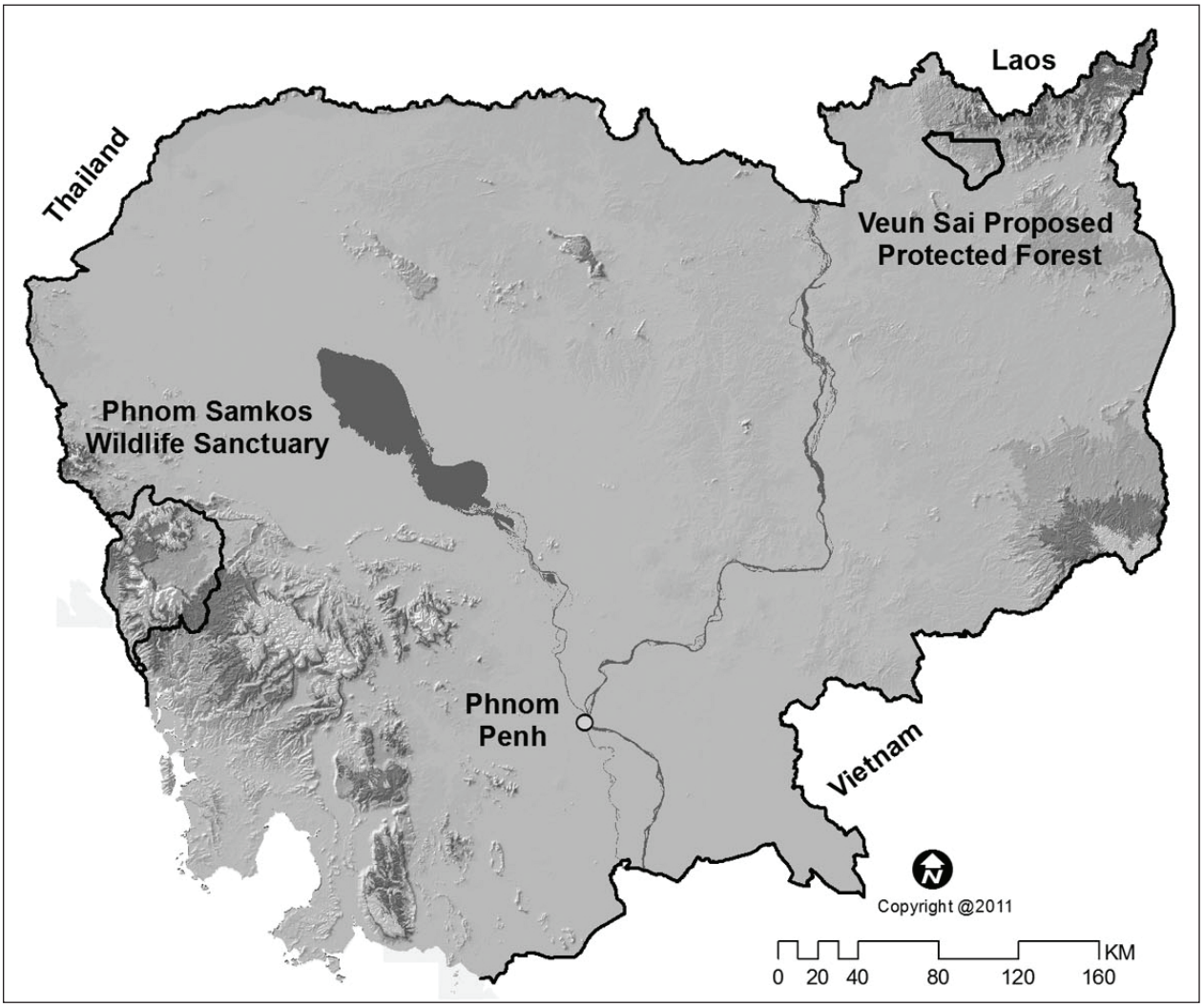

Fig. 1 Locations of the Veun Sai Proposed Protected Forest and Phnom Samkos Wildlife Sanctuary in Cambodia.

by guides to the presence of ethnic minority villages approximately 3-4 km to the south.

The 332,566 ha Phnom Samkos Wildlife Sanctuary is located in the Cardamom Mountains in the Pursat, Battambong and Koh Kong provinces of Southwest Cambodia (Fig. 1). The sanctuary ranges in elevation from 100–1,717 m a.s.l. and encompasses a variety of vegetation types, including large areas of dry dipterocarp forest, lowland evergreen forest and hill evergreen forest (Daltry & Momberg, 2000; Webb, 2005). We conducted surveys along a mountain ridge in an area of disturbed hill evergreen forest (12°07′31.9″N, 103°07′32.9″E) at 546 m a.s.l. within the Pursat region of the sanctuary. This area was selectively logged during the early 1990s for dipterocarp and valuable tree species including, more recently, rosewood *Dalbergia cochinchinensis*.

Sampling methods

In the Siem Pang District of Veun Sai, visual encounter searches were undertaken from 19 February to 2 March 2010. These focused on the O'Kapin stream and on searches of leaf litter and rotten logs in nearby forest areas. In Phnom Samkos, sampling was undertaken using two trap lines and supplemented by day time and night time searches from 16 to 27 July 2010. Each trap line consisted of 20 pitfall traps (trap depth: 60 cm, diameter: 30 cm) spaced at 5 m intervals and directed by a drift fence (height: 60 cm). Trap lines were checked twice daily at 0700h and 2030h. Following collection and euthanasia (using Finguel MS222 solution) of voucher specimens at both sites, liver tissue was taken for storage in 97% ethanol and specimens were preserved with 10% formalin for at least 24 hours and then transferred to 70% ethanol for long-term storage. All voucher specimens were deposited in the zoological reference collection of the Centre for Biodiversity Conservation (CBC) at the Royal University of Phnom Penh.

Morphological measurement

Morphological characters were measured with a digital calliper to the nearest 0.1 mm under a Nikon SMZ 645 dissecting microscope. Characters measured on both lizards and snakes included: snout to vent length (SVL – distance from the tip of the snout to the vent); and head length (from the tip of the snout to the posterior margin of the mandible). Scale counts common to both lizards and snakes included counts of supralabial and infralabial scales. Additional characters for lizards included the number of subdigital lamellae on the fourth finger and toe. Additional characters for snakes included occiput scale counts – the number of scale rows at the posterior-most part of the mandible; dorsal scale rows at neck (DSN – the number of scale rows at one head length posterior to the head); dorsal scale rows at mid-body (DSM – the number of scales at mid-body); dorsal scale rows anterior to the vent (DSV – the number of dorsal scales at one head length anterior to the vent); ventral scales (VS – counted as the number of scales from the first ventral scale posterior to the gular scales to the scale immediately anterior to the anal plate); and subcaudal scales (SC – the number of divided scales excluding the terminal scute). Paired characters are given in right (R) / left (L) order.

Results

A total of 19 amphibian and 26 reptile species from the Veun Sai Proposed Protected Forest and 18 amphibian and 18 reptile species from the Phnom Samkos Wildlife Sanctuary were recorded during the field surveys (Neang, unpublished data). Among these species, one gecko from Veun Sai and one pitviper from Phnom Samkos are reported below as new country records for Cambodia. The other species will be reported elsewhere.

Gekkonidae

Garnot's house gecko or Indo-Pacific gecko *Hemidactylus garnotii* Dumeríl & Bibron, 1836.

Material examined: CBC01326, collected by Neang Thy and Hun Seiha on 27 February 2010 in Veun Sai Proposed Protected Forest, Siem Pang District, Stung Treng Province (Fig. 2).

The single adult female (SVL 57.9 mm) from Veun Sai matches the description of Taylor (1963) and the expanded description of Zug *et al.* (2007) in having a relatively flattened body and tail; edges of tail serrated; rostral scale large with mid-dorsal clef; 10 supralabial scales; 10R/9L infralabial scales; series of enlarged femoral scales; median subcaudal scales rectangular and widened; sharp ventrolateral granular folds; first finger half the length of the second, fifth toe less than half that of fourth; all fingers and toes bearing transversely divided subdigital lamellae along part of their way. Our specimen has 11 subdigital lamellae on fourth finger, two proximal undivided, eight distal divided and distal-most single; 11 lamellae on fourth toe, three proximal undivided, seven distal divided and distal-most single on right, with two proximal undivided on left. Dorsal surface of body, limbs, flanks, tail and head have small, similarly sized conical scales; belly scales and scales beneath thigh and tibia smooth and larger than those on throat and chest; ventral scales cycloid.

Fig. 2 *Hemidactylus garnotii*, Siem Pang District, Veun Sai Proposed Protected Forest, Northeast Cambodia (© Gabor Csorba).

Fig. 3 *Ovophis convictus*, Veal Veng District, Phnom Samkos Wildlife Sanctuary, Southwest Cambodia (© Neang Thy).

In life, the specimen had a greenish-grey colour on the dorsum, head and tail, with minute dark brown markings and elongate to irregular grey markings arranged in short transverse lines or dots forming five longitudinal rows, narrowing to three rows on the base of tail and appearing as large blotches on its distal portion; fine scattered grey dots occurred on the head, with two grey spots almost in contact and forming a short line extending through the eye; anterior part of head lighter greyish-brown, iris copper coloured; surface of limbs light pinkish-brown with fine dark brown markings and larger brownish-grey spots; upper surface of fingers and toes dark grey with lighter greyish spots; surface of inner fingers and toes yellowish; lamellae uniformly bluish-grey; venter, beneath limbs, throat, infralabials scales and chin yellowish. In preservation, the specimen is brownish-grey above and whitish below.

The single specimen was encountered at 2040h on the underside of a tree that had fallen across a 13 m wide section of a slow-moving stream, approximately 1 m above the surface of the water in an area of lowland semi-evergreen forest at (14°06′42.5″N, 106°41′26.9″E) at 98 m a.s.l. The area was reported to have been disturbed by an ethnic minority group that formerly lived there.

Viperidae

Mountain pit viper *Ovophis convictus* Stoliczka, 1870.

Material examined: CBC01012, collected by Neang Thy, Kris Meanrith and Chhin Sophea on 24 July 2010 in Phnom Samkos Wildlife Sanctuary, Veal Veng District, Pursat Province (Fig. 3).

The single juvenile specimen (SVL 181 mm) has the first supralabial completely separated from nasal; a stout and short body; a sharply truncate rostrum; a pair of large internasals; supraoculars separated by eight small scales; the second upper labial forms the anterior margin of the facial pit; eight supralabial scales with the third being largest; 9R/ 10 L infralabials; 29 scales at occiput; 25 DSN; 25 DSM; 18 DSV; 136 VS; 27 SC, anal plate entire; dorsal scales weakly keeled. Many of the diagnostic characters of the Samkos specimen closely match those of *O. convictus* described by Stoliczka (1870) and revised by Malhotra *et al.* (2011b) from Penang Island, West Malaysia, and distinguish it from *O. monticola* (see Discussion).

In life, the specimen had a large rusty brownish cream stripe extending posteriorly from the nasal scale through loreal scales, eye and upper side of head and downward to the posterior end of the mandible, connecting with the same colour pattern on body; another rusty cream stripe running from posterior margin of the nasal scale through the lower preocular scale, below eye through the sixth, seventh and eighth supralabial scales, crossing the ninth infralabial on the right and the tenth on left side, downward to the mandible; three black lines projecting posteriorly on the neck, the median thinnest; back and flanks brownish-cream with minute rusty or dark spots; black crossbar behind neck; 13–14 black squarish blotches alternating on each side of back, separated by a faint dark vertebral line; two black blotches on upper surface of tail base, two-thirds of posterior section of tail lighter brown with few white spots on upper surface; belly and subcaudal region have dark brown mottling; posterior portion of tail pale brown; mental scale and chin shields with greyish cream mottling; underside of head darker

brown except for two white gular scales. In the preserved specimen, the rusty colouration faded to white.

The single specimen from Phnom Samkos was discovered at 0700h in a pitfall trap 40 m from a small rocky stream in an area of slightly disturbed hill evergreen forest (12°07′31.9″N, 103°07′32.9″E) at 546 m a.s.l. This is highly likely to be a nocturnal, cryptic montane forest floor dweller.

Discussion

Outside Cambodia, *Hemidactylus garnotii* has been reported to occur in Vietnam, Laos, Thailand, Myanmar, Taiwan, southern China, India, Nepal, Malaysia, Indonesia, Philippines, New Caledonia, Polynesia, Samoa, Pakistan and the United States of America (Grismer 2011; Taylor, 1963; Zug *et al.*, 2007; Nguyen *et al.*, 2009; Das, 2010). Our record of this species in Cambodia fills a biogeographical gap from the southwestern portion of Indochina. Zug *et al.* (2007) reported that *H. garnotii* is frequently found in human settlements and its occurrence in Veun Sai is consistent with this observation because it was encountered within an area associated with a former ethnic minority habitation.

Ovophis convictus was originally described by Stoliczka (1870) from Penang Island, West Malaysia. Recently, two tissue samples of this species from the Cameron Highlands and one tissue sample from Langkawi Island, West Malaysia, were sequenced by Malhotra *et al.* (2011b) in an attempt to resolve the confusion caused by the morphological similarity of the Southeast Asian members of the *Ovophis* complex: *O. makazayazaya* (David & Tong, 1997), *O. tonkinensis* (Bourrett, 1934), *O. monticola* (Günther, 1864), *O. zayuensis* (Jiang, 1977) and *O. convictus* (Stoliczka, 1870). In following this revision, the single Cambodian specimen from Phnom Samkos differs from *O. makazayazaya* and *O. tonkinensis* in the third supralabial being larger than the fourth (versus the fourth being larger than the third), and the former species occurs far to the north in eastern and western China and northern Vietnam, and the latter occurs in southern China and northern and central Vietnam. It is also distinguished from *O. zayuensis* from Xizang, Yunann, northeastern India and Myanmar in having paired subcaudals (versus single subcaudals) and a lower number of ventral scales (136) (versus a higher ventral scale range of 158–175). The Samkos specimen somewhat resembles *O. monticola*, the southernmost record of which is from Laos, in having a large third supralabial scale and divided subcaudal scales (Malhotra *et al.*, 2011b). However, it is distinguished from *O. monticola* in having supraoculars separated by eight small scales (versus six or seven), and having 27 SC (versus 36–47; Stuart & Heatwole, 2008). Lastly, in having a low number of ventral scales (136), a lower number of subcaudal scales (27), our specimen falls within the ranges of 120–139 ventral scales and 19–33 subcaudal scales for *O. convictus* (Malhotra *et al.* 2011b; unpublished data), and 132 VS and 29 SC had been reported for *O. convictus* by Stoliczka (1870).

The occurrence of *O. convictus* in Southwest Cambodia currently represents the northern limit of this species and our confirmation of *O. convictus* from Cambodia supports Malhotra *et al.*'s (2011b) speculation that it is likely to occur in mountainous areas of southern Vietnam and in South and Southeast Thailand. In summary, our findings demonstrate the importance of continuing herpetological surveys in Cambodia to improve understanding of species status and distribution ranges.

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Confirmation of seven bat species for Cambodia

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មូលន័យសង្ខេប

ផ្អែកលើការសំយោគឯកសារ កម្ពុជាមានសត្វប្រចៀវត្រឹមតែ៥៣ប្រភេទ តួលេខនេះបង្ហាញពីកំរិតទាបខ្លាំងបើធៀបទៅនឹងប្រទេសជិតខាង។ តាមរយៈការសិក្សារូបសាស្ត្រនៃភាគសំណាកដែលបានប្រមូលក្នុងរយៈពេល១១ឆ្នាំ (២០០០ដល់២០១១) ដោយឧបករណ៍មង (mist nets) និងអន្ទាក់កាំង (harp traps) នៅក្នុងនិងក្រៅតំបន់ការពារនៃជាយប្រទេសយើងបានរកឃើញសត្វប្រចៀវប្រាំពីរប្រភេទបន្ថែមទៀតរួមមាន៖ *Rhinolophus yunanensis, Hipposideros diadema, Saccolaimus saccolaimus, Myotis ater, M. horsfieldii, Murina cyclotis* និង *Kerivoula picta*។ ដូច្នេះចំនួនសរុបនៃប្រចៀវកម្ពុជាបច្ចុប្បន្នគឺ៦០ប្រភេទ កំណត់ត្រានេះបង្ហាញពីភាពខ្វះខាតក្នុងការរុករកតួលេខពិតដែលមាន។ តាមទស្សនវិស័យអភិរក្ស មានសត្វប្រចៀវតែ៣ប្រភេទប៉ុណ្ណោះពីប្រទេសកម្ពុជាដែលបានចុះក្នុងបញ្ជីIUCN។ ពីរប្រភេទចាត់ចូលក្នុងក្រុមកង្វះទិន្នន័យ (Data Deficient) និងមួយទៀតជាប្រភេទកំពុងរងគ្រោះ (Vulnerable) ហើយជ្រាកដណាស់មានពិតមានជាច្រើនទៀតស្តីពីសត្វប្រចៀវនៅកម្ពុជាដែលយើងមិនទាន់ដឹងនូវឡើយ។ របកគំហើញប្រភេទសត្វប្រចៀវថ្មីៗជាមួយនឹងការស្រាវជ្រាវដ៏តិចតួចនិងគ្របដណ្តប់មួយភាគតូចនៅឡើយបានឆ្លុះបញ្ចាំងពីលទ្ធភាពខ្ពស់ក្នុងការរកឃើញប្រភេទថ្មីៗច្រើនថែមទៀតនាពេលអនាគត។

Abstract

Relative to neighbouring countries, the Cambodian bat fauna is poorly known, with only 53 species reported in the peer-reviewed literature. Through a morphological review of specimen material collected over an 11-year period (2000-2011) with mist nets and harp traps in protected and non-protected areas, mostly in border regions, we confirm the occurrence of seven additional bat species: *Rhinolophus yunanensis, Hipposideros diadema, Saccolaimus saccolaimus, Myotis ater, M. horsfieldii, Murina cyclotis* and *Kerivoula picta*. These records highlight the incompleteness of existing information, and the new national total of 60 bat species undoubtedly falls short of the true figure. Only three of the bat species known to occur in Cambodia are listed by the IUCN in categories other than Least Concern. Two species are considered Data Deficient and one Vulnerable, and major gaps remain in knowledge. In view of the recent spate of bat species new to science described from Cambodia and the limited survey effort and coverage achieved to date, the likelihood of additional discoveries in future field studies would appear to be high.

Keywords

Bat taxonomy, new records.

Introduction

The bats of Cambodia are poorly known. Although research effort has intensified in recent years, a recent study found only 50 bat species documented in the peer-reviewed literature for this country (Kingsada *et al*., 2011). Three bat species new to science were subsequently described from sites in East and Northeast Cambodia and have been added to this number: *Glischropus bucephalus* Csorba, 2011, *Murina cineracea* Csorba & Furey, 2011 and *M. walstoni* Furey, Csorba & Son, 2011 (Csorba *et al*., 2011). This lags far behind similar figures for neighbouring Thailand, Vietnam and Laos, which include at least 126, 110 and *circa* 80 bat species respectively (Francis *et al*., 1999; Can *et al*., 2008; Kingsada *et al*., 2011).

A number of additional bat species were included in range maps or reported for Cambodia by Corbet & Hill (1992), Matveev & Csorba (2007) and Francis (2008) without explanation. This paper validates the presence of six such species through a morphological review of specimens collected in the country and provides the first documented evidence of a seventh. Notes on the distribution and ecology of each species are also provided.

Methods

Study areas

Voucher specimens referred to in this paper were collected over 11 years in Cambodia. From 2000 to 2005, specimens were collected by J. Walston in several provinces of the country: Kampong Speu (February 2000), Preah Vihear (December 2000), Kandal (December 2001) and Phnom Penh (November 2005) (Fig. 1). These were deposited at the Hungarian Natural History Museum (HNHM, Budapest, Hungary) and Harrison Institute (HZM, Sevenoaks, United Kingdom, formerly Harrison Zoological Museum) and examined by the authors. From 2005 to 2011, specimens were collected during studies by the authors in several protected areas and proposed protected areas, as summarised below (Fig. 1). Four-bank harp traps and mist nets of varying sizes were employed in the surveys and selection of sampling locations largely focused on flyways within the forest understory, such as trails, watercourses and natural linear breaks in the vegetation. Specimens from these studies were deposited at the Centre for Biodiversity Conservation (CBC, Zoological Collection, Royal University of Phnom Penh), HNHM and HZM.

In July 2005 and January 2006, bat surveys were undertaken in the Seima Protection Forest by G. Csorba and S.H. Hout and by G. Csorba, L. Duval and G. Ronkay, respectively. During these surveys, three harp traps and several mist nets were used. The Seima Protection Forest is in the low-lying eastern plains of Cambodia (Mondulkiri Province) and covers 303,400 ha. The site supports a high diversity of forest types, including evergreen forest, mixed deciduous formations, and dry dipterocarp forest (Pollard, 2007). In January 2006, bats were surveyed in Bokor National Park by G. Csorba, L. Duval and G. Ronkay. The same survey equipment was employed as in the Seima Protection Forest surveys. The national park is in the southern coastal province of Kampot and covers 140,000 ha. The park centres on a sandstone massif, with an extensive plateau at around 1,000 m a.s.l (above sea level). Habitats include semi-evergreen and evergreen forest, while the plateau is dominated by dwarf evergreen forest and includes small cleared areas of grassland (Seng *et al*., 2003).

In July 2005 and February-March 2011, bat surveys were undertaken in Preah Vihear Protected Forest by G. Csorba, B. Hayes and Hout S.H. and by Ith S., G. Csorba, N. Furey, Seng R., Chea N. and M. Csorba, respectively. During the 2005 survey, mist nets were solely employed, while in the 2011 survey several mist nets and three harp traps were used. The protected forest is located in the northern plains and abuts the Cambodia-Thailand border in Preah Vihear Province. The landscape of the area is dominated by dry dipterocarp forest and grassland, interspersed with patches of semi-evergreen forest (Walston & Bates, 2001).

In November 2009, a brief survey was undertaken in the Preah Vihear sector of the Kulen Promtep Wildlife Sanctuary by Ith S. and G. Csorba using one harp trap and three mist nets. The wildlife sanctuary lies to the west of Preah Vihear Protected Forest and encompasses parts of the Oddar Meanchey, Preah Vihear and Siem Reap provinces. The landscape and habitats of the wildlife sanctuary are similar to those of the Preah Vihear Protected Forest.

In December 2009 and 2010, surveys were undertaken by N. Furey in the Pursat sector of Phnom Samkos Wildlife Sanctuary using several mist nets. This wildlife sanctuary covers 332,566 ha and is located in the Cardamom Mountains of the Pursat, Battambong and Koh Kong provinces in Southwest Cambodia. The wildlife sanctuary has an elevation range of 100-1,717 m a.s.l. and includes large areas of dry dipterocarp forest, lowland evergreen forest and hill evergreen forest (Daltry & Momberg, 2000).

In February-March and August 2010, field studies were undertaken in the Veun Sai Proposed Protected Forest by Ith S., G. Csorba, N. Furey, Phauk S. and T.

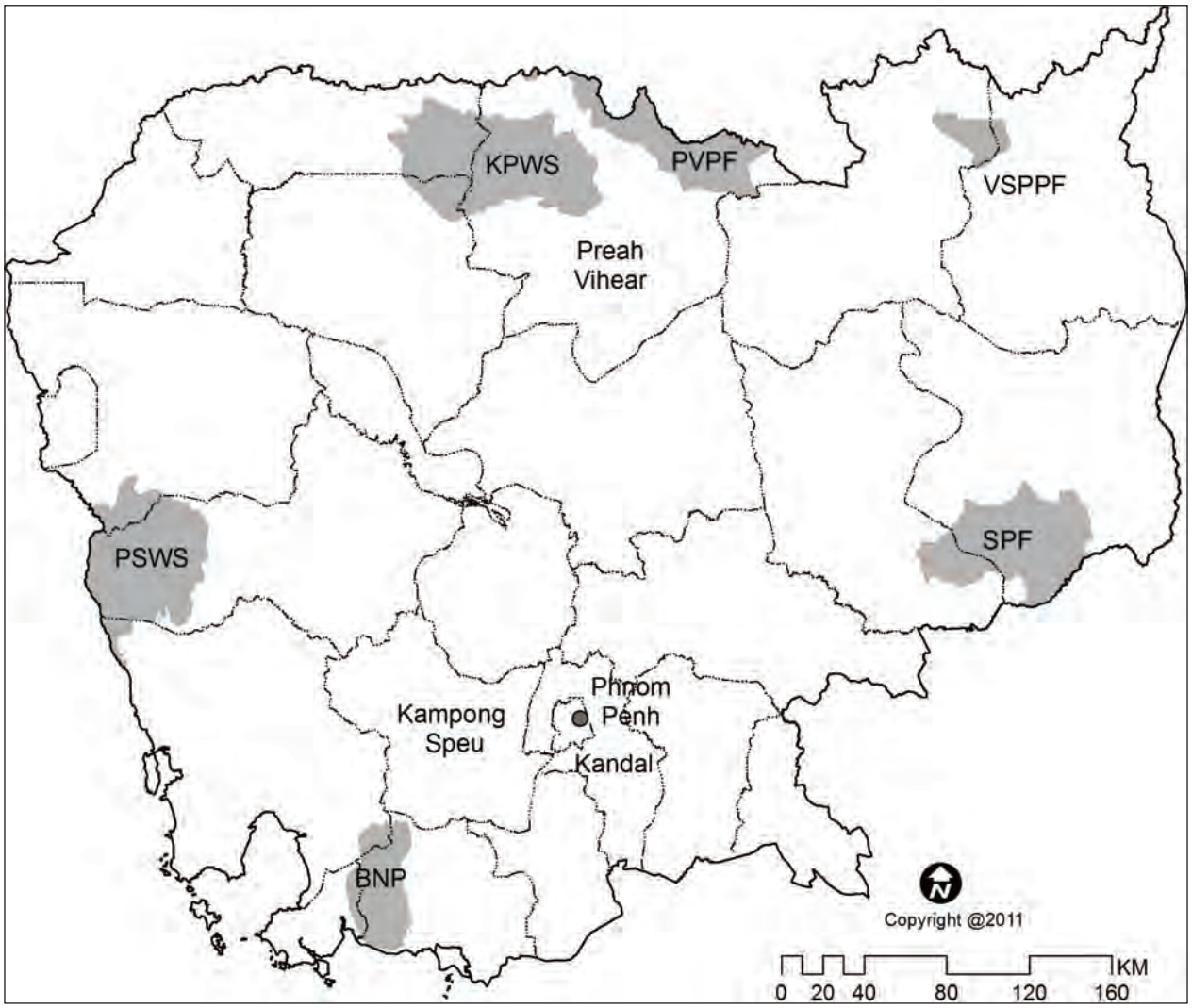

Fig. 1 Location of bat survey areas in Cambodia. BNP = Bokor National Park, KPWS = Kulen Promtep Wildlife Sanctuary, PSWS = Phnom Samkos Wildlife Sanctuary, PVPF = Preah Vihear Protected Forest, SPF = Seima Protection Forest, VSPPF = Veun Sai Proposed Protected Forest.

Gorfol using several harp traps and mist nets. Veun Sai Proposed Protected Forest covers approximately 55,000 ha in Veun Sai District, Ratanakiri Province, and Siem Pang District, Steung Treng Province of Northeast Cambodia. Habitats in the site comprise lowland evergreen and semi-evergreen forest at elevations between 100 and 400 m, with more northerly areas mountainous and southern parts characterized by grasslands (B. Rawson, pers. comm.).

Morphological assessment

Age and reproductive status were assessed following Anthony (1988) and Racey (1988). External measurements were taken from dry skins and alcohol-preserved specimens to the nearest 0.1 mm, while craniodental measurements were taken to the nearest 0.01 mm using digital callipers under a stereo microscope. Measurements herein include only those taken from non-juvenile individuals, as indicated by 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: 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; and 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).

Definitions for craniodental measurements were as follows: GTL: greatest length of skull - greatest anteroposterior diameter of the skull, taken from the most projecting point at each extremity along the median line of the skull (including the premaxilla); CBL: condylobasal length - from the exoccipital condyle to the anterior rim of 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^3L: maxillary toothrow length - from the front of upper canine to the back of the crown of the third molar; C^1C^1W: width across the upper canines - greatest width, taken across the outer borders of upper canines; M^3M^3W: 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_3L: 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 specimen material examined is given in Annex 1.

Results

Rhinolophus yunanensis Dobson, 1872a (Fig. 2)

Material examined: One male from Kampong Speu Province and one female from Phnom Samkos Wildlife Sanctuary (Fig. 1, Annex 1).

Possessing a sella with a wide base and characteristic middle constriction, the two specimens were readily identified as members of the *pearsonii* group which comprises two species in the Indochinese Subregion: *R. pearsonii* Horsfield, 1851 and *R. yunanensis*. As these taxa are strikingly similar and differ primarily in size (Csorba *et al*., 2003), species diagnosis was based on craniodental measurements. Though some measurements were intermediate between ranges for the two species (Table 1 and 2), skull length (*sensu* Csorba *et al*., 2003), CM^3L, MAW, ML and CM_3L measurements of the two specimens exceeded upper limits for *R. pearsonii* provided by Csorba *et al.* (2003), and the specimens were therefore referred to *R. yunanensis* (skull length = 24.72 & 25.00 mm versus 24.33 mm; CM^3L= 10.08 & 10.26 mm versus 9.97 mm; MAW= 11.37 mm versus 11.33 mm; ML= 17.86 & 17.54 mm versus 17.39 mm; CM_3L= 10.75 & 11.11 mm versus 10.70 mm, respectively).

The single female from Phnom Samkos Wildlife Sanctuary was caught at 1840h in a mist net over a stream in an area of disturbed hill evergreen forest. Time-expanded (x10) echolocation calls with a frequency of maximum energy of 53.6 kHz were recorded from the animal while held motionless in the hand. *Rhinolophus yunanensis* occurs in India, Myanmar and China, southwards almost to Peninsular Thailand (Simmons, 2005; Francis, 2008) and the above specimens represent the first records in Cambodia.

Hipposideros diadema (E. Geoffroy, 1813) (Fig. 3)

Material examined: One male from Preah Vihear Province, four males and three females from Veun Sai Proposed Protected Forest, and two males from Preah Vihear Protected Forest (Fig. 1, Annex 1).

Ten specimens were referred to *H. diadema* on the basis of the following characteristics: FA, CCL, CM^3L and ZYW (Tables 1 and 2) in accordance with ranges given by Corbet & Hill (1992); presence of pale patches on dorsum (which distinguish this species from all other Asian members of the genus *Hipposideros*; Francis, 2008); posterior noseleaf wider than anterior noseleaf; absence of fleshy outgrowths behind posterior noseleaf; intermediate noseleaf with median ridge; frontal depression present; second lower incisor (I_2) not greatly enlarged.

In Veun Sai Proposed Protected Forest, seven individuals were caught on trails and streams in semi-evergreen forest at 1820h, 1845h and 2000h in mist nets and one overnight in a harp trap. In Preah Vihear Protected Forest, two individuals were collected before 2000h: one in a mist net in dry dipterocarp forest and one in a harp trap beside a pool in semi-evergreen forest. A geographically widespread species occurring in the Nicobar Islands (India), Myanmar, Thailand, south Vietnam and Laos, through Indonesia and the Philippines to Australia (Simmons, 2005), Corbet & Hill (1992) included *H. diadema* in range maps for Cambodia without explanation, although Kock (2000) concluded that its presence was uncertain. The present records therefore confirm its occurrence, as more recently suggested by Francis (2008).

Saccolaimus saccolaimus (Temminck, 1838)

Material examined: One male from Phnom Penh (Fig. 1, Annex 1).

This specimen was identified as *S. saccolaimus* based on the following characteristics: external and cranial

measurements (Tables 1 and 2) in accordance with published ranges (Bates & Harrison, 1997; Borissenko & Kruskop, 2003); dorsal pelage dark brown with irregular white markings; ventral pelage paler; radio-metacarpal pouch almost absent; well-defined gular sac present; interfemoral membrane, hind limbs and feet naked; wing membrane attached to the ankle; anterior upper premolar (P^2) large, approximately 30% of posterior premolar (P^4) in crown area.

Ranging from India and Sri Lanka through mainland Southeast Asia, the Philippines, Indonesia and Papua New Guinea to Northeast Australia, the occurrence of *S. saccolaimus* in Cambodia was mentioned by Simmons (2005), Matveev & Csorba (2007) and Francis (2008) without details. The above record therefore confirms its presence and its capture in an urban environment is consistent with the species' known habit of occasionally roosting in buildings (Bates & Harrison, 1997).

Myotis ater (Peters, 1866) (Fig. 4)

Material examined: Three males from Preah Vihear Province, two females from Kulen Promtep Wildlife Sanctuary, two males from Phnom Samkos Wildlife Sanctuary, four females from Veun Sai Proposed Protected Forest, and ten males and seven females from Preah Vihear Protected Forest (Fig. 1, Annex 1).

Though it is unclear whether bats from mainland Southeast Asia are the same as those from Maluku, the type locality of *M. ater* (Francis, 2008), the specimens from Cambodia were referred to the species and distinguished from the similar *M. muricola* (Gray, 1846) on the basis of the following characteristics: average FA slightly longer at 36.5 mm (range = 34.8-38.8 mm) (Table 1); feet small, half or less than the length of the tibia; wing membrane attached to base of toes; skull larger with CBL averaging 13.55 mm (13.15-14.20 mm) and CCL averaging 12.84 mm (12.49-13.39 mm) (Table 2); crown area of first (I^2) and particularly second upper incisor (I^3) considerably larger; upper canine (C^1) also larger, exceeding posterior premolar (P^4) in height; upper middle premolar (P^3) small and displaced inwards, such that anterior (P^2) and posterior premolar are very close or in contact; lower canine (C_1) distinctly exceeds posterior premolar (P_4) in height; lower middle premolar (P_3) small and usually intruded such that the anterior (P_2) and posterior premolars are almost in contact.

In Kulen Promtep Wildlife Sanctuary, two individuals were caught at 1840h in semi-evergreen forest. In Preah Vihear Protected Forest, two individuals were caught in harp traps and the remainder in mist nets from 1900h to 2200h in semi-evergreen forest and dry dipterocarp forest. In Phnom Samkos Wildlife Sanctuary, two individuals were caught at 1940h and 2100h in mist nets in disturbed evergreen forest. In Veun Sai Proposed Protected Forest, two individuals were caught in mist nets at 2010h on a trail and stream in semi-evergreen forest and two individuals in harp traps at 1920h in a banana plantation and in semi-evergreen forest. As currently understood, *M. ater* occurs in Vietnam, Peninsular Thailand and Malaysia through the Indonesian islands and the Philippines to New Guinea (Simmons, 2005). The above records validate previous reports of its occurrence in Cambodia (Matveev & Csorba, 2007).

Myotis horsfieldii (Temminck, 1840) (Fig. 5)

Material examined: One male and female from Preah Vihear Province, one male from the Seima Protection Forest, and four males and two females from Veun Sai Proposed Protected Forest (Fig. 1, Annex 1).

Nine specimens were identified as *M. horsfieldii* on the basis of the following characteristics: FA, TIB, HF, CCL and CM^3L measurements (Tables 1 and 2) according with published ranges for Indochina (Bates *et al.*, 1999; Hendrichsen *et al.*, 2001; Borissenko & Kruskop, 2003); feet relatively large, slightly more than half the length of the tibia; wing membrane attached to outer metatarsal, 1-2 mm from the base of the toes; upper canine (C^1) nearly twice the height of the posterior premolar (P^4); upper anterior (P^2) and middle premolar (P^3) small, the latter slightly displaced inwards and sometimes compressed; lower canine (C_1) greatly exceeding the lower posterior premolar (P_4) in height; crown area of lower middle premolar (P_3) approximately half that of the anterior premolar (P_2).

In Veun Sai Proposed Protected Forest, *M. horsfieldii* was caught at 1900h and 1920h and overnight in harp traps on trails and in a mist net at 1920h in a dry river basin in semi-evergreen forest. The species occurs throughout Southeast Asia from India eastwards to southern China and southwards to Indonesia and the Philippines (Simmons, 2005). The present records validate previous reports of the species for Cambodia by Matveev & Csorba (2007) and Francis (2008).

Murina cyclotis Dobson, 1872b (Fig. 6)

Material examined: One female from Bokor National Park, one male from the Seima Protection Forest, two females from Veun Sai Proposed Protected Forest, and three females from Preah Vihear Protected Forest (Fig. 1, Annex 1).

Seven specimens were identified as *M. cyclotis* on the basis of the following characteristics: external and cranial measurements (Tables 1 and 2) according with published ranges (e.g. Bates & Harrison, 1997); upper canine (C^1)

Fig. 2 *Rhinolophus yunanensis*: CBC01208, Phnom Samkos Wildlife Sanctuary (© N. Furey).

Fig. 3 *Hipposideros diadema*: CBC01146, Veun Sai Proposed Protected Forest (© N. Furey).

Fig. 4 *Myotis ater*: CBC00620, Veun Sai Proposed Protected Forest (© G. Csorba).

Fig. 5 *Myotis horsfieldii*: CBC01142, Veun Sai Proposed Protected Forest (© N. Furey).

Fig. 6 *Murina cyclotis:* CSOCA266, Preah Vihear Protected Forest (© G. Csorba).

Fig. 7 *Kerivoula picta*: CSOCA272, Preah Vihear Protected Forest (© G. Csorba).

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

Taxon	FA	HB	T	E	TIB	HF
Rhinolophus yunanensis	56.6, -	58.4, -	21.1, -	27.1, -	26.5, -	11.3, -
	(55.0-58.2) 2	(54.9-61.8) 2	(20.0-22.1) 2	(25.7-28.4) 2	(26.3-26.7) 2	(11.1-11.4) 2
Hipposideros diadema	86.8, 2.9	90.3, 2.6	50.2, 4.5	27.6, 2.0	35.0, 1.4	16.2, 1.0
	(83.2-93.2) 10	(86.8-95.1) 10	(44.3-57.2) 10	(23.3-30.8) 10	(33.5-37.8) 10	(15.1-18.1) 10
Saccolaimus saccolaimus	69.2, -	28.5, -	28.5, -	17.4, -	28.5, -	12.5, -
	(-) 1	(-) 1	(-) 1	(-) 1	(-) 1	(-) 1
Myotis ater	36.5, 1.0	41.7, 2.1	38.7, 2.1	12.8, 1.0	15.4, 0.4	7.2, 0.4
	(34.8-38.8) 28	(38.0-45.7) 25	(33.6-44.0) 25	(10.1-14.0) 28	(14.7-16.4) 25	(6.0-8.0) 28
Myotis horsfieldii	35.3, 1.0	45.2, 2.1	37.2, 3.0	13.7, 1.3	16.3, 0.5	8.7, 0.5
	(34.2-37.6) 9	(41.9-48.7) 9	(32.9-43.1) 9	(10.8-15.1) 9	(15.5-16.9) 9	(7.5-9.1) 9
Murina cyclotis	32.8, 0.8	42.3, 2.0	35.7, 1.4	14.4, 0.9	18.3, 0.4	7.9, 0.4
	(31.4-33.8) 7	(39.1-45.1) 7	(34.0-37.5) 7	(13.5-15.9) 7	(17.8-18.9) 7	(7.2-8.5) 7
Kerivoula picta	34.2, 1.5	36.3, 0.8	40.3, 1.3	11.2, 1.1	15.2, 0.7	6.7, 0.7
	(32.3-36.8) 6	(35.0-37.2) 5	(38.6-42.0) 5	(10.1-12.8) 6	(14.3-16.0) 5	(5.6-7.5) 6

significantly exceeding posterior premolar (P^4) in height, with an equivalent or larger basal area; basal area of the upper anterior premolar (P^2) two-thirds to nearly equal that of the posterior premolar; mesostyles absent from upper molars (M^1, M^2); lower anterior premolar (P_2) large; area of talonids on lower molars approximately one-third of respective trigonids.

In Veun Sai Proposed Protected Forest, *M. cyclotis* was captured in a harp trap set overnight on a trail in semi-evergreen forest and at 1935h in a harp trap in a banana plantation. In Preah Vihear Protected Forest, three individuals were captured before 2000h in a harp trap set at a small pool in a dry streambed in semi-evergreen forest. *Murina cyclotis* occurs throughout Southeast Asia from India and Sri Lanka through to China, the Philippines and Indonesia (Simmons, 2005). Although included in range maps for Cambodia by Corbet & Hill (1992), its presence in Cambodia was considered unconfirmed by Kock (2000). The present records consequently affirm its occurrence, as more recently suggested by Matveev & Csorba (2007) and Francis (2008).

Kerivoula picta (Pallas, 1767) (Fig. 7)

Material examined: One female from Kandal Province, and three males and two females from Preah Vihear Protected Forest (Fig. 1, Annex 1).

Kerivoula picta is unmistakable morphologically, because no other member of the *Kerivoula* genus has contrasting orange and black wings, including the similar-sized *K. hardwickii* (Horsfield, 1824) and *K. titania* in Cambodia (Bates *et al.*, 2007). All six specimens examined possess this feature and the distinctive pelage of *K. picta*: bright orange on the dorsal surface and buff coloured on the medial ventral surface. External and cranial measurements of the Cambodian specimens (Tables 1 and 2) accord with measurements from specimens elsewhere in this species' range (Bates & Harrison, 1997) and all exhibit the large, bicuspid first upper incisor (I^2) characteristic of *K. picta*.

In Preah Vihear Protected Forest, five individuals were captured before 2000h in harp traps set in dry dipterocarp forest and over a small pool in a dry streambed in semi-evergreen forest. Geographically widespread, *K. picta* ranges from India and Sri Lanka eastwards to China and southwards through Peninsular Thailand and West Malaysia to Indonesia (Simmons, 2005). The inclusion of the species in range maps for Cambodia by Francis (2008) is validated by these records.

Discussion

Our confirmation of seven additional bats for Cambodia raises the total number of bat species known from the country to 60. This figure undoubtedly falls short of the true total, however, because additional specimen material - including at least five previously unconfirmed species

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

Taxon	GTL	CBL	CCL	ZYW	MAW	CM^3L	C^1C^1W	M^3M^3W	ML	CM_3L	CPH
Rhinolophus yunanensis	25.96, -	23.04, -	22.24, -	12.75, -	11.37, -	10.17, -	6.66, -	9.62, -	17.70, -	10.93, -	3.70, -
	(25.87-26.05) 2	(22.87-22.31) 2	(22.11-22.36) 2	(12.6-12.89) 2	(11.37) 2	(10.08-10.26) 2	(6.65-6.67) 2	(9.62) 2	(17.54-17.86) 2	(10.75-11.11) 2	(3.54-3.86) 2
Hipposideros diadema	31.96, 0.66	28.82, 0.60	28.11, 0.49	18.39, 0.47	15.04, 0.21	12.61, 0.16	8.25, 0.16	12.44, 0.22	22.56, 0.48	13.89, 0.26	7.08, 0.29
	(31.04-33.08) 7	(27.81-29.74) 7	(27.41-28.83) 7	(17.81-19.17) 7	(14.76-15.31) 7	(12.46-12.96) 7	(8.04-8.47) 7	(12.15-12.83) 7	(21.83-23.05) 7	(13.62-14.38) 7	(6.86-7.57) 7
Saccolaimus saccolaimus	25.04, -	-	22.24, -	15.69, -	13.41, -	10.00, -	5.4, -	10.8, -	18.09, -	11.26, -	7.22, -
	(-) 1	-	(-) 1	(-) 1	(-) 1	(-) 1	(-) 1	(-) 1	(-) 1	(-) 1	(-) 1
Myotis ater	14.65, 0.27	13.55, 0.23	12.84, 0.22	9.40, 0.22	7.45, 0.14	5.55, 0.13	3.92, 0.11	6.03, 0.19	10.86, 0.30	5.88, 0.14	3.30, 0.15
	(14.30-15.41) 28	(13.15-14.20) 28	(12.49-13.39) 28	(8.90-9.86) 27	(7.10-7.75) 28	(5.29-5.82) 28	(3.72-4.16) 28	(5.67-6.31) 28	(10.32-11.75) 28	(5.64-6.15) 28	(2.99-3.62) 28
Myotis horsfieldii	15.51, 0.36	14.06, 0.29	13.27, 0.26	9.27, 0.23	7.80, 0.16	5.66, 0.15	4.23, 0.08	5.87, 0.13	11.01, 0.19	6.11, 0.42	3.35, 0.11
	(15.18-16.16) 8	(13.73-14.51) 8	(12.97-13.72) 8	(9.01-9.75) 7	(7.63-8.14) 8	(5.46-5.93) 8	(4.09-4.32) 8	(5.65-6.04) 8	(10.83-11.43) 8	(5.79-7.05) 8	(3.17-3.50) 8
Murina cyclotis	16.87, 0.33	14.97, 0.38	14.45, 0.37	9.54, 0.20	7.88, 0.17	5.42, 0.14	4.12, 0.10	5.39, 0.13	11.28, 0.17	5.81, 0.26	4.35, 0.30
	(16.58-17.48) 6	(14.66-15.68) 6	(14.12-15.12) 6	(9.36-9.93) 6	(7.64-8.11) 6	(5.27-5.64) 6	(4.00-4.30) 6	(5.19-5.59) 6	(11.08-11.57) 6	(5.36-6.12) 6	(3.82-4.66) 6
Kerivoula picta	14.41, 0.21	12.94, 0.29	12.40, 0.22	8.56, 0.26	7.33, 0.12	5.60, 0.17	3.05, 0.11	5.40, 0.17	10.17, 0.21	5.78, 0.14	2.65, 0.19
	(14.12-14.68) 6	(12.58-13.38) 6	(12.20-12.77) 6	(8.29-8.99) 6	(7.17-7.50) 6	(5.39-5.85) 6	(2.88-3.20) 6	(5.08-5.55) 6	(10.01-10.57) 6	(5.61-5.99) 6	(2.43-2.95) 6

for Cambodia - is currently being identified (Furey *et al.*, 2011). Given the limited extent of survey effort and coverage achieved to date, the potential for additional discoveries in future field research also appears strong, particularly in understudied forests of the country's Southwest, Northeast and Northwest (Kingsada *et al.*, 2011).

At present, only three Cambodian bat species appear on the IUCN Red List (2011) in categories other than Least Concern: *Murina harrisoni* Csorba & Bates, 2005, which is listed as Data Deficient, being known only from the holotype from Kirirom National Park; *Otomops wroughtoni* (Thomas, 1913), also Data Deficient and in Cambodia known only from a single animal found in Preah Vihear (Walston & Bates, 2001); and *Pteropus lylei* Andersen, 1908, considered Vulnerable and in Cambodia known from colonies in the Phnom Penh and Siem Reap cities (Matveev, 1999; B. Hayes, pers. comm.), though seemingly also present in other areas (Francis, 2008). While the status of the three bat species recently described from Cambodia has yet to be assessed, two (*G. bucephalus* and *M. cineracea*) are unlikely to qualify for a threatened category being widespread in Southeast Asia (Csorba, 2011; Csorba *et al.*, 2011), although the third (*M. walstoni*) may qualify for listing as Data Deficient, being known only from singletons from Yok Don National Park (Vietnam) and Botum-Sakor National Park, and a few records from Northeast Cambodia (Csorba *et al.*, 2011; Furey & Csorba unpublished data).

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NEIL FUREY has worked in Southeast Asia since 1997, spending many years in Vietnam and completing assignments in Cambodia, China, India, Indonesia and Myanmar. He studied the ecology of Vietnamese karst bat populations for his doctorate and has a special interest in community ecology and systematics. Much of his work in Southeast Asia focuses on strengthening conservation and research capacity.

Appendix 1

[Specimens denoted 'CSOCA' are presently held at the Centre for Biodiversity Conservation and intended for deposition at the Hungarian Museum of Natural History].

Rhinolophus yunanensis: HZM 15.36144, male, in spirit, skull removed, collected by J. Walston in February 2000, Kirirom National Park, Kampong Speu Province, 11°31 N, 104°08 E; CBC01208, parous female, in spirit, skull removed, collected by N. Furey in December 2010, Phnom Samkos Wildlife Sanctuary, 12°09.787 N, 102°59.956 E, 1,281 m a.s.l.

Hipposideros diadema: HZM 6.34184, juvenile male, in spirit, skull removed, collected by J. Walston in December 2000, M'lou Prey, Preah Vihear Province, 13°59.081 N, 105°16.232 E; CBC00626, mature male, in spirit, skull removed, collected by Ith S. and G. Csorba in February 2010, Veun Sai Proposed Protected Forest, 14°01.654 N, 106°43.745 E; HNHM 2011.2.2, HNHM 2011.2.1, nuliparous and parous female, in spirit, collected by G. Csorba and Ith S. in February and March 2010, Veun Sai Proposed Protected Forest, 14°00.589 N, 106°44.935 E and 14°00.854 N, 106°45.001 E (approximate coordinates) respectively; CBC00644, mature male, in spirit, skull removed, collected by Ith S. and G. Csorba in March 2010, Veun Sai Proposed Protected Forest, 14°00.854 N, 106°45.001 E (approximate coordinates); CBC01145, CBC01146, parous female and mature male, in spirit, skulls removed, collected by N. Furey, Ith S. and Tamas Gorfol in

/August 2010, Veun Sai Proposed Protected Forest, 14°00.937 N, 106°45.135 E; HNHM 23637, mature male, in spirit, collected by N. Furey, Ith S. and Tamas Gorfol in August 2010, Veun Sai Proposed Protected Forest, 14°02.205 N, 106°44.269 E; CBC01276, CSOCA275, mature males, in spirit, skulls removed, collected by Ith Saveng and G. Csorba in March 2011 in the Baray Mountains and O'Cheuteal area, Preah Vihear Protected Forest, 14°01.231 N, 105°37.133 E (200 m a.s.l.) and 13°59.825 N, 105°33.862 E (100 m a.s.l.) respectively.

Saccolaimus saccolaimus: HNHM 2006.13.1, juvenile male, in spirit, skull removed, collected by J. Walston in November 2005, Phnom Penh city, 11°33′ N, 104°55′ E.

Myotis ater: HZM 10.34188, HZM 11.34189, HZM 8.34186, three males, in spirit, skulls removed, collected by J. Walston in December 2000, M'lou Prey, Preah Vihear Province, 13°58.907 N, 105°16.466 E; CBC00466, CBC00467, nuliparous females, in spirit, skulls removed, collected by Ith S. in November 2009, Takeung village, Kulen Promtep Wildlife Sanctuary, 13°53.255 N, 104°52.961 E, 60 m a.s.l.; CBC00579, CBC00580, mature males, in spirit, skulls removed, collected by N. Furey in December 2009, O'Peam, Phnom Samkos Wildlife Sanctuary, 12°12.240 N, 103°04.201 E, 274 m.a.s.l; CBC00620, CBC00646, parous females, in spirit, skulls removed, collected by G. Csorba and Ith S. in February and March 2010, Veun Sai Proposed Protected Forest, 14°00.937 N, 106°45.135 E; CBC01143, CBC01152, parous and nuliparous female, in spirit, skulls removed, collected by N. Furey, Ith S. and T. Gorfol in August 2010, Veun Sai Proposed Protected Forest, 14°01.818 N, 106°43.285 E and 14°00.933 N, 106°44.975 E respectively; CBC01225, CBC01227, CBC01228, CBC01229, CBC01230, CBC01231, CSOCA209, CSOCA210, CSOCA213, CSOCA216, five mature males and five nuliparous females, in spirit, skulls removed, collected by G. Csorba, N. Furey and Ith S. in February 2011, Trapaeng Pring, Preah Vihear Protected Forest, 13°53.064 N, 105°22.556 E, 120 m a.s.l.; CBC01234, CBC01241, CSOCA219, CSOCA221, CSOCA232, CSOCA233, CSOCA234, five mature males and two nuliparous females, in spirit, skulls removed, collected by G. Csorba, N. Furey and Ith S. in February 2011, Ka Kheuk, Preah Vihear Protected Forest, 14°03.556 N, 105°17.017 E, 110 m a.s.l.

Myotis horsfieldii: HNHM 2005.81.5, HNHM 2005.81.6, parous female and mature male, in spirit, skulls removed, collected by G. Csorba, B. Hayes and Hout S.H, in July 2005, Kvay, Preah Vihear Province, 13°34.000 N, 105°00.250 E, 70 m a.s.l.; HNHM 2006.34.53, juvenile male, in spirit, skull removed, collected by G. Csorba, L. Duval and G. Ronkay in January 2006, Seima Protection Forest, 12°10.950 N, 107°01.100 E, 190 m a.s.l.; CBC00627, HNHM 2011.2.14, mature male and nuliparous female, in spirit, skulls removed, collected by Ith S., G. Csorba and Phauk S. in February 2010, Veun Sai Proposed Protected Forest, 14°01.478 N, 106°43.978 E, 110 m a.s.l.; CBC00641, HNHM 2011.2.13, mature male and nuliparous female, in spirit, male with skull removed, collected by Ith S., G. Csorba and Phauk S. in February 2010, Veun Sai Proposed Protected Forest, 14°02.210 N, 106°44.278 E, 110 m a.s.l.; CBC01128, CBC01142, juvenile and mature male, in spirit, skulls removed, collected by N. Furey, Ith S. and T. Gorfol in August 2010, Veun Sai Proposed Protected Forest, 14°02.832 N, 106°41.623 E and 14°01.818 N, 106°43.285 E respectively.

Murina cyclotis: HNHM 2006.34.2, parous female, in spirit, skull removed, collected by G. Csorba, L. Duval and G. Ronkay in January 2006, Bokor National Park, 10°36.100 N, 104°05.167 E, 270 m a.s.l.; HNHM 2006.34.38, mature male, in spirit, skull removed, collected by G. Csorba, L. Duval and G. Ronkay in January 2006, Seima Protection Forest, 12°15.733 N, 107°03.817 E, 360 m a.s.l.; HNHM 2011.2.9, HNHM 23840, nuliparous and parous females, in spirit, skull of latter removed, collected by G. Csorba, N. Furey, Ith S. and T. Gorfol in February and August 2010, Veun Sai Proposed Protected Forest, 13°59.971 N, 106°42.034 E and 14°03.413 N, 106°43.516 E (170 m a.s.l.) respectively; CBC01277, CBC01278, CSOCA266, nuliparous females, in spirit, skulls removed, collected by G. Csorba, N. Furey and Ith S. in March 2011, Baray Mountains, Preah Vihear Protected Forest, 14°01.231 N, 105°37.133 E, 200 m a.s.l.

Kerivoula picta: HZM 1.35275, female, in spirit, skull removed, collected by J. Walston in December 2001, Prek Kampues, Kandal Province, 11°27′ N, 104°54′ E; CBC01262, CBC01286, mature male and nuliparous female, in spirit, skulls removed, collected by N. Furey, G. Csorba and Ith S. in February and March 2011, O'Cheuteal, Preah Vihear Protected Forest, 14°00.686 N, 105°39.900 E, 130 m a.s.l.; CBC01282, CSOCA272, CSOCA273, two mature males and one female, in spirit, skulls removed, collected by G. Csorba, N. Furey and Ith S. in March 2011, Baray Mountains, Preah Vihear Protected Forest, 14°01.231 N, 105°37.133 E, 200 m a.s.l.

Behaviour and habitat use of the Bengal slow loris *Nycticebus bengalensis* in the dry dipterocarp forests of Phnom Samkos Wildlife Sanctuary, Cambodia

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មូលន័យសង្ខេប

រញីប្រផេះ *Nycticebus bengalensis* គឺជាព្រីម៉ាតត្រូវបានសិក្សាតិចតួច ដែលរស់នៅតែក្នុងប្រទេសបង់ក្លាដែស កម្ពុជា ចិន ឥណ្ឌា ប៊ូតាន ឡាវ ភូមា ថៃ និងវៀតណាម។ ទិន្នន័យពីឥរិយាបថនៃប៉ូពុយឡាស្សុងសត្វព្រៃអាចជួយយ៉ាងមានសក្តានុពលដល់ការគ្រប់គ្រង និងការអភិរក្សនៃរញីប្រផេះនេះ។ រញីប្រភេទនេះ ត្រូវបានចាត់ថ្នាក់ដោយអង្គការសហភាពអន្តរជាតិសម្រាប់ការអភិរក្សធម្មជាតិ និងធនធានធម្មជាតិ (IUCN) ថាងាយរងគ្រោះដោយកង្វះជម្រកនិងសម្ពាធខ្លាំងក្លានៃការបរបាញ់។ នេះជារបាយការណ៍ទិន្នន័យនៃការសង្កេត៣៩ម៉ោងយ៉ាងពិបាករបស់យើងលើរញីប្រផេះ *N. bengalensis* នៅដែនជម្រកសត្វព្រៃភ្នំសំកុស ប្រទេសកម្ពុជា។ នៅពេលយប់ រញីប្រផេះចំណាយពេលវេលាភាគច្រើនរបស់វាសំរាប់ការសំរាក (៤១%) រីឆ្លាស់ទី (៣៦%) ដែលធ្វើដំណើរយ៉ាងឆ្ងាយបាន៤០ ម៉ែត្រ។ ជាធម្មតា ការសង្កេតត្រូវបានបញ្ឈប់នៅពេលដែលរញីទាំងនោះឆ្លាស់ទីដោយល្បឿនលឿនចូលទៅក្នុងព្រៃក្រាស់ជាងនៃព្រៃខ្លងត្បែងស្ងួត តូយ៉ាងនៅពេលជិតភ្លឺ។ ការស៊ីចំណីអាហារត្រូវបានសង្កេតឃើញ៦%នៃរយៈពេលជួបប្រទះ ដែលរួមមានស្លឹករុក្ខជាតិ (*n*=10) អាកត្រូប៉ូ(*n*=9) និងសំបកដើម ឈើ(*n*=3)។ វដ្តព្រះចន្ទនិងអាកាសធាតុបានជះឥទ្ធិពលដល់ឥរិយាបថ ដែលរញីប្រផេះនេះបែរជាសកម្មជាងនៅក្នុងលក្ខខណ្ឌសើម និងនៅពេលរនោច។ ភាគច្រើនបំផុត រញីប្រផេះនេះប្រើប្រាស់មែកឈើតូច។(៥១%) រីមែកឈើមធ្យម(៥៦%) ដែលទ្រេតទៅលើ។ មិនដូចអ្វីដែលយើងគិតទុក រញីរស់នៅក្នុងព្រៃទាំងនេះត្រូវបានប្រទះឃើញញឹកញាប់បំផុតនៅកន្លែងស្រឡះជាងនៃព្រៃខ្លងត្បែងស្ងួត ដែលវាប្រើស្មៅក្រាស់ដើម្បីឆ្លាស់ទីចន្លោះដើមឈើ។ ទោះបីជាការចាប់ផ្តើមដំបូងក៏ដោយ ការសង្កេតទាំងនេះផ្តល់អោយនូវការយល់ដឹងដំបូងពីឥរិយាបថនៃរញីប្រផេះនៅប្រទេសកម្ពុជា។ បើរញីប្រផេះ *N. bengalensis* ច្រើនតែនៅកន្លែងស្រឡះៗដូចនេះ វាអាចជួយពន្យល់ពីអត្រាជួបប្រទះទាបក្នុងការសិក្សាមុនៗ ដែលយកចិត្តទុកដាក់សំខាន់លើកន្លែងព្រៃក្រាស់ជាង។ ដោយសាររញីប្រផេះនេះនៅតែត្រូវការបន្តទៀតសំរាប់ធ្វើថ្នាំបុកណា វិធីសិក្សាស្រាវជ្រាវប្រសើរៗគឺពិតជាចាំបាច់បំផុត។

Abstract

The Bengal slow loris *Nycticebus bengalensis* is a little-studied primate native to Bangladesh, Cambodia, China, India, Bhutan, Laos, Myanmar, Thailand and Vietnam. Behavioural data from wild populations could potentially aid the conservation management of this species, which is classified by IUCN as Vulnerable due to habitat loss and severe pressures from hunting. Here we report data from 39 hours of opportunistic observations of *N. bengalensis* in Phnom Samkos Wildlife Sanctuary, Cambodia. The nocturnal, non-habituated lorises spent most of their time resting (41%) or moving (36%), travelling up to 40 metres over a period of 5 hours. Observations usually ceased when lorises moved off at speed into the more densely wooded parts of the dry dipterocarp forest, typically near dawn. Feeding was observed during 6% of encounters, including leaves (*n* = 10), arthropods (*n* = 9) and tree bark (*n* = 3). Moon cycles and weather affected behaviour, with the lorises becoming more active during wet conditions and during the dark moon phase. Lorises most

commonly used small (41%) or medium-sized (56%), upward-sloping branches. Unexpectedly, these normally forest-dwelling lorises were most frequently detected in more open areas of dry dipterocarp forests, where they used the thick grass to move between trees. Although preliminary, these observations provide the first insight into the behaviour of this species in Cambodia. If *N. bengalensis* often occurs in such open areas, this could help explain low encounter rates in previous studies, which have concentrated on more densely forested areas. Because lorises are still in persistent demand for traditional medicines, improving survey techniques is vital.

Keywords

Activity budget, exudativory, moon phase, *Nycticebus coucang*.

Introduction

Nycticebus bengalensis is a small nocturnal strepsirrhine primate in Southeast Asia, commonly known as the Bengal, northern or ashy slow loris. Previously considered a subspecies of *N. coucang*, Groves (1998) recognised *N. bengalensis* as a distinct species. Subsequent authors have recognized even greater diversity within this widespread genus (Chen *et al.*, 2006; Groves & Maryanto, 2008; Nekaris & Jaffe, 2007; Roos, 2003): a revelation that has had implications for the conservation status of slow lorises. Although few data are available on any slow loris species in the wild, dramatic habitat loss in Asia, coupled with the popularity of lorises in the illegal wildlife trade, means that all slow loris species are threatened with extinction. Most efforts to detect wild slow lorises have resulted in low abundance estimates, and further studies are urged to assess their conservation status, including behaviour and population data (Nekaris *et al.*, 2008).

Nycticebus bengalensis is the widest-ranging of the slow loris species, occurring across north-eastern India, Bhutan, southern China, Laos, Myanmar (Burma), Thailand, Vietnam and Cambodia (Brandon-Jones *et al.*, 2004). A number of short surveys of *N. bengalensis* have been conducted. In India, they are considered relatively uncommon (Das *et al.*, 2009; Rhadakrishna *et al.*, 2006) whereas in Laos they are considered among the most common mammals (Evans *et al.*, 2000), despite encounter rates still being low (Nekaris *et al.*, 2008). In Cambodia, Starr *et al.* (2010b) found *N. bengalensis* in only two out of seven sites, despite covering 198 km on 49 transects. They pointed towards the heavy use of lorises in traditional medicines as a likely cause of these low encounters. Considering these factors, *N. bengalensis* is listed as Vulnerable on the IUCN Red List (Streicher *et al.*, 2008).

Starr *et al.* (2010b) identified Phnom Samkos Wildlife Sanctuary as having both a reasonable encounter rate and being a suitable habitat in which to study lorises, and urged further studies of *N. bengalensis* to take place in this site.

Two short field studies have investigated the feeding ecology of *N. bengalensis*. Swapna *et al.* (2010) found that *N. bengalensis* in India devote 17% of their time to feeding on a variety of foodstuffs, but tree exudates make up 87% of their food intake. Pliosungnoen *et al.* (2010) found that in Thailand, *N. bengalensis* rarely fed on gum, relying instead on floral nectar, fruit and animal matter. The only completed longer-term investigations of *Nycticebus* species come from Wiens (2002: *N. coucang* in Malaysia), Streicher (2004: *N. pygmaeus* in Vietnam), and Starr *et al.* (2010a: *N. pygmaeus* in Cambodia).

With such a scarcity of knowledge about this species, it is almost impossible to determine their conservation needs. An understanding of how an animal divides up its behaviours throughout its active period is necessary to understanding its interaction with the habitat (Passamani, 1998). Behaviour is one of the attributes most affected by changes in environment (Lawes & Piper, 1992) and determining baseline behaviour is important for the management of a species. Here we present the first data on the behaviour of non-habituated *N. bengalensis* in Cambodia.

Methods

Study site

The Cardamom Mountains are one of the most dominant geographical features of Cambodia, consisting of several mountain complexes including Mount (Phnom) Samkos, the Central Cardamom Mountains and Mount Aural (Momberg & Weiler, 1999). Mount Samkos reaches 1,717 m a.s.l. and Mount Aural, the highest point in Cambodia, reaches 1,771 m a.s.l. (Long & Swan, 2000). Phnom Samkos Wildlife Sanctuary (Fig. 1), where we carried out our study, was established by a Royal Decree in November 1993 and encompasses 3,338 km^2 (Daltry & Momberg, 2000). The study was based in a lowland area named the 'Samkos Basin' (Webb, 2005); the centre of the study site was at 12°21'N and 103°07'E (Garmin eTrex Vista HCx).

Behaviour sampling

Systematic data collection took place during the wet season, between May and June 2009. A line transect study that took place in the same time period (Coudrat *et al.*, 2011) identified a high density of lorises in the dry dipterocarp forest. Because behavioural observations needed to be accomplished without radio collars, we decided to focus all night behavioural observations on this habitat type. Of 12 full behavioural observation nights, we found between one and six lorises every night. We used focal animal sampling (Altmann, 1974) and instantaneous point sampling with data recorded at five-minute intervals (*cf.* Nekaris, 2001; Nekaris & Rasmussen, 2003). We opportunistically sampled lorises (Abernethy, 2000) from searches along transects and the main road using a combination of red and white light. We conducted observations only with red lights, which are less disturbing to lorises (Nekaris, 2001). We adapted categories of behaviour from Gursky (2003) and Nekaris (2001) (Table 1). For feeding events on an instantaneous sample point, we recorded the food item consumed and feeding behaviour. The sun set by 1930h and began to rise at 0420h, and, because *Nycticebus bengalensis* is fully nocturnal, observations took place between 2000h to 0400h. For nocturnal animals that are difficult to follow, behaviours noted at first contact are argued to provide a less biased form of observation (Charles-Dominique, 1977; Nekaris, 2001). We thus collected "first contact" records for *N. bengalensis* to compare with point sampling records.

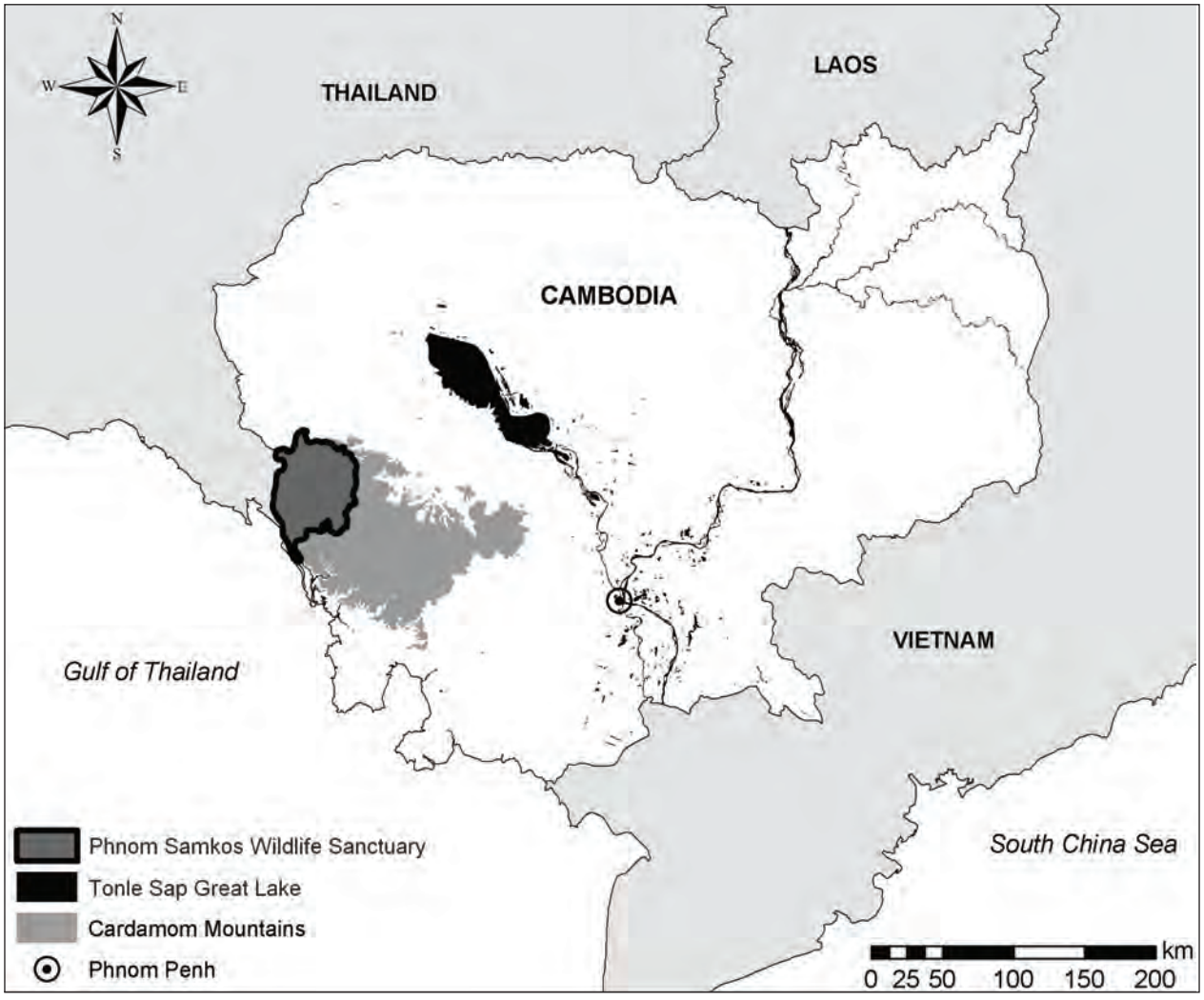

Fig. 1 Location of Phnom Samkos Wildlife Sanctuary in the Cardamom Mountains, Cambodia. Map provided by C.N.Z. Coudrat.

Table 1 Ethogram: behavioural categories at first contact (adapted from Nekaris, 2001; Gursky, 2003).

Activity	Description
Resting	Body immobile and not involved in activity.
Sleeping	Assuming specific position for sleep ('Schlafkugel') and not alert to environmental changes.
Moving	Any mobile activity.
Alert	Animal is distracted by/ concentrating on factors in the environment (*cf.* Resting).
Feeding	Consuming animal or plant matter.
Other	Less frequent behaviours such as grooming, social interaction and vocalization were grouped into one category.

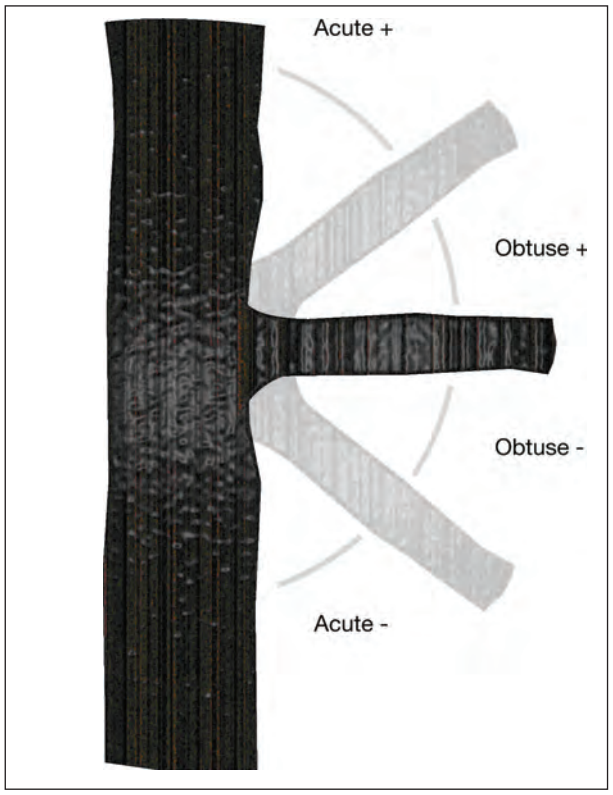

Fig. 2 Diagram showing the categories of substrate angle where the trunk is a vertical substrate and the horizontal substrate is at 90° from the trunk. Obtuse angles were between 90° and 45° and acute angles between 45° and 0°.

Moon phases and weather

We categorised moon phases into a binary variable of "light moon", when any portion of moon was visible in the sky, and "dark moon", when the moon had set. We categorised weather conditions into wet and dry nights. "Wet nights" were those where it had been raining throughout the previous day or was raining at the time observations took place. "Dry nights" had no rain and clear skies.

Habitat use

We collected data on habitat use at 10-minute intervals. At each point we recorded: *tree species*, *tree diameter at breast height (DBH)*, *tree height*, and *height of loris in tree*. We identified tree species by obtaining local Khmer names from guides familiar with the area, which we later assigned to scientific names with the aid of Neang Thy, Ministry of Environment, Cambodia.

Other habitat data were: *connectivity*, measured by the number of branches and vines connecting it to the nearest tree (categories included: 0 connectors, 1-2 connectors, 3-5 connectors and 5+ connectors); *horizontal density at the herb layer,* measured by estimating the complexity enclosed within a circle with a 1 m radius around the base of each tree defined as 0-0.5 m above ground level (categories included; 0-25%, 26-50%, 51-75% and 76-100% cover) (Stokes *et al*., 2003); *substrate size,* estimated diameter of the branch (small: ≤5 cm, medium: 6-10 cm, large: >10 cm) (Garber & Pruetz, 1995); and *substrate angle,* following Dykyj (1980) and Glassman & Wells (1984) (Fig. 2).

Analysis

We used non-parametric statistics to explore behaviour and habitat use, excluding periods when the lorises were out of sight. We compared contact rates with point sampling records to gain insight into whether observer presence affected the behaviour of these non-habituated animals. We analysed data using SPSS 17.0, and added Yates correction where necessary to chi-square analyses. We set significance at $p \leq 0.05$ (Zar, 1999).

Results

We encountered lorises 18 times, observing them between 10 minutes and seven hours (mean 2.14 ± 2.10 hours) yielding 469 instantaneous sample points. The only three behaviours (moving, resting or alert) observed at first contact did not differ in frequency from those observed throughout the later observation periods (X^2= 2.01, *d.f.* = 3, p = 0.37).

Nycticebus bengalensis spent the largest proportion of sample points resting (41%) or moving (36%). The remainder of sample points were spent alert (7%), sleep-

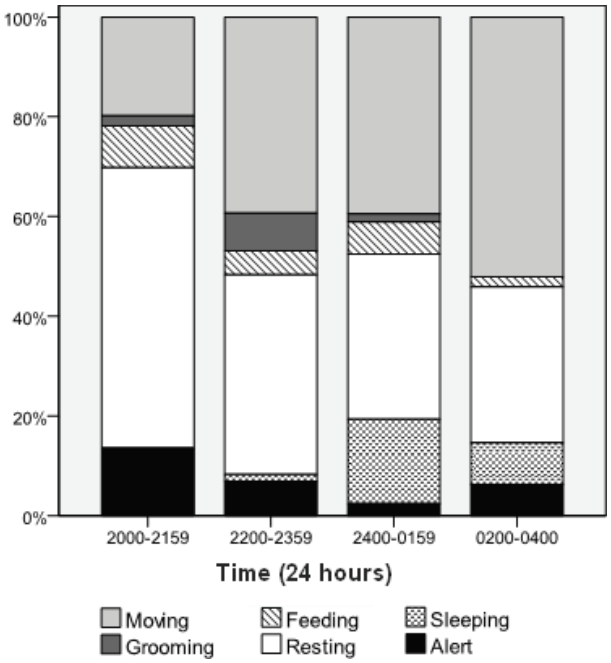

Fig. 3 Activity of *N. bengalensis* in four periods throughout the night (2000-2100h: 23% of samples; 2200-2300h: 35% of samples; 0000-0100h: 30% of samples; and 0200-0400h: 12% of samples).

ing (7%), feeding (6%) and grooming (4%). Grooming activity comprised fur licking/ toothcomb use (67%) and scratching (33%).

We analysed behaviour during four blocks of time (Fig. 3). In the early evening (2000h-2159h), *N. bengalensis* generally rested whilst remaining alert. During 0200h-0400h, the lorises became more active, usually moving into the dense evergreen forest, where observations ended. The maximum distance travelled by an individual loris was 40 metres over a period of five hours. Neither vocalisations nor social interactions were observed, but during three observations, a loris was in "neutral proximity" (10-15 m) to a conspecific.

Lorises were more active during the dark moon (X^2_{Yates}= 18.75; *d.f.* = 1; $p \leq 0.001$), with only 4% of activity during "light moon" compared with 50% during "dark moon". The animals were significantly more active during wet weather (56%) than dry weather (41%) (X^2_{Yates}= 8.35; *d.f.* = 1; $p \leq 0.004$).

Nycticebus bengalensis was observed feeding at 24 sample points. Leaves of *Terminalia alata* were consumed most frequently (n = 10). On three occasions, flying insects were caught with a one-handed grab, and on six occasions, lorises engaged in head-down foraging, licking insects from the trunk and branches of trees. Twice, *N.*

Table 2 Tree species used by *N. bengalensis* in Phnom Samkos Wildlife Sanctuary during this study. Scientific names are given where known.

Khmer name	Scientific name	Family
bada	not identified	
bag doa	*Gardenia* sp.	Rubiaceae
but drea prea	not identified	
bru	*Garcinia schefferi*	Clusiaceae
chelli	*Terminalia alata*	Combretaceae
desay	*Heritiera littoralis*	Malvaceae
dralat	*Canarium album*	Burseraceae
drea	*Ficus* sp.	Moraceae
ga doet prea	*Phyllanthus emblica*	Phyllanthaceae
grote	not identified	
kplier	not identified	
kreil	*Gluta laccifera*	
la meng	*Diospyros ehretioides*	Ebenaceae
pichuck	*Shorea obtusa*	Dipterocarpaceae
piou	not identified	
som ra	not identified	
sralao	*Lagertroemia calyculata*	Lythraceae

Table 3 Percentage use of different branch sizes and angles (n = 469). Lorises were observed more frequently on small and medium sized substrates and were most often found on upward sloping branches, especially those with low inclines.

Substrate size		Substrate angle (see Fig. 2)	
Small	41%	Vertical	14%
Medium	56%	Acute +	22%
Large	3%	Obtuse +	44%
		Horizontal	10%
		Obtuse -	8%
		Acute -	2%

Fig. 4 Grass-dominated area of dry dipterocarp forest typically used by Bengal slow lorises during the behavioural observations. Lorises were found in trees with very little canopy cover and almost no connectivity: the grass was the only form of continuous cover for many areas.

bengalensis removed pieces of bark from dead trees to reach termites and once, a loris appeared to be chewing the end of a branch.

The lorises used at least 17 different tree species (Table 2). *Nycticebus bengalensis* was most frequently observed on *T. alata* (61%) and *Diospyros ehretioides* (12%). They were found in trees with a median height of 10 m (2-20 m), at a median height of 8 m (1-18 m) and with a mean DBH of 19.09 ± 12.24 cm. We observed most of the animals (84%) in the sparser grasslands within the dry dipterocarp forest (Fig. 4). These areas were dominated by tall grasses, characterised by high horizontal complexity around tree bases. Over half (59%) of the trees in which we found *N. bengalensis* were in areas characterised by 76-100% complexity. Of trees in which we found *N. bengalensis*, 6% were isolated. On three occasions we observed animals move through the grass to reach other trees.

Nycticebus bengalensis exploited small and medium-sized branches at relatively equal frequencies. Only 3% of observations were of animals on large substrates. Although not significantly different, resting was observed more frequently on medium-sized branches (26%) than small branches (19%) and we observed more movement on small branches (17%) than medium ones (12%). Slightly upward-sloping branches were most frequently used by *N. bengalensis* (44% of observations), followed by acute upward-sloping branches and vertical substrates (Table 3). Lorises were rarely found on horizontal or downwards facing branches in comparison to other categories ($X^2_{Yates} = 18.48$; *d.f.* = 1; $p \leq 0.001$) (Table 3).

Discussion

Nycticebus bengalensis spent equal amounts of time resting or moving during the two months they were observed during the wet season. A longer study in India also found *N. bengalensis* to be fairly inactive (22%) (Swapna *et al.*, 2010), and this is almost half the frequency shown by the lorises in this study.

The average distance moved by lorises during this study was less than for *N. pygmaeus* (600 m per hour: Starr, 2011), and *N. javanicus* (550 m per hour: Moore, unpub. data; Nekaris, unpub. data). The greatest distances were recorded at the end of observation periods (approximately 0400h) when lorises moved into the denser forest at great speed and were subsequently lost in this dense vegetation: their actual travel distances are surely far greater and can only be revealed with radio tracking, allowing an observer to follow them into this dense habitat. A radio tracking study of this species urgently needs to be carried out in Cambodia to determine its habitat needs. It is most probable that *N. bengalensis*, being the largest of all the slow lorises, also has larger home ranges than its congeners (*N. pygmaeus*: 22 ha; *N. javanicus:* 31 ha; *N. coucang:* 10.1 ha) (Nekaris & Bearder, 2011).

Nycticebus bengalensis in this study and those observed by Swapna *et al.* (2010) were not habituated to human presence. It is therefore possible that they could have been displaying freezing as an anti-predator response. The closely related Mysore slender loris *Loris lydekkerianus lydekkerianus* was easily habituated within one hour of observation and could be approached by up to 1 m by observers (Nekaris, 2001). Those slender lorises lived in scrub farmland adjacent to villages where they heard or saw villagers regularly, and from which animals were captured for the fortune telling trade. If the study animals in our more remote study area had experience with humans, it might have been with hunters, but most hunters catch lorises on the first attempt (Starr *et al.*, 2010a). The absence of a significant difference between the first contact record and the rest of the behavioural observations suggests that there was little effect of observer presence. Many researchers view behaviour at first contact to be less biased (Charles-Dominique, 1977), and our long experience with lorises shows that freezing behaviour only normally happens when lorises are observed by large groups, using white lights and when observers move less than 5 m to the animal (Nekaris *et al.*, 2008), none of which occurred during this study.

Studies of the diet of *Nycticebus bengalensis* at other sites have concluded that they predominantly consume gum (Das *et al.*, 2009; Pliosungnoen *et al.*, 2010). Indeed, Swapna *et al.* (2010) stated that *N. bengalensis* was the most exudativorous loris. They found that lorises fed on exudates 94% of the time in winter and 67% of the time in summer, making gums the most dominant food source during the study. Eating gum is a noisy and lengthy event: Nekaris *et al.* (2010) even recommended that it might be a way to detect lorises in a forest. Tree families most commonly exploited by slow lorises for exudates are Combretaceae and Fabaceae (Nekaris *et al.*, 2010; Streicher *et al.*, in press). Interestingly, in this study lorises were never observed feeding on exudates even though the area was found to contain both Combretaceae and Fabaceae trees, and lorises were most often observed in *Terminalia alata*, from the Combretaceae family. These trees were found to be important food sources for slow lorises by both Pliosungnoen *et al.* (2010) and Wiens (2002). In previous studies exudates were vital to slow loris diets especially during the winter months where there may have been a shortage of other food (Streicher, 2004). The fact that our study was conducted during the summer months when

food, in particular flying insects, is readily available may explain why lorises were not observed feeding on exudates. Starr *et al.* (2010a) observed similar behaviour amongst pygmy lorises in Cambodia, which decreased their feeding on exudates during the wet season. *Nycticebus bengalensis* in our study were observed feeding on the leaves of *Terminalia alata*, one of the first observations of leaf consumption in this genus. This observation supports Ravosa's (1998) prediction that the various taxa of slow lorises seem to be selected for varying diets, and he suggested that *N. bengalensis* may be relatively more herbivorous.

Nycticebus bengalensis in our study were significantly more active after the moon had set. Trent *et al.* (1977) reported that captive *N. coucang* also decreased their activity during full moon. *Nycticebus pygmaeus* in Cambodia are also lunarphobic, and only active during the light moon if temperatures are high. Starr *et al.* (2011) interpreted lunarphobia in pygmy slow lorises as a possible response to predation pressure. Known slow loris predators include pythons, monitor lizards and hawk eagles (Starr *et al.*, 2011), all of which occur in Phnom Samkos Wildlife Sanctuary. For predators that hunt on the ground, crossing between trees in the dry dipterocarp forests is a risky strategy, especially in the moonlight. During a light moon, although lorises become more visible to predators, they also can better see such predators (Gursky, 2003). Nocturnal mammals are expected to become less active during the lighter phases of the moon or retreat into more densely covered forest areas to avoid predation (Sutherland & Predavec, 1999): this is supported by the behaviour of the *N. bengalensis* in this study.

Nycticebus bengalensis occurs in a wide range of habitats from evergreen forest to mangrove swamps. In most of these, the average height at which lorises were observed was 8 m (Dang, 1998; Pliosungnoen *et al.*, 2010; Radhakrishna *et al.*, 2006; Swapna *et al.*, 2008), but even as high as 15 m (Das *et al.*, 2009). *Nycticebus bengalensis* has not previously been found in dry dipterocarp forest, but this was the case for most of the lorises in our study. Lorises are capable of moving on the ground (Streicher & Nadler, 2003; Nekaris, 2001), although this makes them more vulnerable to predation (Nekaris, 2001; Wiens & Zitzmann, 1999). Where habitats are open, their inability to leap means lorises have no option but to cross the ground (Nekaris, 2001). Indeed, lorises have been observed crossing roads where no suitable habitat exists to reach other patches of forest (Pliosungnoen *et al.*, 2010; Radhakrishna, 2006) often leading to the death of lorises from passing vehicles (Radhakrishna, 2006). The tall grass in the dry dipterocarp forests acts as a continuous cover allowing safely hidden movement between trees.

The trees most frequently used by the lorises provided 51-75% canopy cover, which seemed to be just enough for active behaviour. However, all lorises moved off into the thicker dry dipterocarp forest or evergreen forest in the early morning. This suggests that the trees in the dry dipterocarp grassland did not provide suitable sleeping sites due to their lack of canopy, vines and lianas, in which lorises can sleep concealed (Nekaris & Bearder, 2011). During this survey, the grasslands in Phnom Samkos Wildlife Sanctuary lacked a number of terrestrial predators of *Nycticebus bengalensis* such as civets and felids, which were only found in the evergreen forests of Phnom Samkos Wildlife Sanctuary (Rogers, 2009). If there is a high prevalence of birds of prey (Bearder *et al.*, 2002; Wiens & Zitzmann, 1999), this could explain the movement of lorises into the more covered areas of forest when they are most vulnerable (i.e. during sleep).

Nycticebus bengalensis may rely on a mosaic of forest types, particularly in the dry season when grass may be burned, which is common throughout the country. Villagers in Cambodia rely heavily on non-timber products for survival especially when the rice yield is poor (Lawrence *et al.*, 2004). Roughly 100,000 people living around forested areas in Cambodia make a living from resin tapping of dipterocarp tree species such as cheuteal *Dipterocarpus alatus*. Resin collectors burn the forest at least twice a year in eastern Cambodia to remove grass for easier access to trees (Starr *et al.*, 2010b). Little is known of the fire ecology in Cambodia and future studies during the dry season may prove useful to determine the impact fire has on lorises living in this forest type. As mentioned above, lorises cannot leap to escape a danger such as fire, and would only be able to escape over the ground.

In conclusion, this research offers a preliminary insight into the behaviour of *Nycticebus bengalensis* during the wet season in Cambodia. It is vital to their conservation that a longer-term study of distribution and more detailed observations on the behaviour of lorises takes place. Starr *et al.* (2010b) intensely surveyed many sites in Cambodia for Bengal slow loris and found them only at two sites. As was suggested by Starr *et al.* (2011), surveyors may need to adjust their techniques to account for seasonality of torpor to see lorises. Surveys conducted when lorises are inactive may account for some low encounter rates. Furthermore, most surveys conducted by Starr *et al.* (2010b) were in forests where one would typically expect to find lorises, but it is becoming clear that slow lorises can inhabit unexpected habitats. For example, recent studies of Javan slow lorises *N. javanicus* found them to thrive in vegetable gardens (Winarti, 2011) and *N. bengalensis* in India can persist in scrub forest (Swapna, *et al.*, 2010). Changing our survey tech-

niques to include habitats such as dry dipterocarp forests may improve our understanding of their true population numbers.

Finally, resin tapping in Phnom Samkos Wildlife Sanctuary encourages communities to indirectly preserve wildlife through protecting resin trees and their habitats, and provides communities with a livelihood (Neang, 2009). Work needs to be conducted with these communities to ensure proper practice is followed in terms of burning, and information provided to communities on the negative impacts caused by illegal hunting of lorises and other wildlife. Phnom Samkos Wildlife Sanctuary offers a perfect environment to conduct a long-term study of this species. To date it is one of few places *N. bengalensis* has been found in Cambodia, so it is imperative for their conservation to protect the lowland areas of Phnom Samkos Wildlife Sanctuary.

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Evaluating the status of Cambodia's coral reefs through baseline surveys and scientific monitoring

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ប្រទេសកម្ពុជាសម្បូរទៅដោយផ្កាថ្មប៉ប្រះទឹកជាច្រើនទ្រង់ទ្រាយ ប៉ុន្តែស្ថានភាពទូទៅរបស់ផ្កាថ្មទាំងនេះត្រូវបានស្រាវជ្រាវនិងរក្សាទុកជាឯកសារតិចតួចណាស់។ អង្គការអភិរក្សផ្កាថ្ម Coral Cay Conservation រួមគ្នាជាមួយក្រសួងកសិកម្ម រុក្ខា និងនេសាទនៃប្រទេសកម្ពុជា បានដឹកនាំការស្រាវជ្រាវពីផ្កាថ្មប៉ប្រះទឹកពីខែកុម្ភៈ ឆ្នាំ២០១០ ដល់ខែកុម្ភៈ ឆ្នាំ២០១១ នៅជុំវិញកោះរុង កោះកុង និងកោះរុងសន្លឹម ខេត្តព្រះសីហនុ។ ទិន្នន័យត្រូវបានប្រមូលរួមមានសមាសភាពនិងប្រភេទផ្សេងៗនៃត្រីនិងសត្វរស់នៅបាតសមុទ្រ រាក់ៗក៏ដូចជាទិន្នន័យពីសារធាតុលាងជម្រះនិងជម្ងឺផ្កាថ្មដែរ។ ការស្រាវជ្រាវរបស់យើងបានរកឃើញថាផលប៉ះពាល់បង្កឡើងដោយមនុស្សមានកំរិតទាប ដូច្នេះហើយកំណាដីល្បាប់មានកំរិតខ្ពស់។ ផ្កាថ្មរឹងនៅរស់មានប្រហែល២៥% ជាមួយនឹងតំបន់ផ្កាថ្មប៉ប្រះទឹកល្អបំផុតរហូតដល់៤0%។ គឺមានទំរង់ដុលនៃជីវិតផ្កាថ្មច្រើនលើសលុប និងមិនសូវមានទំរង់ស្លឹកនិងបែកមែកទេ។ អំបូរត្រីសំខាន់ៗបានបង្ហាញនូវសញ្ញានៃការថយចុះ ទោះបីកន្លែងខ្លះនៅមានប្រភេទត្រីដែលបង្ហាញថានៅមានធនធានត្រីក៏ដោយ។ ឈើងសមុទ្រនិងសត្វឥតឆ្អឹងកងបាតសមុទ្រតក់ៗដូចជាបង្កងប៉ាក ត្រូវបានប្រមូលផលជាពាណិជ្ជកម្មកម្រនឹងជួបប្រទះណាស់ ដែលបង្ហាញថាមានការប្រមូលផលហួសកំរិត។ នៅកោះរុង មានការអភិវឌ្ឍយ៉ាងសំខាន់ ដែលអាចបង្កជាសម្ពាធទៅលើប្រព័ន្ធផ្កាថ្មប៉ប្រះទឹកនៅតំបន់នោះទៅអនាគត។ អនុសាសន៍នៃការគ្រប់គ្រងរួមមានការអនុវត្តតំបន់ការពារសមុទ្រពហុប្រយោជន៍ ដែលរួមបញ្ចូលនូវតំបន់មិនធ្វើអាជីវកម្មមួយចំនួន អាចអោយផ្កាថ្មនិងធនធានត្រីនៅទីនោះកកើតឡើងវិញបាន។ ផែនការគ្រប់គ្រងមានប្រសិទ្ធភាព ត្រូវតែបង្កើតឡើងជាចាំបាច់សំរាប់ការកសាងសមត្ថភាពរដ្ឋអំណាចមូលដ្ឋាននិងរដ្ឋាភិបាល ដើម្បីបន្តយការអាស្រ័យលើចំណេះដឹង ជំនាញរបស់បរទេស និងបង្កើតមុខរបរផ្សេងៗក្រៅពីការនេសាទសំរាប់ជីវភាពរស់នៅក្នុងមូលដ្ឋានសំដៅទៅរកទេសចរណ៍មាននិរន្តរភាព។

Abstract

Cambodia is rich in fringing coral reefs, but the general status of these reefs is poorly researched and documented. Coral Cay Conservation, in association with Cambodia's Ministry of Agriculture, Forestry and Fisheries, conducted research on coral reefs from February 2010 to February 2011 around the islands of Koh Rong, Koh Kon and Koh Rong Samloem, Phreah Sihanouk Province. Data collected included benthic and fish diversity and composition as well as coral disease and bleaching data. Our research found that anthropogenic impacts were low although there were high levels of siltation. Live hard coral cover was around 25% with the best coral reef sites having up to 40% coral cover. There was a dominance of massive coral life forms and a lack of foliose and branching lifeforms. Key fish families showed signs of depletion although some sites still had representative species, indicating that recovery of fish stocks is possible. Commercially harvested holothurians and benthic invertebrates, such as lobsters, were rarely encountered, indicating overharvesting. The island of Koh Rong is due to undergo significant development, which will likely put further pressure on the area's reef systems. Management recommendations include the implementation of a multiple-use marine protected area that incorporates several no-take areas to allow local reefs and their associated fish stocks to recover. An effective

management plan must also address the need to build local and governmental capacity to lower the dependency on foreign expertise, and diversify local livelihoods away from fishing and towards sustainable tourism.

Keywords

Coral Cay Conservation, Coral Reefs, Ecosystem Management, Koh Rong.

Introduction

The coastline of Cambodia stretches along the Gulf of Thailand and includes 64 islets that support rich diversity of marine species (ICEM, 2003). Most coral reefs in Cambodia are fringing reefs, located along islands with a rocky substrate, which provide shelter for many fish, invertebrates and other species that thrive in coral reefs and related ecosystems (ICEM, 2003; Burke *et al.*, 2002; Kim *et al.*, 2004). In addition to their biological significance, coral reefs have a high socioeconomic value and provide ecosystem services such as supporting fisheries, improving tourism development and providing coastal protection (Kim *et al.*, 2004). In Cambodia, most people living in coastal areas earn their livelihood through the use of natural resources provided by nearshore waters, and reefs are therefore an important asset to the wellbeing of the nation (Yeang, 2009; World Bank, 2007).

Cambodia is rich in fringing coral reefs, but the general status of these reefs is poorly researched and documented. Most reef systems are considered to be under high potential threat, with impacts including overfishing, pollution, coastal development (increased sedimentation), reef destruction (destructive fishing methods, coral extraction), coral bleaching and coral disease (Wilkinson & Souter, 2008). Therefore, there is an urgent need to collect accurate data on these natural resources to assess the biological and socio-economic importance of coral reef ecosystems in the country (Chou *et al*, 2003; Wilkinson & Souter, 2008). Koh Rong island has been designated for extensive, tourism-related coastal development (see www.kohrong.com.kh). Anthropogenic impacts on coral reefs are predicted to increase, placing pressure on the marine species they support. The effects of intensified coastal development cannot be assessed accurately if there is little knowledge and information detailing the current status and health of reef ecosystems. In Cambodia, existing knowledge about local reef habitats has been limited, and this can be detrimental to the application of several management approaches in conserving coral reefs, including the implementation of marine protected areas (Chong, 2005).

To conduct scientific baseline assessments of Koh Rong and Koh Rong Samloem's coastal resources, Coral Cay Conservation (CCC), a U.K.-based NGO, was invited by the Fisheries Administration (FiA) of the Ministry of Agriculture, Forestry and Fisheries (MAFF), to establish a research project in 2010 following an initial pilot project in the same area. The main objective of this project is to collect detailed scientific baseline data to develop a higher level of scientific knowledge of the reefs of Cambodia and help to establish an effective management tool for multiple use zoning schemes around these islands. In addition, the project gathered scientific survey data from the mass coral bleaching event which affected the Gulf of Thailand between May and October 2010.

Methods

The survey area was around the islands of Koh Rong, Koh Kon and Koh Rong Samloem, Phreah Sihanouk Province (Fig. 1). The data collection methodology followed the survey protocol 'Reef Check', which was designed to be used by volunteer recreational divers who are trained, qualified and led by marine scientists in the field (Hodgson *et al.*, 2006). Reef Check is based on the identification of indicator organisms on coral reefs to quantify the abundance, diversity and composition of selected fish, invertebrate and benthic groups (Hodgson *et al.*, 2006). The Reef Check methodology is widely accepted and applied in several aspects of coral reef research (Hughes *et al.*, 2010; Bruno & Selig, 2007). A total of 37 survey sites were set up around the islands of Koh Rong, Koh Kon and Koh Rong Samloem where data was collected throughout the course of the research project by trained volunteers.

Data were recorded along a 100 metre (m) transect parallel to the shore at two different depth bands: 2-6 m ("shallow") and 6-12 m ("deep"). Volunteers worked in two pairs and covered a total transect length of 95 m (four replicates of 20 m length, separated by 5 m gaps) (Fig. 2). Four types of data were recorded: *site description* (e.g. geographical coordinates, water temperature, turbidity and other observational data), *diversity and abundance* of target fishes and invertebrates, *substrate cover and composition* and the *prevalence of coral bleaching and diseases*.

Fish and invertebrates were recorded within belt transects (four replicates per depth band, each 20 m x 5 m; fish counted up to 5 m above the sea floor), with the

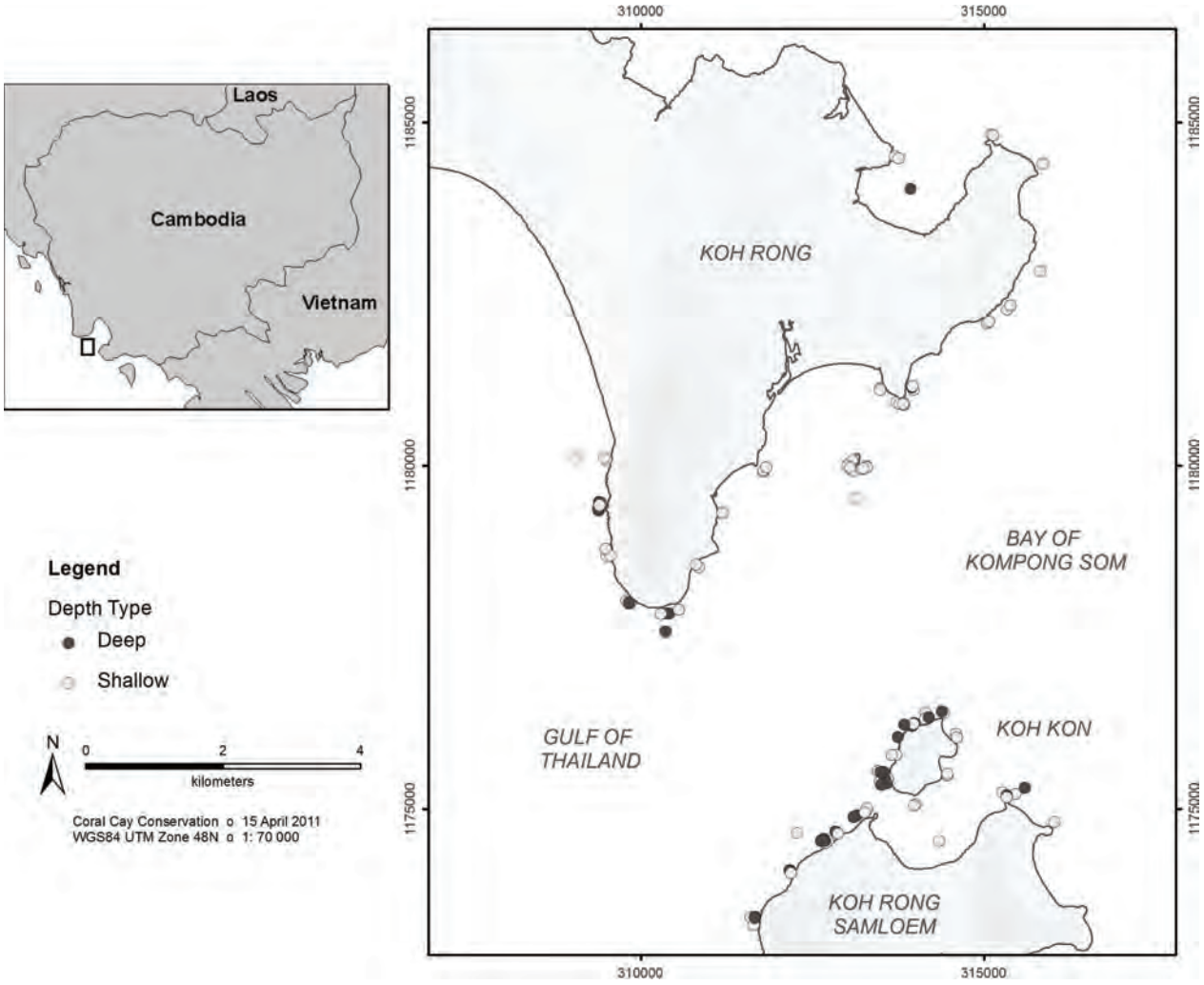

Fig. 1 Locations of survey sites around the islands of Koh Rong, Koh Kon and Koh Rong Samloem. Inset: Map of the Kingdom of Cambodia with the survey area outlined.

number of individuals counted within four imaginary 'boxes' along four 20-m replicates. Substrate composition was assessed along a line transect (four replicates per depth band, each 20 m long) and benthic data were recorded every 50 cm using point intercept samples. Along the point intercept transect, divers also counted the number of recently killed, bleached and diseased coral colonies as a percentage of coral cover. Where possible, the coral disease was identified to black band, white band, brown band or pink *Porites* disease. Damage was recorded on a categorical scale from 0 to 3 (0 = none, 1 = low, 2 = medium, 3 = high). Impact on the site from garbage was recorded and separated into general and fishing nets/ traps. Coral damage types were divided into 'boat/ anchor', 'dynamite' and 'other'.

In addition to the standard Reef Check indicator species, several other locally dominant indicator species were selected (Hodgson *et al.*, 2006). Hard coral colonies

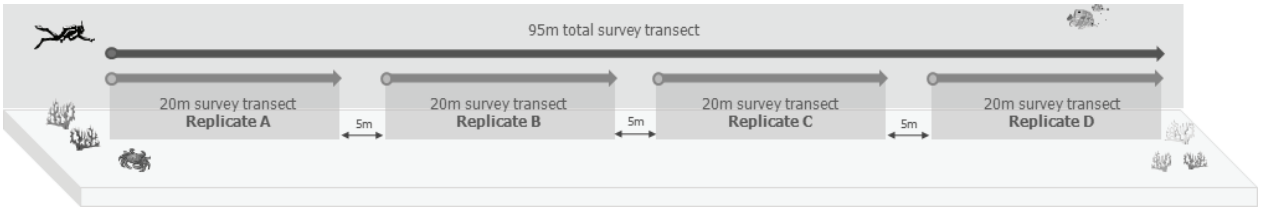

Fig. 2 Transect layout for coral reef surveys.

were categorised into 11 growth lifeforms and identified to either species (14) or genus (11, including *Heliopora, Tubipora* and *Millepora*) level, or grouped into distinct morphological categories of closely related species (6). A total of 52 selected fish families and species, recognized as being good indicators of fishing pressure, aquarium collection and reef health, were included as target species. The body length of species of Serranidae and Scaridae were estimated to the nearest 10 cm. Thirty-three target motile benthic invertebrates were selected using similar criteria.

Thirty-seven coral reef sites were surveyed over 126 survey dives between February 2010 and February 2011. The field data was entered into a Microsoft Excel database. ArcGIS (ESRI software) was used to facilitate data analysis and display survey results on Geographic Information System (GIS) maps. The Shannon-Wiener diversity index was used in order to calculate coral diversity and it was generated in PRIMER-5 software (Plymouth Routines in Multivariate Ecological Research).

Results

Anthropogenic impacts observed were generally low. Although the impact of garbage varied between sites, observed coral damage was consistently low at all survey sites (< 0.5 impact severity measured). Some sites had a clear indication of fishery-related impacts such as anchor damage and fishing nets. Siltation levels changed dramatically throughout the survey period with the onset of heavy rainfall and all reef sites suffered from elevated sediment levels. High levels of siltation of over 20% cover were found around both of the main islands. High siltation levels of up to 28% were found on the south-western point of Koh Rong.

The dominant benthic substrates observed at all survey sites were rock, sand and live hard coral (Fig. 3). The highest frequency of live hard coral cover (~40%) was found around the north-western side of Koh Kon and the northern side of Koh Rong Samloem (Fig 6). Mean hard coral cover was 25% for all sites. The level of nutrient indicator algae was generally below 1% for all sites (Fig. 3). Cover of soft corals and other animals such as hydroids, anemones, gorgonians and ascidians combined were below 6% at all survey sites. Coral diversity across all sites was generally low, with branching and foliose corals rarely encountered and massive colonies such as *Porites* sp. and *Diploastrea helipora*, apparent at all sites. Massive *Porites* colonies were the most dominant coral species, comprising over 50% of coral cover (Fig. 4).

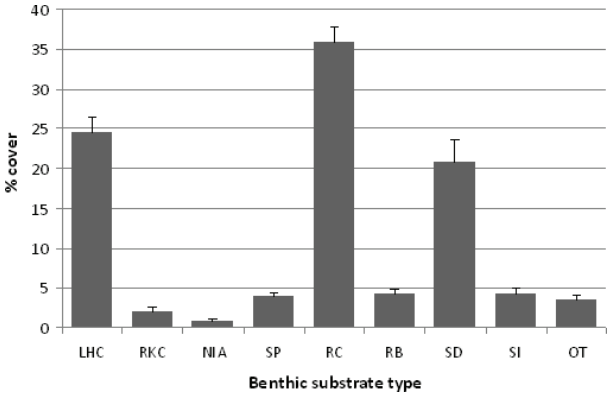

Fig. 3 Benthic composition of main substrate categories around Koh Rong and Koh Rong Sanloem. Error bars indicate standard error. LHC = Live Hard Coral, RKC = Recently Killed Coral, NIA = Nutrient Indicator Algae, SP = Sponge, RC = Rock, RB = Rubble, SD = Sand, SI = Silt, OT = Other substrates.

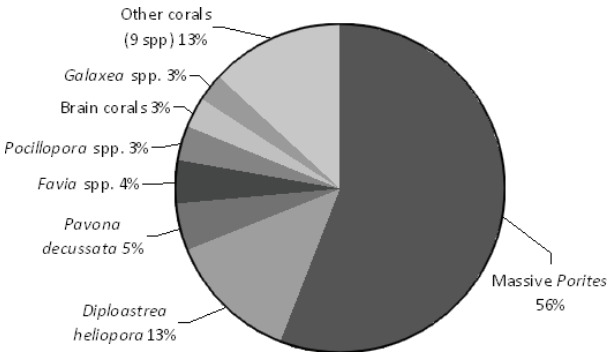

Fig. 4 Coral composition as a percentage of all target coral species and groups encountered on surveys.

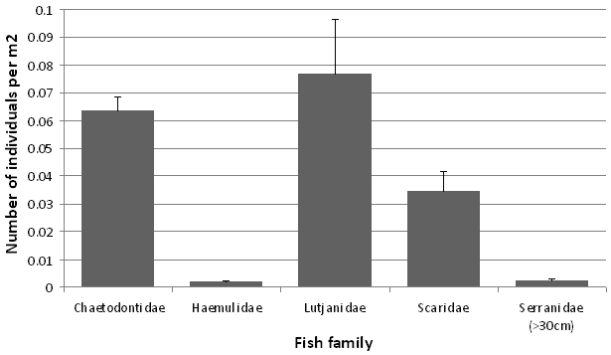

Fig. 5 Abundance of key fish families. Error bars indicate standard error.

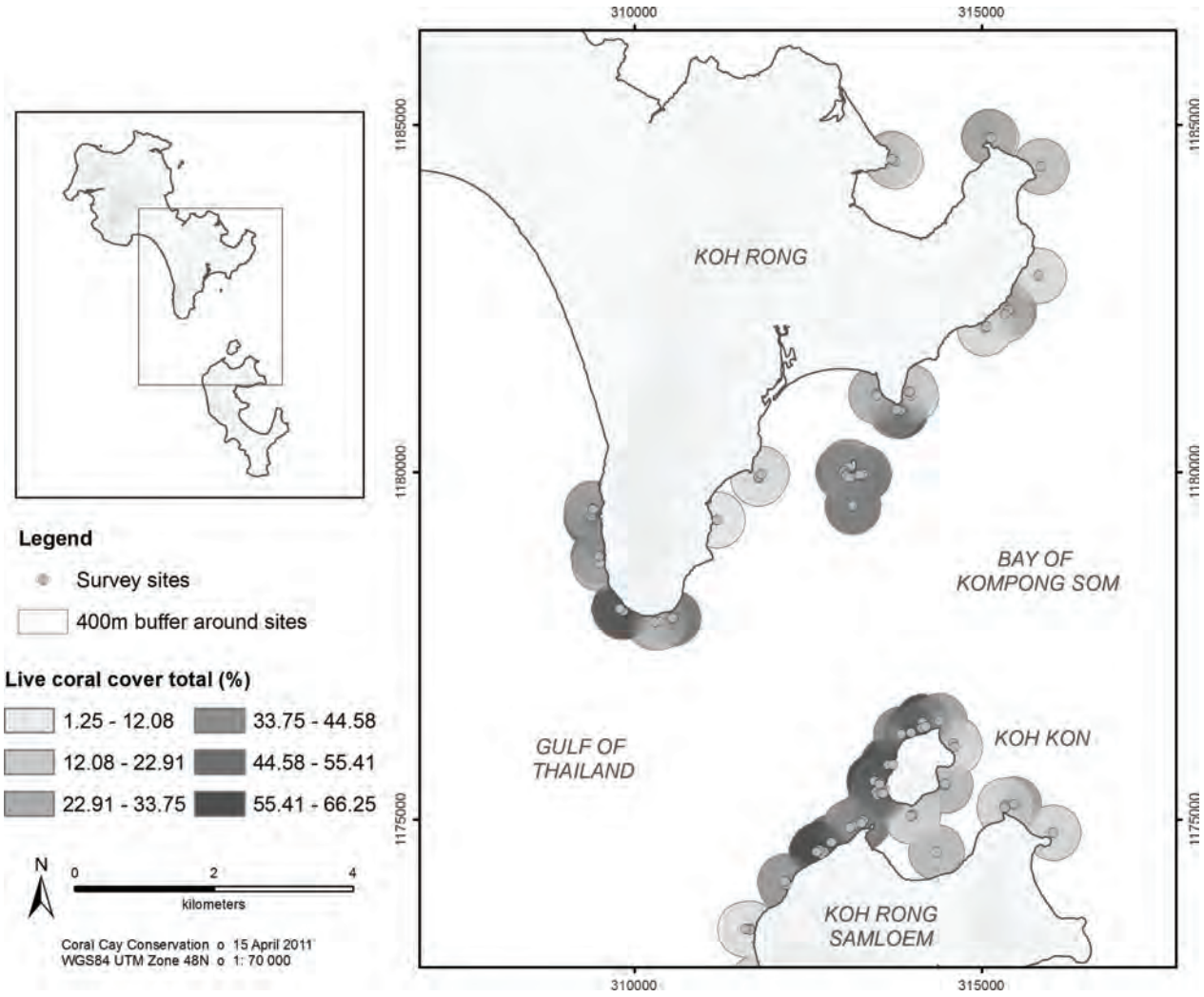

Fig. 6 Map of live hard coral cover around the islands of Koh Rong, Koh Kon and Koh Rong Samloem. The level of shading of the coloured buffer around each survey site indicates the live coral cover as a percentage of the total coral cover.

Butterflyfish (Chaetodontidae) densities varied between surveyed sites, with higher densities in areas where the coral cover was high. Mean butterflyfish density was 0.06 individuals per m^2 (ind./m^2, Fig. 5). Parrotfish (Scaridae) density also varied between sites, but was generally low (0.035 ind./m^2). Snapper (Lutjanidae) numbers (0.07 ind./m^2) were higher than those of other key commercial fish families including groupers (Serranidae, 0.002 ind./m^2) and sweetlips (Haemulidae, 0.002 ind./m^2).

After combining all commercially important fish families and mapping their total densities on GIS maps, we found relatively high densities of 1.2-1.6 ind./m^2 around Koh Kon and some more sheltered sites around Koh Rong and Koh Rong Samloem (Fig. 7). Comparisons with similar studies of the same area in 2003 and 2009 indicate there has been a decrease in the density of groupers and snappers, although there are only limited data to support this.

Diadema (longspine) sea urchins were found on most surveys around the islands. Sites around Koh Rong Samloem had particularly high densities, reaching nearly 2.4 ind./m^2. The density of giant clams *Tridacna* spp. ranged from 0 to 1.35 ind./m^2, with high variation between reef sites (Fig. 8). Sea cucumbers (Holothuria) and lobsters (Palinuridae) were not observed on over 90% of surveys (<0.0005 ind./m^2 for all survey sites). Similarly, the density of crown-of-thorns starfish *Acanthaster planci* was below 0.00017 ind./m^2.

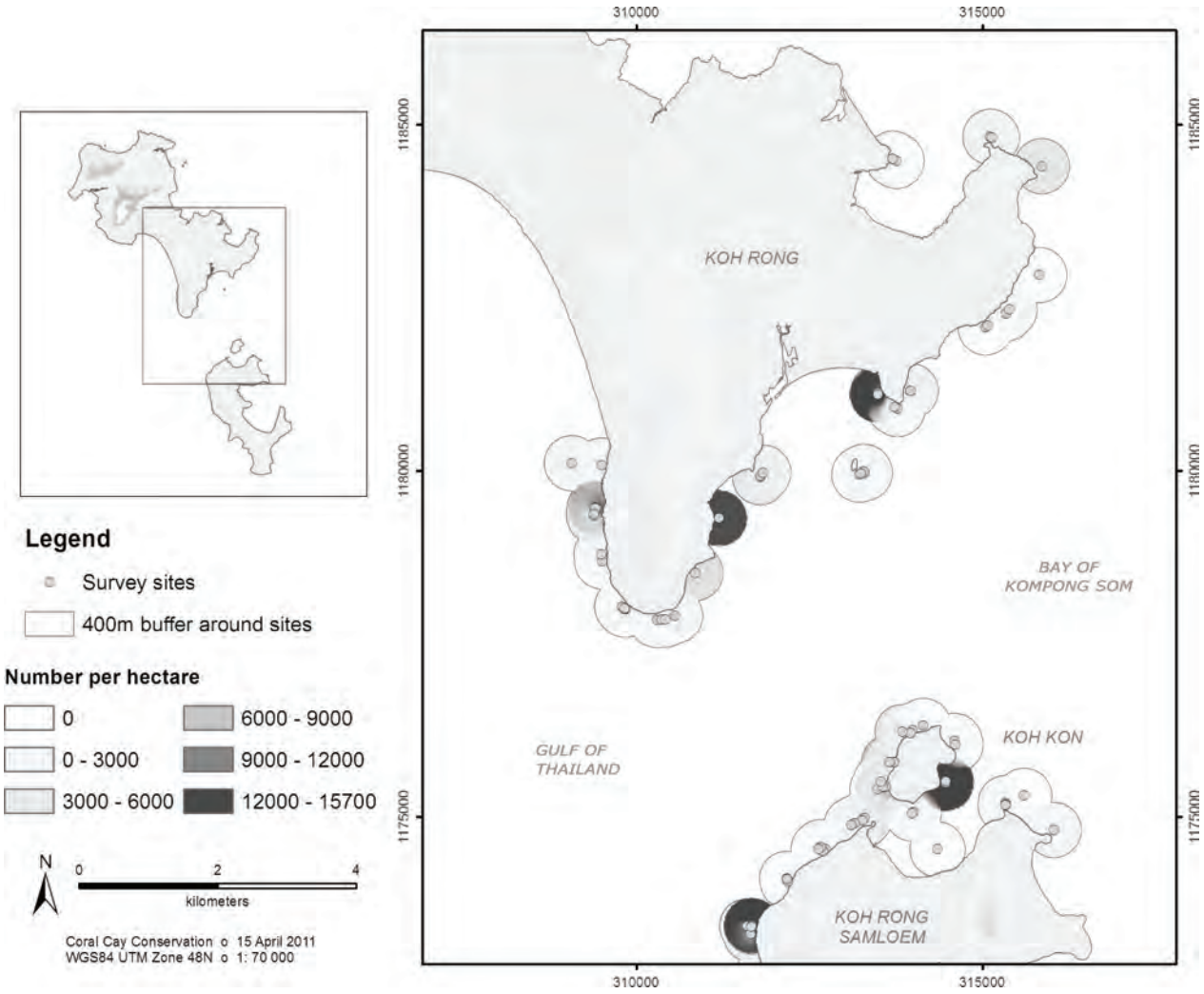

Fig. 7 Map of commercial fish density around the islands of Koh Rong, Koh Kon and Koh Rong Samloem. The level of shading of the coloured buffer around each survey site indicates the number of commercially important fish individuals per hectare. Families include Serranidae, Scaridae, Lutjanidae, Haemulidae Sphyraena and Carangidae.

Discussion

The surveys conducted as part of this programme provided a highly detailed baseline assessment of the status of the areas coral reefs preceding the mass-bleaching event of the second half of 2010. Although some sites still had relatively high coral cover (~40%), the dominance of massive coral species such as *Porites* and *D. heliopoara* and lack of foliose and branching coral lifeforms may be attributed to previous coral degradation, likely a result of high and prolonged sedimentation levels from land runoff, harvesting of corals for the curio trade and regional impacts such as storms. Dead coral, rock and rubble cover was around 40%: 10% higher than the percentage recorded in 2009 at similar sites (van Bochove *et al.*, 2009). Ongoing monitoring will determine the extent of degradation caused by the mass-bleaching event.

Groupers and snappers were rarely seen on most surveys, indicating high fishing pressure on the islands' fringing reefs. However, relatively high numbers of commercial fish families were found around Koh Kon and around some sheltered sites around Koh Rong. Therefore, there is hope that with large (>20 ha) no-take zones at the best reef sites, fish populations may start to increase. These no-take areas should be set up around the best reef sites where fish stock recovery can have the best chance of succeeding. Areas should include Koh Kon and sites around Koh Rong and Koh Rong Samloem, highlighted to contain relatively high coral cover and high densities of commercial fish. These areas will also provide a source of coral larvae to areas that are severely degraded.

There are strong indications that the condition of coral reefs around the islands is still deteriorating, however.

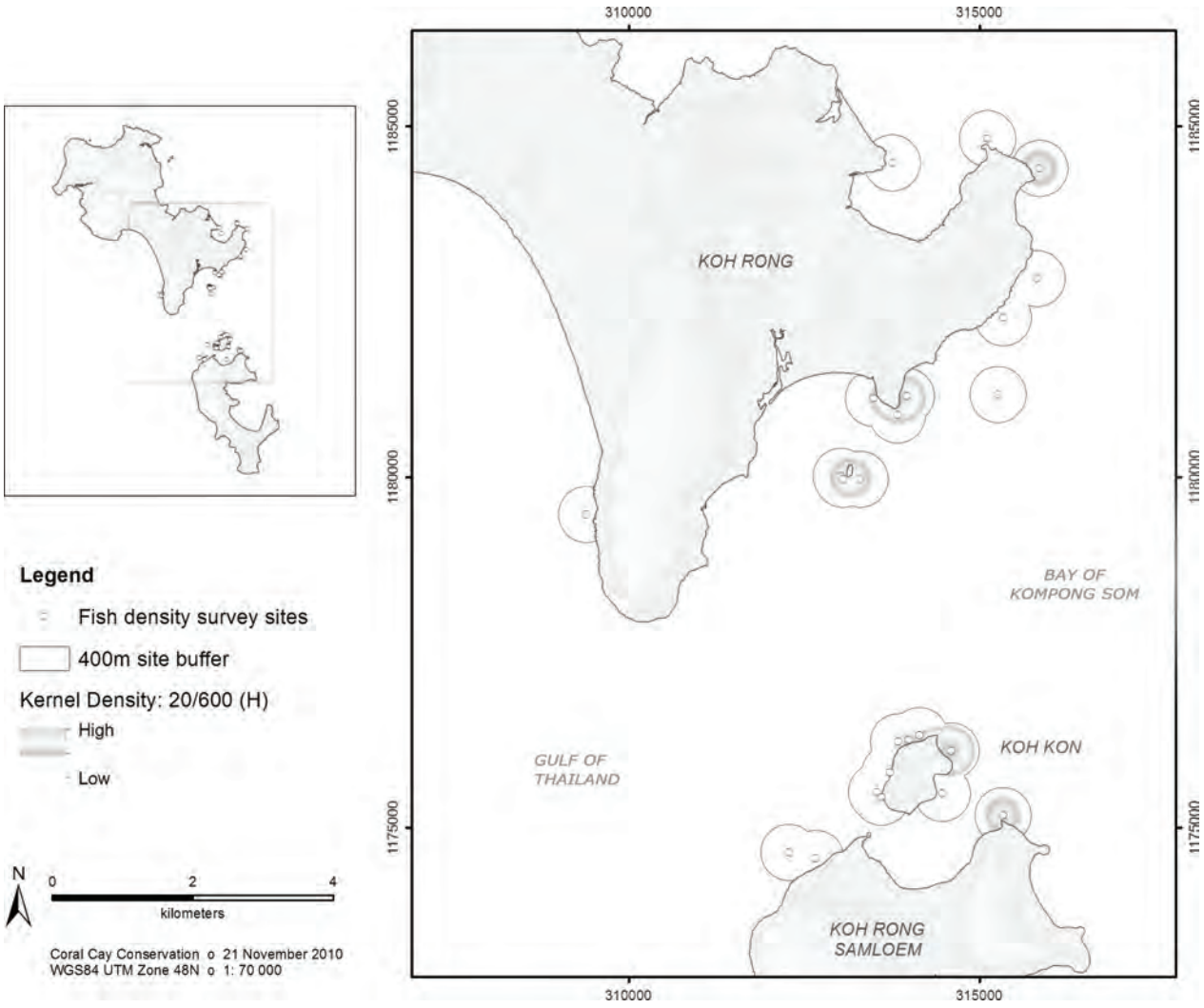

Fig. 8 Map of the abundance of giant clams *Tridacna* spp. around the islands of Koh Rong, Koh Kon and Koh Rong Samloem. The darkness of the coloured buffer around each survey site indicates the density of giant clams.

Comparisons with previous research in the area in 2003 (Chou *et al.*, 2003) and 2009 (van Bochove *et al.*, 2009) indicate that commercially valuable fish species are decreasing in number. However, the lack of extensive and accurate data make it impossible to quantify and assess temporal changes over the past decade. The baseline data now available will be invaluable for ongoing monitoring of the same reefs to assess post-bleaching degradation and subsequent recovery. The baseline information can furthermore be used to assess the impact of management initiatives for the area. The FiA is currently working with stakeholders and local NGOs, including CCC, to develop a multiple-use marine protected area that includes no-take and limited fishing zones. This marine protected area is planned to be established in 2012.

This work has highlighted local and regional stress factors that threaten the health of coral reefs around Koh Rong, Koh Kon and Koh Rong Samloem. Local factors such as overfishing, sedimentation and pollution continue to threaten the reef systems and it is likely they are restricting the recovery of these systems from the 2010 bleaching event. Therefore, it is essential that every effort is made to minimise these impacts through appropriate mitigation measures that promote coastal management and marine conservation. Management recommendations include the implementation of a multiple zone marine reserve around the island of Koh Rong. This is particularly important in light of the significant tourism development that is set to take place on the island over the coming years. It is likely that this will increase anthropogenic impact levels to the already stressed reef systems around the islands.

What is of particular concern is the high amount of siltation that was observed during the rainy season.

Much of this siltation is a result of runoff from the mainland and a holistic and regional management should be considered to effectively address this issue.

The implementation of the marine protected area should also be complemented by education and capacity-building programmes for the local community to ensure that conservation efforts are effective. The development of alternative livelihoods in tourism will help relieve local dependence on dwindling fish stocks and help diversify livelihood dependency away from marine resource extraction. Capacity development schemes in the area should be further expanded to provide conservation awareness and improve the technical expertise of government employees and community officials to support the establishment of a marine protected area, thereby reducing dependency on foreign NGOs for coastal monitoring and management. CCC is providing ongoing capacity building and educational activities in addition to scientific survey work to support the conservation of the areas marine resources. Support from local officials, the private sector and the community is crucial for the effective sustainable management of this area in the face of significant coastal development.

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Butterfly assemblages (Lepidoptera, Papilionoidea) of the Cardamom Mountains, Southwest Cambodia

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មូលន័យសង្ខេប

មេអំបៅនៃប្រទេសកម្ពុជាត្រូវបានស្គាល់តិចតួចណាស់ គឺមានតែ៣០ប្រភេទប៉ុណ្ណោះនៅទូទាំងប្រទេស នៅក្នុងកំណត់ត្រានៃអត្ថបទស្រាវជ្រាវកន្លងមក។ តាមការសិក្សារយៈពេល៣៨ថ្ងៃក្នុងព្រៃធម្មជាតិ ២៣៣ប្រភេទនៃអំបូរច្បង Papilionoidea ត្រូវបានកត់ត្រាជាលើកដំបូង នៅភ្នំក្រវាញនៃភាគនិរតីប្រទេសកម្ពុជា។ ភាគសំណាកមេអំបៅនៃដែនជម្រកសត្វព្រៃភ្នំសំកុសទាំងនោះជាសហគមន៍តំបន់ដីទំនាបយ៉ាងច្រើន ទោះបីមានប្រភេទតំបន់ភ្នំតូយ៉ាងខ្លះក៏ដោយ។ ក្នុងន័យនៃសមាសភាពជីវភូមិសាស្ត្ររបស់វា ពពួកមេអំបៅនេះគឺប្រហាក់ប្រហែលទៅនឹងមេអំបៅនៃតំបន់ភ្នំផ្សេងទៀតនៅភាគខាងត្បូងប្រទេសវៀតណាម ប៉ុន្តែវាហាក់ដូចជាមានប្រភេទដែលមានដើមកំណើតនៅទីនេះតិចតួចគួរអោយឆ្ងល់។ មេអំបៅភាគច្រើនដែលត្រូវបានប្រទះឃើញនៅកន្លែងសិក្សា មាននៅពាសពេញតំបន់ម៉ាឡាយ៉ា-ឥណ្ឌា (Indo-Malayan) ដូច្នេះវាមាននៅកោះសាន់ដា (Sunda) និងផ្នែកផ្សេងទៀតនៃដីគោកនៅអាស៊ីអាគ្នេយ៍។

Abstract

The butterfly fauna of Cambodia is poorly known, with previous literature recording as few as 30 species nationwide. In 38 person-days of fieldwork, 233 species of the superfamily Papilionoidea were recorded for the first time from the Cardamom Mountains in Southwest Cambodia. The butterfly assemblages in Phnom Samkos Wildlife Sanctuary are predominantly lowland communities, although some typical montane species are also present. In terms of its biogeographical composition, the butterfly fauna is similar to other montane areas in southern Vietnam, but appears to contain surprisingly few endemic species. Most of the butterflies found at the site occur throughout the Indo-Malayan realm and thus are present in the Sunda Islands and other parts of mainland Southeast Asia.

Keywords

Biogeography, butterflies, Cambodia, Cardamom Mountains.

Introduction

Judging from the number of publications and butterfly collections from Cambodia in European natural history museums, it can be concluded that this group of insects has not been seriously studied yet. Only a few Cambodian butterfly species, collected during the French colonial period, can be found in the natural history museums in Paris and London, and this material often lacks labels detailing their locations, habitats and collectors. Some data concerning species in Cambodia can be found in old (Seitz, 1908-1928; Dubois & Vitalis de Salvaza, 1919, 1921, 1924) and relatively recent literature (Shirôzu & Yata, 1973; Pinratana, 1979-1996; Ek-Amnuay, 2006). Fruhstor-

fer, Jordan and Röber contributed to the fundamental monograph by A. Seitz (1908-1928) on the butterflies of the Indo-Australian region, which mentioned approximately 30 butterfly species in Cambodia. However, Cambodia still lacks a preliminary checklist, and some of the specimens deposited in the museums need additional study to determine their identity. Moreover, there is a lack of information about the butterflies that inhabit any particular Cambodian site, including the Cardamom Mountains.

Methods

Study areas and data collection

Our survey was conducted in the vicinity of Mount Tumpor and Mount Khmaoch in the Phnom Samkos Wildlife Sanctuary in Veal Veng District, Pursat Province (Fig. 1) in 2006 and 2010. The wildlife sanctuary (3,326 km^2) was designated as a protected area by Royal Decree in 1993, and is located at the western end of the Cardamom Mountains range in Southwest Cambodia. This protected area contains a wide variety of landforms, elevations and geology, and can thus be expected to be highly biologically diverse. It also contains much of the unlogged forest that remains in the Cardamom Mountains, including probably nearly all of the primary lowland forest (Webb, 2005). The first detailed information on the ecology of Phnom Samkos Wildlife Sanctuary was obtained during preliminary surveys by Fauna & Flora International and the Government of Cambodia (Momberg & Weiler, 1999; Daltry & Momberg, 2000). Additional valuable information can also be found in the reports by Webb (2005), Chay *et al.* (2005) and Daltry (2002).

Martin (1997), Rundel (1999) and Webb (2005) recognised several forest classes in Phnom Samkos Wildlife Sanctuary, including (1) Montane forest (above 1,500 m) dominated by Fagaceae and with abundant spiny palms in the understorey; (2) Evergreen hill forest, which covers most of the study site and may be divided: (2a) Low to mid-elevation evergreen forest on sandstone (the commonest type throughout Phnom Samkos, including the Mount Khmaoch site); (2b) Basalt evergreen forest characterised by very tall trees including giant *Ficus*, the genera *Irvingia*, *Syzygium* and *Garcinia,* and various representatives of the Lauraceae (this forest type occurs in the Mount Tumpor site); and (2c) Mid elevation (400-800 m) and high elevation (1,000-1,500 m) evergreen forests dominated by Dipterocarpaceae and Fabaceae (also present in the Mount Khmaoch site). Location details, survey dates and habitats studied are shown in Table 1.

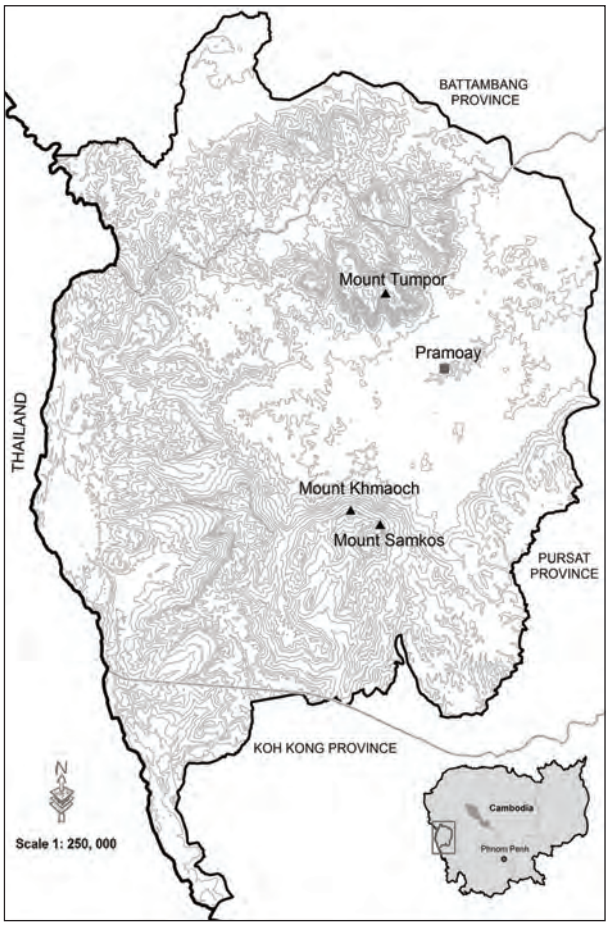

Fig. 1 Map showing the butterfly survey areas in the vicinity of Mount Tumpor and Mount Khmaoch. Phnom Samkos Wildlife Sanctuary, Southwest Cambodia (after Daltry & Momberg, 2000)..

Collection methods

Butterflies were collected opportunistically throughout the study areas, in a variety of habitats, using standard construction nets and butterfly traps (Austin & Riley, 1995). The traps were suspended from trees at forest edges, with fresh and rotting bananas as bait. Specimens were immobilised by manually squeezing the thorax. The material collected was deposited in the authors' organizations.

Taxonomic studies

Specimens were identified using a variety of literary references (Pinratana, 1979-1996; Corbet & Pendlebury, 1992; Osada *et al.*, 1999; Aoki *et al.*, 1982; Bascombe *et al.*, 1999; Monastyrskii, 2005, 2007a) and existing reference collections of Indochinese butterfly specimens in the natural history museums in London and Paris.

Table 1 Details of collecting areas (all in Veal Veng District, Pursat Province).

Collecting area	Collecting dates and sampling effort (man-days)	Habitat	Altitude (m)
Tumpor massif	18-19 February 2006 (6 man-days)	Riverine habitats on sandstone, near Pramaoy village	200-250
	21-27 February 2006 (21 man-days)	Montane forest edges and peak vegetation on basalt	1,450
		High elevation evergreen forest on basalt	1,050-1,150
		Low to mid-elevation evergreen forest, scrubland and other habitats on basalt	300-800
Khmaoch massif	11-21 December 2010 (11 man-days)	High elevation evergreen forest on sandstone	800-1,250
		Wooded area at lower elevations on sandstone	250-350

The higher taxonomic classification system used in this report was taken from the works for Vietnamese and regional butterflies (Ackery, 1989; Ackery *et al.*, 1999; Vane-Wright and de Jong, 2003; Wahlberg *et al.*, 2003; Monastyrskii, 2005).

Results

Butterfly species richness

A total of 233 butterfly species belonging to the superfamily Papilionoidea were recorded on Tumpor and Khmaoch massifs in Phnom Samkos Wildlife Sanctuary during this study. These species belong to five families: the Papilionidae (19 species); Pieridae (28 species); Nymphalidae (108 species); Riodinidae (5 species); and Lycaenidae (73 species). A list of the butterfly species collected on Tumpor and Khmaoch is presented Appendix 1.

The number of butterfly species recorded on Tumpor massif at the end of the dry season (201 species) was much higher than number of species found on Khmaoch massif at the beginning of dry season (94 species). On Tumpor, 136 species were recorded above 800 m and 107 species below 800 m, including riverine habitat near Pramaoy village. The number of butterfly species discovered at elevations above 800 m is shown in Table 2.

Potential new butterfly taxa

Preliminary taxonomical studies show that none of the butterflies found during the surveys in 2006 and 2010 are new to science at species level, but some might qualify as new subspecies. One species belonging to the Pieridae family, *Delias vietnamensis* Monastyrskii & Devyatkin, 2000 (Fig. 2) has only recently been described from eastern Indochina (central Vietnam) and is endemic to the Indochinese peninsula. The local population of *D. vietnamensis* has unusual yellow markings on the hindwing underside, which distinguish it from the nominotypical subspecies in central and southern Vietnam.

The population of *Neptis anjana* Moore, 1881, on Mount Tumpor has a different wing pattern to the nominate subspecies in central and southern Myanmar. It is possible that this population could also represent a separate subspecies.

New distribution records

Practically all butterfly species found in the Cardamom Mountains during both surveys and listed in the Appendix are new national records. Most of these are well known from the adjacent areas of Vietnam, Laos and Thailand, but are hereby recorded in Cambodia for the first time. Thus, their ranges have not been extended, but are now more fully documented. However, *Byasa polyeuctes* (Doubleday, 1842) is a montane species previously known only from highland areas of northern and central Indochina, and our Cardamom Mountains record has significantly extended this range to southern Indochina. Similarly, this study has extended the known distribution range of *D. vietnamensis*, which was previously known only from the Kon Tum and Da Lat plateaux (central Vietnam).

Two representatives of Satyridae family *Ypthima nebulosa* Aoki & Uemura, 1982, and *Y. singorensis* Aoki & Uemura, 1984, have only recently been described. First described from Sumatra, *Y. nebulosa* has been found in Myanmar (Burma), Thailand, Laos and Vietnam, and Cambodia's Cardamom Mountains is a new locality for this species. *Ypthima singorensis*, originally described from Peninsular Thailand and found in Laos and Vietnam, is also a new record for Cambodia.

Threatened species

One swallowtail recorded during this study is on Appendix II of the Convention on International Trade in Endan-

Table 2 Number of butterfly species recorded at high elevations on the Tumpor and Khmaoch massifs in the Cardamom Mountains.

Family/ subfamily	No. of species	Tumpor		Khmaoch	
		Total	>800m	Total	>800m
Papilionidae	19	19	12	9	6
Pieridae	28	27	15	10	9
Nymphalidae:	108	92	65	43	39
Danainae	17	16	11	7	5
Satyrinae	26	24	17	8	7
Amathusiinae	8	4	4	5	4
Libytheinae	1	1	1	0	0
Heliconiinae	9	8	5	5	5
Limenitidinae	25	22	15	9	9
Biblidinae	8	7	3	2	2
Nymphalinae	9	5	4	5	5
Apaturinae	1	1	1	1	1
Charaxinae	4	4	4	0	0
Riodinidae	5	0	1	0	5
Lycaenidae	73	59	40	27	26
Total	233	201	136	94	85

Fig. 2 *Delias vietnamensis* Monastyrskii & Devyatkin, 2000, from the Tumpor massif (© K. Odagiri).

gered Species of Wild Fauna and Flora (CITES): the birdwing *Troides aeacus* (Papilionidae). Although this species is relatively abundant in Indochina, it is considered by CITES to be internationally threatened by commercial exploitation and so its international trade is regulated.

Butterfly species of the montane communities

The classic montane butterfly fauna was not prominent in the study area. Among the 180 species found above 800 m during the dry season, only 22 species (12.2%) are considered to represent the montane forest community of Indochina and the Malay Peninsula (Corbet & Pendlebury, 1992; Monastyrskii, 2005, 2007b) (Appendix). More than half of these species belong to the families Lycaenidae (*Celastrina lavendularis, Celatoxia marginata, Eliotia jalindra, Flos areste, Heliophorus epicles, Udara placidula* and *U. albocaerulea*), Nymphalidae: Danainae (*Parantica melaneus, P. swinhoei* and *P. sita*) and Amathusiinae (*Enispe duranius, Melanocyma faunula* and *Thaumantis diores*). The recorded swallowtails (Papilionidae) included only one montane species, *Byasa polyeuctes*. Two montane species are pierids (*Delias vietnamensis* and *D. agostina*), and two from each of Nymphalidae: Satyrinae (*Elymnias patna* and *Mycalesis anaxias*), Nymphalidae: Limenitidinae (*Neptis anjana* and *Sumalia daraxa*) and Riodinidae (*Dodona deodata* and *Stiboges nymphidia*).

Discussion

We spent an unequal time studying the butterfly communities at lower and higher elevations because the main aim of the current study was to assess the diversity and taxonomy of butterflies at higher altitudes. This bias prevents us from rigorously comparing these assemblages. Nevertheless, our preliminary biogeographical and ecological data can be compared to lowland and montane sites in Vietnam, also in southern Indochina.

Distinctiveness and uniqueness

The butterfly fauna discovered in Phnom Samkos Wildlife Sanctuary during the dry season was not highly distinct or unique. No species was found to be endemic to this area. The overwhelming majority of butterfly species recorded during both survey periods are well known from adjacent territories of the Indochina peninsula and from other countries in mainland Southeast Asia.

At the same time, the group of species notably includes *Neptis anjana* (Nymphalidae) and lycaenids *Horaga syrinx, Jamides philatus, Loxura cassiopeia, Nacaduba calauria, N. solta, N. kirtoni, Pratapa icetoides* and *Virachola smilis*, which demonstrate a link with Malayan and Sundaic faunas. These species are hereby recorded in Indochina for the first time, although they are also known from Northeast India and Myanmar. The rare and unmistakable *Charaxes durnfordi* is also well known from the Malay Peninsula, and has also been found in North-

Table 3 Geographic range types of the butterfly faunas of the Cardamom Mountains and selected areas of Vietnam. Figure show the percentage of species in each range category: (1) Endemic to Indochina; (2) Sino-Himalayan; (3) Indo-Burmese; (4) Indo-Malayan or Oriental; (5) Indo-Australian; (6) Australo-Oriento-Palaearctic; (7) Palaeotropical; (8) Holarctic; and (9) Cosmopolitan (Monastyrskii, 2007b).

Location	Geographical range types								
	1	2	3	4	5	6	7	8	9
Cambodia: Cardamom Mountains	1.29	2.15	21.89	54.51	15.88	1.29	3.00	0.00	0.00
Vietnam: Da Lat Plateau: Hon Ba	4.8	7.4	26.8	44.7	11.9	2.2	2.2	0.0	0.0
Bi Doup	3.3	14.6	33.3	26.0	12.2	4.9	4.9	0.0	0.8
Bao Lan	2.7	2.7	24.4	54.8	10.1	2.3	2.3	0.5	0.0
Vietnam: lowland: Nam Cat Tien	0.7	1.1	18.8	61.3	14.4	1.1	2.6	0.0	0.0

east India (Assam) and Myanmar, but has been never recorded in Indochina before.

Biogeography

Modern knowledge on the geographic distribution of many of the species collected was recently presented in works concerning Vietnamese butterflies (Monastyrskii, 2006, 2007b, 2009). This biogeographical analysis of the Indochinese butterfly fauna was based on hierarchic principles, including the classification of geographical ranges. All of the region's butterfly species were classified according to their global geographic ranges from the most restricted to most widespread. To the north and northeast of Indochina, butterfly ranges spread to Siberia and Far East Asia. Other groups of the northern ranges spread from Indochina to Europe and the Mediterranean. The southern ranges of Indochinese butterflies, on the other hand, appear to extend from Africa through the southern regions of Asia to Australia. A total of nine types of geographical range was recognised by Monastyrskii (2007b): See caption to Table 3.

We have previously demonstrated that Vietnamese butterfly species are characterised by different types of geographical distribution, from restricted endemic ranges to cosmopolitan ranges. Most Vietnamese butterflies have Indo-Malayan (~40% of species), Indo-Burmese (25%) and Sino-Himalayan (~20%) ranges. Some isolated areas of central Vietnam (Kon Tum and Da Lat plateaus) have endemic species (Monastyrskii, 2007b, 2009): in some parts of Da Lat plateau, endemism ranges from 2.7% to nearly 5% of species. With this in mind, one might predict similarly high butterfly endemism in such an isolated area as the Cardamom Mountains. However, the preliminary data collected demonstrate fewer endemics in the Cardamom Mountains than in the nearest highlands in southern Vietnam (Table 3). During our survey of the dry season butterfly communities, only three Indochina endemic species were discovered in Phnom Samkos: the pierids *Delias vietnamensis* and *Eurema novapallida* and nymphalid *Stichophthalma cambodia*.

Generally, the biogeographical pattern of the Cardamom Mountains butterfly fauna during the dry season is similar to those of the southern mountain areas of Vietnam, but with fewer Indochinese endemics (Table 3). What distinguishes the Cardamom Mountains fauna is the relative lack of Sino-Himalayan species (only 2% of all butterfly species inhabiting higher elevations in Tumpor and Khmaoch massifs) or Indo-Burmese butterfly species, whereas there are a greater number of species with Indo-Australian ranges. It is remarkable that the proportion of species with Oriental distributions is so much higher in the Cardamom Mountains than in mountainous sites of the Da Lat plateau (Chu Yang Sin, Bi Doup and Hon Ba). This means that the Cardamom Mountains butterfly fauna includes more montane species with Oriental ranges, while the South Vietnamese highlands are saturated by the Sino-Himalayan species. Perhaps the central Cambodian plain and the Mekong River basin are barriers to the distribution of some stenotopic species represented such taxonomic groups as Nymphalidae (Satyrinae, Amathusiinae), Lycaenidae and Riodinidae.

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Appendix 1

Checklist of butterflies recorded in Phnom Samkos Wildlife Sanctuary. T = Tumpor massif; K = Khamaoch massif; l = lower elevation (<800 m); h = higher elevation (>800m).

Family/	T		K	
Species	l	h	l	h
Papilionidae				
Troides aeacus aeacus (C. & R. Felder, 1860)	*	*		*
Byasa polyeuctes polyeuctes (Doubleday, 1842)		*		*
Pachliopta aristolochiae goniopeltis (Rothschild, 1908)	*			
Chilasa slateri slateri (Hewitson [1859])		*		
C. clytia clytia (Linnaeus, 1758)	*			
Papilio demoleus malayanus Wallace, 1865	*		*	
P. helenus helenus Linnaeus, 1758		*		*
P. mahadeva mahadeva Moore [1879]	*			
P. memnon agenor Linnaeus, 1758	*			*
P. paris paris Linnaeus, 1758		*		
P. polytes romulus Cramer, 1776	*			
Graphium agamemnon agamemnon (Linnaeus, 1758)		*		*
G. aristeus hermocrates (C. & R. Felder [1865])	*	*		
G. macareus indochinensis (Fruhstorfer, 1901)	*	*		
G. megarus megapenthes (Fruhstorfer, 1902)	*	*	*	
G. sarpedon sarpedon (Linnaeus, 1758)		*	*	
G. xenocles lindos (Fruhstorfer, 1901)		*		
Lamproptera curius walkeri (Moore, 1902)		*		*
L. meges virescens (Butler [1870])	*			
Pieridae				
Delias acalis acalis (Godart, 1819)		*		
D. agostina annamitica Fruhstorfer, 1901		*		
D. vietnamensis Monastyrskii & Devyatkin, 2000		*		*
D. pasithoe nigrescens Talbot, 1928		*		
D. descombesi descombesi (Boisduval, 1836)		*		
D. hyparete indica (Wallace, 1867)		*		
Leptosia nina (Fabricius, 1793)	*			*
Prioneris thestylis thestylis (Doubleday, 1842)		*		
Cepora nadina nadina (Lucas, 1852)		*		
C. iudith (Fabricius, 1787)	*			
Appias lyncida eleonora (Boisduval, 1836)	*			
A. libythea olferna Swinhoe, 1890	*			
A. albina darada (C. & R. Felder [1865])	*	*		*
A. indra thronion Fruhstorfer, 1910		*		*
Hebomoia glaucippe glaucippe (Linnaeus, 1758)	*			
Eurema brigitta hainana (Moore, 1878)	*			
E. laeta pseudolaeta (Moore, 1906)	*			
E. hecabe hecabe (Linnaeus, 1758)	*		*	*
E. simulatrix inouei Shirôzu & Yata, 1973		?		
E. blanda silhetana (Wallace, 1867)	*	*	*	*
E. andersoni sadanobui Shirôzu & Yata, 1982	*	*	*	
E. ada indosinica Yata, 1991		*		*
E. novapallida Yata, 1992		*		
E. sari sodalis (Moore, 1886)			*	
Gandaca harina burmana Moore [1906]	*			*
Catopsilia pyranthe pyranthe (Linnaeus, 1758)	*			
C. pomona pomona (Fabricius, 1775)	*			
C. scylla cornelia (Fabricius, 1787)	*			
Nymphalidae				
Danainae				
Danaus genutia genutia (Cramer [1779])		*		
D. melanippus indicus Fruhstorfer, 1899	*			
Tirumala septentrionis septentrionis (Butler, 1874)	*	*	*	
Parantica aspasia aspasia (Fabricius, 1787)		*		
P. aglea melanoides (Moore, 1883)	*	*		
P. melaneus melaneus (Cramer [1775])		*		*
P. swinhoei szechuana (Fruhstorfer, 1899)				*
P. sita sita (Kollar, [1844])		*		*
Ideopsis similis persimilis (Moore, 1879)	*	*		
Euploea modesta modesta Butler, 1866	*	*		
E. crameri inouei Morishita, 1970	*			
E. core godartii Lucas, 1853	*	*		
E. algea limborgii Moore [1879]	*		*	
E. sylvester harrisii C. & R. Felder [1865]	*	*		
E. mulciber mulciber (Cramer [1777])	*	*		*
E. klugii erichsonii C. & R. Felder [1865]	*			
E. radamanthus radamanthus (Fabricius, 1793)	*			*
Satyrinae				
Melanitis leda leda (Linnaeus, 1758)	*	*	*	*
Elymnias patna stictica Fruhstorfer [1902]		*	*	
E. hypermnestra meridionalis Fruhstorfer, 1902	*			
E. nesaea (Linnaeus, 1764)	*			
E. malelas ivena Fruhstorfer, 1911	*	*		
Lethe confusa confusa Aurivillius [1898]			*	
L. kansa vaga Fruhstorfer, 1911		*		*
L. minerva tritogeneia (Fruhstorfer, 1911)	*			
L. europa gada Fruhstorfer, 1911			*	
L. chandica suvarna Fruhstorfer, 1908				*
L. vindhya vindhya (C. & R. Felder, 1859)				*
Erites falcipennis falcipennis Wood-Mason & de Nicéville 1883		*		

Checklist of butterflies recorded in Phnom Samkos Wildlife Sanctuary *cont.*

Family/	T		K		Family/	T		K	
Species	l	h	l	h	Species	l	h	l	h
Orsotriaena medus medus (Fabricius, 1775)	*	*			*P. sandaka davidsoni* Eliot, 1969	*			
Mycalesis anaxias aemate Fruhstorfer, 1911		*		*	*Athyma perius perius* (Linnaeus, 1758)	*	*		
M. gotama charaka Moore, 1874	*				*A. pravara indosinica* (Fruhstorfer, 1906)		*		
M. lepcha (Moore, 1880)	*				*A. larymna* (Doubleday, 1848)	*			
M. perseus tabitha (Fabricius, 1793)			*	*	*A. kanwa phorkys* (Fruhstorfer, 1912)		*		
M. mineus mineus (Linnaeus, 1758)			*	*	*A. selenophora batilda* (Fruhstorfer, 1908)		*		*
M. perseoides perseoides (Moore, 1892)		*	*		*A. zeroca* Moore, 1872		*		
Ragadia crisilda Hewitson (1862)		*			*A. cama camasa* (Fruhstorfer, 1906)		*		
Ypthima baldus baldus (Fabricius, 1775)		*			*A. nefte* (Cramer, 1779)	*	*		
Y. lisandra lisandra (Cramer, 1780)		*			*Sumalia daraxa* (Doubleday, 1848)				*
Y. nebulosa Aoki & Uémura, 1982		*		*	*Lebadea martha martha* (Fabricius, 1787)	*			*
Y. singorensis indosinica Uémura & Monastyrskii, 2004	*	*			*Parthenos sylvia gambrisius* (Fabricius, 1787)	*			*
Y. norma annamitica Fruhstorfer, 1911		*			*Tanaecia julii* (Lesson, 1837)	*			*
Y. savara savara Grose-Smith, 1887	*				*T. lepidea* (Butler, 1869)	*	*		*
Amathusiinae					*Euthalia aconthea garuda* Moore, 1858	*	*		
Faunis canens arcesilas Stichel, 1933		*			*E. alpheda jama* (C. & R. Felder, 1867)				*
Melanocyma faunula (Westwood, 1850)		*			*E. lubentina lubentina* (Cramer [1777])				*
Stichophthalma cambodia (Hewitson, 1862)		*			Biblidinae				
Amathusia phidippus phidippus (Linnaeus, 1763)				*	*Cyrestis cocles cocles* (Fabricius, 1787)	*			
Amathuxidia amythaon annamensis Talbot, 1932			*		*C. thyodamas* (Doyère, 1840)		*		*
Thaumantis diores Doubleday, 1845				*	*Chersonesia risa risa* (Doubleday, 1848)				*
Discophora deo fruhstorferi Stichel, 1901				*	*C. intermedia* Martin, 1895	*			
Enispe duranius Fruhstorfer, 1911		*		*	*Dichorragia nesimachus* (Doyère, 1840)		*		
Libytheinae					*Ariadne ariadne pallidor* (Fruhstorfer, 1899)	*			
Libythea narina rohini Marshall, 1881	*	*			*A. merione tapestrina* (Moore, 1884)		*		
Heliconiinae					*A. specularia arca* (Fruhstorfer 1906)	*			
Cethosia cyane cyane (Drury, 1773)	*	*			Nymphalinae				
Terinos atlita miletum Oberthür, 1877				*	*Kaniska canace canace* (Linnaeus, 1763)		*		
Vindula erota erota (Fabricius, 1793)	*	*		*	*Symbrenthia lilaea* (Hewitson, 1864)				*
Cirrochroa tyche rotundata Butler, 1879	*	*		*	*S. hypselis* (Godart [1824])				*
Paduca fasciata fasciata (C. & R. Felder, 1860)	*				*Junonia iphita iphita* (Cramer, 1779)				*
Vagrans egista (Cramer, 1780)		*		*	*J. atlites atlites* (Linnaeus, 1763)	*	*		*
Cupha erymanthis (Drury, 1773)		*		*	*J. almana almana* (Linnaeus, 1758)	*			
Phalanta phalantha (Drury, 1773)	*				*J. lemonias lemonias* (Linnaeus, 1758)	*	*		
P. alcippe alcippoides (Moore, 1900)	*				*Hypolimnas bolina* (Linnaeus, 1758)	*	*		
Limenitidinae					*Kallima inachus* (Doyère, 1840)				*
Neptis clinia susruta Moore, 1872		*			Apaturinae				
N. cartica Moore, 1872		*			*Rohana parisatis pseudosiamensis* Nguyen-Phung, 1985		*		*
N. hylas kamarupa Moore, 1874	*	*							
N. leucoporos Fruhstorfer, 1908		*			Charaxinae				
N. soma soma Moore, 1858		*		*	*Polyura athamas athamas* (Drury, 1773)		*		
N. anjana Moore, 1881 spp.		*			*P. schreiber assamensis* (Rothschild, 1899)		*		
Phaedyma columella martabana Moore, 1881	*				*Charaxes bernardus hierax* (C. & R. Felder, 1867)		*		
Pantoporia hordonia hordonia (Stoll [1790])	*				*C. durnfordi* Distant, 1884		*		

Checklist of butterflies recorded in Phnom Samkos Wildlife Sanctuary *cont.*

Family/	T		K		Family/	T		K	
Species	l	h	l	h	Species	l	h	l	h
Riodinidae					*N. subperusia* (Snellen, 1896)		*		*
Zemeros flegyas flegyas (Cramer [1780])				*	*Nacaduba kirtoni* Eliot, 1984		*		
Dodona deodata deodata Hewitson, 1876		*		*	*Ionolyce helicon merguiana* (Moore, 1884)		*		
Abisara neophron chelina (Fruhstorfer [1904])		*		*	*Prosotas bhutea bhutea* (de Nicéville [1884])	*			
Taxila haquinus berthae Fruhstorfer [1904]		*		*	*P. nora ardates* (Moore [1875])		*		*
Stiboges nymphidia nymphidia Butler, 1876		*		*	*P. pia marginata* Tite, 1963		*		
Lycaenidae					*Heliophorus epicles* Godart, 1823		*		*
Miletus mallus mallus (Fruhstorfer, 1913)	*			*	*Arhopala agaba* (Hewitson, 1862)		*		
M. chinensis learchus C. & R. Felder [1865]	*				*A. arvina aboe* de Nicéville, 1895				*
Allotinus unicolor rekkia Riley & Godfrey, 1921				*	*A. cleander* (Evans, 1925)	*			
Logania marmorata marmorata Moore, 1884				*	*A. hellenore hellenore* Doherty, 1889		*		
Castalius rosimon rosimon (Fabricius, 1775)			*		*A. perimuta perimuta* (Moore [1858])				*
Discolampa ethion ethion (Westwood [1851])	*				*A. paraganesa zephyretta* (Doherty, 1891)		*		
Caleta roxus roxana (de Nicéville, 1897)	*				*A. paralea* Evans, 1925				*
Everes lacturnus lacturnus (Godart [1824])	*				*Flos apidanus saturata* (Snellen, 1892)		*		
Pithecops corvus correctus Cowan, 1966				*	*F. areste* (Hewitson, 1862)		*		
Neopithecops zalmora zalmora (Butler [1870])				*	*F. diardi diardi* (Hewitson, 1862)	*	*		
Megisba malaya sikkima Moore, 1884	*				*Surendra vivarna amisena* (Hewitson, 1862)	*			
Callenya lenya lenya (Evans, 1932)				*	*S. quercetorum neritos* (Fruhstorfer, 1907)	*			*
Acytolepis puspa gisca (Fruhstorfer, 1910)	*	*			*Iraota timoleon timoleon* (Stoll [1783])		*		
Udara dilecta dilecta (Moore, 1879)	*	*			*Drina donina* (Hewitson [1865])				*
U. placidula howarthi (Cantlie & Norman, 1960)		*		*	*Loxura atymnus continentalis* Fruhstorfer [1912]	*			*
U. albocaerulea albocaerulea (Moore, 1879)				*	*L. cassiopea* Distant, 1884	*			*
Celastrina lavendularis limbata (Moore, 1879)		*			*Yasoda tripunctata* (Hewitson [1863])	*	*		*
Celatoxia marginata marginata (de Nicéville [1884])				*	*Cheritra freja evansi* Cowan, 1965				*
Lestranicus transpectus (Moore, 1879)		*			*Drupadia ravindra boisduvalii* Moore, 1884				*
Zizina otis sangra (Moore [1866])	*				*Horaga syrinx* Felder, 1860	*			
Zizula hylax hylax (Fabricius, 1775)	*				*Pratapa icetoides* (Elwes [1893])		*		
Chilades lajus lajus (Stoll [1780])	*				*Tajuria cippus cippus* (Fabricius, 1798)		*		
Euchrysops cnejus cnejus (Fabricius, 1798)	*				*Eliotia jalindra* (Horsfield [1829])		*		
Catochrysops panormus exiguus (Distant, 1886)	*				*Hypolycaena erylus himavantus* Fruhstorfer [1912]	*			
Leptotes plinius plinius (Fabricius, 1793)	*	*			*H. amasa amasa* Hewitson [1865]	*	*		
Jamides alecto alocina Swinhoe, 1915		*		*	*Deudorix epijarbas amatius* Fruhstorfer, [1912]		*		
J. celeno celeno (Cramer [1775])	*	*	*	*	*Artipe eryx eryx* (Linnaeus, 1771)		*		
J. philatus (Snellen, 1878)				*	*Virachola smilis (*Hewitson, 1863)		*		
Nacaduba kurava euplea Fruhstorfer, 1916	*	*		*	*Rapala duma duma* (Hewitson, 1878)		*		
N. sanaya naevia Toxopeus, 1929		*			*R. manea schistacea* (Moore, 1879)		*		
N. beroe gythion Fruhstorfer, 1916		*			*R. scintilla* de Niceville, 1890		*		
N. calauria (C. Felder, 1860)		*		*	*R. varuna orseis* Hewitson [1863]		*		
N. solta Eliot, 1955		*			*Semanga superba deliciosa* Seitz [1926]		*		

Preliminary reconstruction of Late Quaternary environment at Bat Trang, Southwest Cambodia

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មូលន័យសង្ខេប

សំណាកកម្ទេចកំណែដែលមានអាយុកាលនៅចុងសម័យហូឡូសែន (Late Holocene) ត្រូវបានយកចេញដើម្បីធ្វើការសិក្សាអំពីលម្ហូងរុក្ខជាតិ នៅឃុំបិតត្រាង ខេត្តព្រះសីហនុ ភាគនិរតីនៃប្រទេសកម្ពុជា។ កម្ទេចកំណែនៅតំបន់ធ្វើការសិក្សាស្រាវជ្រាវ បានផ្សំឡើងពីកម្ទេចកំណែទំនាបជំនោរ-លំនាច និងកម្ទេចកំណែទំនាបឆ្នេរ។ ការសិក្សាអំពីលម្ហូងរុក្ខជាតិនៅតំបន់វាលភក់ និងតំបន់ទំនាប ជំនោរ-លំនាចនេះ បានផ្តល់នូវកំណត់ត្រាមួយពីបម្រែបម្រួលបរិស្ថានដែលមានអាយុកាលក្រោយ ៥០០០ ឆ្នាំមុនពេលបច្ចុប្បន្ន។ ការប្រែប្រួលប្រភេទរុក្ខជាតិក្នុងការឆ្លើយតបទៅនឹងការប្រែប្រួលអាកាសធាតុ និងលទ្ធភាពនៃឥទ្ធិពលរបស់មនុស្ស ត្រូវបានស្ថាបនាឡើងវិញតាមរយៈការវិភាគអំពីលម្ហូងរុក្ខជាតិ ហើយយើងបានកំណត់អត្តសញ្ញាណលម្ហូងរុក្ខជាតិជាបីផ្នែក។ ផ្នែកទី ៣ (zone BT-3) (នៅជិតបាតសំណាកកម្ទេចកំណែ) គឺសម្បូរដោយប្រភេទរុក្ខជាតិតំបន់ភ្នំ-តំបន់កូនភ្នំ និងរុក្ខជាតិតេរីដូភីត។ ថ្វីបើតេរីដូភីតមានភាពញឹកញាប់ទាបបំផុតសម្រាប់សំណាកទាំងមូលនៅអំឡុងពេលនោះក៏ដោយ ក៏ផ្នែកនេះបានឆ្លុះបញ្ចាំងពីអាកាសធាតុស្ងួតហើយត្រជាក់ធៀប។ ផ្នែកទី ២ (zone BT-2) តំណាងឲ្យដំណាក់កាលអាកាសធាតុត្រជាក់ ហើយកាន់តែសើម ដែលត្រូវបានបង្ហាញតាមរយៈភាពនៅតែសម្បូរបែបនៃប្រភេទលម្ហូងរុក្ខជាតិតំបន់ភ្នំ-តំបន់កូនភ្នំ និងការកើនឡើងភាគច្រើននៃរុក្ខជាតិតេរីដូភីត។ នៅក្នុងផ្នែកទី១ (zone BT-1) អាកាសធាតុហាក់ដូចជាបានផ្លាស់ប្តូរទៅជាកាន់តែសើម និងកាន់តែក្តៅជាងមុន ដោយត្រូវបានបង្ហាញតាមរយៈការថយចុះយ៉ាងគំហុកនៃប្រភេទរុក្ខជាតិតំបន់ភ្នំ-តំបន់កូនភ្នំ ការកើនឡើងយ៉ាងគំហុកនៃប្រភេទរុក្ខជាតិតំបន់ទំនាប-តំបន់វាលភក់និងបរិមាណដ៏ច្រើនសន្ធឹកនៃប្រភេទរុក្ខជាតិតេរីដូភីត និងប្រភេទរុក្ខជាតិស្មៅ។

Abstract

A sediment core dating from the Late Holocene was extracted for palynological study from Bat Trang Commune, Prey Nub District, Preah Sihanouk Province, Southwest Cambodia. Sediments were composed of tidal flat and coastal plain deposits. The palynological study provided a record of environmental changes over the past 5,000 years. Changes in vegetation in response to climatic fluctuations and possible human impact were reconstructed using pollen analysis, and three pollen zones were identified. Zone BT-3 (near the base of the core) was dominated by submontane/ montane forest and pteridophytes, although the latter were at their lowest frequency for the entire core, reflecting a dry and relatively cool climate. Zone BT-2 represented a cool and wetter period, indicated by the still-dominant submontane/ montane pollen types and an increased abundance of most pteridophyte species. In the most recent zone, BT-1, the climate seems to have become wetter and warmer as suggested by an abrupt decrease of submontane/ montane forest types, a sharp increase in lowland/ peatland types, and the greatest quantity of pteridophytes and grassland species.

Keywords

Monsoon, palaeo-environment, palynology, Quaternary, Southeast Asia, vegetation.

Introduction

The monsoon system is the principal influence on climate and environment in mainland Southeast Asia. Monsoonal climate is characterized by prominent seasonal changes in wind direction, precipitation and temperature between a warm, humid summer and a dry, cooler winter (Yi *et al.*, 2006). Climate records in the Asian monsoon region (e.g. Gupta *et al.*, 2003) reveal considerable variation in monsoon dynamics during the Holocene. The climate in northeastern Cambodia under late Glacial conditions was cooler and drier than today, as estimated from the presence of submontane vegetation and evidence of fire activity (Maxwell, 1999). Between 8.4 and 5.3 kyr before present (BP), the monsoonal regime strengthened and climatic conditions were wetter and probably warmer than present. Subsequent expansion of secondary forests suggests a drier climate. More frequent fire disturbance is associated with increasing seasonality or human influence after *circa* 3.5 kyr BP (Maxwell, 2001). The level of the Tonlé Sap lake increased more than 2.5 m during the early-mid Holocene (Nguyen *et al.*, 2000), and a 2-3 m increase in mean sea level in the mid Holocene caused inland flooding from the Mekong Delta into southern Cambodia (Penny, 2006). A strong presence of the mangrove family Rhizophoraceae, an indicator of high sea level, was noted at Angkor Borei in southern Cambodia during the late Holocene (Bishop *et al.*, 2003).

This paper presents a preliminary pollen record from a coastal site in Cambodia, which is important for understanding environmental changes and vegetation evolution influenced by Holocene summer monsoon fluctuations and/or humans. In the late Holocene, human activities strongly influenced the natural vegetation through deforestation and the expansion of agriculture, and human impact is indicated by increases in Gramineae (including rice pollen) and "disturbance taxa" such as pine trees (genus *Pinus*).

Methods

Study area

A sediment core was recovered from a swampy tidal-flat area in Bat Trang commune, Prey Nub District, Preah Sihanouk Province, Southwest Cambodia (Fig. 1). The core site is located in a basin which is seasonally inundated with brackish water, and has an altitude of *circa* 2 m above sea level (a.s.l.) above a tidal flat inlet (Boeung Thom Angkep). Mean tidal range is *circa* 1 m. There is seasonal flow of water through the basin towards the sea, via a network of channels (Fig. 1).

The core site is characterized by acid lithosols, located on the narrow coastal plain west of the Mesozoic-age Cardamom and Elephant uplands. Hills in the immediate vicinity rise to c. 200 m a.s.l. and are dominated by claystone and sandstone of Jurassic and Cretaceous age (Workman, 1997), with a mantle of red-yellow podzols.

The study area experiences a monsoonal regime. Current mean annual precipitation is 4,046 mm (annual data from the Meteorological Station of Sihanoukville, Cambodia, to 2007), approximately 90% of which falls during the southwesterly monsoon, from May to October (Maxwell, 1999). This monsoon results in heavy rainfall in Cambodia, especially in the coastal areas, central plains and mountain ranges. In contrast, the northeast monsoon (November to April) brings cooler, dry air from areas of high atmospheric pressure to the north (Nieuwolt, 1981, cited in Maxwell, 1999). In addition, tropical cyclones influence the study area, bringing rainfall from the South China Sea, which is to the east and south-east of the study site.

Local flora includes mangrove and estuary marsh vegetation, with bamboo-dominated secondary forest and submontane dry evergreen forest species occupying the surrounding hills. Principal land use is the cultivation of rice; *Cocos nucifera* (coconut) plantations are also present. During the dry season, limited cattle grazing occurs at this site.

Core extraction and analysis

The Bat Trang core was retrieved on 11-12 May 2010, using a gouge auger. Core sections were packed for processing in the Palynological Laboratory, Mahasarakham University, Thailand. To determine the chronology of the core, one basal core sample was sent to Rafter Radiocarbon Laboratory, GNS Science, New Zealand for ^{14}C analysis.

Core samples with fossil palynomorphs were treated chemically and pollen was extracted from the core samples using standard palynological preparation methods (Fægri & Iversen, 1989; Lowe & Walker, 1997), although pollen concentration was not calculated.

Twenty-eight core samples were processed. Pollen determination was made using a light microscope with x1,000 magnification, with reference to standard nomenclature (Hesse *et al.*, 2009). Minimum pollen counts for each sample were 300 pollen and spores, with at least 100 identified tree pollen grains.

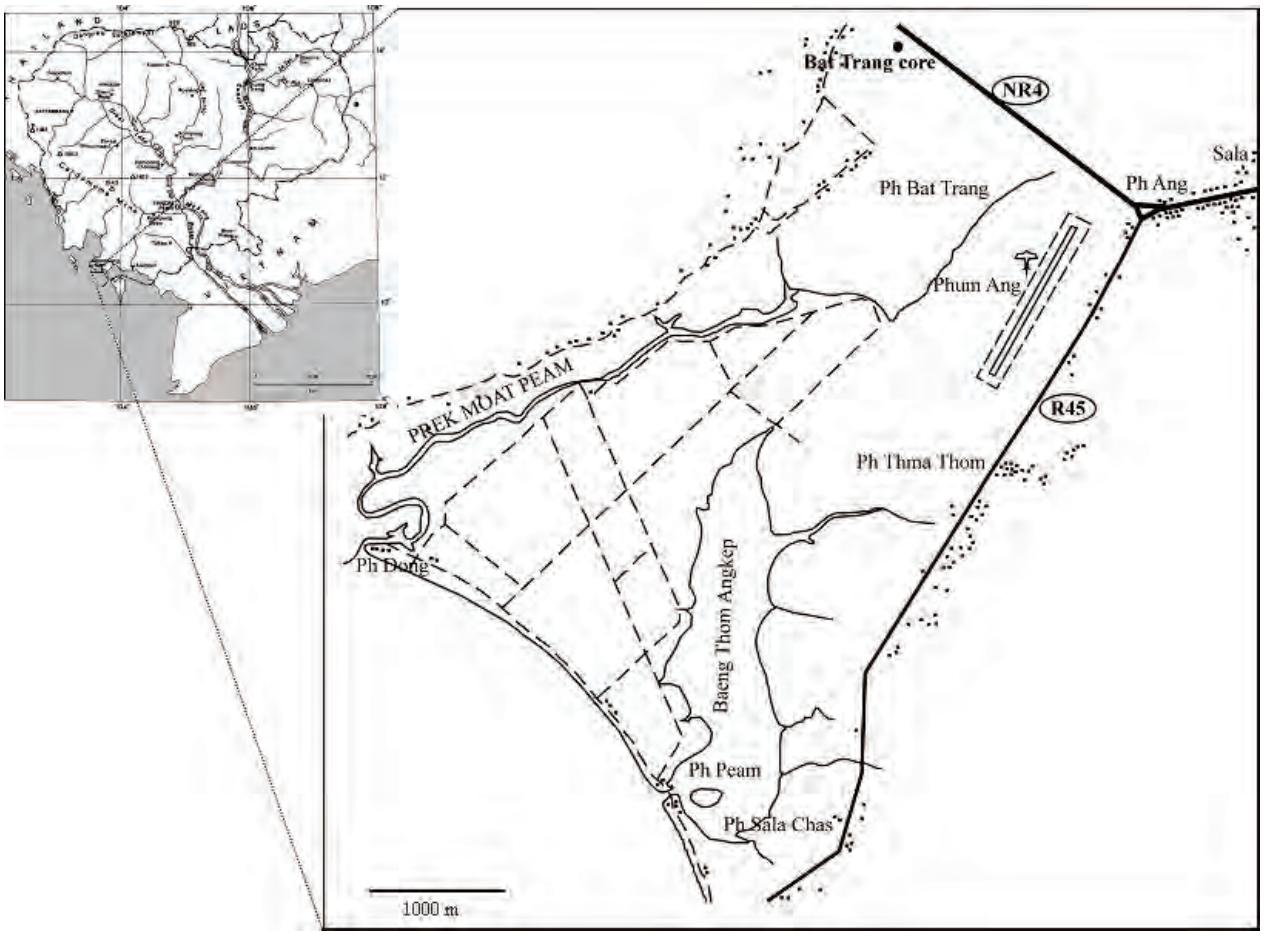

Fig. 1 Location of the study area, with core site.

Results

Stratigraphy and chronology

A core was drilled to a depth of 324 cm, revealing a sequence containing five units: modern soil (0-29 cm), light grey fine sandy-silt (29-83 cm), green-grey silt (83-111 cm), grey clay (111-164 cm) and grey-brown clay containing mollusc shells (164-324 cm). The core material could not be recovered between 139-148 cm depth. The lithological boundaries throughout the core were gradual, and showed no evidence of erosional truncation or non-deposition.

The radiocarbon age of 4,404 ± 25 years was determined for one sample of grey-brown clay from the base of the core (314-324 cm; Table 1). The accelerator mass spectometry (AMS) analysis indicated that the core represents a period spanning approximately the last 5.0 cal. kyr.

Pollen groups

Pollen taxa in the Bat Trang core were grouped into five vegetation groups (*cf.* Yulianto *et al.*, 2004) including mangroves, lowland/ peatland, submontane/ montane, grassland and pteridophytes (Figs 2 and 3).

Mangrove vegetation

This type of vegetation grows on the inundation flood-flat area, in the zone influenced by tidal fluctuations. Mangrove plants identified in the Bat Trang core were *Acanthus* spp., *Avicennia* spp., *Barringtonia acutangula, Excoecaria* spp., *Oncosperma* spp., Rhizophoraceae, and *Sonneratia* sp.

Lowland/ peatland vegetation

Tropical lowland forest is one of the most dense and species-rich forests in the world (Vormisto *et al.*, 2004). It is characterized by a high diversity of life forms and species

Table 1 Radiocarbon age determination (using AMS) for organic-rich material sampled at Bat Trang, Cambodia. Radiocarbon ages were transformed to calibrated calendar age ranges using the CALIB rev. 6.0 programme of Stuiver & Reimer (1993) and the calibration data of Reimer *et al.* (2009).

Sample depth (cm)	Laboratory code	Radiocarbon age (^{14}C yr BP)	δ^{13}C (‰)	δ^{14}C (‰)	Calibrated 2σ age range (cal yr BP)
314 - 324	R32675	4,404 ± 25	-25.1	-426.4 ± 1.7	5,044 - 4,872

in the understory including a range of shrubs, grasses, and herbs. There were numerous lowland forest taxa in the Bat Trang core, including Araceae, Arecaceae, Canthium, Leguminosae and Myrtaceae.

Submontane/ montane forest vegetation

Submontane/ montane forests are dominant in the study area. Bisaccates and monosaccates (Pinaceae and Podocarpaceae) were the most abundant pollen types in the core. Native pine trees still grow in Kirirom National Park, approximately 100 km north of the study area.

Grassland vegetation

Grasses are common in the study site. They commonly grow in open areas and indicate a dry and seasonal climate (Maloney, 1990), or may be associated with rice cultivation or forest disturbance. Gramineae pollen were not distinguished below the family level in this study.

Pteridophytes

Fern pollen types were very common in the palynomorph assemblages in Bat Trang core. Typically, this group of plants occupies humid lowland areas. For example, *Acrostichum* species (Pteridaceae) and *Stenochlaena palustris* are often found among mangrove communities (e.g. Rugmai, 2007), the latter indicative of humid, lowland conditions.

Pollen diagram

Three pollen zones were distinguished, based on conspicuous changes in the pollen stratigraphy (Figs 2 and 3), in the following order from the base (oldest sections) upwards:

Zone BT-3 (238-324 cm)

Zone BT-3 was characterized by a high representation of submontane/ montane vegetation and pteridophytes and a low representation of mangrove taxa. The most common pollen types in this zone were bisaccates, which showed their highest value (41% of pollen) of the entire core. Trilete spores (multiple, unidentified species) gradually decreased upwards through the zone, whereas Gramineae showed a slight increase. Polypodiaceae, monolete spores, Lycopodiaceae, Cyatheaceae, *Oncosperma* spp. and Rhizophoraceae were also present, ranging from *circa* 3-10% of all pollen detected. Other Fagaceae were absent from this zone, whereas *Quercus* species gradually decreased from the bottom to the top of the zone. Musaceae, an indicator of agricultural activity, reached its highest value (albeit only 1.4%) in the core at the top of this zone.

Submontane/ montane forest pollen types reached their peak of 45% in the lower part of the zone. Pteridophytes slightly decreased upwards through the zone, reaching their lowest value of the entire core (23%). Lowland/ peatland and grassland vegetation showed percentages similar to each other, while mangrove forest reached its highest value of 12%.

Zone BT-2 (90-238 cm)

In this zone, the relative abundance of pteridophytes and grassland was slightly higher than in Zone BT-3, whereas submontane/ montane forest pollens were slightly less frequent than in Zone BT-3. Bisaccates abruptly dropped from 39% at the zone base to 22% at the top of the zone. Gramineae fluctuate, but overall rose from about 6% at the base of the zone to about 11% near the top. Trilete spores also displayed an overall increase from 6% at the bottom to about 9% at the top of the zone, whereas other pteridophytes, such as Cyatheaceae, *Davallia* spp., Lycopodiaceae, and monolete spores were present throughout this zone, averaging 5% frequency. Polypodiaceae reached their highest value (13%) at 117 cm depth. Arecaceae and Lauraceae were relatively unchanged, at around 4%. Fagaceae were present at low density, and *Quercus* species decreased from 1% at the bottom to zero at the top of the zone. Rhizophoraceae showed a slight decrease from 4% near the bottom to 1% at the top of the zone, while some mangrove taxa, such as *Barringtonia acutangula, Excoecaria* spp. and *Sonneratia* sp., were absent from the upper part of this zone. Musaceae remained present in this zone, but their frequency was below 1%.

Submontane/ montane and mangrove forest types decreased from about 43% at the bottom to about 31% at the top of the zone and from about 11% near the lower

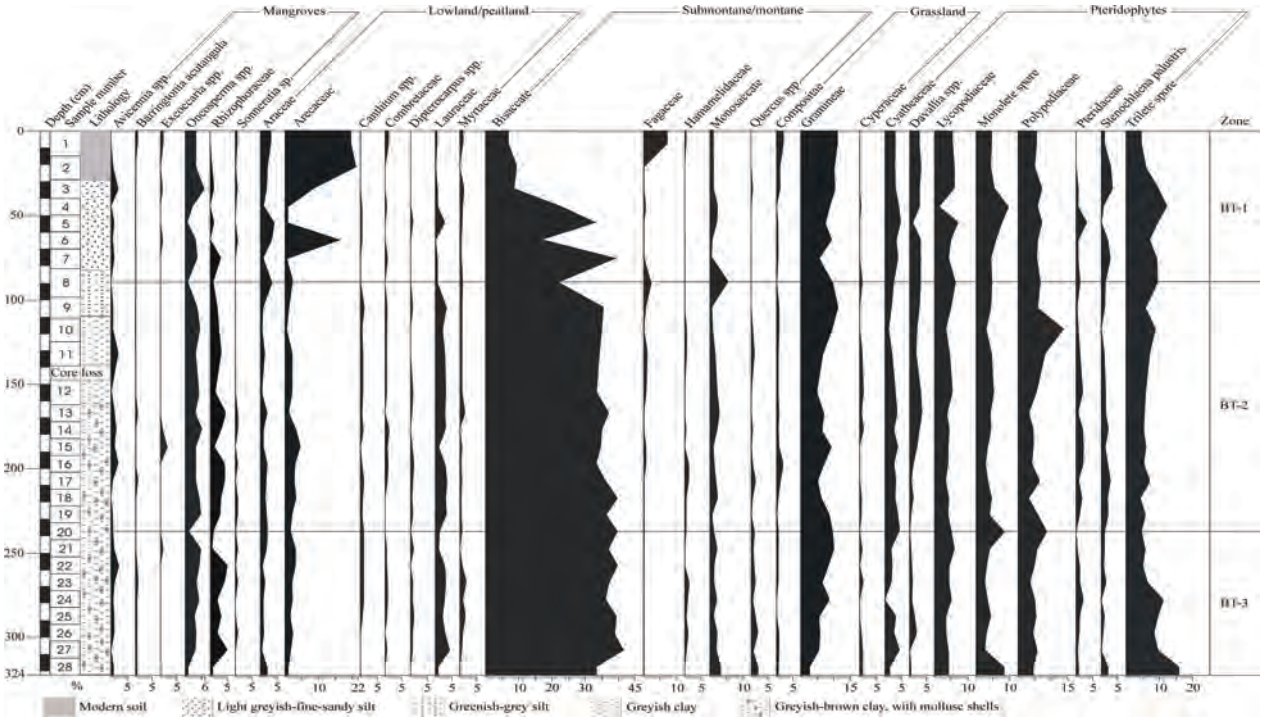

Fig. 2 (above) Selected taxa percentages of the Bat Trang core.

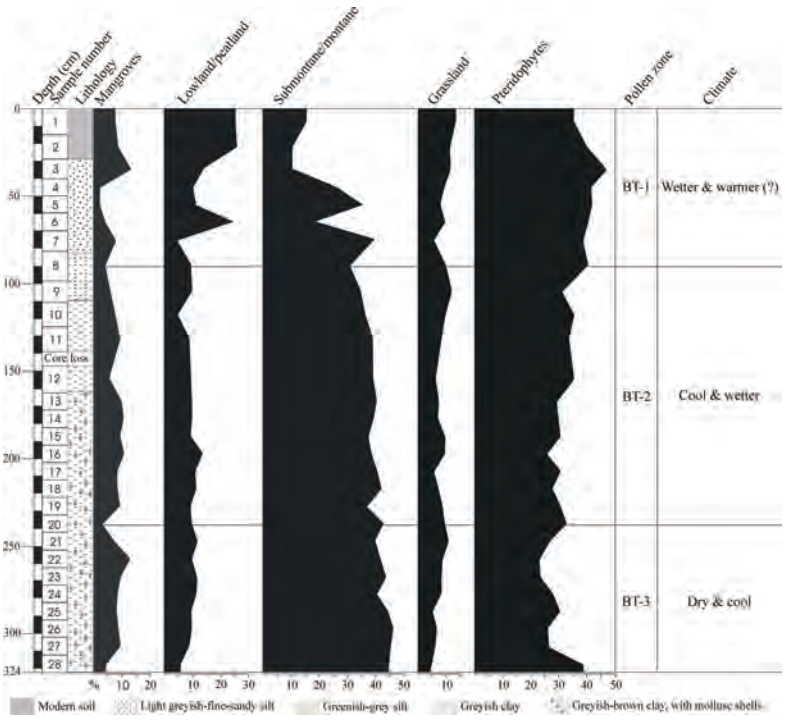

Fig. 3 (right) Grouped taxa percentages of the Bat Trang core.

part of the zone to about 4% at the uppermost part of the zone, respectively. Pteridophytes and grassland vegetation fluctuated, but exhibited slight overall increases from about 32% at the bottom to about 41% at the top of zone, and from 6% near the bottom to about 12% near the uppermost part of the zone. Lowland/ peatland frequency was relatively uniform in this zone.

Zone BT-1 (0-90 cm)

Zone BT-1 was characterized by the lowest representation of submontane/ montane and mangrove vegetation and the highest representation of pteridophytes and lowland/ peatland vegetation. This zone displayed two distinct peaks of bisaccates. Bisaccates abruptly dropped

to their lowest value of 7% at the top of the zone, while Fagaceae reached their highest value of the entire core (7%). Arecaceae were dominant in this zone, with their highest value of 21% (Fig. 2). *Canthium* spp., *Dipterocarpus* spp. and Cyperaceae were barely present. Evidence of pteridophytes, such as monolete and trilete spores, showed increasing frequency, while *Davallia* spp. and *Stenochlaena palustris* decreased in the middle of the zone. Gramineae slightly increased from about 9% to 11%. *Oncosperma* spp. showed their highest value of the entire core with 6% near the middle part of the zone, immediately followed by a dip coinciding with dips in *Davallia* spp. and *Stenochlaena* spp. Rhizophoraceae and Pteridaceae dropped to zero at the uppermost part of zone. Combretaceae, and Myrtaceae were relatively scarce (<1% of pollen). Musaceae practically disappeared in this zone, while Polygonaceae first appeared at 90 cm depth.

Submontane/ montane taxa showed two distinct peaks. This pollen type slightly increased from the bottom of the zone to about 39% at 76 cm depth, and decreased abruptly from 35% at 50 cm depth to their lowest frequency of about 10% at 35 cm depth. Lowland/ peatland forest types showed their lowest value of about 5% at 76 cm depth, and sharply increased from 76 to 65 cm depth, to about 24%. After decreasing, they sharply increased again to about 26%. Pteridophytes reached their highest frequency of 47% at 35 cm depth. Grassland shows a slight increase from about 6% near the lower part of the zone to around 13% at the top of the zone. Mangrove forest shows their lowest frequency of about 2% in 55 cm depth and their highest value (of the entire core) of 13% at 35 cm depth.

In summary, Zone BT-3, in the oldest part of the core, was dominated by submontane/ montane forest and pteridophytes. In Zone BT-2, pteridophytes and grassland taxa showed slight general increases from the bottom to the top of the zone, whereas submontane/ montane taxa declined and mangrove vegetation showed a slight decrease upwards through this zone. In Zone BT-1, submontane/ montane and mangrove forests showed their lowest frequencies, while lowland/ peatland forest, grassland vegetation and pteridophytes reached their peak abundance.

Discussion

Ecological significance of the major pollen taxa

Pollen in the Bat Trang core was dominated by taxa of tropical upland forest (bisaccates of the families Pinaceae and Podocarpaceae). Montane conifer taxa, such as bisaccates and monosaccates, frequently grow at more than 800 m elevation (Zheng & Lei, 1999). The four pine species currently found in Southeast Asia are *Pinus merkusii, P. kesiya, P. dalatensis* and *P. krempfi* (Penny, 2006). *Pinus merkusii* and *P. kesiya* are most common and widespread, with *P. kesiya* generally representing higher elevation flora, while *P. dalatensis* and *P. krempfi*, are restricted to the highlands of southern Vietnam (Richardson & Rundel, 1998). In Cambodia today, only *P. merkusii* is widespread and is most abundant to the west of the Mekong River, in uplands around Tonle Sap lake (Penny, 2006) and the Elephant Mountains, although *P. kesiya* was possibly formerly widespread also (*cf.* Thomas, 2007). In mainland Southeast Asia, *P. merkusii* is considered to be a fire-tolerant plant, which is capable of colonizing exposed, nutrient-poor soils in seasonal environments (Penny, 2006). *Pinus* trees are also known to have been broadly distributed throughout Indochina in the past, under markedly cooler and drier climates when wildfires were common (Penny, 2001). The Bat Trang area lies almost at sea level, but the substantial amount of conifer (bisaccate) pollen in this core (especially zones BT-3 and BT-2) may have formerly come from uplands surrounding the study area.

Environmental and vegetational reconstruction

Given that the lithological boundaries in the Bat Trang core are not abrupt, it is tempting to speculate on the chronology of the core, despite the paucity of radiocarbon age data. Such an approach assumes a constant interpolated sedimentation rate, and that trampling by livestock has had a negligible impact on the integrity of the core. Pending further research, we therefore propose a provisional, tentative chronology, with the Zone BT-3/ BT-2 and Zone BT-2/ BT-1 boundaries approximating to *circa* 3.7 cal. kyr BP and *circa* 1.4 cal. kyr BP, respectively.

The sediments from the core base to 168 cm depth are greyish-brown clay, with mollusc shells and fragments that suggest a marine origin, although no clear differentiation of pollen taxa at this level could be made. Major floristic components of mangroves at Bat Trang are Rhizophoraceae and Acanthaceae (*Avicennia*). Because Rhizophoraceae are sensitive to sea-level fluctuations (Yulianto *et al.*, 2004), their gradual decrease probably reflects the upward growth of the inter-tidal zone to produce a tidal flat environment. The presence of mangrove pollen in the core indicates that the study area was probably formerly inundated by the sea, because mangrove pollen is usually deposited close to its parent plant (Somboon, 1990).

The increase of Gramineae from the core base to 238 cm depth (Zone BT-3) and the accompanying low abun-

dance of lowland/ peatland taxa indicate dry and cool conditions for this interval, as does the heavy representation of *Pinus* (*cf.* Penny, 2006). The variable but overall decrease of pteridophytes in this zone also suggests an increasingly dry climate.

From 238 to 90 cm depth (Zone BT-2), the core indicated a shift to a cool and wetter climate, as shown by the increased abundance of conifer (bisaccate) pollen. The increase of pteridophytes could be evidence of increasing precipitation (Van der Kaars, 1998), although other factors may be responsible for this trend. However, a slight overall increase in pteridophytes (Fig. 3) lends some support to this view, suggesting a greater abundance of ferns in moist forest conditions. The frequency of Gramineae in the core fluctuated around 5-10% from 238 to 90 cm depth, suggesting the presence of a more open, grassland vegetation at that time, although the upward increase is marginal.

From 90 cm depth to the surface (Zone BT-1), the pollen analysis shows possible evidence for the climate becoming wetter and warmer. The continued increase in pteridophyte frequencies lends support to the view that the climate became wetter during that period, and the sharp decrease in submontane/ montane forest taxa from 90 cm depth to the top of the core could represent a warming trend. However, it is possible that these trends may alternatively be explained by human interference with groundwater conditions, surface runoff and forest cover. Indeed, the continued, slight overall increase of Gramineae values in this zone possibly corresponds with forest clearance for agricultural cultivation (*cf.* Wang *et al.*, 1997; Li *et al.*, 2006; Yi *et al.*, 2006). Further research is required before these preliminary conclusions can be regarded with confidence.

Mid-late Holocene cooling at Bat Trang

Contrary to the traditional view of a stable Holocene climate (e.g. Dansgaard *et al.*, 1993), many studies have shown notable regional climatic fluctuations between warm and cool or wet and dry conditions during the past 10,000 years (e.g. Sun & Chen, 1991; Overpeck *et al.*, 1996; Bond *et al.*, 1997; Oppo, 1997; de Menocal *et al.*, 2000; de Menocal, 2001; Maxwell, 2001).

There is widespread evidence for an event at *circa* 5.0-4.5 cal. kyr BP throughout the Asian monsoon region (e.g. Morrill *et al.*, 2003; Li *et al.*, 2006; Yi *et al.*, 2006), when the climate became cooler and/or drier, associated with weakened southwest monsoon strength and an abrupt cooling event in the North Atlantic. A mid-Holocene shift to a more seasonal and seasonally drier climate has been identified in Northeast Cambodia (Maxwell, 2001, 2004) and the Tonlé Sap lake (Penny, 2006), which has been attributed to declining southwest monsoon strength. While this cooling event cannot be confirmed by the present data from Bat Trang, the period represented by the base of the core (dated to *circa* 5.0 cal. kyr) appears to have been the coolest period described in this study, as indicated by the high percentage of taxa that are currently found only at high elevations.

Conclusions

The data presented here demonstrate changes in vegetation, climate, and land use at Bat Trang, Southwest Cambodia during the past 5.0 cal. kyr.

The climate corresponding with Zone BT-3 was dry and relatively cool, as indicated by the high abundance of conifer forest types, relatively low percentages of pteridophytes, and overall increasing Gramineae. Cooling continued into Zone BT-2, but was accompanied by more humid conditions. In this period, the climate remained relatively cool and became wetter, as demonstrated by the still-dominant conifer taxa and a significant increase of pteridophytes. The final change, recorded in Zone BT-1, was an apparent shift to the present wetter and warmer conditions, suggested by the highest abundance of pteridophytes and grassland vegetation, a sharp increase in lowland/ peatland vegetation, and an abrupt decrease in submontane/ montane vegetation. Finally, this study provides modest evidence for Late Holocene human influence on the local natural vegetation, for example through possible expansion of agricultural cultivation plots and deforestation.

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We would like to thank ASEA-UNINET Thailand On-Place Scholarship Program for Se Bunleng. We also thank Hong Seang Aun, Keo Sothea, Ou Sothy, Phin Sony and Se Sokhen for assistance with fieldwork, and Alastair Curry for checking the English language of the text. The paper benefitted considerably from constructive comments by Andrew Maxwell and Paul Bishop.

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Recent Master's Theses

This section presents the abstracts of research theses produced by Royal University of Phnom Penh graduates awarded the degree of Masters of Science in Biodiversity Conservation. The abstracts have been slightly edited for English.

A baseline butterfly survey of Kbal Spean, Phnom Kulen National Park: a comparison of species diversity and relative abundance between forest and non-forest habitats

Chantha Nasak

Rapid changes in Lepidoptera abundance, relative to other groups, following environmental change have encouraged their frequent use as biological indicators of ecosystem health. Baseline butterfly surveys provide an understanding of local species diversity and abundance and establish a basis for longer term monitoring of the effects of land use changes on invertebrate populations.

A baseline butterfly survey was conducted in Phnom Kulen National Park of Siem Reap Province during the 2011 dry season. The goal of my study was to compare species diversity and relative abundance of butterflies in two different habitats: forest and non-forest. Four 300-m long transects were sampled in each habitat for 30 days from February to April. Numbers of species and individuals were recorded and indices of species richness, evenness and diversity were calculated and compared using statistical tests.

A total of 187 butterfly species representing 9 families (Papilionidae, Pieridae, Danaidae, Satyridae, Amathusiidae, Nymphalidae, Lycaenidae, Libytheidae and Hesperiidae) were recorded, including what appear to be a large number of new country records. My analysis suggests that: (i) butterfly species richness is notably higher in forest habitats (153 species) than non-forest habitats (78 species); (ii) butterfly abundance is also higher in forest habitat (1,207 individuals) relative to non-forest habitat (433 individuals); and (iii) these differences are statistically significant.

A variety of factors likely affect the abundance and species richness of butterflies at Phnom Kulen, including geographical location, vegetation structure, disturbance levels and microclimate variations. Butterfly species diversity can be used to improve understanding of the biodiversity of ecosystems as a whole, and in turn strengthen policies for forest conservation. There is, however, a need for longer term research on composition and biology of butterfly species at Phnom Kulen National Park.

A systematic review of the horseshoe bat fauna (Rhinolophidae) of Cambodia

Chheang Sarak

Previous studies of bats in Cambodia have confirmed the occurrence of 53 bat species in the country, of which eight are horseshoe bats (Rhinolophidae, genus *Rhinolophus*). The goal of my study was to undertake a systematic review of these bats to: (i) create an identification key and detailed accounts for each species; (ii) determine diagnostic characters for their identification; and (iii) evaluate the extent of sexual dimorphism in each species.

To achieve these aims, I undertook a literature review and examined specimen material held at the Centre for Biodiversity Conservation. In addition to taking a series of external and craniodental measurements from every specimen, I examined qualitative characters including pelage colouration, noseleaf structure and variations in nasal swellings and other cranial characters. Biometric data was compiled and differences between and within species were tested for statistical significance.

Including one new record for Cambodia (*R. yunanensis*), my results bring the number of rhinolophids known for the country to nine, the other eight being *R. acuminatus, R. affinis, R. chaseni, R. luctus, R. malayanus, R. microglobosus, R. pusillus* and *R. shameli*. Detailed accounts and an identification key are provided for all of these species. Of the six species evaluated for sexual dimorphism, evidence for this was found in four species (*R. acuminatus, R. chaseni, R. malayanus* and *R. shameli*), but not in two (*R. microglobosus* and *R. pusillus*). Morphological comparisons of two often confused species (*R. malayanus* and *R.*

microglobosus) suggest that significant differences exist in many quantitative characters.

The "global taxonomic impediment" is acknowledged as having a major impact on our ability to conserve, use and share the benefits of biological diversity sustainably. In providing species accounts and keys for identification of rhinolophid bats in Cambodia, my study will assist future research on this diverse and threatened group.

A comparison of bird communities in disturbed and pristine forest in Phnom Samkos Wildlife Sanctuary, Southwest Cambodia

Chhin Sophea

Little is known about the effects of increased human activities on the Cambodian avifauna and the extent and rate of possible declines in bird species. My study aimed to compare the biodiversity value of a pristine forest with that of a previously disturbed forest, to guide the development of conservation priorities for these sites. As selective logging frequently targets forest areas containing large high-value timber species, my hypothesis was that these areas, although disturbed, may nonetheless represent crucial biodiversity sites.

The study was undertaken in Phnom Samkos Wildlife Sanctuary from February to April 2011. Point counts and mist nets were used to census birds at two representative sites, and sampling methods and effort were standardized to ensure valid comparisons. A total of 1,437 individuals of 100 bird species, representing 33 families, were recorded during the study. Numbers of birds detected in point counts were significantly higher than those captured in mist nets, although differences in the numbers of species recorded were not significant. While this suggests that point counts are more effective in bird censuses, both methods should be employed in studies where inventory completeness is important.

My results indicate that disturbed forest had significantly higher bird species richness, abundance and diversity than pristine forest, although differences in estimated species richness were not significant. Thirty-one species, including threatened hornbill and partridge species, were recorded in both habitats, but had higher abundance in pristine forest. For instance, the chestnut-headed partridge *Arborophila cambodiana* (endemic to the uplands of Southwest Cambodia and Southeast Thailand) was more abundant in pristine forest, suggesting the species is intolerant of disturbance. I suggest that most of the bird species occurring at higher abundance in disturbed forest may be due to the presence of larger trees or higher diversity of tree species providing food sources.

Comparison of invertebrate community structure on the rocky shores of two islands off the coast of Cambodia

Ke Socheata

Knowledge of rocky intertidal invertebrate communities and how environmental perturbations affect them is vital for informed decision making and sustainable coast management, particularly in conservation areas. My study investigated the effect of marine protected areas on the vertical distribution and structure of these communities on the Koh Bong (protected) and Koh Smach (non-protected) islands of Cambodia.

Intertidal areas on each island were split into three zones (low, middle and high) and sampling of these was undertaken once a month at low tide from March to June 2011. Seawater chemistry was also analysed. The vertical distribution and structure of intertidal invertebrates inhabiting the two islands was compared in terms of species richness, diversity, evenness, abundance and composition. Comparisons were made at three levels: (i) between the two islands overall; (ii) pair-wise comparisons of the three intertidal zones between islands; and (iii) comparisons of the three intertidal zones combining data from each island.

No significant difference was found in average species richness or diversity of the invertebrate communities inhabiting the two islands, although mean species abundance was significantly higher on Koh Bong. Some differences were detected in species composition between the islands, but not in the properties of the seawater surrounding them and no positive correlation was apparent between the two.

Further research on the influence of surrounding environments on intertidal invertebrates is needed, particularly in marine conservation areas. Management practices to mitigate potential pollution threats should also be considered.

Population estimation and habitat selection of Oldham's leaf turtle *Cyclemys oldhamii* at the Kbal Spean River, Phnom Kulen National Park

Kim Chamnan

In 2010, the discovery of a previously unknown breeding population of *Cyclemys* turtles was announced at Phnom Kulen National Park. They was putatively identified as *C. aff. atripons*. The aim of my study was to further investigate the occurrence of *Cyclemys* turtles within the national park and provide information on their population size and habitat preferences.

To this end, three stretches - lowland, rocky, and sandy - of the Kbal Spean River within the national park were sampled from February to April 2011. To assess the abundance of *Cyclemys* turtles, 46 mesh traps were placed in pools 60-100m apart within the three stretches. Sampling consisted of two 10-night sessions and every trap was baited in the same way with chicken, fermented fish paste, papaya, coconut and banana. Peterson's mark-recapture model was used to estimate population size.

Over the course of sampling, 40 *Cyclemys* turtles were captured. All were identified as *C. oldhamii* based on the colouration of juvenile and adult turtles. *Cyclemys atripons* was not recorded, but as more than half of turtles captured were hatchlings (which cannot be reliably identified), genetic analysis will be required to determine whether one or two *Cyclemys* species occur in the Kbal Spean River.

Capture rates were significantly higher in the rocky stretch than in other river stretches. This is believed to be due to the rocky section providing more suitable habitats for the reproduction and survival of *Cyclemys* turtles. No turtles were found in the lowland stretch of the river. Mark-recapture analysis suggests that the *C. oldhamii* population in the sampled stretches consists of 45 individuals. This information will assist future efforts to conserve the species at Phnom Kulen National Park.

Comparison of the rotifer fauna of lakes and reservoirs in the upper part of Cambodian Mekong River Basin

Sor Ratha

Despite the importance of rotifers in freshwater ecosystems and their dominance in zooplankton lake communities, the group is little studied in Southeast Asia. As rotifers have potential as bio-indicators - for example in assessing the impact of creating reservoirs in large dam projects - increased knowledge could be beneficial for wider scientific research.

The aim of my study was to compare the rotifer fauna of lakes and reservoirs in Northeast Cambodia and assess whether seasonal variation occurs. Forty water samples were collected from 10 sampling sites in lakes and reservoirs in the Kratie, Stung Treng and Ratanakiri Provinces using a 30 micrometer mesh plankton net. Twenty of the samples were collected in the late dry season (April 2010) and the remainder from the same localities in the late wet season (November 2010).

A total of 107 rotifer species belonging to 33 genera and 18 families were recorded, including two genera and 25 species representing new country records for Cambodia. Eight taxa were not identifiable to species. The most diverse family was Lecanidae (found in 25% of localities), followed by Brachionidae (15%), Trichocercidae (13%) and Colurellidae (12%). The most common species were *Trichocerca similis, Anuraeopsis fissa, Hexarthra cf. intermedia, Lecane bulla* and *L. hamata*.

Rotifer communities were compared in terms of species richness, diversity, density and overall composition. No significant difference was detected in the rotifer fauna of lakes and reservoirs using these measures, nor was any significant difference found between the dry and wet seasons. Further studies are warranted to confirm this finding, however, and especially to determine the influence of different environmental factors upon rotifer communities in 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. The lead authors may be willing to provide free reprints or electronic copies on request and their email addresses, where known, are included in the summaries below.

Documents that use the Digital Object Identifier (DOI) System can be opened via the website http://dx.doi.org (enter the full DOI code in the text box provided, and then click Go to find the document).

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New species and taxonomic reviews

Chaicharoen, R., La-orsri S. & Hołyńska, M. (2011) A review of the genus *Thermocyclops* (Crustacea: Copepoda: Cyclopoida) in Cambodia. *Zoological Studies,* **50,** 780-803.

Through surveys in seven provinces, the following miniature crustaceans were confirmed: *Thermocyclops crassus, T. decipiens, T. maheensis, T. rylovi, T. vermifer* and *T. wolterecki*. All but the first are new records for Cambodia. This paper provides an identification key to the six species. Author: mariahol@miiz.waw.pl; Online: http://zoolstud.sinica.edu.tw/Journals/50.6/780.pdf

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.

Two bat species, both new to science, are described from East and Northeast Cambodia: *Murina cineracea* Csorba & Furey, 2011, and *M. walstoni* Furey, Csorba & Son, 2011. Author: csorba@nhmus.hu

Day, L. (2011) Odonata seen at Tatai, Koh Kong Province, Cambodia. *IDF-Report (Newsletter of the International Dragonfly Fund),* **42,** 7-10.

In March 2011, 32 species of dragonflies and damselflies were recorded near the Tatai River in the Cardamom Mountains, Southwest Cambodia. They included two new national records: *Heliaeschna crassa* and *Orchithemis pulcherrima*. Author: samuibutterflies@gmail.com

Evans, T. & Goes, F. (2011) *Cambodia Recent Bird Reports.* Http://www.samveasna.org/report [accessed 15 December 2011].

A continuing series of reports compiling bird counts and unusual records throughout Cambodia. The May-July 2011 issue, for example, contains the country's first record of the collared babbler *Gampsorhynchus torquatus*. Author: tevans@wcs.org

Grismer, L.L., Grismer, J.L, Wood, P.L., Ngo V.T., Neang T. & Chan, K.O. (2011) Herpetology on the fringes of the Sunda Shelf: a discussion of discovery, taxonomy and biogeography. In *Tropical Vertebrates in a Changing World* (ed. K.-L. Schuchmann), pp. 57-97. Bonner Zoologische Monographien no. 57. Forschungs Museum Koenig, Bonn, Germany.

Includes a checklist of reptiles and amphibians from "the Cardamom Region", broadly defined here as comprising the Cardamom Mountains, Elephant Mountains and adjoining coastal areas in southern Cambodia and Vietnam's island of Phu Quoc. This chapter includes the first record of the lizard *Hemiphyllodactylus typus* in Cambodia (Botum Sakor National Park). Author: lgrismer@lasierra.edu

Heatubun, C.D. (2011) Seven new species of *Areca* (Arecaceae). *Phytotaxa*, **28,** 6-26.

The palm *Areca riparia* is described as a new species, endemic to Cambodia. The holotype was collected by the Tatai Chveng waterfall, Koh Kong Province. Author: charlie_deheatboen@yahoo.com

Hwang, I.C., Moon, M.-O., Kim, C.H., Keth N., Chhang P. & Sun, B.-Y. (2011) A checklist of the ferns of Cambodia. *Paper presented to the 43rd Annual Meeting of the Korean Society of Plant Taxonomists, 23-24 August 2011, Ewha Women's University, Seoul, South Korea.*

In 2009 and 2010, 137 fern taxa were collected, including 75 new records for Cambodia. This work has raised the national checklist to 219 taxa, including 80 genera and 34 families. Voucher specimens of all species observed were deposited in the Herbarium of Chonbuk National University and National Institute Biological Resources, South Korea. Author: sunby@chonbuk.ac.kr; Online (abstract only): http://www.pltaxa.or.kr/board.html?table=scholarship&mode=read&idx=21&page=2&category=total

Jałoszyński, P. (2011) New species and new records of *Syndicus* Motschulsky (Coleoptera, Staphylinidae, Scydmaeninae). *Zootaxa,* **2991,** 21-28.

A new beetle, *Syndicus kampucheanus* sp. nov., is described from Mondulkiri Province. This paper also reports on the first national record of *S. paeninsularis bilobatus*, also in Mondulkiri. These are the first members of the Scydmaeninae to have been recorded in Cambodia. Author: scydmaenus@yahoo.com

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

This illustrated report on the author's survey in Southwest Cambodia adds a further 15 dragonflies and damselflies to the national checklist, raising the total to 106 species. The confirmed new records are: *Aristocypha fenestrella*, *Rhinagrion viridatum*, *Lestes elatus, L. platystylus, Aciagrion tillyardi, Agriocnemis f. femina, Archibasis viola, Ceriagrion calamineum, Mortonagrion aborense, M. falcatum, Pseudagrion microcephalum, Paragomphus capricornis, Hemicordulia* sp. nov., *Macrodiplax cora* and *Nannophya pygmaea*. Author: kosterin@bionet.nsc.ru; Online: http://dragonflyfund.org/mediapool/88/888478/data/IDF_Report_40_Kosterin_2011_small.pdf

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

Between 2006 and 2011, 22 species of dragonflies and damselflies were photographed in Southwest Cambodia. Two species, *Agriocnemis lacteola* and *Coeliccia yamasakii* are new national records. Author: kosterin@bionet.nsc.ru; Online: http://pisum.bionet.nsc.ru/kosterin/pdf/kosterin_holden.pdf

Lim, J. & Lee, S. (2011) A new species of *Prorops* Waterston 1923 (Hymenoptera: Bethylidae) from Cambodia with a key to world species. *Zootaxa,* **3040,** 25-28.

A new wasp, *Prorops mandibularis* Lim sp. nov., is described from O'Som Commune, Veal Veng District, in the Central Cardamoms Protected Forest. Author: seung@snu.ac.kr

Masuyama, S. & Watano, Y. (2010) Cryptic species in the fern *Ceratopteris thalictroides* (L.) Brongn. (Parkeriaceae): IV. taxonomic revision. *Acta Phytotaxonomica et Geobotanica*, **61,** 75-86.

This review includes the description of a new fern, *Ceratopteris oblongiloba* Masuyama & Watano, which appears to be widely distributed throughout Southeast Asia, including Cambodia and Thailand. Author: masu@lab.twcu.ac.jp

Mootnick, A.R. & Fan P.-F. (2011) A comparative study of crested gibbons (*Nomascus*). *American Journal of Primatology,* **73,** 135-154.

This paper provides photographs, detailed descriptions of external characteristics and distribution ranges of gibbons in the genus *Nomascus,* with the aim of assisting in their identification. Author: alan@gibboncenter.org; Online: http://birdlifeindochina.org/sites/default/files/A_Comparative_Study_Crested_Gibbons_Babbler38.pdf [*This paper describes six species in detail, and highlights the crested gibbons in Northeast Cambodia as potentially belonging to a new taxon. The latter have in fact been named as a new species,* Nomascus annamensis *Van, Mootnick, Vu, Nadler & Roos 2010 - Ed.*].

Nguyen V.D., Regalado, J.C. & Chinh V.T. (2010) A new species of *Alocasia* (Araceae-Colocasieae). *Gardens' Bulletin Singapore*, **62,** 121-126.

A new species of arum, *Alocasia jiewhoei* V.D. Nguyen, is described from Phnom Kulen National Park, Siem Reap Province, Cambodia. The holotype was found at 150 m above sea level. Author: vandu@iebr.vast.ac.vn

Ou C., Montaña, C.G., Winemiller, K.O. & Conway, K.W. (2011) *Schistura diminuta*, a new miniature loach from the Mekong River drainage of Cambodia (Teleostei: Nemacheilidae). *Ichthyological Exploration of Freshwaters,* **22,** 193-200.

A new fish is described from the lower Sekong River. This is only the third species of the genus *Schistura* to have been reported in the Cambodian Mekong, and additional species may be discovered. Author: kevin.conway@tamu.edu; Online: http://www.pfeil-verlag.de/04biol/pdf/ief22_3_01.pdf

Thompson, C. (2011) *Wild Mekong: New Species in 2010 From the Forests, Wetlands and Waters of the Greater Mekong, Asia's Land of Rivers.* WWF Greater Mekong, Hanoi, Vietnam.

This report summarises 208 species new to science that were described in the Greater Mekong Region in 2010. The list includes seven new species from Cambodia: four plants and three reptiles. Author: christian-thompson@hotmail.co.uk; Online: http://assets.wwf.org.uk/downloads/greater_mekong_species_report_web_ready_version_nov_14_2011_1.pdf [*Unfortunately this report contains some important errors and omissions. For example, the total figure for Cambodia erroneously includes the lizard* Cnemaspis niyomwanae*, which is currently known only from southern Thailand, but fails to include the new mammal* Crocidura phanluangi*, which was confirmed in Cambodia as well as Vietnam in 2010 (see the* Cambodian Journal of Natural History*, vol. 2010, issue 1, p. 66). Furthermore, the report counts only higher plants and vertebrate animals, and omits the many invertebrate animals and other life forms described in Cambodia and neighbouring countries during 2010 - Ed.*].

Biodiversity inventories

Gaylarde, C.C., Rodrıguez, C.H., Navarro-Noya, Y.E. & Ortega-Morales, B.O. (2011) Microbial biofilms on the sandstone monuments of the Angkor Wat Complex, Cambodia. *Current Microbiology,* **60,** 105-115.

Biofilms from the temples Angkor Wat, Preah Khan, and the Bayon and West Prasat in Angkor Thom contain a microbial community dominated by coccoid cyanobacteria. Genetic analyses were used to identify the taxa. These microbial biofilms are highly resistant to dehydration and irradiation, and could cause the sandstone to deteriorate over time. Author: cgaylarde@googlemail.com; Online: http://www.springerlink.com/content/w0n078h75253633m/fulltext.pdf

Ohtaka, A., Narita, T., Kamiya, T., Katakura, H., Araki, Y., Im S., Chhay R. & Tsukawaki, S. (2011) Composition of aquatic invertebrates associated with macrophytes in Lake Tonle Sap, Cambodia. *Limnology*, **12,** 137-144.

Aquatic invertebrates that live on submerged plants are an important prey for fish and other higher predators. Invertebrate communities were studied in different parts of the Tonle Sap Lake, with particular attention to the root systems of the freefloating, alien water hyacinth *Eichhornia crassipes*. Nine invertebrate phyla were collected, of which oligochaetes, shrimps, *Limnoperna* mussels and meiobenthic crustaceans were the most abundant. The Tonle Sap might be unique in its abundance of sessile animals, such as sponges, bryozoans and mussels, in its macrophyte-associated fauna. Water movement controls the dispersal of larvae and is an important factor determining the distribution and abundance of the sessile animals. Author: ohtaka@cc.hirosaki-u.ac.jp

Ulziijargal, B., Ju, Y.-D., Oi, M.-J., Le, X.-V., Thuch P., Park, J.K. & Bae, Y.-S. (2011) Faunal notes of family Arctiidae (Insecta, Lepidoptera) from Cambodia. *Entomological Research,* **41,** 278. Article first published online 17 November 2011, doi: 10.1111/j.1748-5967.2011.00374.x

A moth survey in the Seima Protection Forest and the central and northern Cardamom Mountains found 183 species belonging to 13 families of Lepidoptera, including 70 species of tiger moths (family Arctiidae). Author: baeys@incheon.ac.kr

Species ecology and status

Antoine, P.-O. (2011) Pleistocene and Holocene rhinocerotids (Mammalia, Perissodactyla) from the Indochinese Peninsula. *Comptes Rendus Palevol,* doi:10.1016/j.crpv.2011.03.002

Drawing on palaeontological and archaeological literature, this paper explores the historical distribution ranges of rhinoceroses in Indochina and adjoining regions. Only one species has been confirmed in Cambodia, the Javan rhino *Rhinoceros sondaicus*, with fossil evidence of this species in Phnom Loang dating back to the Middle Pleistocene. During the Holocene, the Javan rhino is inferred to have been fairly abundant and widespread. Author: pierre-olivier.antoine@univ-montp2.fr; Online (pre-press version): http://www.rhinoresourcecenter.com/pdf_files/131/1313209161.pdf

Blasdell, K., Cosson, J.F., Chaval, Y., Herbreteau, V., Bounneuang D., Jittapalapong, S., Lundqvist, A., Hugot, J.-P., Morand, S. & Buchy, P. (2011) Rodent-borne hantaviruses in Cambodia, Lao PDR, and Thailand. *EcoHealth.* Article first published online 29 November 2011, doi: 10.1007/s10393-011-0725-7.

Paper not seen. Author: pbuchy@pasteur-kh.org

Chu, D.K.W., Leung, C.Y.H., Gilbert, M., Joyner, P.H., Ng, E.M., Tse, T.M., Guan, Y., Peiris, J.S.M. & Poon, L.L.M. (2011) Avian coronavirus in wild aquatic birds. *Journal of Virology*, **85,** 12815-12820.

A high prevalence of novel avian coronaviruses was detected in aquatic wild birds in Cambodia and Hong Kong. Gammacoronaviruses were largely found in ducks and other Anseriformes, whereas deltacoronaviruses were detected in Ciconiiformes, Pelecaniformes and Anseriformes. There was evidence of frequent transmissions of gammacoronaviruses between duck species, but it is possible that these coronaviruses do not cause severe illness to their avian hosts Author: malik@hkucc.hku.hk; Online (advance version): http://jvi.asm.org/content/early/2011/09/28/JVI.05838-11.full.pdf+html

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.

During a wet season survey, five species of primates were observed and their abundance measured: Bengal slow loris *Nycticebus bengalensis*, Indochinese silvered langur *Trachypithecus germaini,* pileated gibbon *Hylobates pileatus*, pig-tailed macaque *Macaca leonina* and long-tailed macaque *M. fascicularis.* The authors conclude that Phnom Samkos Wildlife Sanctuary should be a priority site for primate conservation in Cambodia. Author: camillecoudrat@gmail.com; Online: http://nocturama.org/wp-content/uploads/2011/08/2011CoudratNekaris-et-al-CambodiaPrimateSurveys.pdf

Duong V., Mai T.T.X., Blasdell, K., Lo L.V., Morvan, C., Lay S., Anukool, W., Wongprompitak, P., Suputtamongkol, Y., Laurent, D., Richner, B., Chheang R., Chien B.T., Frutos, R. & Buchy, P. (2011) Molecular epidemiology of *Orientia tsutsugamushi* in Cambodia and Central Vietnam reveals a broad region-wide genetic diversity. *Infection, Genetics and Evolution*. Article first published online 15 January 2011.

Scrub typhus is an infectious zoonotic disease caused by an obligate intracellular bacterium *Orientia tsutsugamushi* following the bite of infected trombiculid mites of the genus *Leptotrombidium.* This study found high genetic diversity in *O. tsutsugamushi* in Cambodia and in Central Vietnam, which could have implications for diagnosis and vaccine development. Author: dveasna@pasteur-kh.org

Eames, J.C. (2011) Satellite tagged black-faced spoonbill in Cambodia and southern Vietnam. *The Babbler (Newsletter of BirdLife International in Indochina)*, **37,** 7.

An Endangered black-faced spoonbill *Platalea minor* carrying a satellite transmitter was recorded among other black-faced spoonbills in Boeung Prek Lapouv Sarus Crane Reserve in February and March 2011. It had received the transmitter while on Guji do islet, South Korea in 2010. Satellite data indicate it flew frequently between Vietnam and Cambodia's Takeo Province. Online: http://www.birdlifeindochina.org/sites/default/files/Babbler37_final.pdf

Eames, J.C. (2011) Kampong Trach: new threats and developments. *The Babbler (Newsletter of BirdLife International in Indochina)*, **37,** 17.

An account of recent changes that could be harmful to sarus cranes and other native species in the Kampong Trach Sarus Crane Reserve, including a new building, domestic dogs and exotic trees. Online: http://www.birdlifeindochina.org/sites/default/files/Babbler37_final.pdf

Eames, J.C. (2011) Boeung Prek Lapouv Sarus Crane Reserve: a new dry grassland? *The Babbler (Newsletter of BirdLife International in Indochina)*, **37,** 19.

This wetland appears to be becoming drier over the years, possibly due to irrigation by farmers outside of the reserve. This in turn is reducing the length of time that sarus cranes can spend in the reserve during the dry season. Online: http://www.birdlifeindochina.org/sites/default/files/Babbler37_final.pdf

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

Camera trapping surveys in this wildlife sanctuary in Mondulkiri province produced images of 23 mammal species, including eight globally threatened species. Encounter rates were lower within one day's walk of villages and evidence was obtained of some mammals switching from diurnal to nocturnal activity, which could be a response to human disturbance and hunting. Author: tomnegray@hotmail.com; Online: http://rmbr.nus.edu.sg/rbz/biblio/592/59rbz311-318.pdf

Gray, T.N.E., Phan C. Pin, C. & Prum S. (2011) *Establishing Baseline Ungulate Densities in Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary*. WWF Greater Mekong, Phnom Penh, Cambodia.

Using 110 line transects, the authors calculated the protected areas to support the following densities of large mammals: banteng 1.1/km^2, red muntjac 2.2/km^2 and wild pigs 1.4/ km^2. The estimated total population of between 2,700 and 5,700 banteng in the two areas is a major proportion of the global population. However, the scarcity of large deer and tigers is a concern. Author: tomnegray@hotmail.com; Online: assets.panda.org/down loads/gray_et_al_monitoring_ungulates_epl_final.pdf

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

A camera trapping survey of *Panthera pardus* in Mondulkiri Protected Forest produced density estimates of approximately 3.9 individuals per km^2. Alternative methods of calculation were compared and most were found to give similar results. Capture probabilities differed between male and female leopards, probably resulting from differences in their use of human-made trails. Author: tomnegray@hotmail.com

Gutiérrez, R.A. & Buchy, P. (2011) The merit release birds: Buddhist ritual and implications in the H5N1 virus contamination cycle. *BMC Proceedings 2011,* **5** (Supplement 1), 64.

Merit Release Birds, such as the Eurasian tree sparrow *Passer montanus* are believed to increase one's positive karma when kissed and released during Buddhist rituals. Sparrows in Cambodia were found to be highly susceptible to the H5N1 viral infection from other birds, with a fatality rate near 100% within five days, and their feathers can carry infectious viral H5N1 particles, which could potentially contaminate humans during Buddhist rituals. Author: pbuchy@pasteur-kh.org; Online: http://www.biomedcentral.com/content/pdf/1753-6561-5-S1-P64.pdf

Leimgruber, P., Azmi, W., Baishya, H., Campos-Arceiz, A., Fernando, P., Jitvijak, W., Maltby, M., Pastorini, J., Pradhan, N., Ritthirat, J., Stewart-Cox, B. & Williams, C. (2011) Workshop on developing adaptive management for mitigating human-elephant conflict across Asia. *Gajah*, **34,** 63-66.

A report on the findings of a workshop on monitoring and mitigating conflict between humans and Asian elephants *Elephas maximus* in Asia, including Cambodia. Among the outcomes agreed was the creation of an informal practitioner's network, the 'Elephant Conservation Group' (ECG). The ECG will transfer and exchange technical information and experience in elephant conser-

vation between existing projects, with a current focus on developing adaptive human-elephant conflict management. Author: LeimgruberP@si.edu; Online: http://asesg.org/PDFfiles/Gajah/34-63-Leimgruber.pdf

Lin, Q., Ai, L., Li, J. & Li, H.L. (2011) Seroprevalence of BV (Macacine herpesvirus 1) in bred cynomolgus monkeys in Cambodia. *Journal of Veterinary Medical Science*. Article first published online 14 October 2011.

Blood samples were collected from 1,710 long tailed macaques *Macaca fascicularis* in Cambodia, and 34% were found to contain Macacine herpesvirus 1 antibodies. Presence of these antibodies was highly correlated with the age of the monkey.

Maltby, M. (2011) Cambodia's elusive elephants caught mating for the camera. *Gajah*, **34,** 58-60.

Camera traps obtained a sequence of 60 photographs of the courtship between two Asian elephants *Elephas maximus* over the course of two hours in Phnom Samkos Wildlife Sanctuary in 2010. Other large mammals photographed during the survey included gaur *Bos gaurus* and Asiatic black bear *Ursus thibetanus*. Author: matt.maltby.ffi@gmail.com; Online: http://asesg.org/PDFfiles/Gajah/34-58-Maltby.pdf

Platt, S.G., Vuthy M., Heng S., Long K. & Rainwater, T.R. (2011) Nesting phenology and clutch characteristics of captive Siamese crocodiles (*Crocodylus siamensis*) in Cambodia. *Zoo Biology.* Article first published online 24 August 2011, doi: 10.1002/zoo.20418.

A study of these Critically Endangered crocodiles on farms in Cambodia in 2000 and 2001 provided detailed information on the timing of nesting, incubation periods, clutch sizes and egg sizes. Author: sgplatt@gmail.com

Siebert, U. & Das, K. (2011) *Evaluation of the Ecotoxicological Effects of POPs and Heavy Metals, Reflecting Pathological, Microbiological and Genetic Analyses, on the Mekong River Population of Irrawaddy Dolphins (*Orcaella brevirostris*).* WWF-Germany, Berlin, Germany.

Samples collected from Irrawaddy River dolphins found dead along the Mekong River between 2006 and 2010 were analysed in laboratories in Europe, Canada and Cambodia to study their histology, toxicology and genetic variation. Author: ursula.siebert@ftz-west.uni-kiel.de

Swei, A., Rowley, J.J.L., Rödder, D., Diesmos, M.L.L., Diesmos, A.C., Briggs, C.J., Brown, R, Cao T.T., Cheng, T.L., Chong, R.A., Han, B., Hero, J-M, Hoang H.D., Kusrini, M.D., Le D.T.T., McGuire, J.A., Meegaskumbura, M, Min, M.-S., Mulcahy, D.G., Neang T., Phimmachak, S., Rao D.-Q., Reeder, N.M., Schoville, S.D., Sivongxay, N., Srei N., Stock, M., Stuart, B.L., Torres, L.S., Tran D.T.A., Tunstall, T.S., Vieites, D. & Vredenburg, V.T. (2011) Is chytridiomycosis an emerging infectious disease in Asia? *PlosOne,* **6,** 1-9.

The disease chytridiomycosis, caused by the parasitic fungus *Batrachochytrium dendrobatidis*, has caused dramatic amphibian population declines and extinctions in Australia, Central and North America, and Europe. A region-wide survey found on average only 2.35% of Asian amphibians were infected, and infected animals were not clumped as would be expected in epizootic events. No infected amphibians were detected in Cambodia during this survey. The authors suggest that this parasitic fungus is either newly emerging in Asia, endemic at low prevalence, or that some other ecological factor is preventing it from fully invading Asian amphibians. Author: swei@berkeley.edu; Online: http://www.plosone.org/article/info:doi/10.1371/journal.pone.0023179

Wikramanayake, E., Dinerstein, E., Seidensticker, J., Lumpkin, S., Pandav, B., Shrestha, M., Mishra, H., Ballou, J., Johnsingh, A.J.T., Chestin, I., Sunarto, S., Thinley, P., Thapa, K., Jiang, G., Elagupillay, S., Kafley, H., Pradhan, N.M.B., Jigme, K., Seng T., Cutter, P., Aziz, M.A. & Utin Than (2011) A landscape-based conservation strategy to double the wild tiger population. *Conservation Letters,* **4,** 219-227.

The governments of all 13 tiger range countries endorsed the St Petersburg Declaration in November 2010, pledging to double the wild tiger population. The reserves in 20 priority tiger landscapes (including those in North, East and Southwest Cambodia) could potentially support more than 10,000 tigers, but most reserves are small and much of the region is subject to rapid land-use change. Maintaining population viability and resilience will depend upon a landscape approach, involving both site-level protection and landscape-scale interventions to secure habitat corridors. Author: eric.dinerstein@wwfus.org; Online: http://www.wwf.de/fileadmin/fm-wwf/pdf_neu/A%20Landscape-Based%20Approach%20for%20Tigers_Conservation%20Letters.pdf

van Zalinge, R., Tran T., Evans, T., Hong C., Seng K.H. & Barzen, J. (2011) *Census of Non-breeding Sarus Cranes in Cambodia and Vietnam, 2011*. Cambodian Lower Mekong Wetlands Project, Wildfowl & Wetlands Trust, Phnom Penh, Cambodia.

Synchronized counts of sarus cranes *Grus antigone* were conducted in Cambodia and Vietnam from January-April 2011, with a peak count of 869 cranes recorded in February across 11 sites. This regional population appears to have remained stable in size since 2001. Author: robertvanzalinge@yahoo.com; Online: http://www.wcscambodia.org/resources/reports/sarus/Final_Census-of-non-breeding-Sarus-Cranes-in-Cambodia-and-Vietnam_2011.pdf

Coasts, wetlands and aquatic resources

Arias, M.E., Cochrane, T.A., Caruso, B., Killeen, T. & Kummu, M. (2011) A landscape approach to assess impacts of hydrological changes to vegetation communities of the Tonle Sap Floodplain. *Paper presented to the 34th World Congress, 26 June - 1 July, 2011, Brisbane, Australia.*

This paper proposes a landscape approach to understand the impacts of hydropower development, irrigation, and climate change on the floodplain's terrestrial vegetation. A land cover map, a digital elevation map and historical water records were used to predict future land coverage - including wet season rice, abandoned fields, flooded shrubland and open lake - under different scenarios. Author: mauricio.arias@pg.canterbury.ac.nz; Online: ir.canterbury.ac.nz/bitstream/10092/5553/1/12631037_LandscapeModellingApproach_IAHR2010_20110326.pdf

Baird, I.G. (2011) The Don Sahong dam: potential impacts on regional fish migrations, livelihoods, and human health. *Critical Asian Studies*, **43,** 211-235.

The construction of the proposed Don Sahong hydropower dam in Laos, a few hundred metres from the Cambodian border, is predicted to have a devastating impact on fish stocks and livelihoods in the Cambodian Mekong Basin. Online: http://robinlea.com/pub/Baird_2011_Don_Sahong.pdf

Becker, S.A. (2011) Mekong dam threatens Cambodia's food security, expert says. *The Babbler (Newsletter of BirdLife International in Indochina)*, **38,** 11-12.

Construction of the Xayaburi dam on the mainstream of the Mekong River in Laos is predicted to cause significant harm to fisheries in Cambodia, according to an environmental economics study. Cambodia's aquatic resources are already in decline due to over-fishing. Online: http://birdlifeindochina.org/sites/default/files/Babbler38.pdf [*This issue of The Babbler contains a number of extracts and summaries of other reports discussing the controversy surrounding the proposed Xayaburi dam in Laos - Ed.*].

Chann S., Wales, N. & Frewer, T. (2011) *An Investigation of Land Cover and Land Use Change in Stung Chrey Bak Catchment, Cambodia.* CDRI Working Paper Series No. 53. Cambodia Development Resource Institute, Phnom Penh, Cambodia.

Using satellite images, questionnaires and field observations, this study revealed interactions between water resources, land use, land cover, and local livelihoods between 1989 and 2008 within the agricultural catchment of the Steung Chrey Bak, a tributary of the Tonle Sap. Author: chann.sopheak@rupp.edu.kh; Online: http://www.cdri.org.kh/webdata/download/wp/wp53e.pdf

Chea C., Nang P., Whitehead, I., Hirsch, P. & Thompson, A. (2011) *Decentralised Governance of Irrigation Water in Cambodia: Matching Principles to Local Realities*. CDRI Working Paper Series No. 62. Cambodia Development Resource Institute, Phnom Penh, Cambodia.

This study examined three irrigation schemes - Rolous and Stung Chinit (Kampong Thom Province) and Damnak Ampil (Pursat Province) - and found flaws in the capacity of the Farmer Water User Communities to manage these initiatives. The authors propose a number of changes to policy and governance structure to provide more support to such communities. Author: cdri@cdri.org.kh; Online: http://www.cdri.org.kh/webdata/download/wp/wp62e.pdf

Cho, K.H., Sthiannopkao, S., Pachepsky, Y.A., Kim, K.W. & Kim, J.H. (2011) Prediction of contamination potential of groundwater arsenic in Cambodia, Laos, and Thailand using artificial neural network. *Water Research*, **45,** 5535-5544.

A model was developed and tested to predict the occurrence of arsenic in groundwater supplies. Author: joonkim@gist.ac.kr

Enomoto, K., Ishikawa, S., Hori, M., Hort S., Srun L.S., Nao T. & Kurokura, H. (2011) Data mining and stock assessment of fisheries resources in Tonle Sap Lake, Cambodia. *Fisheries Science*, **77,** 713-722.

Analysis of catch data indicated that stocks of high-value fishes such as *Channa micropeltes, Hampala* spp., and *Pangasius* spp. have declined in recent decades while those of cheaper fishes, such as *Cirrhinus microlepis, Cyclocheilichthys enoplos* and *Channa striata,* have increased. Author: akrkrh@mail.ecc.u-tokyo.ac.jp

Guppy, L. & Shantz, A. (2011) Groundwater quality in rural Cambodia: measures and perceptions. *Geographical Research*, **49,** 384-394.

A quantitative study in two communes in Cambodia found a high risk of encountering bore water with dangerous levels of chemical contamination. A qualitative study found 60% of bore water users thought their groundwater was of good quality, yet 97% treated their water before drinking. Author: lisaguppy@gmail.com

Irvine, K.N., Richey, J.E., Holtgrieve, G.W., Sarkkula, J. & Sampson, M. (2011) Spatial and temporal variability of turbidity, dissolved oxygen, conductivity, temperature, and fluorescence in the lower Mekong River–Tonle Sap system identified using continuous monitoring. *International Journal of River Basin Management*, **9,** 151-168.

Turbidity, dissolved oxygen, conductivity, temperature and fluorescence were continuously monitored at five locations on the Tonle Sap Lake and the Mekong–Bassac Rivers near Phnom Penh between 2004 and 2010, revealing marked seasonal, daily and spatial trends. The

authors of this paper developed models that could adequately forecast water level and water quality data one month in advance. Author: jrichey@u.washington.edu

Joffre, O. & Sheriff, N. (2011) *Conditions for Collective Action: Understanding Factors Supporting and Constraining Community-based Fish Culture in Bangladesh, Cambodia and Vietnam.* WorldFish Center Studies and Reviews 2011-21. The WorldFish Center, Penang, Malaysia.

Fish production in flood-prone, rice-growing areas in Cambodia is focused on the capture of wild fish. This report concludes that production could be significantly increased by stocking fish in flooded rice fields within individual plots. Online: http://results.waterandfood.org/bitstream/handle/10568/5571/WF_2816.pdf?sequence=1

Kura, Y., Tep B. & Ringler, C. (2011) Understanding the vulnerability of rural communities to changes in access to river, water and forests: implications of the proposed Lower Sesan Dam in Cambodia. *Paper presented to the Third International Forum on Water and Food, 14-17 November, 2011, Tshwane, South Africa.*

The Lower Sesan 2 Hydropower Project has been proposed a short distance below the confluence of the Sesan and Srepok rivers in Northeast Cambodia. This study measured the present value of water from these rivers at both household and sub-basin levels and estimates how these will change after the dam is constructed. Author: y.kura@cgiar.org; Online: http://results.waterandfood.org/bitstream/handle/10568/10550/MRpSe002_Final_RD_1710.pdf?sequence=3

Lyttleton, C. & Nyíri, P. (2011) Dams, casinos and concessions: Chinese megaprojects in Laos and Cambodia. In *Engineering Earth: the Impacts of Megaengineering Projects: Vol. 2* (ed. S.D. Brunn), pp. 1243-1266. Springer-Verlag, London, UK.

Focusing on a dam in Cambodia and two real estate/casino projects in Laos, this chapter examines how areas designated for Chinese-funded investment are transforming livelihoods, land management and governance. Author: chris.lyttleton@gmail.com; Online: http://risingpowers.open.ac.uk/documents/Publication/Dams_and_casinos_revised.pdf

Mainuddin, M., Kirby, M. & Chen, Y. (2011) *Fishery Productivity and its Contribution to Overall Agricultural Production in the Lower Mekong River Basin.* CPWF (Challenge Program for Water and Food) Research for Development Series 03. Consultative Group on International Agricultural Research (CGIAR), Colombo, Sri Lanka.

This report combines official statistics with consumption-based estimates to examine trends in the production and value of capture fish and aquaculture. Of the four Lower Mekong countries, Cambodia currently has the highest consumption of fish (65 kg per person per year). Growing demand in this region will need to be met with increased aquaculture (which is already well advanced in Vietnam), but this may pose risks for wild fish stocks because such farms needs huge quantities of fish fry as feed. Author: mohammed.mainuddin@csiro.au

Meas S. & Sherrell, D. (2011) Fisheries move may net gain for Tonle Sap. *The Babbler (Newsletter of BirdLife International in Indochina)*, **39,** 6.

In August 2011, use of 35 private fishing lots in the Tonle Sap lake was suspended for three years by the Cambodian government to enable the recovery of fish resources. Many of the owners have been accused of using banned gill nets, harvesting under-sized fish or using the poison acetylene to drive fish into their lots. Online: http://birdlifeindochina.org/sites/default/files/Babbler39.pdf

Meynel, J., Carew Reid, J., Baran, E., Rasaenan, T. & Ketelsen, T. (2011) Reintroducing ecological complexity into highly managed catchments. *Paper presented to the Third International Forum on Water and Food, 14-17 November, 2011, Tshwane, South Africa.*

Current trends in hydropower and agricultural intensification are resulting in less diverse and less productive ecosystems. Using examples from the transboundary Sesan River in Cambodia and Vietnam and the Nam Theun/ Nam Kadinh in Laos, the authors conclude it is possible to add diversity back into reservoirs and develop downstream flow regimes that maintain productive habitats and contribute to environmental sustainability and resilience. Author: peterjohn.meynell@gmail.com

Nang P., Khiev D., Hirsch, P. & Whitehead, I. (2011) *Improving the Governance of Water Resources in Cambodia: a Stakeholder Analysis. Understanding Stakeholders' Roles, Perceptions and Constraints for Effective Irrigation and Catchment Management and Development*. CDRI Working Paper Series No. 54. Cambodia Development Resource Institute, Phnom Penh, Cambodia.

Data from key informant interviews, field observations, focus group discussions and workshops were analysed to identify water governance issues and gaps. The present management of water resources is compromised by the lack of effective feedback mechanisms and coordination among different levels of government. This paper outlines a new coordination structure at sub-national level. Author: nangphirun@yahoo.com; Online: http://www.cdri.org.kh/webdata/download/wp/wp54e.pdf

Nguyen V.T., Choi, J.-H. & Won, J.-S. (2011) Monitoring floodplain area of Tonle Sap Lake, Cambodia using multitemporal ALOS PALSAR data. *Paper presented to the Third International Asia-Pacific Conference on Synthetic Aperture Radar (APSAR), 26-30 September 2011, Seoul, South Korea.*

To monitor the annual seasonal changes in flooding, ALOS PALSAR backscattering coefficients were meas-

ured from 2007 to 2010. The study found a decrease in backscattering coefficients decrease when water levels increased. Author: nvtrungvn@yonsei.ac.kr

Nuon V. & Gallardo, W. (2011) Perceptions of the local community on the outcome of community fishery management in Krala Peah village, Cambodia. *International Journal of Sustainable Development & World Ecology,* **18,** 453-460.

Community-based management has led to a more equitable and efficient fishery within Krala Peah village. Although there have not been improvements in fishing habitats and fish catch, community-based management has reduced some harmful factors, including illegal fishing. Author: vannanuon@yahoo.com

Ros B., Ly T. & Thompson, A. (2011) *Catchment Governance and Cooperation Dilemmas: a Case Study from Cambodia*. CDRI Working Paper Series 61. Cambodia Development Resource Institute, Phnom Penh, Cambodia.

Integrated Catchment Management (ICM) is a new approach in the Cambodian national strategy on water management. Based on a case study in Kompong Chhnang, this report highlights the obstacles to enlisting stakeholder cooperation in watershed management, and recommends how they may be overcome. Author: cdri@cdri.org.kh; Online: http://www.cdri.org.kh/webdata/download/wp/wp61e.pdf

So N. & Touch B. (2011) Fisheries resources in Cambodia: implications for food security, human nutrition and conservation. *Paper presented to the International Conference on Asian Food Security (ICAFS2011): Feeding Asia in the 21st Century: Building Urban-Rural Alliances, 10-12 August, 2011, Singapore.*

This paper assesses the importance of fisheries resources in Cambodia for food, and the importance of biodiversity conservation to ensure these resources are sustainable. Online: http://www.rsis.edu.sg/nts/events/docs/ICAFS-So_Nam.pdf

Travers, H., Clements, T., Keane, A. & Milner-Gulland, E.J. (2011) Incentives for cooperation: the effects of institutional controls on common pool resource extraction in Cambodia. *Ecological Economics*, **71,** 151-161.

This study used a game in four villages in Cambodia to investigate how levels of within-group cooperation vary under different institutional arrangements, including opportunities for social approval, external enforcement of rules and individual and collective incentive payments. Treatments that promoted self-organisation were found to have the greatest effect in reducing extraction. The findings suggest that efforts to encourage certain behaviours in local groups may be more successful if they create opportunities for local decision-making. Author: henry.travers@gmail.com

Wee, K.B. (2011) *The duality of flood in Cambodia: has the government helped the villagers?* Masters thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Using Participatory Rural Appraisal methods, this study examined the costs to villagers of bad flood years. Although government support is often insufficient, the author concludes there is a lot more villagers can do to help themselves. Online: http://stud.epsilon.slu.se/3290/1/wee_kb_110929.pdf

Young, L. & Mather, R.J. (2011) *Workshop on the Conservation and Wise Use of Wetlands in the Lower Mekong River Basin: Vientiane, Lao PDR, 22-24 March 2011.* IUCN, Gland, Switzerland.

This is a report on the results of a regional workshop that covered the following issues: working with local communities; management planning; wetland habitat management and monitoring; tourism programmes; inventories of wetlands and their values; national regulations, guidelines and mechanisms; and opportunities for national and regional cooperation. The report contains several brief case studies from Cambodia. Author: young@ramsar.org; Online: http://cmsdata.iucn.org/downloads/iucn_mekong_water_dialogues__march_2011_ramsar_workshop_report.pdf

Forests and forest resources

Akgün, O., Korkeakoski, M., Mustonen, S. & Luukkanen, J. (2011) Theoretical bioenergy potential in Cambodia and Laos. *Paper presented to the World Renewable Energy Congress 2011, 8-13 May 2011, Linköping, Sweden.*

Logging residues, sawnwood and plywood residues, and agricultural waste could contribute approximately 1.4 "million tonnes of oil equivalent" to the energy consumption of Cambodia. Author: orkideakgun@yahoo.com.tr; Online: http://www.ep.liu.se/ecp/057/vol1/045/ecp57vol1_045.pdf

Anonymous (2011) Cambodia: forests under threat. *The Babbler (Newsletter of BirdLife International in Indochina)*, **37,** 6.

The Forestry Administration reported that 56.94% of Cambodia was forested in 2010; a decrease of 2.15% from 2006. This article suggests that the government's Millennium Development Goal of 60% forest cover is unlikely to be met because of the ongoing losses of forested land to economic land concessions. Online: http://www.birdlifeindochina.org/sites/default/files/Babbler37_final.pdf

Anonymous (2011) Titanium mine in Cardamom Mountains denied. *The Babbler (Newsletter of BirdLife International in Indochina)*, **38,** 29.

In April 2011, the Cambodian Prime Minister announced that the 4,400 ha strip mine previously approved in Southern Cardamom Mountains will not go forward. The site is the location of an eco-tourism project, initiated by Wildlife Alliance in 2007. Online: http://birdlifeindochina.org/sites/default/files/Babbler38.pdf

Avtar, R., Takeuchi, W. & Sawada, H. (2011) Full polarimetric PALSAR-based land cover monitoring in Cambodia for implementation of REDD policies. *International Journal of Digital Earth*. Article first published online 3 October 2011, doi: 10.1080/17538947.2011.620639

Land cover in Cambodia was assessed using full polarimetric PALSAR (Phased Array type L-band Synthetic Aperture Radar) data, which was found to provide a highly accurate classification of forested areas. This method could help map forest cover on cloudy days. Author: ram@iis.u-tokyo.ac.jp

Avtar, R., Sawada, H., Takeuchi, W. & Singh, G. (2011) Characterization of forests and deforestation in Cambodia using ALOS/PALSAR observation. *Geocarto International*. Article first published online 23 September 2011, doi: 10.1080/10106049.2011.626081

This study demonstrates the capability of full polarimetric ALOS/Phased Array L-band Synthetic Aperture Radar data for characterising the forests and monitoring deforestation in Cambodia. This method could be use to support Reducing Emission from Deforestation and Forest Degradation (REDD) projects and policies. Author: ram@iis.u-tokyo.ac.jp

Avtar, R., Takeuchi, W. & Sawada, H. (2011) Plantation based natural forests biomass estimation for REDD policies implementation in Cambodia. *Paper presented to the Third International Asia-Pacific Conference on Synthetic Aperture Radar (APSAR), 26-30 September 2011, Seoul, South Korea.*

Using the backscattering properties of ALOS/PALSAR data from cashew plantations in Cambodia, a multilinear regression model was generated and applied to estimate natural forests biomass. In natural deciduous forests, there was a strong correlation between biomass estimated using PALSAR data and biomass measured in the field. This method failed to work in dense evergreen forests, however, due to the PALSAR signal becoming too heavily saturated. Author: ram@iis.u-tokyo.ac.jp

Ender, C. (2011) *Fell a tree, fell a livelihood: assessing the importance of non-timber forest products in Cambodia.* MSc thesis, University of Oxford, U.K.

With particular reference to Oddar Meanchey Province, poorer households in Cambodia were found to be significantly more dependent on forest resources than richer ones, with non-timber forest products contributing to approximately 29% of income. Author: ender.christina@googlemail.com

May T. (2011) Forest on the auction block. *The Babbler (Newsletter of BirdLife International in Indochina)*, **39,** 7.

In July 2011, 28,270 ha of Kulen Promptep Wildlife Sanctuary in Oddar Meanchey, Siem Reap and Preah Vihear provinces were reclassified as state private land for agricultural development. Online: http://birdlifeindochina.org/sites/default/files/Babbler39.pdf

May T. & Sherrell, D. (2011) Protected forest 'is finished'. *The Babbler (Newsletter of BirdLife International in Indochina)*, **39,** 8.

In July 2011, 19,829 ha of Boeung Per Wildlife Sanctuary in Preah Vihear Province were reclassified as state private land for agricultural development. This decision came less than a month after community representatives convened in Rovieng District to protest against a series of large economic land concessions they claim are harming the wildlife sanctuary and the people who depend on its natural resources. Online: http://birdlifeindochina.org/sites/default/files/Babbler39.pdf

Ra K., Pichdara L., Dararath Y., Jiao, X. & Smith-Hall, C. (2011) *Towards Understanding Household-Level Forest Reliance in Cambodia: Study Sites, Methods, and Preliminary Findings.* Forest & Landscape Working Papers 60-2011, Forest and Landscape - Denmark, Copenhagen, Denmark.

The findings from detailed surveys of three Poverty Environment Network sites in Cambodia in Kampong Speu, Kampong Thom and Kampot provinces. The results demonstrate the considerable economic significance of both forest and non-forest environmental resources to rural livelihoods, with forests contributing to 26% of household income on average. Author: rarua@yahoo.com; Online: http://curis.ku.dk/portal-life/files/33874009/Cambodia_WP60.pdf

Suon S. & Khorn S. (2011) Forestland management in Cambodia. In *Country Reports on Forest Tenure in Asia and the Pacific: Proceedings of APFNet Workshop on Forest Tenure* (eds R. McConnell, L. Qian & W. Qian), pp. 19-26. Asia-Pacific Network for Sustainable Forest Management and Rehabilitation, Beijing, China.

A report by senior Forestry Administration staff of the status and management of forests in Cambodia. Statistics include the current area of forest under different management regimes: Protection Forests: 4,534,032 ha (comprising protected areas: 3,100,000 ha; and protected forests: 1,434,032 ha) and Production Forests: 6,196,749 ha (comprising forest concessions: 3,068,888 ha; community forests: 309,354 ha; unclassified: 1,919,225 ha; and land economic concessions: 899,282 ha). Forthcoming activities by the Forestry Administration are to include: completing at least 1,000 km of forest land demarcation per year; attaining 60% forest cover by 2015; reviewing and improving the management of land economic

concessions; strengthening forest law enforcement; and promoting community forestry. Author: ksr_nang2006@yahoo.com; Online: http://zh.apfnet.cn/uploads/capacity_building/Training/2010/0705/Country_Report_final.pdf#page=21

Van R. & Vrieze, P. (2011) Conservation areas see bonanza of concessions. *The Babbler (Newsletter of BirdLife International in Indochina)*, **38,** 19-20.

Between 1 February and 1 April 2011, 17 private economic land concessions were awarded in 10 national parks and wildlife sanctuaries in Cambodia, covering 111,859 ha. Online: http://birdlifeindochina.org/sites/default/files/Babbler38.pdf

Van R. & Vrieze, P. (2011) Land concessions protect forests - Minister. *The Babbler (Newsletter of BirdLife International in Indochina)*, **38,** 17-18.

In May 2011, the Cambodian Ministry of Environment defended recent government approvals of private economic land concessions in protected areas, stating they would help protect the remaining forests from illegal logging. However, a number of environmental groups and human rights organisations argue that the move would significantly endanger both biodiversity and the livelihoods of local residents in these areas. Online: http://birdlifeindochina.org/sites/default/files/Babbler38.pdf

Payments for conservation services, including carbon

Biddulph, R. (2011) Is the Geographies of Evasion hypothesis useful for explaining and predicting the fate of external interventions? The case of REDD in Cambodia. *Paper presented to the conference Globalization and Development: Rethinking interventions and governance, 22-23 November, 2011, University of Gothenburg, Sweden*.

Using the Oddar Meanchey REDD pilot project as a case study, the author explores his new hypothesis to explain how and why rights-based development interventions often fail to work as intended. Author: robin.biddulph@geography.gu.se; Online: http://www.gu.se/digitalAssets/1350/1350795_conf-2011-biddulph.pdf

Sam C. (2010) *The Inclusion of Indigenous Peoples in REDD Project in Mundolkiri Province, Cambodia*. Report to the Cambodia Assessment Report 2010, The Access Initiative (TAI), Thailand Environment Institute, Pakkred, Thailand.

This 53-page report examines and supports the need for the participation of "resource owners" - specifically including indigenous peoples - in REDD initiatives in Cambodia. Author: chanthy.sam@sei.se; Online: http://seachangecop.org/files/documents/TAI_REDD_Report.pdf

Theilade, I. & Schmidt, L. (2011) *REDD+ and Conservation of Prey Long Forest, Cambodia: Summary of Scientific Findings 2007-2010.* Forest & Landscape Working Papers 66, Forest and Landscape - Denmark, Copenhagen, Denmark.

A summary of findings from a series of biological and social studies in Cambodia's Prey Long forest complex. This report identifies priority conservation areas and explains the rationale and steps for developing a REDD+ project in Prey Long. Author: idat@life.ku.dk; Online: http://curis.ku.dk/portal-life/files/35386879/REDD_Scientific_findings_WP.pdf

Climate change

Martin, R. (2011) Climate resilient farming systems for Cambodia. *Paper presented to the Rural Climate Change Solutions Sympsium, 3-4 May, 2011, University of New England, Armidale, Australia*.

The current rice-based farming system in Cambodia is ill-adapted to existing climate variability, let alone prepared for climate change. Improving efficiency of water use efficiency needs to be addressed first. Author: bob.martin@une.edu.au; Online: http://www.une.edu.au/piic/documents/Symposium-Proceedings-Booklet-May-2011.pdf#page=32

Capacity building

Otsuki, K. & Takahashi, S. (2011) *Research Capacity Development for Environmental Management in Cambodia: Outlining a Multi-Sector Approach.* Policy Brief 2, United Nations University, Tokyo, Japan.

Insufficient research capacity in Cambodian academic institutions is hampering environmental planning and management. Drawing on lessons learned from the Royal University of Phnom Penh's project entitled *Multi-Sector Involvement for Research Capacity Development in Cambodia (2009-2011)*, the authors suggest that research development in Cambodia should take a multi-sector approach that builds on (1) the influence of NGOs on research; (2) the link between research and public policy; and (3) inter-university networking. Author: pbuchy@pasteur-kh.org; Online: http://unu.edu/wp-content/uploads/publication/000/016/886/policy-brief-11-02_web.pdf

Lynam, A. Tan S., Rainey, H., Soeun M., Son S., Sorn P. & Phu C. (2011) *Patrol Field Staff Workshops: Preah Vihear Protected Forest, Cambodia, March & April 2011.* Wildlife Conservation Society, Phnom Penh, Cambodia.

A detailed report on ranger training workshops, with recommendations. Author: tlynam@wcs.org; Online: http://birdlifeindochina.org/sites/default/files/Patrol_Staff_Training_Babbler39.pdf

Other livelihoods initiatives

Bith B. (2011) *Community-based ecotourism and empowerment of indigenous people: the case of Yeak Laom community development, Cambodia.* Masters thesis, Lincoln University, Christchurch, New Zealand.

Bith Bunly's study evaluated the potential benefits for indigenous Tampuan people from a community-based ecotourism initiative in the Yeak Laom Protected Area in Ratanakiri Province. The findings indicate that even though the economic benefits are limited, this initiative is an important tool for the community's psychological, social and political empowerment. Online: http://researcharchive.lincoln.ac.nz/dspace/bitstream/10182/3865/4/Bith_MTM.pdf

van der Heydan, T. (2011) Local and effective: two projects of butterfly farming in Cambodia and Tanzania (Insecta: Lepidoptera). *SHILAP Revista de Lepidopterología, Madrid,* **39,** 267-270.

Paper not seen. Author: tmvdh@web.de

Miscellaneous

Browne, W., Franks, D. & Kendall, G. (2011) *The Foundations for Responsible Mining in Cambodia: Suggested Approaches*. Policy Brief. United Nations Development Programme, Phnom Penh, Cambodia.

Introduces various approaches to responsible mining, including governance and environmental considerations. Online: http://xa.yimg.com/kq/groups/19218912/1198818493/name/02_Policy-Brief-En-V5.pdf

Walter, P.G. & Reimer, J.K. (2011) The "ecotourism curriculum" and visitor learning in community-based ecotourism: case studies from Thailand and Cambodia. *Asia Pacific Journal of Tourism Research*. Article first published online 24 October 2011, doi: 10.1080/10941665.2011.627930

Visitor learning is a basic component of community-based ecotourism. This study examines how local environmental, cultural and livelihood knowledge comprise the ecotourism curriculum in two projects in southern Thailand and Cambodia. Author: pierre.walter@ubc.ca

The Recent Literature section was compiled by JENNY C. DALTRY, with additional contributions from Berry Mulligan, Neil Furey, Fredéric Goes, Lee Grismer, Oleg Kosterin and Matthew Maltby. 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

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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.

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