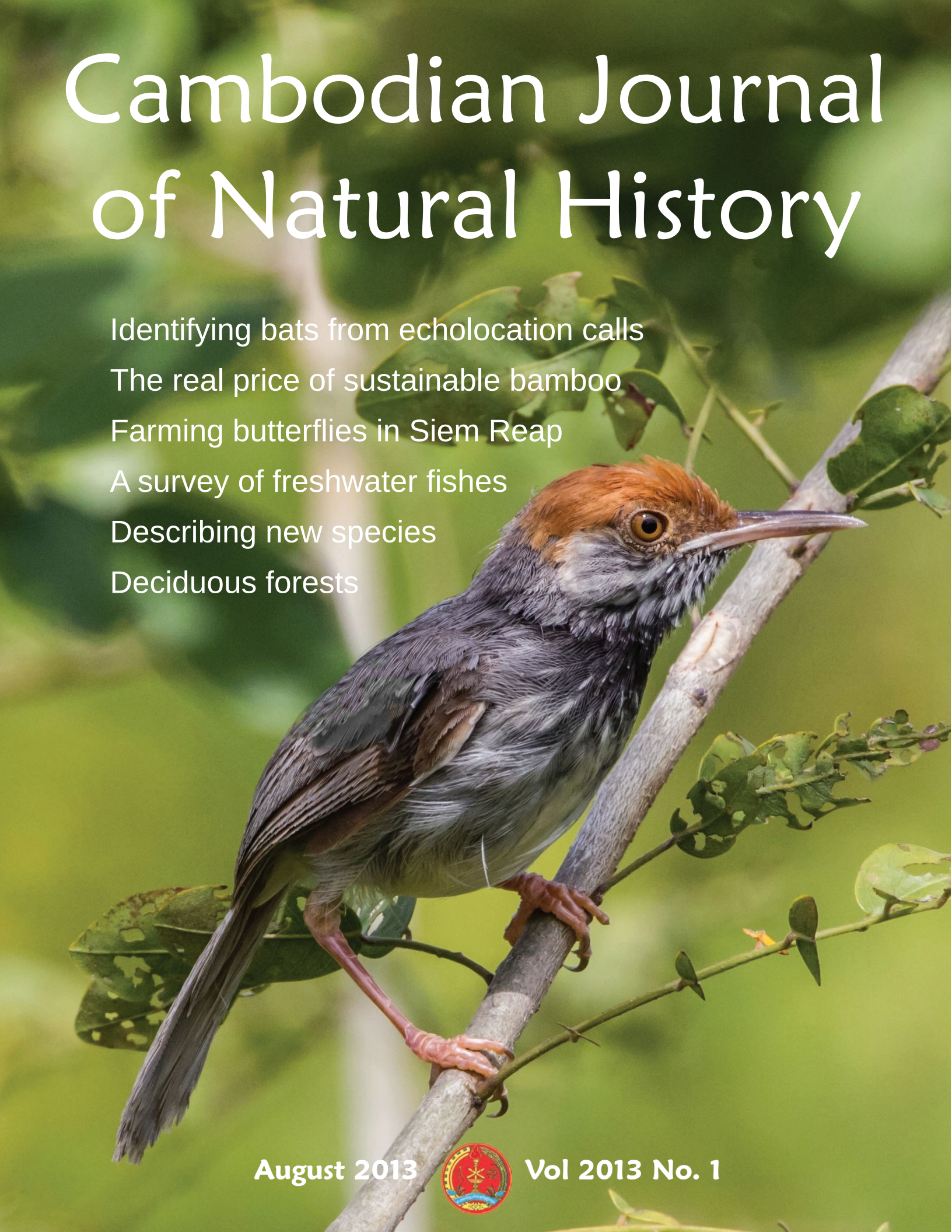
Cambodian Journal of Natural History



Identifying bats from echolocation calls

The real price of sustainable bamboo

Farming butterflies in Siem Reap

A survey of freshwater fishes

Describing new species

Deciduous forests

August 2013 Vol 2013 No. 1

Cambodian Journal of Natural History

ISSN 2226–969X

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

Cover photo: The Cambodian tailorbird *Orthotomus chaktomuk* made international headlines when it was named in 2013, after being discovered at a construction site on the outskirts of Phnom Penh (© Ashish John, Wildlife Conservation Society). In the Guest Editorial, one of the authors of the new bird, Jonathan Eames OBE, gives a personal perspective on where and how to describe new species of animals.

Guest Editorial—Describing new species

Jonathan C. EAMES

BirdLife International Cambodia Programme, #9, Street 29 Tonle Basac, Chamkarmon, P.O. Box 2686, Phnom Penh, Cambodia.

Email Jonathan.Eames@birdlife.org

In the previous issue of the *Cambodian Journal of Natural History* (Volume 2012, No. 2), the editors provided guidance on how to draft a good scientific paper (Daltry *et al.*, 2012). Following the recent publication of the type description of a new species of bird from Cambodia in June 2013 (Mahood *et al.*, 2013), I thought it would be helpful to continue this theme by providing guidance to authors on what to include in a type description for a new animal. This editorial is focused on bird and, to a lesser extent, mammal type descriptions because this is a field where I have some experience. The *International Code of Zoological Nomenclature* is a system of internationally accepted rules and recommendations for naming animals. The *International Code of Nomenclature for algae, fungi, and plants* (McNeill *et al.*, 2012), previously the *International Code for Botanical Nomenclature*, contains some differences and those wishing to describe taxa from these groups of organisms should refer to it instead.

It could be said that all humans are taxonomists. As a species we devote considerable time in our lives to sorting and classifying objects without perhaps even thinking much about what we are doing. This would include such mundane tasks such as sorting ripe from unripe fruit, deciding which Premier League club is worthy of our support, or even choosing a lipstick in a department store.

The urge to discover is one of the strongest motivations a human can experience. Discovery in all its forms enriches our lives endlessly. Scientific discovery can be a revelation upon which the future of civilizations turns. For example, the discovery of the healing properties of penicillin in 1928 has since saved millions of human lives. Species discovery is thrilling too, but for many scientists it may come only once in a career. Once we have discovered a new species we must describe it. It is therefore important to try and get it right.

Published guidance exists on what to publish in a species description, for example Winston (1999). One of the most useful papers on the subject was written partly in response to the disappointment of the authors with the quality of many of the descriptions of new species of bird then appearing (LeCroy & Vuilleumier, 1992). I commend both this paper and a retort (Collar, 1999) to all, and unashamedly draw heavily from the former in what now follows. I also include recent examples of bad and good practice as revealed in the type descriptions of mammals and birds recently published from Asia and elsewhere.

When describing a new species the starting point is to designate a "holotype" or two or more "syntypes". The holotype is a single voucher specimen used by an author to define and represent the species, and this may be the only one found or one of several individuals found. When people talk about "the type" they are referring to this specimen (Winston, 1999). The syntypes are two or more specimens selected from the available material to represent the species when no single specimen has been identified as the holotype (Winston, 1999). To facilitate future comparisons, the holotype or syntypes should be complete specimens and not unsupported illustrations, body parts, and blood or tissue samples. A "type series", comprising the holotype or syntypes and additional specimens (called "paratypes") is desirable because this helps to demonstrate variability within the new species.

While it is highly desirable to have the type specimen(s) permanently deposited in a museum or other publicly available collection, very occasionally it may be impractical to kill an individual, for example a highly endangered mammal (International Commission on Zoological Nomenclature, 2000). Authors and editors that deviate from the convention of collecting type specimens risk confusing the scientific record and the ire of their peers, as the following recent examples clearly show.

In 2005 a new monkey was described from a photograph of an individual animal (Jones *et al.*, 2005). The description of a new primate is a major event and resulted in the type description being published in the journal *Science*. However, the authors, working for a

leading conservation organisation, chose to describe their new species from photographs instead of killing and preserving a specimen, perhaps because of the rarity of the animal or because it was a monkey. Thus the "holotype" in this case was the animal depicted in the photograph, but the *International Code on Zoological Nomenclature* (International Commission on Zoological Nomenclature, 2000) does not permit photographs to be designated as types. In the absence of a voucher specimen, and therefore being obliged to describe the taxon from images only, the monkey was placed in the genus *Lophocebus*, which contains many species (Jones *et al.,* 2005). Later research by a leading museum, which chose to collect a specimen, placed the monkey in the entirely new monotypic genus *Rungwecebus* (Davenport *et al.,* 2006) on the basis of molecular and morphological data. Had the type description been based on a voucher specimen, a far more thorough piece of science could have been published, establishing a new genus and new species in a single paper and giving greater kudos to the authors.

Another example serves to show how confusion can arise when a complete specimen is not obtained and described. In 2006 a new species of babbler was described from India (Athreya, 2006). Whilst the author's reasons for not collecting a voucher specimen were given in the paper, and whilst the type description may meet the provisions of the *International Code on Zoological Nomenclature*, the absence of a complete type specimen and the designation of the image of the bird in photographs as type material renders it flawed and of limited utility to others. Athreya (2006) wrote: "The holotype is the bird from which a few feathers were obtained and which is the subject in a series of photographs presented in this paper. The holotype was captured, photographed, measured and released". Since the holotype was released alive, do the feathers, the photographs or the released bird or all three represent the holotype? The absence of any complete voucher specimens renders it almost impossible for future researchers to make comparisons with congeners.

In another, now infamous example, the Bulo Burti boubou *Laniarius liberatus*, an African bushshrike, was described from blood samples only and lacked a specimen (Smith *et al.,* 1991). New species can be described on the basis of DNA sequences, but, while not mandatory, it is strongly recommended that the type specimen(s) from which the DNA was sequenced is preserved and deposited in a museum with a type label and data linking it to the sequence (International Commission on Zoological Nomenclature, 2000).

The provenance of type material is also critically important. In most recent cases involving vertebrates, it is typical for the collector to be one of the authors of the type description. Thus the provenance of the type material is usually accurately known. Recently, however, from this very region, there was an alarming example where this was not the case. In 1994 the type description of the khiting vhor *Pseudonovibos spiralis* was based on preserved material purchased in a shop (Peter & Feiler, 1994). Whilst the authors acted in good faith, they were rash in rushing to publish a description based on material that was fraudulently crafted from cow horn.

The information that should accompany a type specimen includes a collection catalogue number, the name of the institution where the type is deposited, its age and sex, collecting locality (including coordinates and altitude), date of collection, the name of the collector(s), biometrics and a detailed word description of the type. The inclusion of additional information to help us to judge the validity of the species is also advisable. This may include sonograms of voice recordings (in the case of birds or frogs, for example), tissue and blood samples and notes on behaviour and ecology (LeCroy & Vuilleumier, 1992). Two comprehensive examples of bird type descriptions containing such comprehensive information include Alstrom *et al.* (2010) and Mahood *et al.* (2013).

As the new species will bear a scientific name derived from Latin or Ancient Greek, the etymology and gender of the proposed name must be given. For most of us this means we must seek guidance from a scholar in these obscure languages. The authors must explain why the new species is included within a particular genus, including any new genus they may propose. Importantly, comparisons must be made with closely related congeners, including sympatric and allopatric forms, and maps showing geographical relationships included. This may render lengthy and costly overseas trips to museums in Europe or the United States necessary to examine specimens of previously described species. The biogeography of the new species should be discussed and an explanation given as to why if the new taxon is allopatric, it is a new species and not a new subspecies (LeCroy & Vuilleumier, 1992).

In the case of Athreya's (2006) babbler, the comparison of this new taxon with its close congeners was limited to comparing photographs only. This is not reliable because photographs do not capture colour precisely, and no direct comparison was made with the two most closely related species. The comparison

should have been undertaken with the holotype specimens of the most closely related taxa under museum conditions. In addition the type description appeared in an obscure journal (although it was at least published in the English language).

With a draft type description finished, one must consider to which journal it will be submitted for publication. It is important to pick a peer-reviewed journal that is appropriate for the animal species being described, and one that is familiar with publishing type descriptions according to the *International Code of Zoological Nomenclature*—the set of rules for naming animals and the resolution of nomenclatural problems (International Commission on Zoological Nomenclature, 2000). The International Commission on Zoological Nomenclature acts as adviser and arbiter for the zoological community by generating and disseminating information on the correct use of the scientific names of animals.

The journal should ideally have an International Standard Serial Number (ISSN) and be published in the English language. However proud we may be of our own languages, publication in any language other than English will reduce the impact of the work within the scientific community at large. The publication of type descriptions in books, where the description will be more easily overlooked, should also be avoided. Following these steps will help to ensure the widest possible readership for your work (LeCroy & Vuilleumier 1992).

The description of the Vietnamese pheasant *Lophura hatinhensis* type specimen in a book in Vietnamese did not help to clarify is existence. Only recently was its invalidity as a taxon finally established (Hennache *et al.*, 2012).

Where the holotype, syntypes and other type material will be deposited is also a crucial consideration. Type specimens should always be deposited in a recognised museum collection that has good collection management facilities and that also welcomes visiting scientists. This is necessary to ensure the permanent and safe storage of the priceless type material and to ensure other scientists may have access to it for future study (few museums will consider sending type material on loan by post). To best serve the needs of science, it may be appropriate to split the type series so that some type material is stored in a collection in the country of origin, thereby helping to promote science locally, as well as in an internationally recognised collection. In doing so, the risk of loss or damage to the entire type series is spread and reduced. It is also important that type specimens are labelled and preferably stored separately from the main collection. Bibliographic reference to the published description and the proposed name should be written on the label (LeCroy & Vuilleumier, 1992).

Probably everyone reading this will be familiar with the saola *Pseudoryx nghetinhensis*, which was described in a letter in the prestigious journal *Nature* (Dung *et al.*, 1993). The discovery of a new large mammal genus and the use of DNA analysis were certainly factors that the editors of *Nature* considered when deciding to publish this type description. The holotype was, however, deposited in the collection of the Forest Inventory and Planning Institute in Hanoi, Vietnam. This could hardly be described as a recognised museum collection with good collection management facilities or allowing easy access by visiting scientists. It would have been better for science had the holotype been deposited in a museum with a collection of bovid type material.

Although the golden age of vertebrate species discovery has past, new species are described regularly. In 2010, at least 208 species of higher plants and vertebrate animals were apparently described from the Greater Mekong region, of which at least seven were described from Cambodia (Thompson, 2011). Thus the opportunity to discover a new species in Cambodia is a very real one and I hope that many of you will have in the future.

The *Cambodian Journal of Natural History* does not normally accept formal descriptions of new species, new subspecies or other new taxa. If you wish to submit original taxonomic descriptions, please contact the editors in advance. The journal editors have two reasons for not accepting type descriptions. First, is the need for expert peer reviewers. While the editors have a good range of expert taxonomist contacts for some taxa (e.g. reptiles, bats, amphibians, birds and orchids), they may not be able to secure high calibre reviews for some of the lesser taxa that may be submitted. The last thing any of us would want to do is publish a taxon that turned out to be false or inadequately described and substantiated. That would be a disservice to science— all of us are familiar with the problems caused by poor descriptions.

Second, there are already many excellent places to publish new species. As an author, I would be looking for a robust, well established journal that has a strong track record in publishing taxa and can reach the global audience that need access to the descriptions, both now and in the future (type descriptions stay

forever relevant). For example, a journal like *Zootaxa*, which is available as hard and soft copies in almost every academic library.

I know from speaking with colleagues that a number of new plant and animal species from Cambodia await description. Some of these may currently be known only from photographs and the lack of appropriate type material may be holding up publication in some cases. I urge that such issues are overcome with haste and all effort be made to describe new species for Cambodia. This will help promote Cambodian science and provide a service for science globally.

References

Alstrom, P., Davidson, P., Duckworth, J.W., Eames, J.C., Le T.T., Nguyen C., Olsson, U., Robson, C. & Timmins, R. (2010) Description of a new species of *Phylloscopus* warbler from Vietnam and Laos. *Ibis,* **152,** 145–168.

Athreya, R. (2006) A new species of *Liocichla* (Aves: Timaliidae) from Eaglenest Wildlife Sanctuary, Arunachal Pradesh, India. *Indian Birds*, **2,** 82–94.

Collar, N.J. (1999) New species, high standards and the case of *Laniarius liberatus*. *Ibis,* **141,** 358–367.

Daltry, J.C., Fisher, M. & Furey, N.M. (2012) How to write a winning paper. *Cambodian Journal of Natural History*, **2012,** 97–100.

Davenport, T.R.B., Stanley, W.T., Sargis, E.J., de Luca, D.W., Mpunga, N.E., Machaga, S.J. & Olson, L.E. (2006) A new genus of African monkey, *Rungwecebus*: morphology, ecology, and molecular phylogenetics. *Science,* **312,** 1378–1381.

Dung V.V., Giao, P.M., Chinh N.N., Tuoc D., Arctander, P. & MacKinnon, J.R. (1993) A new species of living bovid from Vietnam. *Nature*, **363,** 443–445.

Hennache, A., Mahood, S.P., Eames, J.C. & Randi, E. (2012) *Lophura hatinhensis* is an invalid taxon. *Forktail,* **28,** 122–129.

International Commission on Zoological Nomenclature (2000) *International Code of Zoological Nomenclature, Fourth Edition*. The International Trust for Zoological Nomenclature, The Natural History Museum, London, United Kingdom. Http://www.nhm.ac.uk/hosted-sites/iczn/code/ [accessed 28 June 2013].

Jones, T., Ehardt, C.L., Butynski, T.M., Davenport, T.R., Mpunga, N.E., Machaga, S.J. & de Luca, D.W. (2005) The highland mangabey *Lopocebus kipunji*: a new species of African monkey. *Science*, **308,** 1161–1164.

LeCroy, M. & Vuilleumier, F. (1992) Guidelines for the description of new species in ornithology. *Bulletin of the British Ornithological Society. Centenary Supplement*, **112A,** 191–198.

Mahood, S.P., John, A.J.I., Eames, J.C., Oliveros, C.H., Moyle, R.G., Hong C., Poole, C.M. & Sheldon, F.H. (2013) A new species of lowland tailorbird (Passeriformes: Cisticolidae: *Orthotomus*) from the Mekong floodplain of Cambodia. *Forktail*, **29,** 1–14.

McNeill, J., Barrie, F.R., Buck, W.R., Demoulin, V., Greuter, W., Hawksworth, D.L., Herendeen, P.S., Knapp, S., Marhold, K., Prado, J., Prud'homme van Reine, W.F., Smith, G.F., Wiersema, J.H. & Turland, N.J. (2012) *International Code of Nomenclature for algae, fungi, and plants (Melbourne Code), Adopted by the Eighteenth International Botanical Congress Melbourne, Australia, July 2011*. Koeltz Scientific Books, Koenigstein, Germany.

Peter, W.P. & Feiler, A. (1994) A new bovid species from Vietnam and Cambodia (Mammalia: Ruminantia). *Zoologische Abhandlungen Museum für Tierkunde Dresden*, **48,** 169–176.

Smith, E.F.G., Arctander, P., Fjeldsa, J. & Amir, O.G. (1991) A new species of shrike (Laniidae: *Laniarius*) from Somalia, verified by DNA sequence data from the only known individual. *Ibis*, **133,** 227–235.

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. Http://assets.wwf.org.uk/downloads/greater_mekong_species_report_web_ready_version_nov_14_2011_1.pdf [accessed 28 June 2013].

Winston, J.E. (1999) *Describing Species: Practical Taxonomic Procedure for Biologists*. Columbia University Press, New York, USA.

News

The Kannitha Fund for female Cambodian conservation scientists

The Kannitha Fund was established in 2012 to provide scholarships to Cambodian women for the Masters of Science in Biodiversity Conservation course at the Royal University of Phnom Penh. The Kannitha Scholarships cover basic materials and living expenses. By removing some of the financial barriers for Cambodian women to become scientists, the fund organisers hope this will be a catalyst to benefit endangered wildlife and poor forest communities for years to come.

The charitable trust fund was created in tribute to Lim Kannitha, a talented conservation student who tragically died from malaria in 2010, aged only 30 years. Ms Lim had been among the first students to enrol on the Masters in Biodiversity Conservation course at the Royal University of Phnom Penh. She was an outstanding young scientist, as Dr Carl Traeholt, one of her lecturers, recalled:

"Kannitha came from a family of very modest means and her educational background was mixed. But Kannitha defied the odds because she had determination, an indomitable spirit and a hunger for knowledge. She studied hard to reach a level of scientific excellence both for herself and for her country. She possessed a rare combination of qualities required to make a good scientist: curiosity, commitment, creativity, intelligence and altruism. Kannitha also had the tenacity to break from traditional conservatism and face new challenges with a smile and without prejudice".

Joe and Jade Heffernan launched the Kannitha Fund with contributions made by friends and family on their wedding day in lieu of gifts. Joe Heffernan (Fauna & Flora International) first met Kannitha in 2006, when she conducted research with the Cambodian Elephant Conservation Group. She later went on to conduct her Masters thesis research on gibbons with Dr Ben Rawson at Conservation International.

Ms Hoem Thavry, from Prey Veng Province, became the first recipient of a Kannitha Scholarship in 2013. Thavry said "The scholarship pays all my tuition fees and this makes a big difference as it was really hard for my family to find money for this before. Because of the award, I now don't need to find a job to support my study costs which means I have a lot more time to study and improve my grades. The scholarship has made me a better student as it really encouraged me to work hard to improve my knowledge and skills".

After she graduates, Thavry hopes to "share the knowledge I've learned, especially with Cambodian people who aren't aware of all the benefits we get from biodiversity. I'd really like to develop educational materials through radio, television and magazines to encourage people to love and protect our natural heritage. To do this, I'd like to learn more by working with a good conservation organization and also if possible to work as a researcher".

Women interested in applying for a scholarship for the Masters of Science in Biodiversity Conservation should contact the Centre for Biodiversity Conservation, Room 415, Main Campus, Faculty of Science, Royal University of Phnom Penh, Confederation of Russian Boulevard, Phnom Penh, Cambodia; Email: mbiodiversity.info@rupp.edu.kh

To learn more about the Kannitha Fund and to make donations to this important cause, please visit the fund website:

Http://kannithafund.wordpress.com/

Announcing the publication of *The Birds of Cambodia - An Annotated Checklist* by Frédéric Goes

Even though the international importance of the Cambodian bird fauna is widely recognised, the only review to date was confined to pre-1970s records for 399 bird species. As information on Cambodian birds has grown exponentially since the 1990s, the country has needed a national treatment synthesizing latest knowledge on its fascinating avifauna for some time.

The Birds of Cambodia - An Annotated Checklist is a landmark publication that addresses this need. It stems from 12 years of ornithological surveys and observations, coupled with six years of collation and review of all available records. The book exhaustively documents the entire bird fauna of Cambodia and

Giant ibis *Pseudibis gigantea* painting by Berry Mulligan, from the cover illustration of Frédéric Goes' *The Birds of Cambodia - An Annotated Checklist*.

identifies all bird species of national conservation concern. As such, it provides an authoritative basis for a national red data book and future conservation legislation.

The book consists of three parts and includes 48 colour plates illustrating major habitats, conservation threats and over 80 bird species photographed in the wild in Cambodia.

The introduction describes the country's natural geography, major habitats, protected areas, ornithological history and survey coverage, then goes on to review conservation successes and challenges and provide guidance for novice birdwatchers.

A systematic section forms the heart of the book and presents peer-reviewed accounts for the 598 bird species currently confirmed for Cambodia. The accounts synthesize latest knowledge on seasonal occurrence, abundance, distribution and habitat, including notes on breeding and conservation. English, Latin, French and Khmer names, including transliteration, are provided for each species. Detailed reviews of records are also provided for rarities and all species of conservation concern, together with a proposed national conservation category.

Several appendices complete the book. These include a reference checklist for Cambodian birds, tables of nationally threatened species and potential future species additions, census results for globally threatened species and a geographical gazetteer.

In addition to stimulating interest and awareness among the general public, *The Birds of Cambodia - An Annotated Checklist* will undoubtedly become an indispensable reference for conservationists and ornithologists in Cambodia, as well as all bird watchers visiting the Kingdom.

All proceeds from sales of the publication will be used to build awareness and capacity for bird conservation among young Cambodians.

Copies can be obtained from Fauna & Flora International Cambodia Programme, #19, Street 360, Boeng Keng Kong 1, Phnom Penh, Cambodia. Email: birdsofcambodia@gmail.com

Short Communication

The Banteay Srey Butterfly Centre: five years of endeavouring to support conservation and poverty alleviation

Torsten VAN DER HEYDEN

Immenweide 83, D-22523 Hamburg, Germany.
Email tmvdh@web.de

Paper submitted 22 March 2013, revised manuscript accepted 24 May 2013.

Sustainable butterfly farms have been established in several tropical developing countries with the aims of supporting local rural livelihoods and conserving forests with high biodiversity. For example, Kenya (Gordon *et al.*, 2011), Tanzania (Morgan-Brown *et al.*, 2010; van der Heyden, 2011) and Guyana (Sambhu & van der Heyden, 2010).

In 2008, Ben Hayes, originally from the United Kingdom, started the Banteay Srey Butterfly Centre (BBC) near the Phnom Kulen National Park in Siem Reap Province. It was based on the Zanzibar Butterfly Centre, a similar project he started in Tanzania in 2006 (van der Heyden, 2011). Both projects operate within or near protected areas where there is a lot of pressure on natural resources from local communities. Ben Hayes and two Cambodians, Nhoek Sakhaun and Thoung Chantha, are the directors of the BBC. The centre is managed by another Cambodian, Om Srey Vat.

The BBC is in Sanday Village, near the Banteay Srey Temple and the Cambodia Landmine Museum. It offers a live butterfly exhibition to residents and tourists, which is the largest of its kind in Southeast Asia. Hundreds of free-flying butterflies—all of them native species of Cambodia—can be observed in a netted tropical enclosure, approximately 30 m x 40 m. The centre is visited by approximately 10,000 foreign and 3,000 Cambodian visitors every year. They are informed about the different species on display, the butterfly life cycle and their ecology by trained local staff members. Through these talks, the BBC aims to give visitors an increased knowledge of local Cambodian biodiversity and hence stimulate interest in conservation and protection issues.

The BBC also focuses on enabling local rural communities to gain a livelihood by rearing butterfly species and selling pupae to the BBC. Farmers in Sanday Village and remote communities currently farm 35 species of butterflies and moths from various families: *Atrophaneura aristolochiae, Attacus atlas* (Fig. 1), *Catopsilia pomona, C. scylla, Cethosia cyane, Charaxes solon, Danaus genutia, Delias pasithoe, Dysphania sagana, Elymnias hypermnestra, E. nesaea, Euploea core, E. mulciber, Euthalia aconthea, E. lubentina, Graphium agamemnon* (Fig. 2), *G. antiphates, G. doson, G. sarpedon, Hebomoia glaucippe, Hypolimnas bolina, Junonia almana, Lebadea martha, Lexias dirtea, Melanitis leda, Papilio clytia, P. demoleus* (Fig. 3), *P. demolion, P. helenus, P. memnon, P. polytes, Parantica aglea, Parthenos sylvia, Polyura athamas* and *Tirumala septentrionis*. All of these species are farmed every year, but the number of specimens reared and displayed may vary depending on the season.

In small netted enclosures in the farmers' backyards (Fig. 4), female butterflies deposit their eggs on the specific food plants of the respective species. The eggs are harvested by the farmers and the hatched larvae are transferred to their food plants in a "nursery". After pupation, the pupae are sold to the BBC and displayed in the centre (Fig. 5), where the butterflies emerge. The duration of the breeding cycle varies depending on the species. Most species take several weeks to complete the cycle from egg to adult butterfly.

CITATION: van der Heyden, T. (2013) The Banteay Srey Butterfly Centre: five years of endeavouring to support conservation and poverty alleviation. *Cambodian Journal of Natural History*, **2013,** 7–9.

Fig. 1 *Attacus atlas* (Saturniidae) (© T. van der Heyden).

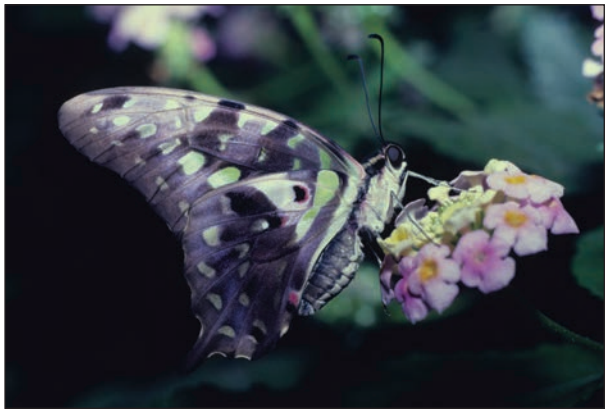


Fig. 2 *Graphium agamemnon* (Papilionidae) (© T. van der Heyden).

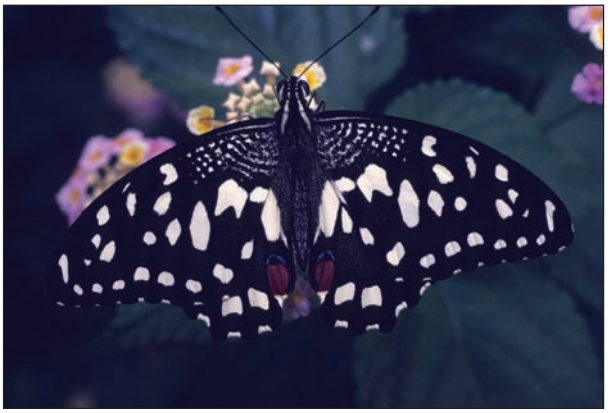


Fig. 3 *Papilio demoleus* (Papilionidae) (© T. van der Heyden).

Fig. 4 Breeding cage owned by a farmer with the Banteay Srey Butterfly Centre (© B. Hayes).

Because only a few butterflies are caught from the wild to start the farming process, these collections are not thought to harm the wild populations. A number of the pupae reared by the farmers are used for breeding purposes, thus avoiding unnecessary consecutive collections from the wild. To prevent rare or threatened species being caught, the BBC does not buy any rare species and all farmers have been taught to farm only common, non-threatened species.

The BBC buys pupae only from local farmers that are members of the project. By rearing and selling butterflies from home, the farmers are able to increase and diversify their income, which helps to alleviate poverty. The additional monthly income is very variable, depending on how many pupae the farmers produce and of which species, but some farmers have earned US$ 100 per month from this part time work. This is twice the local average monthly income.

In addition, the farmers are able to gain the knowledge that an intact natural environment is vital for their business, which could motivate them to conserve their natural surroundings instead of destroying them for agriculture or other purposes. Forest clearance and other forms of habitat destruction could potentially be

Fig. 5 Pupae of *Papilio memnon* (Papilionidae) at the Banteay Srey Butterfly Centre (© B. Hayes).

reduced, having a positive impact on wild species, both plants and animals.

As of March 2013, about 30 male and female farmers work with the BBC. Their business of rearing and selling butterflies is an example of the sustainable use of natural resources. Revenue generated from admission fees to the BBC is used to support the farmers and their families with a supplementary income as well. Additional people from local communities are employed by the BBC to manage the centre, train and support the butterfly farmers, and guide visitors. Part of the revenue from tourist admissions is also used to support conservation projects, for example, biodiversity surveys. The BBC is a member of ConCERT (Connecting Communities, Environment & Responsible Tourism) based in Siem Reap, a network of local partners involved in conservation.

Currently, there are no quantitative or qualitative data to evaluate the impact of the BBC on the conservation of natural resources. I therefore recommend conducting a survey to investigate these aspects and to determine if and how attitudes and behaviours towards natural resources have changed within the local communities. Generally, such a survey or evaluation should be done for all butterfly farming projects of this kind throughout the world to understand their environmental impacts. Morgan-Brown *et al.* (2010) examined a commercial butterfly farming project in Tanzania and found butterfly farmers were significantly more active in forest conservation than other community members because they "perceive a link between earnings from butterfly farming and forest conservation". It is possible that similarly positive results will be found in other sustainable butterfly farming projects, including the BBC.

A future aim of the BBC is to farm more species of Saturniidae, in addition to *Attacus atlas* (Fig. 1). Research is currently being carried out to increase the number of species farmed and the BBC is also planning to increase the number of farmers involved. To enlarge this business, it will be necessary to export pupae, for example, to butterfly exhibitions in Europe or North America. The BBC is awaiting an export license to do this. Finally, another challenge facing the centre is the production of pupae all year round. Because many of the butterfly farmers are engaged in rice cultivation, little or even no butterfly farming takes place during the harvest period.

I agree with Gordon *et al.* (2011) and Morgan-Brown *et al.* (2010) that initiatives like the BBC are appropriate to support rural communities in tropical developing countries to improve their living conditions without harming nature.

Acknowledgements

I would like to thank Ben Hayes from the Banteay Srey Butterfly Centre who provided me with information about the project and two of the photographs.

References

Gordon, I., Fungomeli, M. & Githitho, A. (2011) Butterfly farming as an NTFP: 19 years of Kipepeo: 1993-2012. *Paper presented to the Kenya Trees and Forests Conference, 27-29 February 2011, Brackenhurst, Kenya*. Http://www.outremer.total.com/os/content/NT00061F1A.pdf [accessed 24 May 2013].

Morgan-Brown, T., Jacobson, S.K., Wald, K. & Child, B. (2010) Quantitative assessment of a Tanzanian integrated conservation and development project involving butterfly farming. *Conservation Biology*, **24,** 563–572.

Sambhu, H. & van der Heyden, T. (2010) Sustainable butterfly farming in tropical developing countries as an opportunity for man and nature—the "Kawê Amazonica Butterfly Farm" project in Guyana as an example (Insecta: Lepidoptera). *Sociedad Hispano-Luso-Americana de Lepidopterología (SHILAP) Revista de lepidopterología*, **38,** 451–456.

van der Heyden, T. (2011) Local and effective: two projects of butterfly farming in Cambodia and Tanzania (Insecta: Lepidoptera). *Sociedad Hispano-Luso-Americana de Lepidopterología (SHILAP) Revista de lepidopterología*, **39,** 267–270.

About the Author

TORSTEN VAN DER HEYDEN—apart from being a teacher of Biology and Geography—is a German independent researcher specialising in Lepidoptera and Heteroptera. He has published papers on butterflies, moths and true bugs, focussing on their biology, ecology and distribution, as well as papers on several butterfly centres and farms and their impact on conservation and protection. The author is a member of various scientific associations and societies, e.g. a fellow of the Linnean Society of London and the Royal Entomological Society, and a member of the Spanish Real Sociedad Española de Historia Natural. He is a member of the editorial boards of *Atalanta—Zeitschrift der Deutschen Forschungszentrale für Schmetterlingswanderungen*, *BV news Publicaciones Científicas* and *Lepcey—The Journal of Tropical Asian Entomology*.

Short Communication

Records of freshwater fish species from Phnom Kulen National Park, northwestern Cambodia

Timo HARTMANN[1,*], Sebastian HÜLLEN[1], Peter GEISSLER[1], Markus HANDSCHUH[2], SENG Rattanak[3], Friedrich Wilhelm MIESEN[1] and Fabian HERDER[1]

[1] Zoologisches Forschungsmuseum Alexander Koenig, Adenauerallee 160, D-53113 Bonn, Germany.

[2] Angkor Centre for Conservation of Biodiversity (ACCB), Kbal Spean, Phnom Kulen National Park, P.O. Box 93 054, Siem Reap, Cambodia.

[3] General Department of Administration for Nature Conservation and Protection (GDANCP), Ministry of Environment, 48 Samdech Preah Sihanouk, Tonle Bassac, Chamkarmorn, Phnom Penh, Cambodia.

*Corresponding author. Email t.hartmann.zfmk@uni-bonn.de

Paper submitted 14 April 2013, revised manuscript accepted 15 June 2013.

Cambodia's fish fauna remains only partially explored, with most of the ichthyological literature dating back to the early 20th century when Cambodia was under French jurisdiction (e.g. Leclère, 1901; Durand, 1915; Chabanaud, 1926; Chevey, 1932). In the 1960s, François d'Aubenton undertook the first extensive scientific collection of fishes from all over Cambodia, which were later identified and revised by Kottelat (1985). The following years of civil unrest in Cambodia hampered further research. Besides a field guide on the *Fishes of the Cambodian Mekong* (Rainboth, 1996) and an atlas on the *Fishes of the Greater Mekong Ecosystem* (Rainboth *et al.*, 2012), recent work has focused mainly on the Tonle Sap lake and river system (Lim *et al.*, 1999; Motomura *et al.*, 2002).

Phnom Kulen National Park is a 37,375-hectare protected area in Banteay Srei, Svay Leu and Varin Districts, Siem Reap Province, northwestern Cambodia (Fig. 1). Hills dominate the park's topography, with most areas above 200 m elevation, but with few peaks above 450 m. Most of the park is covered by disturbed semi-evergreen forest that suffers from ongoing forest clearance and selective logging. The national park contains numerous small, often seasonal streams, which are not mapped.

Here we present recent records of freshwater fishes from three sites in the Phnom Kulen National Park: Site A—Phnom Kbal Spean, Bantey Srei District (13°40′45.5″N, 104°01′25.0″E); Site B—Phnom Kbal Spean, Bantey Srei District (13°41′13.0″N, 104°00′56.0″E); Site C—Phnom Kulen, Svay Leu District (13°31′40.3″N, 104°07′10.8″E). These records were a by-product of a wider herpetological survey. Sites A and B are upland tributaries of the Kbal Spean River in the Northwest of the national park. During the early rainy season, in May and June 2011, Site A was a shallow stream meandering between rocks, with a moderate to slow current and a sandy bottom (Fig. 2). Site B also had a sandy bottom and was up to one metre deep, with a moderate current (Fig. 3). Site C is a small tributary of the Phnom Kulen River, up to one metre deep, with a very slow current and rocky to sandy bottom (Fig. 4). At each site we captured fish opportunistically in all accessible micro-habitats.

Fish were caught using a dip net (50 cm x 70 cm; mesh size 3.2 mm). After capture, life pictures were taken, and then the fishes were anaesthetized with clove oil, following the methods of Oetinger (2003), and subsequently fixed in 95% ethanol. Specimens were deposited at the Zoologisches Forschungsmuseum

CITATION: Hartmann,T., Hüllen, S., Geissler, P., Handschuh, M., Seng R., Miesen, F.W. & Herder, F. (2013) Records of freshwater fish species from Phnom Kulen National Park, northwestern Cambodia. *Cambodian Journal of Natural History*, **2013,** 10–15.

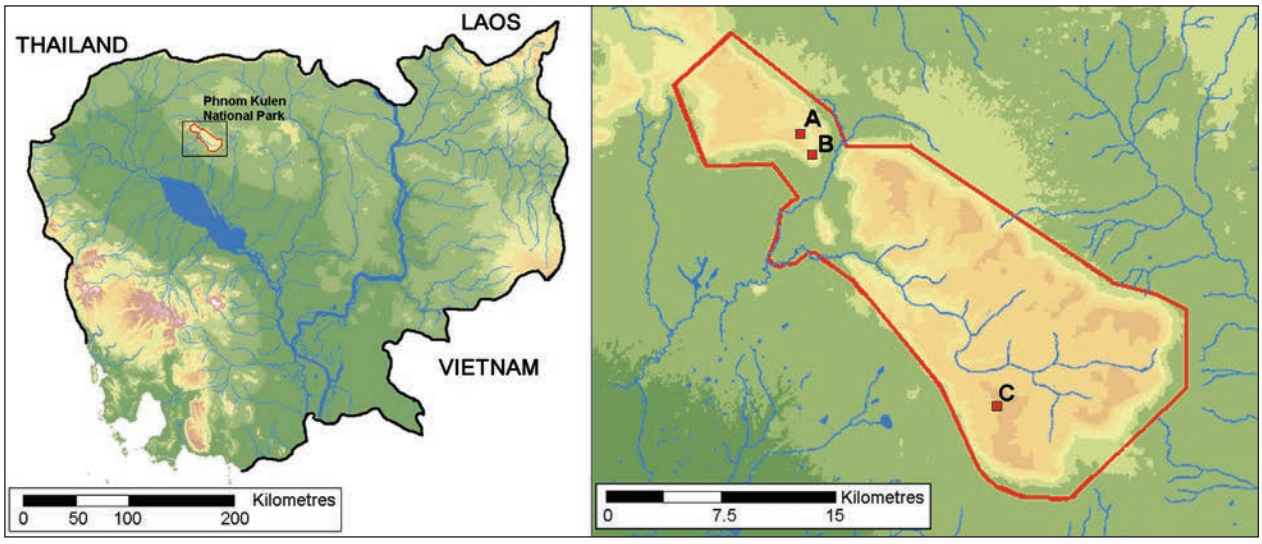


Fig. 1 Left: The Kingdom of Cambodia, showing the Phnom Kulen National Park, Siem Reap Province. Right: Phnom Kulen National Park, showing sampling localities and main water bodies. Maps designed using ArcGIS 9.3.

Fig. 2 Site A—Phnom Kbal Spean, Bantey Srei District, at 100 m a.s.l. (© T. Hartmann).

Fig. 3 Site B—Phnom Kbal Spean, Bantey Srei District, at 198 m a.s.l. (© P. Geissler).

Fig. 4 Site C—Phnom Kulen, Svay Leu District, at 315 m a.s.l. (© P. Geissler).

Fig. 5 Variation in *Puntius aurotaeniatus* (© P. Geissler).

Fig. 6 *Danio albolineatus* (© P. Geissler).

Fig. 7 *Rasbora paviana* (© P. Geissler).

Fig. 8 *Lepidocephalichthys hasselti* (© P. Geissler).

Fig. 9 *Nemacheilus pallidus* (© P. Geissler).

Fig. 10 *Dermogenys siamensis* (© P. Geissler).

Fig. 11 *Betta prima* (© P. Geissler).

Alexander Koenig (ZFMK), Bonn, Germany, and the Institute of Animal Physiology and Genetics (IAPG), Liběchov, Czech Republic. Each collection number refers to a single specimen.

Our collection contains 13 species, as listed below. We also give the known distribution in Cambodia for each of these species, assigning old locality names from literature to currently used names where possible, and provide further clarifying remarks on species where necessary.

Compared to the immense species richness found during ichthyological surveys elsewhere in Indochina (e.g. Freyhof *et al*., 2000; Motomura *et al*., 2006), our opportunistic and very short-term approach certainly cannot determine the full diversity of the freshwater fishes in Phnom Kulen National Park. An in-depth survey of the park's ichthyofauna would certainly lead to the finding of numerous additional species. By presenting this list of freshwater fish species, we hope to encourage future Cambodian ichthyologists to undertake further work on this understudied taxonomic group in the Phnom Kulen National Park and elsewhere in Cambodia.

Cyprinidae: Barbinae

***Puntius rhombeus* Kottelat, 2000**

Site A: ZFMK 44887–44888; Site B: ZFMK 44795–44807; 44869.

Mekong Basin (Kottelat, 2000).

***Puntius aurotaeniatus* (Tirant, 1885)**

Site A: ZFMK 44892–44894.

Mekong Basin and in coastal drainages of the Gulf of Thailand (Rainboth, 1996). Specimens vary remarkably in the pattern and distinctiveness of their vertical bars (Fig. 5 A, B).

Cyprinidae: Danioninae

***Danio albolineatus* (Blyth, 1860)**

Site A: ZFMK 44899–44901; Site B: ZFMK 44845–44862; Site C: ZFMK 44866–44868 (Fig. 6).

Mekong Basin (Rainboth, 1996; Kottelat, 2001); O Po Kampon, Boum Long (= probably Banlung), Snoc Trou, Toek Sap, Kirikum (= Kirirom), Sihanoukville, Bokéo (= Bokor) and Sré Umbel (= Sre Ambel) (Kottelat, 1985).

Remarks: Our specimens are in accordance to Fang & Kottelat's (2000) observations on *Danio albolineatus* in having a lateral line and 13 to 14 soft anal fin rays.

Cyprinidae: Rasborinae

***Rasbora paviana* Tirant, 1885**

Site A: ZFMK 44906–44916; Site B: ZFMK 44809–44826; 44836–44844 (Fig. 7).

Mekong Basin (Rainboth, 1996, Kottelat, 1998), including Tonle Sap River and Tonle Sap Lake (Lim *et al*., 1999, Motomura *et al*., 2002).

Cobitidae

***Acanthopsoides hapalias* Siebert, 1991**

Site A: IAPG A5451, ZFMK 45232.

Lower Mekong (Rainboth, 1996; Doi, 1997; Kottelat, 1998; Kottelat, 2001).

***Lepidocephalichthys hasselti* (Valenciennes, 1846)**

Site A: IAPG A5449, ZFMK 45233 (Fig. 8).

Mekong Basin (Kottelat *et al*., 1993; Rainboth, 1996; Kottelat, 2001).

Balitoridae

***Nemacheilus pallidus* Kottelat, 1990**

Site A: IAPG A5450, ZFMK 45234–45235 (Fig. 9).

Mekong Basin (Kottelat, 1990; Rainboth, 1996). Tonle Sap Lake (Motomura *et al*., 2002).

Clariidae

***Clarias spec. aff. batrachus* 'Indochina' Linnaeus, 1758**

***Clarias aff. batrachus* 'Indochina' (Ng & Kottelat, 2008)**

Site B: ZFMK 44794.

Ng & Kottelat (2008) designated a neotype for *Clarias batrachus* (Linnaeus, 1758), a species previously thought to be widely distributed throughout Southeast Asia. It is now understood *Clarias batrachus* is restricted to Java and the Indochinese form represents a distinct species, *Clarias aff. batrachus* 'Indochina', but the whole complex requires further taxonomic research. ZFMK 44794 has 77 soft dorsal fin rays and 53 soft anal fin rays; the first pectoral spine is thickened and the inner edge is serrated. The dorsolateral colouration of the preserved specimen is brown,

Fig. 12 Juvenile of *Trichopsis vittata* (© P. Geissler).

without white dots. The ventral side is whitish to brown in colour; fins and head are darker.

Zenarchopteridae

***Dermogenys siamensis* Fowler, 1934**

Site A: ZFMK 44918–44922; Site C: ZFMK 44886 (Fig. 10).

Mekong Basin (Kottelat, 2001; Meisner, 2001).

Channidae

***Channa gachua* (Hamilton, 1822)**

Site A: ZFMK 44917; Site B: ZFMK 44827–44835; 44863–44865.

Mekong Basin (Kottelat, 1998; Kottelat, 2001).

Channa striata (Bloch, 1793)

Site A: ZFMK 44897–44905; Site C: ZFMK 44870–44873.

Mekong Basin (Kottelat, 1998), including Tonle Sap River and Lake (Nao & Sina, 1998; Lim *et al.*, 1999; Motomura *et al.*, 2002), Ratanakiri, Boum Long (= probably Banlung), Kampong Chnang, Ream, Boeng Kbal Damrey, Sihanoukville and Angkor (= Siem Reap) (Kottelat, 1985).

Osphronemidae

***Betta prima* Kottelat, 1994**

Site C: ZFMK 44874–44885 (Fig. 11).

Mekong Basin (Kottelat, 1994, 2001) and coastal drainages in Cambodia and Vietnam (Allen, 2012).

***Trichopsis vittata* (Cuvier, 1831)**

Site A: ZFMK 44895–44896 (both juveniles) (Fig. 12).

Mekong Basin (Rainboth, 1996); Kirirom, Toek Sap, Boeng Kbal Damrey, Stung Sen and O Po Kampon (Kottelat, 1985).

Acknowledgements

We are grateful to His Excellency Chay Samith, General Director of the General Department of Administration for Nature Conservation and Protection (GDANCP), Ministry of Environment of the Royal Government of Cambodia, for kindly issuing the relevant permits. We thank Sokkheng Novin, Director of National Park and Wildlife Sanctuary Department of GDANCP, and Hong Daravuth, Director of Phnom Kulen National Park and Director of Angkor Cluster Protected Areas of GDANCP, for their generous support. Special thanks to Neang Thy (GDANCP) for facilitating the permit process. We are grateful to Jörg Bohlen and Tan Heok Hui for providing assistance with species identification. We thank Dr Hiroyuki Motomura (Kagoshima University Museum, Japan) for providing literature, and Lara Mielke and Alistair Mould for assistance during the field surveys. Field work was supported by the Alexander Koenig Stiftung. The manuscript benefited from comments and suggestions by Dr. Maurice Kottelat, Dr. Walter J. Rainboth and an anonymous referee.

References

Allen, D. (2012) *Betta prima.* In *IUCN Red List of Threatened Species. Version 2012.1*. Http://www.iucnredlist.org/details/181251/0 [accessed 9 October 2012].

Chabanaud, P. (1926) Inventaire de la faune ichthyologie de l'Indochine: première liste. *Bulletin économique de l'Indochine*, **169,** 561–581.

Chevey, P. (1932) Inventaire de la fauna ichthyologique de l'Indochine. *Notes de l'Institut Océanographique de l'Indochine*, **19,** 1–31.

Doi, A. (1997) A review of taxonomic studies of cypriniform fishes in Southeast Asia. *Japanese Journal of Ichthyology*, **44,** 1–33.

Durand, P. (1915) *Industrie de la Pêche Dans la Région des Lacs au Cambodge.* Saigon (Ho Chi Minh City), Vietnam.

Fang, F. & Kottelat, M. (2000) *Danio roseus*, a new species from the Mekong basin in northeastern Thailand and northwestern Laos (Teleostei: Cyprinidae). *Ichthyological Exploration of Freshwaters*, **11,** 149–154.

Freyhof, J., Serov, D.V. & Nguyen T.N. (2000) A preliminary checklist of the freshwater fishes of the River Dong Nai, South Vietnam. *Bonner zoologische Beiträge*, **49,** 93–99.

Kottelat, M. (1985) Fresh-water fishes of Kampuchea. *Hydrobiologia*, **121,** 249–279.

Kottelat, M. (1990) *Indochinese Nemacheilines: A Revision of Nemacheiline Loaches (Pisces: Cypriniformes) of Thailand, Burma, Laos, Cambodia and Southern Viet Nam*. Pfeil-Verlag, Munich, Germany.

Kottelat, M. (1994) Diagnoses of two new species of fighting fishes from Thailand and Cambodia (Teleostei: Belontiidae). *Ichthyological Exploration of Freshwaters*, **5,** 297–304.

Kottelat, M. (1998) Fishes of the Nam Theun and Xe Bangfai basins, Laos, with diagnoses of twenty-two new species (Teleostei: Cyprinidae, Balitoridae, Cobitidae, Coiidae and Odontobutidae). *Ichthyological Exploration of Freshwaters*, **9,** 1–128.

Kottelat M. (2000) Diagnoses of a new genus and 64 new species of fishes from Laos (Teleostei: Cyprinidae, Balitoridae, Bagridae, Syngnathidae, Chaudhuriidae and Tetraodontidae). *Journal of South Asian Natural History*, **5,** 37–82.

Kottelat, M. (2001) *Fishes of Laos.* WHT Publications Ltd., Colombo, Sri Lanka.

Kottelat, M., Whitten, A.J., Kartikasari, S.N. & Wirjoatmodjo, S. (1993) *Freshwater Fishes of Western Indonesia and Sulawesi / Ikan Air Tawar Indonesia Bagian Barat dan Sulawesi*. Periplus Editions, Hong Kong, China.

Leclère, A. (1901) La pêche dans le Grand Lac au Cambodge. *Bulletin Économique de l'Indochine*, **38,** 675–679.

Lim, P., Lek S., Touch S.T., Mao S.-O. & Chhouk B. (1999) Diversity and spatial distribution of freshwater fish in Great Lake and Tonle Sap River (Cambodia, Southeast Asia). *Aquatic Living Resources*, **12,** 379–386.

Meisner, A.D. (2001) Phylogenetic systematics of the viviparous halfbeak genera *Dermogenys* and *Nomorhamphus* (Teleostei: Hemiramphidae: Zenarchopterinae). *Zoological Journal of the Linnean Society*, **133,** 199–283.

Motomura, H., Tsukawaki, S. & Kamiya, T. (2002) A preliminary survey of the fishes of Lake Tonle Sap near Siem Reap, Cambodia. *Bulletin of the National Museum of Nature and Science*, **28,** 233–246.

Nao T. & Sina, L. (1998) Review of the fisheries and aquaculture sector in Cambodia. In *Natural Resources-based Development Strategy for the Tonle Sap Area, Cambodia. Final Report, Volume 2*. (ed. Cambodian National Mekong Committee/ Nedeco), pp. 35–36. Mekong River Commission and United Nations Development Programme, Phnom Penh, Cambodia.

Ng H.H. & Kottelat, M. (2008) The identity of *Clarias batrachus* (Linnaeus, 1758), with the designation of a neotype (Teleostei: Clariidae). *Zoological Journal of the Linnean Society*, **153,** 725–732.

Oetinger, F.C. (2003) *Betäubung von Regenbogenforellen (*Oncorhynchus mykiss*) mit Nelkenöl und BHA—Stressbelastung und Produktqualität*. LMU München—Tierärztliche Fakultät, Munich, Germany.

Rainboth, W.J. (1996) *Fishes of the Cambodian Mekong: FAO Species Identification Field Guide for Fishery Purposes.* Food and Agriculture Organisation, Rome, Italy.

Rainboth, W.J., Vidthayanon, C. & Mai D.Y. (2012) *Fishes of the Greater Mekong Ecosystem with Species List and Photographic Atlas.* Miscellaneous Publications, Museum of Zoology, University of Michigan. Ann Arbor, USA.

Cambodian bat echolocation: a first description of assemblage call parameters and assessment of their utility for species identification

PHAUK Sophany[1,*], PHEN Sarith[1] and Neil M. FUREY[1,2]

[1] Centre for Conservation Biodiversity, Room 415, Department of Biology, Faculty of Science, Royal University of Phnom Penh, Confederation of Russia Boulevard, Phnom Penh, Cambodia.

[2] Fauna & Flora International, Cambodia Programme, 19, Street 360, BKK 1, Chamkarmorn, Phnom Penh, Cambodia.

*Corresponding author. Email phauk.sophany@rupp.edu.kh

Paper submitted 3 May 2013, revised manuscript accepted 15 June 2013.

មូលន័យសង្ខេប

ពពួកសត្វប្រចៀវបង្កបានជាសមាសភាគសំខាន់នៃថនិកសត្វចំរុះនៅតំបន់អាស៊ីអាគ្នេយ៍ និងជាសូចនាករមានសក្តានុពលនៃផលប៉ះពាល់ជីវៈចម្រុះទូលំទូលាយ ដែលបណ្តាលមកពីការបាត់បង់ទីជម្រក និងការប្រែប្រួលអាកាសធាតុ។ ការអភិវឌ្ឍវិធីសាស្ត្រ ដែលមានប្រសិទ្ធភាពសម្រាប់ការធ្វើបញ្ជីសារពើភណ្ឌនិងការសង្កេតតាមដានប្រចៀវនៅអាស៊ីអាគ្នេយ៍ គឺមានសារៈសំខាន់ណាស់ប្រសិនបើតម្រូវការអភិរក្សនឹងត្រូវបានកំណត់ និងសក្តានុពលជាជីវៈសូចនាករនឹងត្រូវបានដឹង។ ដើម្បីទទួលបានលទ្ធផលនេះ យើងផ្តល់ជូននូវការពណ៌នាដំបូងពីសម្លេងដៅកន្លែងតាមរយៈពេល (Time-expanded echolocation calls) ពីសំណុំប្រចៀវនៅកម្ពុជា ដែលរួមមាន១៧ប្រភេទពីឧទ្យានជាតិភ្នំគូលែន។ យើងនឹងវាយតម្លៃភាពគួរឱ្យជឿបាននៃវិធីសាស្ត្រកំណត់សម្លេងសម្រាប់រកអត្តសញ្ញាណប្រចៀវ១៣ប្រភេទនៃប្រភេទប្រចៀវទាំងនោះ។ ការវិភាគមុខងារខុសៗគ្នានៃ៤២៨សម្លេងដៅកន្លែង (Echolocation calls) ដែលត្រូវបានបញ្ចេញដោយប្រចៀវ១៣ប្រភេទ បានបង្ហាញថាការកំណត់អត្តសញ្ញាណដោយសម្លេងគឺគួរឱ្យជឿជាក់បានក្នុងកាលៈទេសៈភាគច្រើនតាមរយៈការចាត់ថ្នាក់យ៉ាងត្រឹមត្រូវលើ៨៥%នៃសម្លេងដៅកន្លែង។ គំរូល្អបំផុតទាំងនោះគឺអាស្រ័យលើប៉ារ៉ាម៉ែតសម្លេងពីរនិងមានសារៈសំខាន់ណាស់ក្នុងន័យស្ថិតិ។ ការសិក្សាបន្តលើការធ្វើឯកសារជាភូមិសាស្ត្រនិងប្រភពផ្សេងទៀតនៃការប្រែប្រួលសម្លេងដៅកន្លែងទាំងនោះ ដែលត្រូវបានបញ្ចេញដោយសត្វប្រចៀវនៃប្រទេសកម្ពុជា គឺចាំបាច់សម្រាប់ជួយសម្រួលដល់ការអភិវឌ្ឍរបៀបប្រមូលគំរូតាងសម្លេង ដែលជាឧបករណ៍សម្រាប់ការអភិរក្សប្រចៀវទាំងនោះ។

Abstract

Bats form a major component of mammal diversity in Southeast Asia and are potential indicators of wider biodiversity impacts resulting from habitat loss and climate change. The development of effective methods for inventorying and monitoring Southeast Asian bats is critical if their conservation needs are to be determined and their potential as bioindicators realised. To this end, we provide the first description of time-expanded echolocation calls from a Cambodian bat assemblage comprising 17 species from Phnom Kulen National Park. We further evaluate the reliability of acoustic methods for identifying 13 of these taxa. Discriminant function analysis of 428 echolocation calls produced by the 13 bat species indicated that acoustic identification was feasible in most instances by correctly classifying 85% of calls. The best models relied on two call parameters and were statistically significant. Further studies documenting geographical and other sources of variation in the echolocation calls produced by Cambodia's bat fauna are necessary to facilitate development of acoustic sampling as a tool for their conservation.

CITATION: Phauk S., Phen S. & Furey, N.M. (2013) Cambodian bat echolocation: a first description of assemblage call parameters and assessment of their utility for species identification. *Cambodian Journal of Natural History*, **2013,** 16–26.

Keywords
Acoustic sampling, bat species identification, Phnom Kulen National Park.

Introduction

Bats form a major component of the Southeast Asian mammal fauna, constituting approximately 30% of the region's mammal species and as many as half of all mammal species in the tropical rainforest ecoregions (Kingston, 2010). This group provides economically significant ecosystem services in plant pollination, seed dispersal and arthropod suppression (Kunz *et al*., 2011). Bats also possess a variety of traits that support their use as bioindicators, reflecting wider biodiversity impacts from habitat loss and climate change (Jones *et al*., 2009). Like much of the Southeast Asian fauna, however, bats are severely threatened, with only 18% of species populations in the region presently considered stable by the International Union for the Conservation of Nature (IUCN) (Kingston, in press).

The global success, species richness and ability of bats to exploit diverse niches are largely due to their capacity for powered flight and echolocation (Jones & Teeling, 2006). Echolocation entails the use of reflected sound waves whereby bats use the difference between the sounds they produce and the returning echoes they hear to collect information about their surrounding environment. This acoustic process is largely ultrasonic and allows bats to navigate complex three-dimensional spaces in complete darkness. Echolocation tasks exert a strong selective pressure on signal design, favouring species-specific signal types linked to ecological conditions (Schnitzler *et al*., 2003). As a consequence, once adequate reference recordings have been obtained from bats of known identity, these can be used to identify species exclusively by their calls (Brigham *et al*., 2004).

The development of effective methods for inventorying and monitoring bat populations is essential if their conservation needs are to be determined and their potential as bioindicators realised. Because traditional sampling methods for bats—mist nets and harp traps—are rarely employed more than a few metres above ground level in surveys in Asia, they typically fail to capture species that habitually fly in open areas and/or above the forest canopy, even in the most intensive studies. Detecting bats from their calls is widely viewed as a means of overcoming these limitations (Brigham *et al*., 2004). Recent studies indicate that acoustic identification of Southeast Asian bat species is feasible and that acoustic methods are indispensable for maximising sampling completeness in field surveys (Furey *et al*., 2009; Hughes *et al*., 2010, 2011), an essential requirement for effective conservation planning.

Despite this, acoustic sampling has been rarely employed in continental Southeast Asia to date and detailed descriptions are lacking for the echolocation calls of most bat species in the region. We address this by providing the first description of time-expanded echolocation calls for an assemblage of Cambodian bats and evaluate the reliability of acoustic methods for species identification. The study was undertaken at Phnom Kulen National Park as part of a series of ongoing bat surveys that primarily rely on harp traps and mist nets in this area. As Cambodia's bats are poorly known relative to neighbouring countries (Kingsada *et al*., 2011; Ith *et al*., 2011a), our overall purpose was to provide information to assist future bat research and conservation efforts in the country.

Methods

Study site

Phnom Kulen National Park is in Siem Reap Province, Northwest Cambodia (Fig. 1). The region has a tropical monsoon climate with a mean annual rainfall of 2,050 mm and an average annual temperature of 24°C (Hou *et al*., 2004). The national park covers an area of 37,350 hectares and encompasses lowland areas and sandstone hills that culminate in two plateaus reaching 450 m above sea level (a.s.l.). Habitats include evergreen and semi-evergreen forests on hillsides and plateaus, while lowland areas were originally dominated by dry dipterocarp forest, of which only small, degraded areas now remain (Neou *et al*., 2008).

Capture methods and species identification

Thirty-two nights of sampling were undertaken in semi-evergreen forest of variable condition within the Kbal Spean area (13°36′22′′N, 104°00′96′′E) of the national park between April and July 2010. Live-trapping was carried out from 18:00–21:00 h each night using a four-bank harp trap (capture surface: 2.4 m^2) and 70 denier mist nets (capture surface: 30 m^2), giving a total sampling effort of 234 m^2 harp-trap-

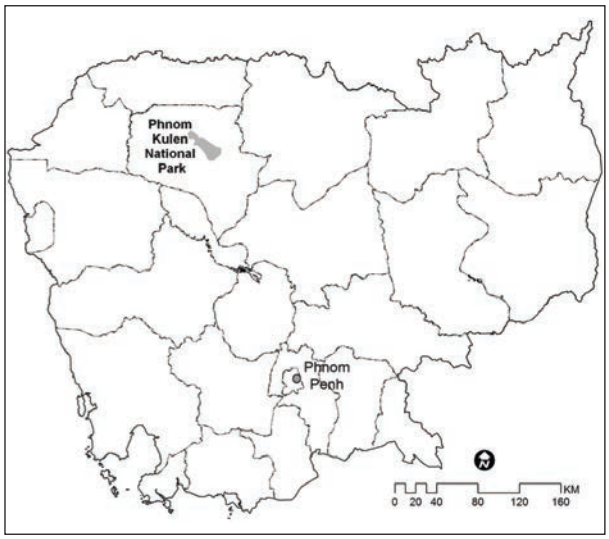


Fig. 1 Location of Phnom Kulen National Park in Cambodia.

hours and 2,889 m^2 mist-net-hours. A single night of sampling was also undertaken from 18:00–19:30 h using a harp trap and mist net (capture surface: 15 m^2) at a cave entrance in a forest area (13°67′74″N, 104°02′01″E, entrance altitude 183 m a.s.l.) in June 2010. Sampling was avoided on consecutive nights at the same location.

All bats captured were measured, photographed and identified in the field using Borissenko & Kruskop (2003) and Francis (2008). Where necessary to confirm species identifications, a minimum number of non-reproductively active individuals were retained as voucher specimens. All other bats were released as near as possible to their capture site. Skulls and bacula (where taxonomically important) of voucher specimens were subsequently examined and all specimens were deposited at the Centre for Biodiversity Conservation Zoological Collection at the Royal University of Phnom Penh. A full list of specimen material examined is given in Annex 1. Nomenclature follows Simmons (2005), with some modifications (Soisook *et al*., 2008).

Acoustic methods and call measurement

Time-expanded (x10) recordings of signals produced by bats were made using a D240x ultrasound detector with a sampling frequency of 307 kHz (Pettersson Electronik AB, Sweden) and stored digitally on an Edirol R-09HR recorder (Roland, USA) using a sampling rate of 44.1 kHz, with 16 bits/sample. Recordings for rhinolophid and hipposiderid bats were obtained from motionless bats held in the hand, whereas recordings for all other species were obtained in flight either from hand-released bats, a flight cage (measuring 10 x 2 x 1.5 m) or a tethered zip-line (Sweczak, 2000). Because habitat structure induces variation in echolocation calls (Schnitzler *et al*., 2003), we acknowledge that this means our sample is biased towards call types that are characteristic of more cluttered environments (i.e. broader bandwidths and shorter durations).

Signal analysis was undertaken using BatSound (vers. 3.31, Pettersson Electronik AB, Sweden). To avoid pseudo-replication, one call per bat was selected for description of call parameters and subsequent analysis. Because two species (*Megaderma spasma* and *Myotis annectans*) were represented by only two individuals, however, two calls were analysed for each of these individuals. Additionally, as only one individual was captured of each of four species (*Hipposideros cineraceus, Kerivoula hardwickii, Tylonycteris pachypus* and *Miniopterus pusillus*), four calls were analysed for each of these individuals.

For each call, five parameters were measured: call duration (duration of a single pulse), inter-pulse interval (IPI, time from the start of one call to the onset of the next), start frequency (frequency value at the start of the call), end frequency (frequency value at the end of the call) and peak frequency (FmaxE, frequency of maximum energy for the whole call). Call duration and IPI (ms) were obtained from oscillograms, FmaxE (kHz) from power spectra, whereas the start frequency (kHz) and end frequency (kHz) were measured from spectrograms using a 512-size Fast Fourier Transformation and a Hanning window. An additional parameter, duty cycle (the amount of time a bat spends calling relative to the amount of time it is silent), was calculated by dividing the call duration by the inter-pulse interval and multiplying by 100 (for a percentage). All measurements were taken from the call harmonic containing the greatest energy. The position of the harmonic containing the most energy and number of harmonics present in each call were also noted for the purposes of describing the echolocation calls produced by each species.

Statistical procedures

To test the efficacy of acoustic data in correctly identifying bat species, a discriminant function analysis was performed. Species represented by a single individual were excluded from the analysis (*H. cineraceus, K. hardwickii, T. pachypus* and *M. pusillus*).

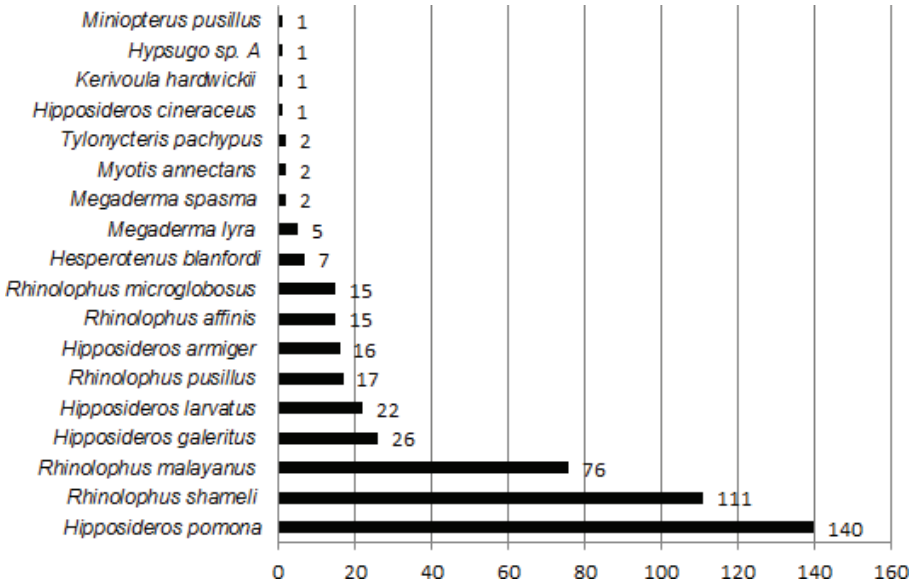


Fig. 2 Relative abundance of echolocating bat species captured in Phnom Kulen National Park, Cambodia. Figures show the total number of individuals captured.

Because examination of covariance matrices using Box's *M* test indicated that these were not homogenous ($F = 13.653$, $P < 0.001$), a quadratic discriminant function analysis was applied. Cross-validation was employed in the analysis. Multivariate analysis of variance (MANOVA) was conducted to examine the significance of the discriminant function analysis models and Wilk's λ values were used to determine the discrimination power of each variable. All tests were performed using MINITAB (vers. 15.0), with the exception of Box's *M* test which was performed using SPSS Statistics (vers. 16.0). In all tests, values of $P < 0.05$ were considered significant.

Results

Species captured

Over the course of the fieldwork, 460 individuals representing 18 echolocating bat species were captured in five families (Megadermatidae: two species; Rhinolophidae: five species; Hipposideridae: five species; Vespertilionidae: five species; Miniopteridae: one species). Relative species abundance was highly uneven with three species representing 71.1% of all captures: *Hipposideros pomona* (140 individuals, 30.4% of captures), *Rhinolophus shameli* (111, 24.1%) and *R. malayanus* (76, 16.5%) (Fig. 2).

One hundred and fifteen individuals (25%) were captured in mist nets, and 345 (75%) were caught in harp traps. Of the 18 echolocating bat species encountered, eight were captured in mist nets and harp traps (*Rhinolophus affinis, R. malayanus, R. pusillus, R. shameli, R. microglobosus, Hipposideros galeritus, H. larvatus* and *H. pomona*), five in mist nets only (*Megaderma lyra, M. spasma, Hipposideros armiger, Hesperoptenus blanfordi* and *Myotis annectans*) and five exclusively in harp traps (*Hipposideros cineraceus, Hypsugo* sp. A., *T. pachypus, K. hardwickii* and *Miniopterus pusillus*).

Description of echolocation calls

Time-expanded recordings of 444 echolocation calls were analysed for all but one of the 18 species captured during the fieldwork. Recordings were not obtained for a single individual designated as *Hypsugo* sp. A, for which the correct specific name has yet to be determined.

The five rhinolophid species in our sample produced calls characterised by a long constant frequency (CF) component which was preceded and terminated by a brief frequency-modulated (FM) component (Table 1, Fig. 3a). The second call harmonic invariably contained the most energy and all five species operated at high duty cycles, with mean values ranging from 73.6 ± 13.9% in *R. malayanus* to 84.2 ± 3% in *R. pusillus*. Peak frequency (FmaxE) values ranged from 69.5 ± 1.7 kHz in *R. shameli* to 112.2 ± 1.3 kHz in *R.*

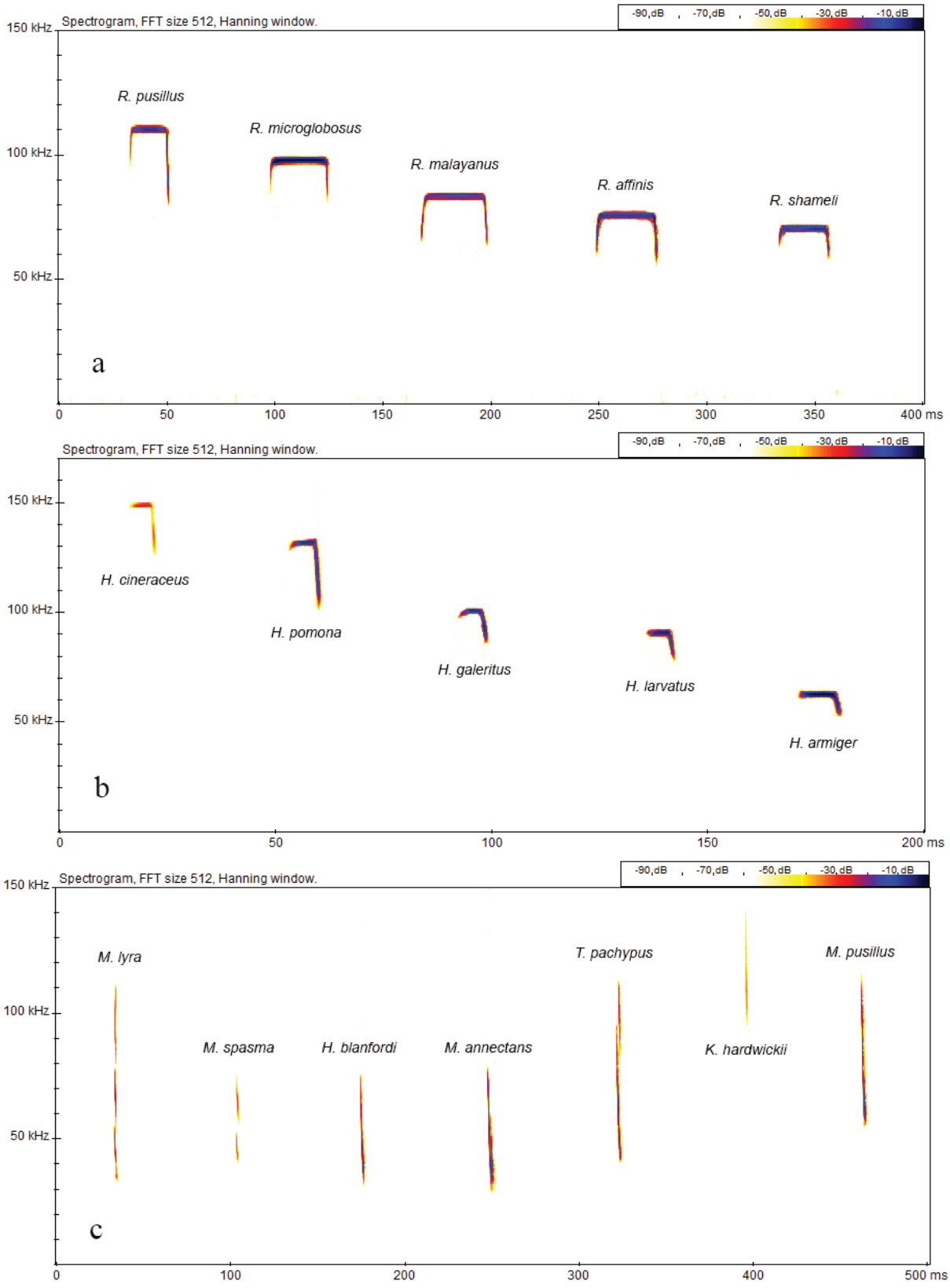


Fig. 3 Echolocation calls of 17 bat species in Phnom Kulen National Park: (a) Rhinolophidae; (b) Hipposideridae; (c) Megadermatidae, Vespertilionidae and Miniopteridae. (Note differences in *x*-axis values between figures).

Table 1 Echolocation call parameters of five rhinolophid and five hipposiderid bat species at Phnom Kulen National Park, Cambodia.

Species	Call Structure	Start Frequency (kHz)	End Frequency (kHz)	Frequency of Maximum Energy (kHz)	Call Duration (ms)	Inter-Pulse Interval (ms)	Duty Cycle (%)	*n*
RHINOLOPHIDAE								
Rhinolophus affinis	FM/CF/FM	70.5 ± 3.1 (66–76)	61.5 ± 2 (60–66)	77.1 ± 0.5 (76.5–78.3)	26.6 ± 5.9 (17.9–36.7)	36.9 ± 14 (20.8–63)	76.2 ± 12.5 (54.1–88.5)	15
Rhinolophus malayanus	FM/CF/FM	76.1 ± 3.9 (71–82)	78 ± 4.8 (62–83)	83 ± 0.7 (81.1–84.7)	27.1 ± 8.8 (14.8–61.8)	40.9 ± 24.4 (19.1–131.4)	73.6 ± 13.9 (26.2–86.4)	61
Rhinolophus pusillus	FM/CF/FM	101.4 ± 4.6 (95–111)	96.8 ± 3.2 (95–105)	112.2 ± 1.3 (108.9–114.1)	22.8 ± 5.3 (14.7–34.1)	27 ± 5.5 (18.2–38.6)	84.2 ± 3 (78.6–89.2)	17
Rhinolophus shameli	FM/CF/FM	64 ± 3.1 (52–69)	61 ± 1.9 (59–69)	69.5 ± 1.7 (65.4–71.8)	31.9 ± 6.6 (15.5–46.4)	45.3 ± 22.1 (18.2–171.7)	76.8 ± 15.1 (22.8–90.9)	105
Rhinolophus microglobosus	FM/CF/FM	94 ± 2.2 (90–97)	93.9 ± 2.1 (90–96)	98.3 ± 0.6 (96.4–98.9)	26.2 ± 7.1 (14.4–39)	34.8 ± 8.5 (21.7–49.4)	74.7 ± 3.4 (66.4–80.1)	15
HIPPOSIDERIDAE								
Hipposideros armiger	CF/FM	62.7 ± 0.7 (62–64)	55.7 ± 1.4 (53–58)	63.9 ± 0.8 (61.4–65)	10.4 ± 1.7 (8–14.4)	41.3 ± 14.8 (26.8–80.1)	26.7 ± 5.5 (15.7–35.8)	16
*Hipposideros cineraceus**	CF/FM	149 ± 0.8 (148–150)	129.3 ± 1.3 (128–131)	150 ± 0.8 (149.2–150.6)	5.5 ± 0.4 (5–5.9)	15.6 ± 2.8 (12.1–18.7)	36.2 ± 4.8 (31.6–41.3)	4
Hipposideros galeritus	CF/FM	99.5 ± 1.4 (97–102)	90.1 ± 1.5 (87–92)	100.7 ± 1 (98.5–102.5)	5.9 ± 1 (3.9–8.7)	23.3 ± 6 (10.9–37.8)	26.5 ± 7.4 (17.8–53.2)	23
Hipposideros larvatus	CF/FM	91.5 ± 0.8 (90–93)	81.5 ± 1.5 (80–87)	92.3 ± 0.8 (90.8–93.5)	6.6 ± 1.2 (5.1–9)	22.6 ± 9.2 (15.3–52.8)	31.5 ± 7.9 (13.6–46.2)	21
Hipposideros pomona	CF/FM	134 ± 1.8 (128–139)	111.3 ± 2.9 (105–111.3)	134.8 ± 1.8 (128.3–139.7)	5.1 ± 0.7 (3.7–7.5)	12.2 ± 7.6 (7.1–93.6)	44.9 ± 7.5 (7.1–60)	135

* One call per individual bat was analysed except for *H. cineraceus*, for which four calls from the same individual were analysed. CF = constant frequency; FM = frequency-modulated. Values are given as mean ± SD (min–max).

pusillus, whereas call duration ranged from 22.8 ± 5.3 ms in *R. pusillus* to 31.9 ± 6.6 ms in *R. shameli*. FmaxE values did not overlap between species, indicating this call parameter will be helpful for the field identification of all of the rhinolophid species in our sample from Phnom Kulen.

The five hipposiderids that were analysed produced calls beginning with a relatively long and almost CF component which terminated in a comparatively brief and downward FM component (Table 1, Fig. 3b). This structure facilitates unequivocal separation of hipposiderid calls from all other bat families in Phnom Kulen. All species produced calls with the greatest energy in the second harmonic and operated at lower duty cycles (mean values ranging from 26.5 ± 7.4% in *Hipposideros galeritus* to 44.9 ± 7.5% in *H. pomona*) than rhinolophids due to their shorter and non-overlapping call durations. Mean values for the latter ranged from 5.1 ± 0.7 ms in *H. pomona* to 10.4 ± 1.7 ms in *H. armiger*, while mean FmaxE values ranged from 63.9 ± 0.8 kHz in *H. armiger* to 150 ± 0.8 kHz in *H. cineraceus*. Like the rhinolophids, FmaxE values did not overlap between species indicating this call parameter will also aid field identification of all hipposiderids in our sample from Phnom Kulen.

The two megadermatids in our sample produced multi-harmonic FM calls (Table 2, Fig. 3c). *Megaderma lyra* emitted signals with a mean FmaxE of 64.7 ± 2.6 kHz, a mean call duration of 2.4 ± 0.8 ms and the third harmonic contained the greatest energy. *Megaderma spasma* produced calls of similar frequency with a mean FmaxE of 65.4 ± 3.1 kHz (third harmonic), but mean call durations were somewhat shorter at 1.1 ± 0.2 ms and the first harmonic appeared to be suppressed.

The four vespertilionids that were analysed produced steep, downward FM calls dominated by the fundamental harmonic (Table 2, Fig. 3c). All four species produced relatively brief calls—mean durations ranging from 0.5 ± 01 ms in *K. hardwickii* to 2.4 ± 0.3 ms in *Myotis annectans*. Mean duty cycles were generally higher than those of megadermatids

Table 2 Echolocation call parameters of two megadermatid, four vespertilionid and one miniopterid bat species at Phnom Kulen National Park, Cambodia.

Species	Call Structure	Start Frequency (kHz)	End Frequency (kHz)	Frequency of Maximum Energy (kHz)	Call Duration (ms)	Inter-Pulse Interval (ms)	Duty Cycle (%)	*n*
MEGADERMATIDAE								
Megaderma lyra	FM	72.4 ± 4.1 (66–76)	57 ± 4.1 (53–62)	64.7 ± 2.6 (61.6–67.5)	2.4 ± 0.8 (1.4–3.2)	93.6 ± 38.3 (38.9–134.1)	2.7 ± 0.7 (1.8–3.6)	5
*Megaderma spasma**	FM	70.8 ± 4.3 (65–74)	62.5 ± 2.1 (60–65)	65.4 ± 3.1 (61.6–69.3)	1.1 ± 0.2 (1–1.3)	68.3 ± 41.9 (25.9–104.4)	2.3 ± 1.5 (1–3.9)	4
VESPERTILIONIDAE								
Hesperoptenus blanfordi	FM	58 ± 10.8 (45–72)	39.3 ± 7 (35–54)	46.5 ± 6.6 (41.9–61.1)	1.5 ± 0.4 (1.2–2)	40 ± 25.6 (14.3–92.3)	4.7 ± 1.9 (2–7.7)	7
*Myotis annectans**	FM	50.8 ± 0.5 (50–51)	38 ± 1.2 (37–39)	39.8 ± 0.7 (39.2–40.8)	2.4 ± 0.3 (2.1–2.8)	54.4 ± 21.1 (31.1–80)	5.2 ± 2.8 (2.9–9)	4
*Tylonycteris pachypus***	FM	68.5 ± 3 (65–71)	46.3 ± 1.5 (45–48)	64.7 ± 1.2 (63.9–66.5)	1.8 ± 0.3 (1.5–2.1)	25 ± 12.6 (14.1–39.5)	8.7 ± 4.8 (3.8–14.1)	4
*Kerivoula hardwickii***	FM	114.8 ± 10.9 (104–126)	101.3 ± 1.5 (99–102)	103.3 ± 2.2 (100.7–106)	0.5 ± 0.1 (0.4–0.6)	15.9 ± 2 (13.8–18)	3 ± 0.4 (2.7–3.5)	4
MINIOPTERIDAE								
*Miniopterus pusillus***	FM	73.5 ± 8.6 (63–84)	59.8 ± 0.5 (58–60)	60.8 ± 0.6 (60.2–61.6)	3.6 ± 0.3 (3.4–3.9)	48 ± 7 (39.7–54.3)	7.7 ± 1.2 (6.3–8.7)	4

One call per bat was analysed except for species marked * for which two calls per individual were measured, and ** for which four calls per individual were measured. CF = constant frequency; FM = frequency-modulated. Values are given as mean ± SD (min–max).

Table 3 Cross-validated classification matrix for species emitting CF calls (genera *Hipposideros* and *Rhinolophus*).

	True Groups								
Classified as	*Hipposideros armiger*	*Hipposideros galeritus*	*Hipposideros larvatus*	*Hipposideros pomona*	*Rhinolophus affinis*	*Rhinolophus malayanus*	*Rhinolophus pusillus*	*Rhinolophus shameli*	*Rhinolophus microglobosus*
Hipposideros armiger	16	0	0	0	0	0	0	0	0
Hipposideros galeritus	0	23	0	0	0	0	0	0	0
Hipposideros larvatus	0	0	21	0	0	0	0	0	0
Hipposideros pomona	0	0	0	135	0	0	0	0	0
Rhinolophus affinis	0	0	0	0	15	0	0	0	0
Rhinolophus malayanus	0	0	0	0	0	61	0	0	0
Rhinolophus pusillus	0	0	0	0	0	0	17	0	0
Rhinolophus shameli	0	0	0	0	0	0	0	105	0
Rhinolophus microglobosus	0	0	0	0	0	0	0	0	15
Total *n*	16	23	21	135	15	61	17	105	15
no. correct	16	23	21	135	15	61	17	105	15
% correct	100	100	100	100	100	100	100	100	100

The discriminant function analysis model relied on two parameters (Duration and FmaxE) and provided an overall correct classification rate of 100% when cross-validated.

and mean FmaxE values ranged from 39.8 ± 0.7 kHz in *M. annectans* to 103.3 ± 2.2 kHz in *K. hardwickii.* The only miniopterid in our sample, *Miniopterus pusillus*, produced steep, downward FM signals similar to vespertilionids, but of longer mean call duration (3.6 ± 0.3 ms) and a mean FmaxE of 60.8 ± 0.6 kHz.

Discriminant function analysis

Thirteen bat species were assessed in the analysis. As these could be unequivocally separated into two groups by their call structures, quadratic discriminant analysis was undertaken for (i) species whose calls contained a CF portion terminating in an FM portion (five rhinolophids and four hipposiderids) ("CF group"); and (ii) species whose calls comprised an FM signal (two megadermatids and two vespertilionids) ("FM group").

Quadratic discriminant function analysis for the CF group resulted in a 100% correct classification rate (408 calls correctly classified) which remained unchanged when cross-validated (Table 3). The best model relied upon two parameters (call duration and FmaxE), which a MANOVA showed was significant (Wilk's λ = 0.00102, F = 1510.276, P < 0.001). Wilk's λ values indicated that the discrimination power of the two variables in decreasing order was: FmaxE (0.00271) and call duration (0.16016).

Table 4 Cross-validated classification matrix for species emitting FM calls (genera *Megaderma*, *Hesperoptenus* and *Myotis*).

	True Groups			
Classified as	*Megaderma lyra*	*Megaderma spasma*	*Hesperoptenus blanfordi*	*Myotis annectans*
Megaderma lyra	3	1	0	0
Megaderma spasma	2	3	1	0
Hesperoptenus blanfordi	0	0	6	2
Myotis annectans	0	0	0	2
Total *n*	5	4	7	4
no. correct	3	3	6	2
% correct	60.0	75.0	85.7	50.0

The discriminant function analysis model relied on two parameters (FmaxE, IPI) and provided an overall correct classification rate of 70.0% when cross-validated.

Despite the small sample sizes for species in the FM group, the best model (relying on two call parameters: FmaxE and IPI) produced a 90% correct classification rate (18 calls correctly classified out of 20) and a 70% correct classification rate when cross-validated (14 calls correctly classified) (Table 4). MANOVA demonstrated that the model was significant (Wilk's λ = 0.08927, F = 11.735, P < 0.001) and Wilk's λ values indicated that the discrimination power of the two variables in decreasing order was: FmaxE (0.1224) and IPI (0.65160).

Discussion

Ours is the first study to describe the echolocation calls produced by a Cambodian bat assemblage and in achieving a correct, cross-validated classification rate of 85% overall, our results indicate that correct acoustic identification of in-country bat species is feasible using the call parameters we employed.

The call parameters we recorded for each species are generally consistent with those of other studies in the region (Soisook *et al*., 2008; Furey *et al*., 2009; Douangboubpha *et al*., 2010; Hughes *et al*., 2010, 2011; Kingsada *et al*., 2011; Ith *et al*., 2011b), although because sample sizes for megadermatid, vespertilionid and miniopterid species were small (and for reasons stated in the methods), it is highly unlikely these encompass the full range of variation in calls produced by these taxa. For instance, because *Kerivoula* spp. are known to produce signals with very high starting frequencies (Kingston *et al*., 1999; Schmieder *et al*., 2010), these were likely missed in our recordings due to insufficient sampling frequencies, resulting in lower starting frequencies and shorter call durations. Notwithstanding this, the rate of correct classification we obtained in discriminant function analysis is comparable to similar studies of bats around the world. For instance, MacSwiney *et al*. (2008) achieved a correct classification rate of 84% for 26 species in Mexico; Russo & Jones (2002) a rate of 82% for 22 species in Italy; and Kofoky *et al*. (2009) a rate of 82% for 15 species in Madagascar. Our results thus support previous suggestions (Furey *et al*., 2009) that acoustic identification of free-flying bats is an equally achievable goal in Southeast Asia.

Significant additional research will be required to realise this goal, however. As intra-specific variation occurs in echolocation calls due to geographical location (Thomas *et al*., 1987), reference recordings from every site under investigation will be required to reliably identify species whose call parameters

may overlap with those of others in certain parts of their range. Second, as habitat structure also induces variation in echolocation calls (Schnitzler *et al*., 2003), recordings from a range of structural environments will be required to elucidate the full repertoire of calls produced by different species. This will require significant field effort to obtain sufficient recordings for less abundant (or simply rarely captured) taxa, as demonstrated by the highly uneven relative species abundances encountered in the present study.

Because acoustic methods are unlikely to improve upon results provided by harp traps for bat species that echolocate at very low intensities (e.g. species within the Murininae and Kerivoulinae and *Coelops frithii*) (Furey *et al*., 2009), this approach is perhaps best regarded as an important complement to, rather than a replacement of, traditional capture methods for inventorying echolocating bats in Southeast Asia. As the taxonomy of many Southeast Asian bats remains uncertain (Francis *et al*., 2010), the need for live-trapping and collecting voucher samples to ensure correct assignment of names and recognition of species limits will inevitably also continue. We nonetheless recommend further studies to facilitate development of acoustic sampling as a tool for improving understanding and conservation of Cambodian bats.

Acknowledgements

We are grateful to H.E. Chay Smith, Mr Hong Daravuth and Mr Seng Rattanak (General Department for Administration of Nature Conservation and Protection, Cambodian Ministry of Environment) for their generous support and kindly facilitating the relevant field permits. Additionally, the authors are grateful to Markus Handschuh, Alistair Mould, Nikki Hulse (Angkor Center for Conservation of Biodiversity) and Ben Hayes for their invaluable help in the field and to Martin Fisher, Stuart Paterson and Elizabeth Allen of Fauna & Flora International who provided many comments on an early draft of this paper. We are similarly indebted to Phal Des and Meak Kamerane (Royal University of Phnom Penh) for their assistance. We also thank Choun Phirom (Fauna & Flora International) for preparing Fig. 1 and Dave Waldien (Bat Conservation International), Tigga Kingston (Texas Tech), Paul Bates (Harrison Institute) and Paul Racey (University of Exeter) for their steadfast support. The research was supported by the Darwin Initiative (14-011; 14-037; 18-002; EIDPO028), the John D. and Catherine D. MacArthur Foundation (US: 09-92411-000-GSS), the Zoological Parks and Gardens Board of Victoria (Australia) and the Critical Ecosystem Partnership Fund (through a grant provided to the Harrison Institute). Lastly, our special thanks to Arjan Boonman and one anonymous reviewer who kindly commented on the text.

References

Borissenko, A.V. & Kruskop, S.V. (2003) *Bats of Vietnam and Adjacent Territories: An Identification Manual*. Joint Russian-Vietnamese Science and Technological Tropical Centre, Zoological Museum of Moscow M.V. Lomonosov State University, Moscow, Russia.

Brigham, R.M., Kalko, E.K.V., Jones, G., Parsons, S. & Limpens, H.J.G.A. (eds) (2004) *Bat Echolocation Research: Tools, Techniques and Analysis*. Bat Conservation International, Texas, USA.

Douangboubpha, B., Bumrungsri, S., Satasook, C., Bu, S.S.H., Harrison, D.L. & Bates, P.J.J. (2010) A taxonomic review of *Hipposideros halophyllus, H. ater* and *H. cineraceus* (Chiroptera: Hipposideridae) in Thailand and Myanmar. *Acta Chiropterologica*, **12,** 29–50.

Francis, C.M. (2008) *A Guide to the Mammals of South-East Asia*. Princeton University Press, Princeton, New Jersey, USA.

Francis, C.M., Borissenko, A.V., Ivanova, N.V., Eger, J.L., Lim, B.K., Guillén-Servent, A., Kruskop, S.V., Mackie, I. & Hebert, P.D.N. (2010) The role of DNA barcodes in understanding and conservation of mammal diversity in Southeast Asia. *PLoS ONE*, **5,** e12575; doi: 10.1371/journal.pone.0012575.

Furey, N.M., Mackie, I.J. & Racey, P.A. (2009) The role of ultrasonic bat detectors in improving inventory and monitoring surveys in Vietnamese karst bat assemblages. *Current Zoology*, **55,** 327–341.

Furey, N.M., Phauk S., Phen S., Chheang S., Ith S., Bates, P.J.J. & Csorba, G. (2012) New country records for five bat species (Chiroptera) from Cambodia. *Cambodian Journal of Natural History,* **2012,** 141–149.

Hou K., Ken Serey R., Ung L. & Mao S. (2004) *Management of Pilot Watershed Areas in Cambodia: Baseline Survey*. Working paper 12b. Mekong River Commission and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) Cooperation Programme, Vientiane, Lao PDR.

Hughes, A.C., Satasook, C., Bates, P.J.J., Soisook, P., Sritongchuay, T., Jones, G. & Bumrungsri, S. (2010) Echolocation call analysis and presence-only modeling as conservation monitoring tools for rhinolophid bats in Thailand. *Acta Chiropterologica*, **12,** 311–327.

Hughes, A.C., Satasook, C., Bates, P.J.J., Soisook, P., Sritongchuay, T., Jones, G. & Bumrungsri, S. (2011) Using echolocation calls to identify Thai bat species: Vespertilionidae, Emballonuridae, Nycteridae and Megadermatidae. *Acta Chiropterologica*, **13,** 447–455.

Ith S., Csorba, G., Bates, P.J.J. & Furey, N.M. (2011a) Confirmation of seven bat species for Cambodia. *Cambodian Journal of Natural History*, **2011,** 93–103.

Ith S., Soisook, P., Bumrungsri, S., Kingston, T., Puechmaille, S.J., Struebig, M.J., Si Si, H.B., Vu D.T., Furey, N.M., Thomas, N.M. & Bates, P.J.J. (2011b) A taxonomic review of *Rhinolophus coelophyllus* Peters 1867 and *R. shameli* Tate 1943 (Chiroptera: Rhinolophidae) in continental Southeast Asia. *Acta Chiropterologica*, **13,** 41–59.

Jones, G. & Teeling, E.C. (2006) The evolution of echolocation in bats. *Trends in Ecology and Evolution*, **21,** 149–156.

Jones, G., Jacobs, D.A., Kunz, T.H., Willig, M.R. & Racey, P.A. (2009) *Carpe noctem*: the importance of bats as bio-indicators. *Endangered Species Research*, **8,** 93–115.

Kingsada, P., Douangboubpha, B., Ith S., Furey, N., Soisook, P., Bumrungsri, S., Satasook, C., Vu D.T., Csorba, G., Harrison, D., Pearch, M., Bates, P. & Thomas, N. (2011) A checklist of bats from Cambodia, including the first record of the intermediate horseshoe bat *Rhinolophus affinis* (Chiroptera: Rhinolophidae), with additional information from Thailand and Vietnam. *Cambodian Journal of Natural History*, **2011,** 49–59.

Kingston, T. (2010) Research priorities for bat conservation in Southeast Asia: a consensus approach. *Biodiversity and Conservation*, **19,** 471–484.

Kingston, T. (in press) Response of bat diversity to forest disturbance in Southeast Asia – insights from long-term research in Malaysia. In *Bat Evolution, Ecology, and Conservation* (eds R.A. Adams & S.C. Pedersen). Springer Science Press, USA.

Kingston, T., Jones, G., Zubaid, A. & Kunz, T. (1999) Echolocation signal design in Kerivoulinae and Murininae (Chiroptera: Vespertilionidae) from Malaysia. *Journal of Zoology (London),* **249,** 359–374.

Kofoky, A.F., Randrianandrinina, F., Russ, J., Raharinantenaina, I., Cardiff, S.C., Jenkins, R.K. & Racey, P.A. (2009). Forest bats of Madagascar: results of acoustic surveys. *Acta Chiropterologica,* **11,** 375–392.

Kunz, T.H., Braun de Torrez, E., Bauer, D., Lobova, T. & Fleming, T.H. (2011) Ecosystem services provided by bats. *Annals of the New York Academy of Sciences*, **1223,** 1-38.

MacSwiney, M.C.G., Clarke, M.F. & Racey, P.A. (2008) What you see is not what you get: the role of ultrasonic detectors in increasing inventory completeness in Neotropical bat assemblages. *Journal of Applied Ecology,* **45,** 1364-1371.

Neou B., Khou E. & Touch S. (2008) *Preliminary Study of the Kulen National Park for Development of a Botanical Garden.* Ministry of Environment, Royal Government of Cambodia, Phnom Penh, Cambodia.

Russo, D. & Jones, G. (2002) Identification of twenty-two bat species (Mammalia: Chiroptera) from Italy by analysis of time-expanded recording of echolocation calls. *Journal of Zoology (London),* **258,** 91–103.

Schmieder, D.A., Kingston, T., Hashim, R. & Siemers, B.M. (2010) Breaking the trade-off: rainforest bats maximise bandwidth and repetition rate of echolocation calls as they approach prey. *Biology Letters*, **6,** 604–609.

Schnitzler, H.U., Moss, C.F. & Denzinger, A. (2003) From spatial orientation to food acquisition in echolocating bats. *Trends in Ecology and Evolution*, **18,** 386–394.

Simmons, N.B. (2005) Order Chiroptera. In *Mammal Species of the World: a Taxonomic and Geographic Reference, Third Edition* (eds D.E. Wilson & D.M. Reeder), pp. 312–529. Johns Hopkins University Press, Baltimore, USA.

Soisook, P., Bumrungsri, S., Satasook, C., Thong V.D., Bu S.S.H., Harrison, D.L. & Bates, P.J.J. (2008) A taxonomic review of *Rhinolophus stheno* and *R. malayanus* (Chiroptera: Rhinolophidae) from continental Southeast Asia: an evaluation of echolocation call frequency in discriminating between cryptic species. *Acta Chiropterologica,* **10,** 221–242.

Sweczak, J.M. (2000) A tethered zip-line arrangement for reliably collecting bat echolocation reference calls. *Bat Research News*, **41,** 142.

Thomas, D.W., Bell, G.P. & Fenton, M.B. (1987) Variation in echolocation call frequencies recorded from North American vespertilionid bats: a cautionary note. *Journal of Mammalogy*, **68,** 842–847.

About the authors

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

PHEN SARITH is a Cambodian national from Kampot Province. After studying the effects of forest disturbance on bat species in Phnom Kulen National Park, he graduated from the Royal University of Phnom Penh with an MSc in 2011. Following this, he worked as a part-time field researcher for Fauna & Flora International and the Wildlife Conservation Society. His interests include the ecology of cave-dwelling bats.

NEIL FUREY has worked in Southeast Asia since 1997, spending a decade in Vietnam and completing various assignments in Cambodia, China, India, Indonesia and Myanmar. A biologist by training, he studied the ecology of Vietnamese karst bat assemblages 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.

Annex 1

RHINOLOPHIDAE—*Rhinolophus affinis*: CBC00927, male, in spirit, skull removed, collected on 25 April 2010, 13°41.028N, 104°01.366E, 82 metres above sea level (m a.s.l.); CBC00942, CBC00943, males, in spirit, skulls removed, collected on 23 June 2010, 13°41.409N, 104°00.733E, 177 m a.s.l.; CBC00947, CBC00948, CBC00949, males, in spirit, skulls removed, collected on 24 July 2010, 13°40.301N, 104°01.510E, 72 m a.s.l. (described by Kingsada *et al*., 2011). *Rhinolophus malayanus*: CBC00904, male, in spirit, skull removed, collected on 21 April 2010, 12°46.887N, 103°27.806E, 205 m a.s.l.; CBC00921, male, in spirit, skull removed, collected on 22 April 2010, 13°40.855N, 104°01.244E, 72 m a.s.l. *Rhinolophus pusillus*: CBC00933, male, in spirit, skull removed, collected on 19 May 2010, 13°41.295N, 104°00.739E, 215 m a.s.l.; CBC00935, female, in spirit, skull removed, collected on 20 May 2010, 13°41.189N, 104°00.642E, 182 m a.s.l. *Rhinolophus shameli*: CBC00905, CBC00906, females, in spirit, skulls removed, collected on 21 April 2010, 12°46.887N, 103°27.806E, 205 m a.s.l.; CBC00926, female, in spirit, skull removed, collected on 25 April 2010, 13°41.028N, 104°01.366E, 82 m a.s.l.; CBC00928, female, in spirit, skull removed, collected on 18 May 2010, 13°41.340N, 104°00.668E, 171 m a.s.l. *Rhinolophus microglobosus*: CBC00901, male, in spirit, skull removed, collected on 21 April 2010, 12°46.887N, 103°27.806E, 205 m a.s.l.; CBC00930, female, in spirit, skull removed, collected on 18 May 2010, 13°41.340N, 104°00.668E, 171 m a.s.l.; CBC00936, female, in spirit, skull removed, collected on 20 May 2010, 13°41.189N, 104°00.642E, 182 m a.s.l.

HIPPOSIDERIDAE—*Hipposideros armiger*: CBC00923, CBC00924, male and female, in spirit, skulls removed, collected on 24 April 2010, 13°40.944N, 104°01.134E, 97 m a.s.l.; CBC00938, male, in spirit, skull removed, collected on 23 May 2010, 13°40.598N, 104°01.506E, 66 m a.s.l.; CBC00941, female, in spirit, skull removed, collected on 22 June 2010, 13°41.495N, 104°00.647E, 204 m a.s.l. *Hipposideros cineraceus*: CBC00944, female, in spirit, skull removed, collected on 26 June 2010, 13°40.816N, 104°00.973E, 183, m a.s.l. *Hipposideros galeritus*: CBC00898, CBC00899, CBC00900, two females and one male, in spirit, skulls removed, collected on 21 April 2010, 12°46.887N, 103°27.806E, 205 m a.s.l.; CBC00931, male, in spirit, skull removed, collected on 18 May 2010, 13°41.340N, 104°00.668E, 171 m a.s.l.; CBC00932, male, in spirit, skull removed, collected on 19 May 2010, 13°41.295N, 104°00.739E, 215 m a.s.l.; CBC00950, male, in spirit, skull removed, collected on 25 July 2010, 13°40.092N, 104°01.399E, 68 m a.s.l. *Hipposideros larvatus*: CBC00925, female, in spirit, skull removed, collected on 27 April 2010, 13°40.949N, 104°01.416E, 80 m a.s.l.; CBC00929, female, in spirit, skull removed, collected on 18 May 2010, 13°41.340N, 104°00.668E, 171 m a.s.l. *Hipposideros pomona*: CBC00902, male, in spirit, skull removed, collected on 21 April 2010, 12°46.887N, 103°27.806E, 205 m a.s.l.; CBC00903, female, in spirit, skull removed, collected on 24 April 2010, 13°40.944N, 104°01.134E, 97 m a.s.l.; CBC00934, female, in spirit, skull removed, collected on 20 May 2010, 13°41.189N, 104°00.642E, 182 m a.s.l.; CBC00939, CBC00940, male and female, in spirit, skulls removed, collected on 20 June 2010, 13°40.796N, 104°01.593E, 65 m a.s.l.

MEGADERMATIDAE—*Megaderma lyra*: CBC00919, female, in spirit, skull removed, collected on 21 April 2010, 12°46.887N, 103°27.806E, 205 m a.s.l.; CBC00920, female, in spirit, skull removed, collected on 24 April 2010, 13°40.944N, 104°01.134E, 97 m a.s.l. *Megaderma spasma*: CBC00945, female, in spirit, skull removed, collected on 20 July 2010, 13°41.339N, 104°00.970E, 188 m a.s.l.

VESPERTILIONIDAE—*Hesperoptenus blanfordi*: CBC00907, CBC00911, CBC00912, CBC00913, CBC00914, CBC00915, CBC00916, four females and three males, in spirit, skulls removed, collected on 21 April 2010, 12°46.887N, 103°27.806E, 205 m a.s.l. *Hypsugo* sp. A: CBC00917, male, in spirit, skull and baculum removed, collected on 21 April 2010, 12°46.887N, 103°27.806E, 205 m a.s.l. *Myotis annectans*: CBC00909, CBC00918, females, in spirit, skulls removed, collected on 21 April 2010, 12°46.887N, 103°27.806E, 205 m a.s.l.; CBC00937, female, in spirit, skull removed, collected on 23 May 2010, 13°40.598N, 104°01.506E, 66 m a.s.l. *Tylonycteris pachypus*: CBC00908, CBC00910, females, in spirit, skulls removed, collected on 21 April 2010, 12°46.887N, 103°27.806E, 205 m a.s.l. *Kerivoula hardwickii*: CBC00946, female, in spirit, skull removed, collected on 21 July 2010, 13°41.574N, 104°00.633E, 206 m a.s.l.

MINIOPTERIDAE—*Miniopterus pusillus*: CBC00951, male, in spirit, skull removed, collected on 25 July 2010, 13°39.810N, 104°01.862E, 68 m.a.s.l (described by Furey *et al*., 2012).

Structure and composition of deciduous dipterocarp forest in the Eastern Plains Landscape, Cambodia

PIN Chanrattana[1], PHAN Channa[1,2], PRUM Sovanna[1] and Thomas N.E. GRAY[1,3,*]

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

[2] (Current address) Fauna & Flora International: Cambodia Programme, House #19, Street 360, Sangkat Boeung Keng Kang 1, Phnom Penh, Cambodia.

[3] (Current address) WWF Greater Mekong, House 39, Unit 05, Ban Saylon, Vientiane, Lao PDR.

*Corresponding author. Email tomnegray@hotmail.com

Paper submitted 30 April 2013, revised manuscript accepted 24 June 2013.

មូលន័យសង្ខេប

ព្រៃខ្ពុងត្បែងជ្រុះស្លឹកប្រចាំឆ្នាំ(Deciduous dipterocarp forest) មានលក្ខណៈដោយឡែកសម្រាប់តែតំបន់អាស៊ីអាគ្នេយ៍ ហើយព្រៃខ្ពុងត្បែងជ្រុះស្លឹកប្រចាំឆ្នាំដ៏ទូលំទូលាយនៃភាគខាងជើង និងភាគខាងកើតប្រទេសកម្ពុជាមានសារៈសំខាន់ជាសកលសម្រាប់ការអភិរក្សជីវៈចម្រុះ។ ប៉ុន្តែមានការសិក្សាតិចតួចណាស់ត្រូវបានបោះពុម្ពផ្សាយពីទំរង់និងសមាសភាពរុក្ខសាស្ត្រនៃព្រៃខ្ពុងត្បែងជ្រុះស្លឹកប្រចាំឆ្នាំដែលមាននៅប្រទេសកម្ពុជា។ យើងបានធ្វើបញ្ជីសារពើភណ្ឌដើមឈើទាំងអស់ដែលមានបន្ទាត់ផ្ចិតកំពស់ទ្រូង>៥cm នៅក្នុងឡូត៍ព្រៃខ្ពុងត្បែងជ្រុះស្លឹកប្រចាំឆ្នាំទំហំមួយហិតា២កន្លែង នៅតំបន់ការពារពីរផ្សេងគ្នា (តំបន់ការពារព្រៃខេត្តមណ្ឌលគីរី និងតំបន់ដែនជំរកសត្វព្រៃភ្នំព្រិច) ដែលបិតនៅតំបន់ទំនាបភាគខាងកើតនៃខេត្តមណ្ឌលគីរី។ ឡូត៍ព្រៃខ្ពុងត្បែងជ្រុះស្លឹកប្រចាំឆ្នាំទាំងពីរកន្លែងសំបូរទៅដោយប្រភេទ *Shorea obtusa* និង*Dipterocarpus tuberculatus*។ ប្រភេទទាំងពីរនេះតាងឱយ៧០-៨០% នៃដើមដែលមានបន្ទាត់ផ្ចិតកំពស់ទ្រូងធំជាង៥cm និង៧៥-៨០%នៃតំបន់មូលដ្ឋានគោល(Basal Area) ក្នុងឡូត៍ព្រៃខ្ពុងត្បែងជ្រុះស្លឹកប្រចាំឆ្នាំ។ ជារួមតំបន់មូលដ្ឋានគោលទាំងពីរមានទំហំប្រហាក់ប្រហែលគ្នា (១៤.២ m²/ha នៅក្នុងតំបន់ដែនជំរកសត្វព្រៃភ្នំព្រិច និង១៥.០ m²/ha នៅក្នុងតំបន់ការពារព្រៃឈើខេត្តមណ្ឌលគីរី) និងស្ថិតនៅក្នុងរង្វង់ទំហំប៉ាន់ប្រមាណបោះពុម្ពផ្សាយពីឡូត៍ព្រៃខ្ពុងត្បែងជ្រុះស្លឹកប្រចាំឆ្នាំនៅឥណ្ឌូចិន។ ទោះបីតំបន់មូលដ្ឋានគោលទាំងនេះមានទំហំប្រហាក់ប្រហែលគ្នាក៏ដោយ ក៏ឡូត៍ព្រៃខ្ពុងត្បែងជ្រុះស្លឹកប្រចាំឆ្នាំក្នុង តំបន់ដែនជំរកសត្វព្រៃភ្នំព្រិចមានដើមដែលមានបន្ទាត់ផ្ចិត >៥cmច្រើនជាងយ៉ាងខ្លាំង ជាពិសេសដើមទំហំតូច។(បន្ទាត់ផ្ចិតកំពស់ទ្រូងពី៥-១០cm)។ យើងអាចសន្និដ្ឋានថា ភាពខុសគ្នាពីទំរង់រវាងឡូត៍ទាំងពីរអាចបណ្តាលមកពីភ្លើងឆេះព្រៃមិនញឹកញាប់ទេនៅក្នុងតំបន់ដែនជំរកសត្វព្រៃភ្នំព្រិច។ ដូច្នេះ ការសិក្សាស្រាវជ្រាវបន្ថែមច្រើនទៀតទាមទារឱយដំណើរការបន្តដើម្បីស្វែងយល់ពីដំណើរការរុក្ខសាស្ត្រនិងអេកូឡូស៊ី ដែលមានឥទ្ធិពលទៅលើព្រៃខ្ពុងត្បែងជ្រុះស្លឹកប្រចាំឆ្នាំនៅប្រទេសកម្ពុជា។

Abstract

Deciduous dipterocarp forests (DDF) are unique to Southeast Asia and the extensive DDF of northern and eastern Cambodia are globally significant for biodiversity conservation. However there are few published studies on the structure and botanical composition of DDF stands in Cambodia. We inventoried all tree stems >5 cm diameter at breast height (dbh) in two one-hectare DDF plots in two protected areas (Mondulkiri Protected Forest and

CITATION: Pin C., Phan C., Prum S. & Gray, T.N.E. (2013) Structure and composition of deciduous dipterocarp forest in the Eastern Plains Landscape, Cambodia. *Cambodian Journal of Natural History*, **2013,** 27–34.

Phnom Prich Wildlife Sanctuary) in the Eastern Plains Landscape, Mondulkiri. Both plots were dominated by two species of deciduous dipterocarp: *Shorea obtusa* and *Dipterocarpus tuberculatus*. These two species represented 70–80% of individual stems >5 cm dbh and 75–80% of the basal area within the plots. Overall basal area was similar between the two plots (14.2 m^2/ha in Phnom Prich Wildlife Sanctuary; 15.0 m^2/ha in Mondulkiri Protected Forest) and within the range of published estimates from DDF plots in Indochina. Despite similar basal areas, the Phnom Prich Wildlife Sanctuary plots had considerably more individual stems >5 cm dbh, particularly within smaller size classes (5–10 cm dbh). We suggest that the structural differences between the plots may be the result of less frequent fires in Phnom Prich Wildlife Sanctuary. However, considerable further research is required to understand the botanical and ecological processes that influence DDF in Cambodia.

Keywords

basal area, botanical plot, deciduous dipterocarp forest, fire ecology, Indochina, Mondulkiri.

Introduction

Deciduous dipterocarp forests (DDF) are endemic to Asia and historically occurred widely across continental Southeast Asia from Northeast India through Myanmar and Thailand to Laos and Vietnam (Bunyavejchewin *et al*., 2011). DDF landscapes are restricted to lowlands below 900 m with a relatively severe dry-season and poor (acidic, shallow, and sandy) soils. A low diversity of tree species and abundance of stems in small classes, compared to other Southeast Asian forest types, are typical (Rundel, 1999; Sahunalu, 2009, Tani *et al*., 2007; Bunyavejchewin *et al*., 2011). One or more of four deciduous species of Dipterocarpaceae (*Shorea obtusa, S. siamensis, Dipterocarpus tuberculatus* and *D. obtusifolius*) dominate DDF (Bunyavejchewin *et al*., 2011). Other important canopy species include *Pterocarpus macrocarpus* (Fabaceae), *Xylia xylocarpa* (Fabaceae), *Gluta usitata* (Anacardiaceae) and several species of *Terminalia* (Combretaceae) (Rundel, 1999; Bunyavejchewin *et al*., 2011). The understory is dominated by grasses and herbaceous bamboo (*Vietnamosasa* spp.) that provide abundant forage for the region's famous, and historically abundant, large ungulates (Wharton 1957; Bunyavejchewin *et al*., 2011).

Historically, DDF was the most extensive forest type across Thailand and Cambodia, but in common with tropical dry forests globally, DDF landscapes have been increasingly degraded and converted to agricultural uses (Tordoff *et al*., 2005). Indeed, tropical dry forests are the most threatened major forest type globally (Janzen, 1988) and the DDF of Indochina represents one of the five largest areas of tropical dry forest remaining. In a recent review, Indochinese DDF was identified as amongst the four most severely threatened dry forest types globally (Miles *et al*., 2006). The DDF within the northern and eastern plains of Cambodia form part of the Lower Mekong Dry Forest Ecoregion and are globally irreplaceable for conservation (Tordoff *et al*., 2005), supporting one of the most intact assemblages of megafauna in Southeast Asia including the largest global populations of banteng *Bos javanicus* (Gray *et al*., 2012) and white-shouldered ibis *Pseudibis davisoni* (Wright *et al*., 2012). However, despite their wide occurrence across Cambodia and high conservation value, there are few recent published studies on the structure and species composition of DDF. The aim of this study was to undertake basic inventories, using repeatable and simple methodologies, of two one-hectare plots in DDF within the Eastern Plains Landscape, Mondulkiri in eastern Cambodia. Our principal focus was to determine stem densities and basal areas of the dominant species which each plot.

Methods

Study Sites

The study was conducted in two protected areas within the Eastern Plains Landscape, Mondulkiri. Phnom Prich Wildlife Sanctuary (2,225 km^2) and Mondulkiri Forest Protected (3,350 km^2) (Fig. 1). Within the two protected areas, DDF make up >75% of forest cover with smaller areas of mixed deciduous forest and, mostly in PPWS, semi-evergreen forest (Fig. 1). The climate, soil and geology of the two protected areas have not been extensively studied, but are believed to be representative of lowland areas of eastern Cambodia, with distinct dry and wet seasons influenced by the tropical monsoon.

Botanical survey

A one-hectare (100 m x 100 m) plot was established

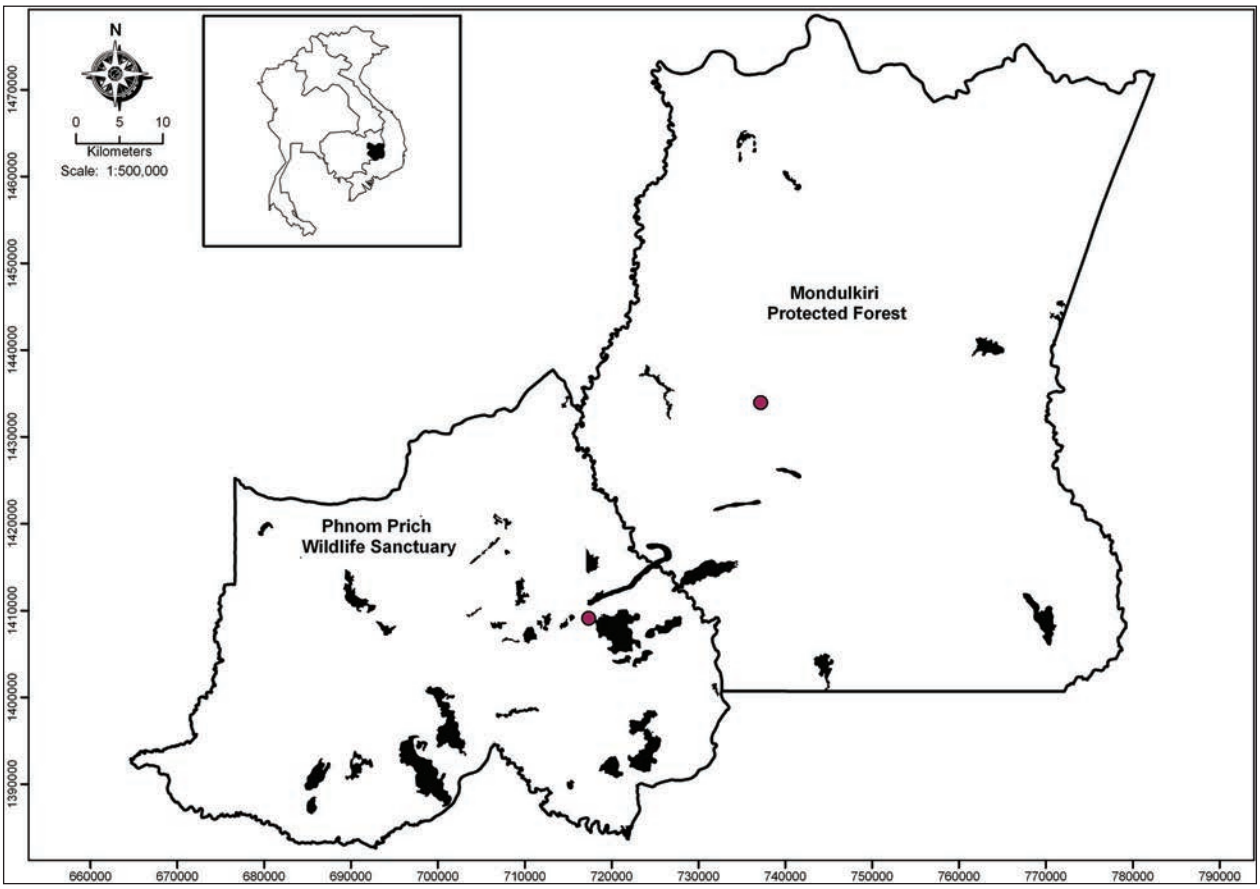


Fig. 1 Location of botanical plots (dots) within Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary, Mondulkiri, Cambodia. Semi-evergreen forests in the protected areas are indicated in black.

within DDF in each of the core zones of Mondulkiri Protected Forest (MPF; UTM 48N 737196E 1433940N, 190 m a.s.l.) and Phnom Prich Wildlife Sanctuary (PPWS; UTM 48N 717388E 1409090N, 220 m a.s.l.) (Fig. 1). The two plots were non-randomly situated so as to be representative of typical DDF within each protected area. Therefore both plots were placed on flat land without rivers or streams and with continuous homogenous DDF and limited habitat heterogeneity. The disturbance history of the two plots is unclear but both are within the core areas of protected areas with no recent forest clearance. However, both plots are likely to experience annual burning, which is widespread throughout the DDF of the Eastern Plains Landscape.

Plots were marked using a compass and measuring tape with each plot divided into one hundred 10 m x 10 m quadrates marked using tape. Within each quadrat all trees with a diameter at breast height (dbh, *c.* 1.3 m) equal to or more than 5 cm were measured (dbh recorded) and identified to species. For species identification, vernacular Khmer names were recorded and checked against Dy Phon (2000) for scientific names. When no consensus on species identification was achieved, individual trees were recorded as unidentified forms. We acknowledge that this approach is not optimal and that herbarium samples should have been taken and properly preserved to allow for subsequent identification. Given that a number of forms likely to represent species were not identified, information on tree species richness and diversity within the plots is necessarily incomplete. Our study is therefore best regarded as providing information on stand structure, basal area, and dominant species composition rather than a complete botanical inventory of tree species richness.

Basal area (m^2) was calculated for each individual stem and summed in each plot for each species and used to calculate total basal area. Fieldwork was conducted during the dry season: February 2012 in Phnom Prich Wildlife Sanctuary, and November 2012 in Mondulkiri Protected Forest.

Table 1 Species list and structural summary based on inventorying all stems >5 cm dbh within one hectare plots in deciduous dipterocarp forest in Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary. Basal Area (BA) was calculated using all stems and presented as m^2.

Species and Family	Stems	Mean dbh	BA	% Stems	% BA
Mondulkiri Protected Forest					
Shorea obtusa Miq. Dipterocarpaeae	171	17.1	5.5	42.8	36.8
Dipterocarpus tuberculatus Roxb. Dipterocarpaeae	100	24.8	5.7	25.0	38.0
Unidentified species (seven forms)	42	15.3	1.1	10.5	7.3
Xylia xylocarpa (Roxb.) Taub. Fabaceae	25	16.5	0.7	6.3	4.9
Terminalia alata Heyne ex. Roth Combretaceae	20	23.7	1.2	5.0	7.9
Catunaregam tomentosa Blume ex DC. Rubiaceae	11	9.7	0.1	2.8	0.6
Terminalia chebula Retz. Combretaceae	9	13.9	0.2	2.3	1.2
Dalbergia spp. Fabaceae	4	7.1	0.0	1.0	0.1
Bauhinia acuminata L. Fabaceae	4	15.0	0.1	1.0	0.5
Lagerstroemia speciosa (L.) Pers. Lythraceae	4	15.0	0.1	1.0	0.6
Pterocarpus macrocarpus Kurz. Fabaceae	3	9.7	0.0	0.8	0.2
Acacia intsia L. Fabaceae	2	31.5	0.2	0.5	1.1
Careya sphaerica Roxb. Lecythidaceae	2	22.8	0.1	0.5	0.6
Diospyros ehretioides Wall. ex G.Don Ebenaceae	1	8.0	0.0	0.3	0.0
Cratoxylum formosum Benth. Hypercaceae	1	5.7	0.0	0.3	0.0
Morinda citrifoila L. Rubiaceae	1	9.9	0.0	0.3	0.1
Phnom Prich Wildlife Sanctuary					
Shorea obtusa Miq. Dipterocarpaeae	512	10.4	6.5	43.0	45.4
Dipterocarpus tuberculatus Roxb. Dipterocarpaeae	418	9.9	4.9	35.1	34.4
Terminalia alata Heyne ex. Roth. Combretaceae	80	12.4	1.3	6.7	8.9
Unidentified species (seven forms)	72	8.9	0.6	6.0	4.4
Albizia myriophylla Benth. Fabaceae	37	9.1	0.3	3.1	2.3
Terminalia chebula Retz. Combretaceae	18	8.3	0.1	1.5	0.8
Xylia xylocarpa (Roxb.) Taub. Fabaceae	8	8.0	0.0	0.7	0.3
Pterocarpus macrocarpus Kurz. Fabaceae	8	7.2	0.0	0.7	0.2
Lagerstroemia speciosa (L.) Pers. Lythraceae	7	14.1	0.1	0.6	1.0
Dipterocarpus obtusifolius Teijsm ex Miq. Dipterocarpaeae	6	7.4	0.0	0.5	0.2
Catunaregam tomentosa Blume ex DC. Rubiaceae	5	7.0	0.0	0.4	0.1
Careya sphaerica Roxb. Lecythidaceae	4	8.2	0.0	0.3	0.2
Lophopetalum spp. Celastraceae	3	7.9	0.0	0.3	0.1
Diospyros ehretioides Wall. ex G.Don Ebenaceae	3	7.1	0.0	0.3	0.1
Phyllanthus emblica L. Phyllanthaceae	3	7.9	0.0	0.3	0.1
Shorea spp. Dipterocarpaeae	2	7.0	0.0	0.2	0.0
Morinda citrifoila L. Rubiaceae	2	8.8	0.0	0.2	0.1
Neonauclea spp. Rubiaceae	2	15.8	0.0	0.2	0.3
Shorea siamensis Miq. Dipterocarpaeae	1	43.0	0.1	0.1	1.0
Antidesma ghaesembilla Gaertn. Phyllanthaceae	1	7.3	0.0	0.1	0.0

Table 2 Total Basal Area (BA), number of stems, species richness, and percentage of stems and BA comprised of the four deciduous dipterocarp species (DD) *Dipterocarpus tuberculatus*, *D. obtusifolius, Shorea obtusa* and *S. siamensis* in published inventories of plots in deciduous dipterocarp forest in Cambodia and Thailand. Note different uses of minimum dbh and plot size between studies. For purposes of comparison, results from this study are presented for trees >5 cm dbh and >10 cm dbh (in parentheses).

Location	>dbh	BA (m^2/ ha)	Number of stems/ ha	% DD BA	% DD stems	Species richness	Reference
Phnom Prich Wildlife Sanctuary (*n*=1)	5 (10)	14.2 (10.7)	1,192 (367)	81 (79)	79 (78)	26 (18)	This study
Mondulkiri Protected Forest (*n*=1)	5 (10)	15.0 (14.6)	400 (297)	75 (75)	68 (74)	24 (21)	This study
Thailand (*n*=11)	10	Mean 20	Mean 440; range 269–646	Mean 67; range 50–86	Mean 51; range 29–74	Mean 40; range 24–64	Bunyavejchewin *et al*. (2011)
Northeast Thailand (*n*=4)	4.5	16.9; range 15–19	Mean 687; range 555–823	n/a	n/a	Mean 35; range 32–37	Suhunalu (2009)
Northeast Thailand (*n*=1)	5	14	602	65	n/a	37	Lamotte *et al*. (1998)
Kratie and Mondulkiri	10	13.8; range 7.9–21.5	n/a	n/a	Mean 54	n/a	Tani *et al*. (2007)
Southwest Cambodia (*n*=9)	3	2.2	195	n/a	n/a	n/a	Wood (2012)

Results

Species composition of the two plots was remarkably similar, with both plots dominated by *Shorea obtusa* (43% of individual trees; 37–45% of basal area) and *Dipterocarpus tuberculatus* (25–35% of individual trees; 38-45% of basal area), two of the four deciduous species of Dipterocarpaceae (Table 1). The other two deciduous dipterocarp species, *S. siamensis* and *D. obtusifolius*, were recorded in small numbers (one and six individual trees respectively) in the PPWS plot.

Overall, the deciduous dipterocarp species comprised 75% of the individual stems >5 cm dbh and 77% of the basal area within the two plots. The proportion of individual stems and basal area comprised by deciduous dipterocarp species is marginally higher than in the limited number of previously published inventories of plots within DDF in Thailand and Cambodia (Table 2). Total basal area was similar between the MPF (15.0 m^2/ha) and PPWS (14.2 m^2/ ha) plots and was within the documented range of the published basal areas within DDF (Table 2).

A total of 19 tree species from nine families (Fabaceae five species; Dipterocarpaceae four species; Combretaceae and Rubiaceae two species each; Ebenaceae, Hypercaceae, Lecythidaceae, Lythraceae and Phyllanthaceae one species each) were identified from within the plots, with an additional four forms identified to genus only (Table 1). Eleven species (60% of those identified) were found in both the MPF and PPWS plots. Seventeen forms (a total of 97 stems; 6% of the total) were given vernacular Khmer names which could not be assigned to a clear species, whilst 15 stems in the MPF plot, of an unknown number of forms, remained unidentified.

Despite their similar overall basal area, the number of individual trees and the mean dbh of trees were very different between the two plots. The PPWS plot contained considerably more trees >5 cm dbh (1,192 vs 400), which were on average smaller (mean dbh 10.2 cm vs 18.7 cm) than those in the MPF plot (Fig. 2). The mean dbh for each of the 11 species recorded in both MPF and PPWS was larger, by between 10% (*Lagerstroemia speciosa*) and 180% (*Careya sphaerica*), in MPF. This pattern was typified by *Dipterocarpus tuberculatus* with mean dbh of 9.9 cm in PPWS and 24.8 cm in MPF (Fig. 3). Within the PPWS plot there was a distinct peak, for all species combined and the two dominant dipterocarp species, in the number of stems of between 5 and 10 cm dbh (Figs 2 and 3).

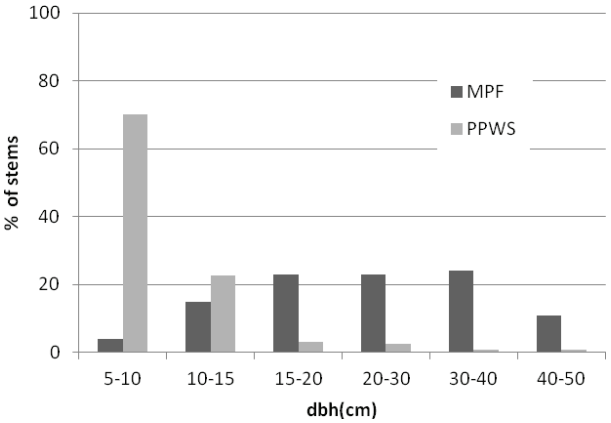


Fig. 2 Diameter size class distribution (% of all stems >5-cm dbh in different size classes) in one hectare deciduous dipterocarp forest plots in Mondulkiri Protected Forest (MPF) and Phnom Prich Wildlife Sanctuary (PPWS).

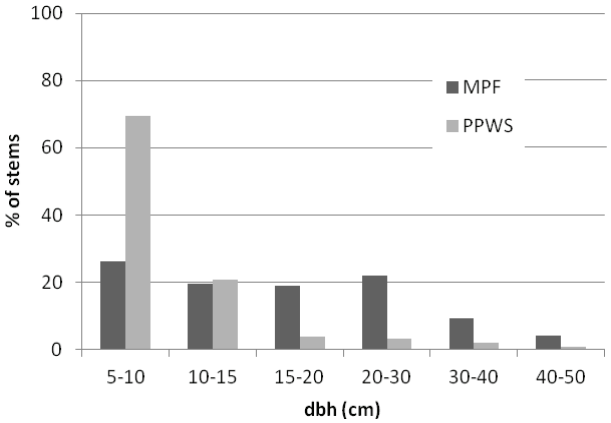


Fig. 3 Diameter size class distribution (% of all stems >5 cm dbh in different size classes) of *Dipterocarpus tuberculatus* stems in one hectare deciduous dipterocarp forest plots in Mondulkiri Protected Forest (MPF) and Phnom Prich Wildlife Sanctuary (PPWS).

Discussion

Despite the ubiquity of DDF across large areas of lowland Cambodia, and the unquestionable global conservation significance of this habitat, there have been few recent published botanical studies of DDF in Cambodia (but see Tani *et al*., 2007; Wood, 2012). Comparing our results with published data on DDF structure and species composition in Southeast Asia are hindered as different studies use different minimum dbh cut-offs for their estimation of basal area and other structural characteristics within plots (Table 2). However, the overall basal area of the plots within both MPF and PPWS is clearly similar to DDF sites in Northeast Thailand (Lamotte *et al*., 1998; Suhunalu, 2009; Bunyavejchewin *et al*., 2011) and Kratie, Cambodia (Tani *et al*., 2007; Table 2). This observation corroborates the review by Rundel (1999) who concluded that whilst the species composition of individual DDF stands may vary "the general canopy structure of deciduous dipterocarp forest is quite consistent throughout the range of this habitat" (p. 37).

Based on dominant species composition, a number of DDF formations have been described from Thailand, Cambodia and southern Laos (references in Rundel, 1999 and Suhunalu, 2009; Tani *et al*., 2007). In Cambodia, Rundel (1999) described two forms of DDF characterised by the strong dominance of a single species of dipterocarp. A community dominated by *Dipterocarpus obtusifolius* characteristic of areas of Cambodia east of the Mekong on sites with thin sandy soils over laterites, often in sites with soils that are waterlogged during the wet season, and with a frequently burning grass understorey. The second community, dominated by "low-growing *Shorea siamensis* with a growth form of twisted trunks", occurs on eroded lithosols or skeletal soils with rarely any well-developed understory. Although Rundel's (1999) description of *Dipterocarpus obtusifolius*-dominated formations matches the geographical and ecological characteristics of our plots, both were dominated by co-occurring *S. obtusa* and *D. tuberculatus*. This generally matches one of the five DDF formations described by Vidal (1956-1960) from Southern Laos, characterised by "mixed dominance of *Dipterocarpus tuberculatus, Shorea siamensis, S. obtusa*, and *Terminalia alata*" and described as "the most widespread form and grows with moderately stunted trunks on shallow sandstone or lateritic soils" (Rundel, 1999, p. 37). It is notable that *T. alata*, one of the commonest species of non-dipterocarp tree in the MPF and PPWS plots, is identified as the most important non-dipterocarp species in DDF in Laos (Rundel, 1999).

After inventorying all stems >10 cm dbh within 20-metre circular plots in Kratie and Mondulkiri, Tani *et al*. (2007) identified three stand types of deciduous dipterocarp forest: 'DDF3', classified based on four plots from lowland forest in Kratie Province east of the Mekong, seems to have a species composition similar to our plots, with the 'indicator species' of this stand type being *S. obtusa, D. tuberculatus* and *Mitragyna*

rotundifolia (Rubiaceae). The mean basal area of 'DDF3' plots (12.2 m^2/ha) recorded by Tani *et al*. (2007) was also similar to our plots although the proportion of basal area contributed by the two dominant species (*Shorea obtusa* 28% and *Dipterocarpus tuberculatus* 24%) was less than we recorded in MPF and PPWS. Tani *et al*. (2007) suggested this forest type "is a typical deciduous dipterocarp forest, and this stand type could be seen in Thailand, Myanmar, Vietnam, and all over the Indochina region". Although DDF is generally regarded as a moderately species-poor forest type (Suhunalu, 2009; Tani *et al*., 2007), our results, with only 24 species detected across both 1 hectare plots, are extreme and lower than in any other published study (Table 2). However, this is likely a result of our limited botanical knowledge (7% of stems, representing a minimum of nine additional 'forms', were unidentified), rather than any genuine ecological processes.

A particularly noticeable feature of our plots was the high density of stems within the PPWS plot. Although total basal area (BA) was remarkably similar in the two plots, the PPWS plot contained almost three times more stems, which were on average smaller than those in MPF. Wood (2012) examined the role of fire history on stem density within DDF in Southwest Cambodia and demonstrated similar basal areas in sites with different burn histories, but densities of individuals, particularly in smaller size classes, increased with increasing time since burn. Whether the high density of trees in the PPWS plots is a result of longer intervals since burning, and whether this relationship is typical of DDF in eastern Cambodia, merits further research. Similarly, while we present basic details of species composition and structure within two DDF plots in eastern Cambodia, considerable further research is required to understand the botanical and ecological processes operating in DDF. Essential areas of future research include the role of fire in shaping tree communities, understory vegetation, and broader patterns of forest distribution (i.e. DDF versus mixed deciduous and semi-evergreen forest) in the landscape, and comparing forest structure, species composition and productivity between forest types. Such studies are critical if efforts to restore populations of threatened ungulates and large carnivores to the landscape are to be achieved.

Acknowledgements

This study was conducted as part of WWF Greater Mekong Cambodia Program's Eastern Plains Landscape project. Work in MPF is with permission of the Forestry Administration and support from H.E. Cheng Kimsun, Keo Omaliss, Song Keang and Keo Sopheak. Work in PPWS is with permission of the Ministry of the Environment and support from H.E. Chay Samith, Han Sakhan and Sanrangdy Vicheth. Men Samorn, Sary Tre, Lien Nor and Vann Sonny assisted with data collection. Mark Wright, Michelle Owen and Thibault Ledecq assisted with project logistics and funding and Ly Bora produce the map. Stuart Davies and two anonymous reviewers provided comments which improved the quality of the manuscript.

References

Bunyavejchewin, S., Baker, P.J. & Davies, S.J. (2011) Seasonally dry tropical forests in continental Southeast Asia: structure, composition, and dynamics. In *The Ecology and Conservation of Seasonally Dry Forests in Asia* (eds W.J. McShea, S.J. Davies & N. Bhumpakphan), pp 9–36. Rowman & Littlefied/ Smithsonian Institute Scholarly Press, Washington DC, USA.

Dy Phon, P (2000) *Dictionary of Plants Used in Cambodia.* Imprimerie Olympic, Phnom Penh, Cambodia.

Gray, T.N.E., Prum S., Pin C. & Phan C. (2012) Distance sampling reveals Cambodia's Eastern Plains Landscape supports largest global population of the endangered banteng *Bos javanicus*. *Oryx*, **46,** 563–566.

Janzen, D. (1988) Tropical dry forests: the most endangered major tropical ecosystem. In *Biodiversity* (ed. E.O. Wilson), pp. 130–137. National Academy of Sciences/ Smithsonian Institution, Washington DC, USA.

Lamotte, S., Gajaseni, J. & Malaisse, F. (1998) Structure and diversity in three forest types of north-eastern Thailand (Sakaerat Reserve, Pak Tong Chai). *Biotechnology, Agronomy, Society and Environment*, **2,** 192–202.

Miles, L., Newton, A.C., Defries R.S., Ravilious, I. May I., Blyth, S., Kapos, V. & Gordon, J.E. (2006) A global overview of the conservation status of tropical dry forests. *Journal of Biogeography*, **33,** 491–505.

Rundel, P.W. (1999) *Forest Habitats and Flora in Lao PDR, Cambodia and Vietnam.* World Wide Fund for Nature, Indochina Programme, Hanoi, Vietnam.

Sahunalu, P. (2009) Stand structure and species composition in the long-term dynamic plots of Sakaerat deciduous dipterocarp forest, Northern Thailand. *Journal of Forest Management*, **3,** 1–20.

Tani, A., Ito, E., Kanzaki, M., Ohta, S., Khorn S., Pith P., Tith B., Pol S. & Lim, S. (2007) Principal forest types of three regions of Cambodia: Kompong Thom, Kratie and Mondulkiri. In *Forest Environments of the Mekong River Basin* (eds H. Sawada, M. Araki, N.A. Chappell, J.V. LaFrankie & A. Shimizu), pp. 201–213. Springer, Tokyo, Japan.

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

Vidal, J. E. (1956-1960) La végétation du Laos, I. Conditions ecologiques. II. Groupements végétaux et flore. *Travaux Laboratoire Forestier de Toulouse*, **5,** 1–582

Wharton, C.H. (1957) An ecological study of the kouprey, *Novibos sauveli* (Urbain). *Monographs of the Institute of Science and Technology, Manila*, **5,** 1–107.

Wood, T.F. (2012) Fire ecology of the dry dipterocarp forest of South West Cambodia. *Cambodian Journal of Natural History,* **2012,** 75–86.

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

Estimating the value of sustainable bamboo resource management in Cambodia: a case study in O Tauch community, Kampot Province

OU Ratanak[1,*] and Mitsuhiro TERAUCHI[2]

[1] World Wide Fund for Nature Greater Mekong Cambodia Country Program, #21, St. 322, Boeung Keng Kang I, Phnom Penh, Cambodia.

[2] Department of Food Environment Economics, Faculty of International Agriculture and Food Studies, Tokyo University of Agriculture, 1-1-1 Sakuragaoka, Setagaya-ku, Tokyo 156-8502, Japan.

*Corresponding author. Email ratanak.ou@gmail.com

Paper submitted 14 May 2013, revised manuscript accepted 27 June 2013.

មូលន័យសង្ខេប

ឫស្សីគឺជាអនុផលព្រៃឈើសំខាន់បំផុតនៅកម្ពុជា ដែលមានចំណូលសរុបប្រចាំឆ្នាំប្រមាណជាង៥.៦លានដុល្លាអាមេរិក។ ឫស្សីដើរតួនាទីសំខាន់ណាស់ មិនត្រឹមតែក្នុងសេដ្ឋកិច្ចជាតិប៉ុណ្ណោះទេ ថែមទាំងរួមចំណែកក្នុងការកាត់បន្ថយភាពក្រីក្រ និងការអភិរក្សទៀតផង។ សហគមន៍អូរតូច ស្ថិតនៅក្នុងខេត្តកំពត ត្រូវបានជ្រើសរើសសម្រាប់ការអនុវត្តវិធីសាស្ត្រគ្រប់គ្រងឫស្សីប្រកបដោយចីរភាពតាំងពី៥ឆ្នាំមុន។ លទ្ធផលសំភាសន៍ចំនួន២៨៧គ្រួសារ ដែលពឹងផ្អែកទៅលើព្រៃឈើនៅតំបន់នេះ បានបង្ហាញថាឫស្សីគឺជាជំរើសមួយក្នុងចំណោមជំរើសសំខាន់ៗបី សម្រាប់ជួយបង្កើនជីវភាពរបស់ពួកគាត់។ គំរូវិភាគជំរើសមានលក្ខខណ្ឌ (conditional logit model) ជាវិធីសាស្ត្រដែលត្រូវបានប្រើសម្រាប់បង្កើតរបៀបប្រើប្រាស់ដ៏សមស្របនៃលក្ខណៈពិសេសខុសៗគ្នាមួយចំនួន សម្រាប់ការគ្រប់គ្រងឫស្សីប្រកបដោយនិរន្តរភាព (ការដាំឡើងវិញ ការប្រមូលផលឫស្សីទៅតាមគម្រោងប្រមូលផល ការគ្រប់គ្រងឫស្សីដោយគម្រោង REDD+ ការការពារប្រភេទរងការគំរាមកំហែង) និងសម្រាប់ប៉ាន់ប្រមាណចំនួនអ្នកដែលអាចនឹងចង់ចំណាយប្រាក់សម្រាប់ការគ្រប់គ្រងប្រកបដោយនិរន្តរភាព។ លក្ខណៈពិសេស(attributes) ទាំងអស់ត្រូវបានរកឃើញថាមានសារៈសំខាន់ក្នុងន័យជាស្ថិតិដោយឡែកពីអត្ថប្រយោជន៍ទទួលបានពីគម្រោងREDD+ ដោយបង្ហាញថាសហគមន៍មូលដ្ឋានមិនយល់ពីគម្រោងREDD+ ឬមិនរំពឹងថាគម្រោងនេះនឹងផ្តល់អត្ថប្រយោជន៍ឱ្យគេ។ ការវិភាគលទ្ធភាពចំណាយប្រាក់តាមបំណងសម្រាប់ការគ្រប់គ្រងឫស្សីប្រកបដោយចីរភាព បានបង្ហាញថាសហគមន៍មូលដ្ឋានចង់ចំណាយប្រាក់ច្រើនទៀតទៅលើការអភិរក្សប្រភេទរងការគំរាមគំហែង និងការស្តារធនធានឫស្សីឡើងវិញនៅក្នុងសហគមន៍របស់គេ តាមរយៈការការពារនិងដាំឫស្សីឡើងវិញនៅតំបន់ព្រៃរិចរិល។ ការសិក្សានឹងជួយអ្នកធ្វើគោលនយោបាយ ដោយការផ្តល់ជូនគាត់នូវចំណេះដឹងនិងការយល់ដឹងពីតម្រូវការចាំបាច់របស់សហគមន៍ និងលក្ខណៈអនុគ្រោះនៃព្រៃឈើសហគមន៍ និងតំបន់ការពារធម្មជាតិ។ ការយកចិត្តទុកដាក់ពីតួនាទីសំខាន់របស់ឫស្សីក្នុងជីវភាពរស់នៅ និងគោលនយោបាយសម្រាប់ការគ្រប់គ្រងឫស្សីគួរតែត្រូវបានអភិវឌ្ឍនិងអនុវត្តនៅប្រទេសកម្ពុជា ដើម្បីគាំទ្រការការពារបរិស្ថាននិងការអភិរក្សជីវៈចម្រុះ។

Abstract

Bamboo is the most important non-timber forest product in Cambodia, generating approximately US$ 5.6 million in Cambodia annually. Bamboo not only plays a crucial role in the national economy but can also contribute

CITATION: Ou R. & Terauchi, M. (2013) Estimating the value of sustainable bamboo resource management in Cambodia: a case study in O Tauch community, Kampot Province. *Cambodian Journal of Natural History*, **2013,** 35–43.

to poverty reduction and conservation. O Tauch community, Kampot Province, was selected for a sustainable bamboo management programme five years ago. Interviews with 287 forest-dependent families revealed that bamboo was one of the top three options for livelihood improvement. The conditional logit model was used to establish the marginal utility of several different attributes for sustainable bamboo management (enrichment planting, harvesting poles based on harvesting plan, management of forest for REDD+ payments, protection of endangered species) and to estimate how much people would be willing to pay for sustainable management. Results reveal that nearly 93% of local people were willing to pay a tax fee to a revolving fund for managing natural resources in their communities. All attributes were found to be statistically significant apart from benefit sharing from REDD+, indicating that the local community either do not understand REDD+ or expect it to benefit them. Analysis of the Marginal Willingness to Pay for sustainable bamboo management showed that the local communities are willing to pay more for conserving endangered species and restoring bamboo resources in their communities through protection and enrichment planting of degraded forest. The study will help policy makers by enlightening them of the community's needs and preferences in community forests and protected areas. Considering the important role of bamboo in livelihoods, new policies for bamboo management should be developed and implemented in Cambodia to support environmental protection and biodiversity conservation.

Keywords

Choice experiment, choice modelling, endangered species, bamboo coverage, harvesting plan, willingness to pay.

Introduction

Forest products account for approximately 5% of Cambodia's Gross National Product (GNP) and 72% of Cambodia's workforce is engaged in agriculture and forestry activities (Forestry Administration, 2008, 2010). Non-timber forest products (NTFPs) form the second most important source for livelihood development and poverty reduction in the country, with approximately 70–90% of households involved in the collection and trade of forest products and NTFPs (McKenney *et al*., 2004). The total average income derived from NTFPs is US$ 300–400 annually (Hansen & Neth, 2006).

Bamboo is one of the top three NTFPs in Cambodia with a value of approximately US$ 5.6 million annually (Enterprise Opportunities Ltd, 2006). Bamboos are normally shaped like woody grasses and some species can reach up to 40 m in height and over 30 cm in diameter. They encompass 1,250 species in 75 genera, most of which are relatively fast-growing, attaining stand maturity within five years (Tropical Tree Crops Program, 1991). According to Forestry Administration (2007) statistics, bamboos are the most commonly traded NTFPs in Cambodia (others include resin and rattan). During the last decade, however, the bamboo trade has fallen dramatically because of land conversion, over-harvesting and unsustainable management (Enterprise Opportunities Ltd, 2006). The sustainable management of bamboo is widely considered a good strategy for biodiversity conservation and rural livelihood development as well as to achieve a larger benefit to the Cambodian economy.

WWF Cambodia selected the O Tauch area (Fig. 1) for piloting a sustainable bamboo production programme. WWF guides policy makers or stakeholders to learn local community preferences and needs before implementing projects or activities. The main activities that may contribute to sustainable bamboo management are: (a) adopting validated harvesting techniques and harvest planning; (b) enrichment planting of native species and economically viable bamboo species on community land; and (c) species conservation in the sustainable harvesting areas by increasing the populations of endangered species. A three-year bamboo harvesting plan was approved by the government in 2010, showing stock, yields and location of bamboo harvested. Based on the O Tauch Community Protected Area's rules and regulations, 10% of the revenue from selling bamboo should be paid into a community trust fund for community resource management. Thus, approximately US$ 0.70 per 100 bamboo poles is paid to the community revolving fund when bamboo is harvested on community land. The fee from harvesting bamboo on community land can be spent on biodiversity conservation and livelihoods development.

There has been limited application of non-market valuation techniques to estimate the benefits of alternative environment management in Cambodia. The choice experience method—a stated preference technique—has been commonly applied in devel-

oping countries and was recently introduced in Cambodia. Choice experience methods can also be useful in designing policies and implementing rural development projects (Köhlin, 2001). The work of Ou & Yabe (2009) in Mondulkiri Province is one of a handful of studies employing the choice experience method to assess the effect of environmental services on ecotourism management by estimating peoples' Willingness to Pay for entrance fees and ecotourism development. Choice models can be applied to non-market goods in accordance with by the Lancasterian microeconomic approach (Lancaster, 1966), in which individuals derive utility from the characteristics of the goods. The first study to apply choice models to non-market valuation was Adamowicz *et al*. (1994, 1998).

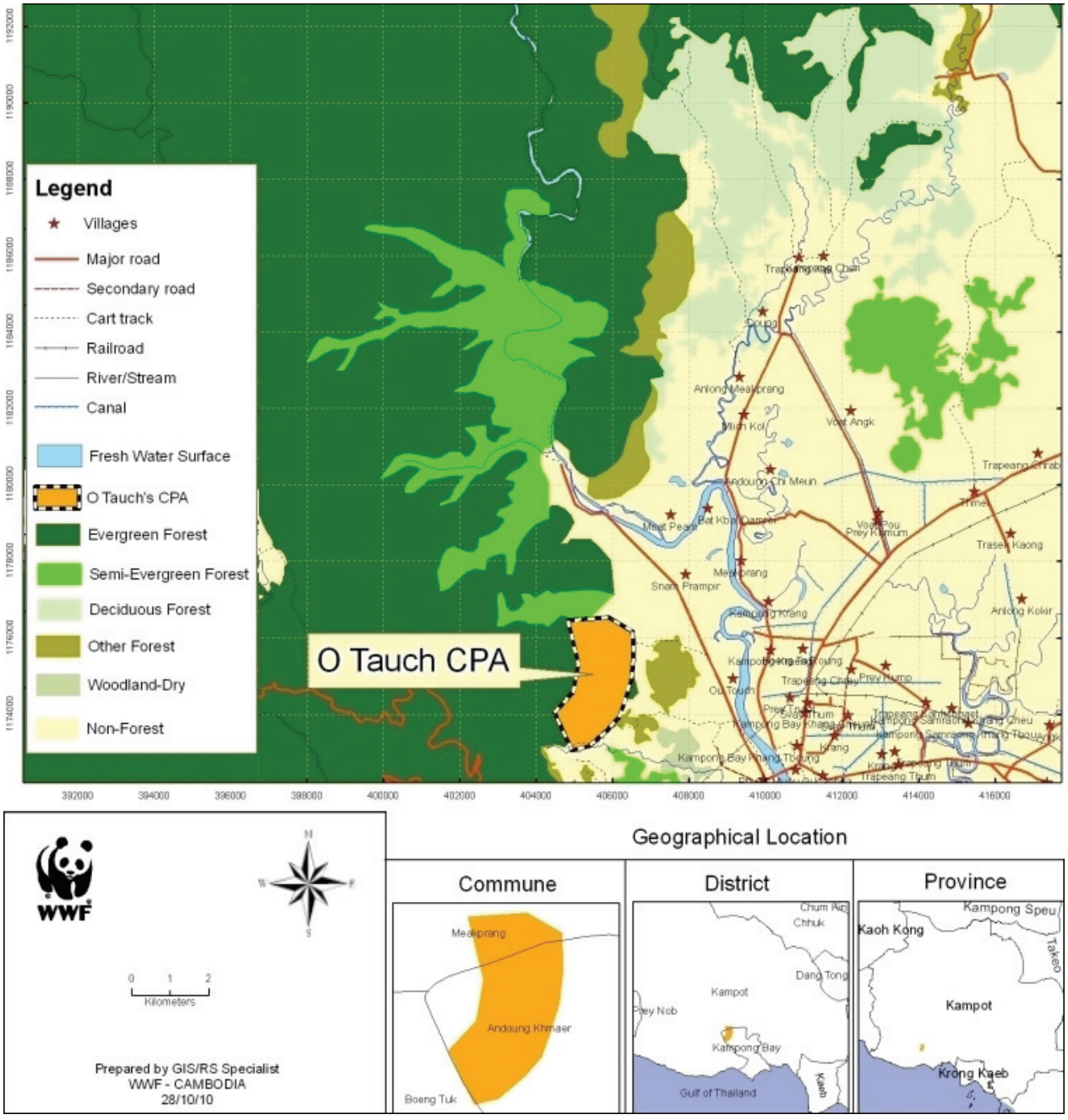


Fig. 1 O Tauch Community Protected Area, Bokor National Park, Kampot Province.

In this study, we use the conditional logit model as an experimental method to determine the marginal utility of various attributes for sustainable bamboo management. We will also use it to estimate how much local communities are willing to pay for management and sustainable production.

Methods

This study used stakeholder analysis, participatory tools and quantitative surveys. The experimental design for two questionnaires for local community members, park rangers, Forestry Administration and local authorities was created using a main effect orthogonal statistical design, generated using SPSS 19. The alternatives for each choice set were generated using a cycled design from the original fractional factorial design. In the researcher-selected questionnaire, a blocking strategy was used to reduce the number of choice tasks given to each respondent. In the respondent-selected questionnaire, the experimental designs followed Table 1. Respondents were advised that they could choose to include any number or type of attributes in their choice decision.

The one-on-one interview survey took place at one village in O Tauch community between June and July 2012 with a total of 287 participants from the local community and local authorities including the Forestry Administration, park rangers and commune council. At first, respondents received general information about the characteristics and management of community with posters, maps and photos of the main bamboo activities, including bamboo harvesting techniques, nursery management, bamboo enrichment planting and large waterbirds and mammals detected using camera-traps in the national park. The second part of the survey included choice modelling questions. Five attributes with four levels were used to create choice sets using a 45 orthogonal main effects design (Louviere *et al*., 2000), which produced 25 choice sets that were blocked into five versions of five choice sets (see Table 1). Finally, the questionnaire also requested information about non-attribute variables such as sex, age, education, income, attitude, perception and the main threats to biodiversity.

The Choice Modelling technique requires respondents to choose only one among three options from each of several sets. The resulting statistical model predicts choice behaviour as a function of the attributes and level that identify the different choice set. According to Lancaster (1966), consumption choices are defined by the utility or value that is derived from the attributes of a particular good and random utility theory, which describes discrete choices in a utility. The relationship of this variable can be introduced by assuming that the relationship between utility and characteristics follows a linear path, and by assuming that the error terms are distributed according to a double leg distribution; the choice probabilities have a convenient closed-form solution known as the multinomial logit model. The conditional logit model used in this study is presented below. Because choice experience involves selection of a substitute policy from several alternatives on the basis of the random utility model (Ben-Akiva & Lerman, 1989), it can be expressed in equations, as shown below.

When the i-th respondent selects j from the set of alternatives, C, the utility u_{ij} can be defined by Equation 1:

$$u_{ij} = v_{ij} + \varepsilon_{ij} \tag{1}$$

where v_{ij} denotes the observable portion of the utility and ε_{ij} indicates error term. When the i-th respondent selects j, the utility u_{ij} of the selected alternative j is higher than the utility u_{ik} of the other alternatives, and its probability can be defined by Equation 2:

$$\begin{aligned} \pi_{ij} &= Pr\,(u_{ij} > u_{ik}\,; \forall\, k \in C) \\ &= Pr\,(v_{ij} + \varepsilon_{ij} > v_{ik} + \varepsilon_{ik}\,; \forall\, k \in C) \\ &= Pr\,(v_{ij} - v_{ik} > \varepsilon_{ik} - \varepsilon_{ij}\,; \forall\, k \in C) \end{aligned} \tag{2}$$

As long as the error terms are independently and identically distributed and follow a Type I extreme value (or Gumbel) distribution, the probability of selecting alternative j can be expressed as follows:

$$\pi_{ij} = \frac{\exp\,(v_{ij})}{\sum\limits_{j \in C} \exp\,(v_{ij})}$$

If a main effect model, confined to the feature vector x_{ij} specific to the alternative, is created for the observable utility function v, it can be defined by equation 3:

$$\pi_{ij} = \frac{\exp\,(x'_{ij}\,\beta)}{\sum\limits_{j \in C} \exp\,(x'_{ij}\,\beta)} \tag{3}$$

Table 1 Attributes and levels used in the Choice Models.

	Levels			
Attributes	**Basic Level**	**Level 1**	**Level 2**	**Level 3**
BC—Bamboo Coverage	0 seedlings	5,000 clumps	10,000 clumps	15,000 clumps
SBH—Sustainable Bamboo Harvesting	50,000 poles	100,000 poles	200,000 poles	300,000 poles
FMRB—Forest Management for REDD+ Benefit	0%	20%	30%	40%
IESC—Increase Endangered Species Conservation	5 species	10 species	15 species	20 species
P—Price	US$ 20	US$ 40	US$ 60	US$ 80

Table 2 Explanation of attribute and non-attribute variables used in the Choice Models.

Variables	**Definition**
Attributes	
ASC—Alternative Specific Constants	
BC—Bamboo Coverage	The number of bamboo seedlings planted every year (enrichment planting)
SBH—Sustainable Bamboo Harvesting	Number of bamboo poles harvested annually based on harvesting plan.
FMRB—Forest Management for REDD+ Benefit	Management of forest for REDD+ payment by donor or government (as percentage of forest).
IESC—Increase Endangered Species Conservation	Number of endangered species protected, based on five-year management plan.
P—Price	Amount the community is willing to pay annually for sustainable bamboo management (in USD)
Non-Attributes	
SEX	Sex (1 = male, 0 = female)
AGE	Age (log(age))
EDU	Education Level (1 = under Grade 1; 2 = Grade 1–6; 3 = Grade 7–9, 4 = Grade 11–12; 5 = over Grade 12)

Where β denotes a parameter vector, x_{ij}. In this case, the logarithmic likelihood function can be defined as follows:

$$LL(\beta) = \sum_i \sum_j (d_{ij} \ln \pi_{ij}) \quad (4)$$

If the alternative is selected, $d_{ij} = 1$. Otherwise, d_y is equal to zero. If parameters can be estimated, the welfare measure of the Marginal Willingness to Pay can be calculated as follows. The indirect utility function v can be defined by Equation 5 if it is assumed to be a linear function involving the attribute x_k, the amount paid, p, and their parameters β_k and β_p :

$$v(x, p) = \sum_k \beta_k x_k + \beta_p p \quad (5)$$

If this equation is subjected to total differentiation, deeming the utility level unchanged ($d_y = 0$) and fixing the attribute x_k (other than attribute x_j) also at the initial level, the Marginal Willingness to Pay (MWTP) for one unit increase in attribute x_j can be defined as follows:

$$MWPT\ x_j = \frac{dp}{dx_j} = -\left[\frac{\partial v}{\partial x_j}\right] \Big/ \left[\frac{\partial v}{\partial p}\right] = -\frac{\beta_j}{\beta_p} \quad (6)$$

In this way, Marginal Willingness To Pay following a change in the alternative policy's level can be calculated.

The attributes with four levels were Bamboo Coverage (BC, the number of bamboo clumps planted every year), Sustainable Bamboo Harvesting (SBH, number of poles harvested annually based on harvesting plan), Forest Management for Reduced Emissions from Deforestation and Degradation (REDD+) Benefit (FMRB, management of forest for REDD+ payment by donor or government), Increase Endangered Species Conservation (IESC, number of endangered species protected based on five-year management plan) and Price (amount of community would pay annually for sustainable bamboo management) (Tables 1 and 2). The attributes for the C option were coded with zero values and the Alternative Specific Constants (ASC) were equal to 1 when either A or B option was selected. The choice data of the conditional logit model and marginal effects were analysed using LIMDEP 8.0 NLOGIT 4.0 (Greene, 2002).

Results

Table 3 shows the respondents' profiles. Almost 64% were male and about 36% were female. The majority of respondents were aged between 26 and 40 years (59.6%), and few were under 25 or over 60 years old. A high percentage of respondents were farmers (82.2%), followed by government staff and fisherman. The educational level of the local community was very low, with almost 61% of respondents below Grade 6 and nearly 92% below Grade 9. Most of the people living in this remote area were strongly dependent on using natural resources and their income was low: 34% of them had monthly incomes below US$ 50 and about 31% earned between US$ 51 and US$ 100.

Nearly 93% of local community members (266 respondents) expressed a willingness to pay for sustainable bamboo management and species conservation in the park. The rest felt that they did not get any benefit from these activities (Table 4). The amount that interviewees were willing to pay for community development ranged from US$ 1 to US$ 10 and was associated with the number of times bamboo was collected. Harvesters collect bamboo throughout the year. Almost 56% of people were willing to pay US$ 1 per month towards the community trust fund, while fewer were willing to contribute US$ 3 (22.9%) or US$ 5 (12.0%).

Table 3 Respondent demographics.

	Category	Respondents	
		Number	Percentage
Gender	Male	183	63.7
	Female	104	36.2
Age (years)	< 25	13	4.5
	26–30	89	31.0
	31–40	82	28.6
	41–50	59	20.6
	51–60	40	13.9
	> 60	4	1.4
Occupation	Farmer	236	82.2
	Fisherman	17	5.9
	Government Staff	31	10.8
	Student	3	1.1
Education Level	< Grade 1	34	11.9
	Grade 1–6	141	49.1
	Grade 7–9	88	30.7
	Grade 11–12	21	7.3
	> Grade 12	3	1.1
Income	< US$ 50	98	34.2
	US$ 51–100	90	31.4
	US$ 101–200	75	26.1
	US$ 201–300	20	7.0
	US$ 301–400	4	1.4

Table 4 Willingness to Pay for sustainable bamboo management.

	Category	Number of respondents	Percentage of respondents
Willing to pay?	Yes	266	92.7
	No	21	7.3
Amount willing to pay (per month)	US$ 0.50	2	0.8
	US$ 1.00	148	55.6
	US$ 2.00	17	6.4
	US$ 3.00	61	22.9
	US$ 5.00	32	12.0
	US$ 7.00	5	1.9
	US$ 10.00	1	0.4

Table 5 Conditional Logit Results. Note *** statistical significance at 1%; ** statistical significance at 5%. See text and Table 2 for explanation of attributes.

Variables/ Attributes	Coefficient	Standard Error	*T*-statistic	*P*
ASC—Alternative Specific Constants	1.2442***	0.13469	9.2380	0.0000
BC—Bamboo Coverage	0.3500***	0.0820	4.2670	0.0000
SBH—Sustainable Bamboo Harvesting	-0.0929**	0.0439	-2.1160	0.0343
FMRB—Forest Management for REDD+ Benefit	-0.0040	0.0027	-1.4810	0.1386
IESC—Increase Endangered Species Conservation	-0.0257***	0.0073	-3.5020	0.0005
P—Price	-1.6317***	0.1836	-8.8880	0.0000
Number of Parameters	6			
Number of Observations	1,435			
Log-livelihood	-1500.679			

Table 6 Marginal Willingness to Pay for sustainable bamboo management (from multinomial logit model modelling). See text and Table 2 for explanation of attributes.

Attributes	Marginal Willingness to Pay per year (95% confidence interval)
ASC—Alternative Specific Constants	US$ 76.26 (49.86, 102.66)
BC—Bamboo Coverage	US$ 21.45 (5.37, 37.52)
SBH—Sustainable Bamboo Harvesting	US$ -5.70 (-14.30, 2.91)
FMRB—Forest Management for REDD+ Benefit	US$ -0.25 (-0.78, 0.29)
IESC—Increase Endangered Species Conservation	US$ -1.58 (-3.02, -0.14)

The Alternative Specific Constants were statistically significant, with the positive sign indicating that all attributes in the choice experience model captured all systematic determinants of alternative choice. Most major activities that contribute to sustainable bamboo management were found to be statistically significant at the 1% and 5% level. Table 5 reveals the estimate of coefficients of the Alternative Specific Constants, Bamboo Coverage, Increase Endangered Species Conservation, and Price were statistically significant at 1% level, while Sustainable Bamboo Harvesting was statistically significant at the 5% level. Only the attribute of Forest Management for Reduced Emissions from Deforestation and Degradation (REDD+) Benefit was not statistically significant.

The respondents' Marginal Willingness to Pay for sustainable bamboo management is summarised in Table 6. Interestingly, the results reveal that the local community was willing to pay the most for bamboo enrichment planting (Bamboo Coverage), totalling around US$ 21 per year. Their second preferences were to pay for sustainable bamboo harvesting (around US$ 6 per year), followed by conserving endangered species. Positive signs for these attributes indicate that the respondents were probably interested in enjoying these activities, while negative signs indicate that price could affect the respondents' choices.

Discussion

This study presents results from the empirical application of a choice experiment to the valuation of sustainable bamboo management. This study aimed to identify the preferences and behaviours of local community members and other stakeholders toward all activities concerning sustainable bamboo management both inside and outside protected areas. Every attribute that was found to be statistically significant should help policy makers to see the interest of people in managing bamboo and other resources at local community level. Additionally, the results showed that nearly 93% of respondents were willing to pay to harvest their resources and sustainably manage bamboo in their communities, with the majority willing to pay US$ 1 per month into a trust fund for their community development. The government and

other stakeholders can use this information for better management of bamboo and species conservation in this rural economy.

The results obtained in this study have several implications for planning and effective management. First, it was observed that bamboo enrichment planting in degraded areas was the first preference, which shows the people are keen on restoring their resources. Second, it was also observed that their Marginal Willingness to Pay values (Table 6) indicate that the local community and other stakeholders appreciate that there are tangible benefits from sustainable bamboo management. Third, among the policy circle and the wider public, there is a need to look outside the public sector for additional funding for biodiversity conservation and environmental protection. Fourth, it is evident that the primary target should be the improvement of sustainable bamboo management for the benefit of both conserving species and improving the living standards of local people. Fifth, although the revolving trust fund would be insufficient to cover all of the conservation and management activities suggested, the local community shows an appreciation of the non-market values of sustainable bamboo management. Finally, local communities are very willing to participate in bamboo management, and these results should be conveyed to the decision makers to define appropriated policies before implementing any projects.

Several research topics could follow up from this study in order to provide clearer insights into the application of choice experience, especially investigating the effects of payments to revolving funds and the potential benefits from REDD+.

Acknowledgements

We would like to gratefully acknowledge Professor Dr Mitsuyasu Yabe, Kyushu University, and Mr Durai Jayaraman, FFI-HARVEST NTFP Specialist for their valuable comments, suggestions, discussion, and providing some materials for research. The first author is grateful to the dedicated members of bamboo team, WWF staff, park rangers, park director, Forestry Administration, authorities and local community for their support during data collecting. I would like to also gratefully acknowledge Tokyo University of Agriculture and Southeast Asian Regional Center for Graduate Study and Research in Agriculture for sponsoring and helping various procedures required during my stay in Japan.

References

Adamowicz, W., Louviere, J. & Williams, M. (1994) Combining revealed and stated preference methods for valuing environmental amenities. *Journal of Environmental Economics and Management,* **26,** 271–292.

Adamowicz, W., Louviere, J. & Swait, J. (1998) *Introduction to attribute-based stated choice methods.* Report to Resource Valuation Branch, Damage Assessment Center, NOAA—National Oceanic and Atmospheric Administration, US Department of Commerce. Advanis, Edmonton, Alberta, Canada.

Ben-Akiva, M. & Lerman, S. (1989) *Discrete Choice Analysis, Theory and Application to Travel Demand*. MIT Press, Cambridge, USA.

Enterprise Opportunities Ltd (2006) *Mekong Bamboo Sector Feasibility Study*. Oxfam Hong Kong, International Finance Corporation—Mekong Private Sector Development Facility and Enterprise Opportunities Ltd, Vietnam.

Forestry Administration (2007) *Cambodia Forestry Statistics 2006*. Forestry Administration, Phnom Penh, Cambodia.

Forestry Administration (2008) *Cambodian Country Paper, Forestry Outlook 2020*. Forestry Administration Phnom Penh, Cambodia.

Forestry Administration (2010) *Cambodian forestry outlook study*. Working paper No. APFSOS II/ WP/ 2010/ 32. Food and Agriculture Organization of the United Nations—Regional Office for Asia and the Pacific, Bangkok, Thailand.

Greene, W. (2002) *LIMDEP Version 8.0 Econometric Modeling Guide, Volume 2*. Plainview, New York, USA.

Hansen, K.K. & Neth T. (2006) *Natural forest benefits and economic analysis of natural forest conversion in Cambodia.* CDRI Working Paper No. 33. Cambodia Development Resource Institute, Phnom Penh, Cambodia.

Köhlin, G. (2001) Contingent valuation in project planning and evaluation: the case of social forestry in Orissa, India, *Environment and Development Economics*, **6,** 237–258.

Lancaster, K. (1966) A new approach to consumer theory, *Journal of Political Economy,* **74,** 132–157.

Louviere, J., Hensher, D. & Swait, J. (2000) *Stated Choice Methods, Analysis and Application.* Cambridge University Press, Cambridge, United Kingdom.

McKenney, B., Yim, C., Prom T. & Evans, T. (2004) *Focusing on Cambodia's high value forest, Phnom Penh*. CDRI Working Paper No. 15. Cambodia Development Resource Institute, Phnom Penh, Cambodia.

Ou R. & Yabe, M. (2009) Analyzing decision-making by tourists for ecotourism development in Cambodia: using latent segment model in Phnom Prich Wildlife Sanctuary. In *Emerging Trends, Challenges and Innovations, Community Based Natural Resource Management (CBNRM) in Cambodia* (eds P. Beaupre, J. Taylor, T. Carson, Keam H. & Heng C.), pp. 493–494. CBNRM Learning Institute, Phnom Penh, Cambodia.

Tropical Tree Crops Program (1991) *Research needs for bamboo and rattan to the Year 2000*. Report to the International Development Research Centre from the International Fund for Agricultural Research and International Network for Bamboo and Rattan, Singapore.

About the Authors

OU RATANAK is a biologist and a planner who specialises in environmental planning. After receiving a Master's degree from Kyushu University (Japan) in Agricultural Economics, he has been working as Rattan Project Manager with WWF and PhD candidate at Tokyo University of Agriculture, Japan. During this time he has conducted various surveys involving wildlife conservation, community development, protected areas management and planning. He has also been involved in various aspects of protected areas management for over six years as a consultant and researcher. His main interests are community-based natural resource management, NTFP policy and management, biodiversity conservation, ecotourism, environmental planning and economics.

MITSUHIRO TERAUCHI is a Professor at Tokyo University of Agriculture (Japan). After receiving a Doctorate from Tokyo University of Agriculture in Agricultural Economics, he has worked as Assistant Professor of Rakuno Gakuen University (Japan), Faculty of Dairy Science, Department of Agricultural Economics. At present, he works in the undergraduate school of the Faculty of International Agriculture and Food Studies, Department of Food Environment Economics, Tokyo University of Agriculture. In addition, he works in the graduate schools of the Department of Agricultural Economics, with the major aims of elucidating and solving Japanese and overseas agricultural and rural problems, food and environmental problems, and international economic issues using a social sciences approach. His main interests are a study of the Construction of the Recycling Society Economic System in Japan and overseas countries based on theoretical and empirical studies.

Recent literature from Cambodia

This section summarises recent scientific publications concerning Cambodian biodiversity and natural resources. The complete abstracts of most articles are freely available online (and can be found using Google Scholar or other Internet search engines), but not necessarily the whole article. Authors are usually willing to provide free reprints or electronic copies of their papers on request and their email addresses, where known, are included in the summaries below.

If you or your organisation have recently published a technical paper or report that you would like to be listed in the next issue, please send an electronic copy, summary or Internet link to Editor.CJNH@gmail.com

New species and taxonomic reviews

de Chambrier, A. & Scholz, T. (2013) A new species of *Australotaenia* (Cestoda: Proteocephalidea) from a snake in Cambodia: host switching or postcyclic parasitism in a distant region? *Folia Parasitologica*, **59,** 279–286.

The genus *Australotaenia* contains two species of worms that parasitize hylid frogs in Australia. A new species, *A. bunthangi* sp. nov., was discovered in the aquatic snake *Enhydris enhydris* (Serpentes: Homalopsidae) from Cambodia, greatly expanding the known geographical range and hosts of this genus. Author: alain.dechambrier@ville-ge.ch

Dubatalov, V.V. (2013) A new species and new combinations of *Danielithosia* from eastern China and Indochina, with check-list of the genus (Lepidoptera: Arctiidae: Lithosiinae). *Acta Entomologica Musei Nationalis Pragae*, **53,** 381–386.

A new species of lichen-moth, *Danielithosia hoenei* sp. nov., is described from eastern China, Cambodia, Thailand, and Vietnam. The Cambodian specimens were collected by Oleg Kosterin in Tatai village, Koh Kong Province. Author: vvdubat@mail.ru; Online: http://szmn.eco.nsc.ru/vvdubat/pdf/AMNP53%281%29381-386.pdf

Eames, J.C. (2013) Rufous-rumped grassbird discovered in Cambodia. *The Babbl*er, **46,** 31.

The rufous-rumped grassbird *Graminicola bengalensis*, a grassland specialist, has been discovered at Bakan in Pursat Province—the first record of this species in Cambodia. Author: Jonathan.Eames@birdlife.org; Online: http://www.birdlife.org/community/wp-content/uploads/2013/07/Babbler46.pdf

Hartmann, T., Sovath, S., Handschuh, M. & Böhme, W. (2012) The taxonomic status of the red-banded butterfly lizard *Leiolepis rubritaeniata* Mertens, 1961, with distributional and natural history notes. *Russian Journal of Herpetology,* **19,** 108–114.

This paper argues for specific rank for *Leiolepis rubritaeniata*, formerly assigned as a subspecies of *L. belliana* or *L. reevesii*. In addition, this paper presents a new country record of *L. rubritaeniata* for Cambodia, gives ecological information on this species and dismantles intraspecific trends of geographical variation in male flank colour patterns. Author: t.hartmann.zfmk@uni-bonn.de

Jameson, M.L. & Drumont, A. (2013) Aroid scarabs in the genus *Peltonotus* Burmeister (Coleoptera, Scarabaeidae, Dynastinae): key to species and new distributional data. *Zookeys*, **320,** 63–95.

A review of the Southeast Asian scarab beetle genus *Peltonotus*. New country records include *Peltonotus nasutus* from southern China and Cambodia. The Cambodian specimens were collected in Phnom Samkos Wildlife Sanctuary (Pursat Province), Ratanakiri Province and Pailin. Author: maryliz.jameson@gmail.com; Online: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3744152/

Jung, S., Duwal, R.K. & Lee, S. (2013) A new species of *Leotichius* Distant (Hemiptera: Heteroptera: Leptopodidae) from Cambodia. *Zootaxa,* **3637,** 97–100.

A new species of spiny-legged bug, *Leotichius schuhi* Jung sp. nov., is described from northern Cambodia. The new species was discovered sharing its habitat with ant lion larvae. Voucher specimens have been deposited in the insect collection of Seoul National University, South Korea. Author: seung@snu.ac.kr

Jung, J., Ryu, Y., Won, H. & Choi, H.-K. (2013) Morphological and molecular characterization of a new record of *Isoëtes coromandelina* subsp. *coromandelina* from Cambodia. *Plant Systematics and Evolution*, doi: 10.1007/s00606-013-0858-y

The quillwort *Isoëtes coromandelina coromandelina*, a heterosporous fern, was collected from a wetland in Pu Rodet Leu, Mondulkiri Province—the first record of this species in Cambodia. This particular subspecies has a wide geographical range across India, Nepal, Sri Lanka and Thailand and neighbouring regions. Molecular data suggest its dispersal has been relatively recent. Specimens from Cambodia were deposited in a herbarium at Ajou University, South Korea. Author: hkchoi@ajou.ac.kr

Kim, C.-J., Olmi, M., Lee, S., Lim, J., Choi, G.-W. & Lee, J.-W. (2013) A checklist of Dryinidae (Hymenoptera: Chrysidoidea) from Cambodia, with new records. *Journal of Asia-Pacific Entomology*. In press.

A checklist and key to the parasitic wasps of the family Dryinidae of Cambodia, containing 14 species, of which

12 are new records for this country. Distribution ranges are provided for each species, together with the known hosts of their larvae. The dryinid species of Cambodia are compared with those of Laos, Thailand and Vietnam. Author: jwlee1@ynu.ac.kr

de Kok, R.P.J. & Nguyen V.D. (2013) *Lespedeza cambodianum* (Leguminosae), a new species from Cambodia. *Kew Bulletin*, **68,** 361–364.

A new species of the plant *Lespedeza* Michx. (Leguminosae) is described from Chida District, Mondulkiri Province: the first record of this genus in Cambodia. Author: r.dekok@rbgkew.org.uk

Lim, J. & Lee, S. (2012) Taxonomy of the family Bethylidae (Hymenoptera: Chrysidoidea) from Cambodia and adjacent countries. I. Genus *Odontepyris* Kieffer (Bethylidae: Bethylinae) with four new species and two new records. *Journal of Natural History*, **47,** doi: 10.1080/00222933.2012.763057

Four new species of wasps are described in this genus: *Odontepyris acutus* Lim, sp. nov., *O. cardamomensis* Lim, sp. nov. and *O. concavus* Lim, sp. nov. from Cambodia, and *O. prolatus* Lim, sp. nov. from Cambodia and Thailand. *Odontepyris muesebecki* Krombein from Cambodia, India and Thailand and *O. formosicola* Terayama from Cambodia, are also newly recorded. A key to Cambodian wasps of the genus *Odontepyris* is also provided, together with distributional records. Author: seung@snu.ac.kr

Lindsay, S. & Middleton, D.J. (2012 onwards) *Ferns of Thailand, Laos and Cambodia*. Royal Botanic Garden Edinburgh, United Kingdom.

A new website aims to provide comprehensive lists of all species of ferns known from Thailand, Laos and Cambodia, with fact-sheets for each species and identification keys. The authors currently recognise 136 fern species in Cambodia (versus 645 species in Thailand and 215 species in Laos). Online: http://rbg-web2.rbge.org.uk/thaiferns/

Mahood, S.P., Eaton, J.A. & Leader, P.J. (2013) Second record of rufous-headed robin *Luscinia ruficeps* outside its breeding range and a description of its first-winter plumage. *BirdingASIA*, **19,** 43–47.

A rufous-headed robin was observed for five days in a garden in Phnom Penh, probably while on migration to wintering grounds further south. This is the first record of this bird in Cambodia and only the second record outside its breeding grounds in China. Author: smahood@wcs.org; Online: http://orientalbirdclub.org/wp-content/uploads/2013/08/Rufous-headed-Robin.pdf

Mahood, S.P., John, A.J.I., Eames, J.C., Oliveros, C.H., Moyle, R.G., Hong C., Poole, C.M., Nielsen, H. & Sheldon, F.H. (2013) A new species of lowland tailorbird (Passeriformes: Cisticolidae: *Orthotomus*) from the Mekong floodplain of Cambodia. *Forktail*, **29,** 1–14.

A new species of lowland tailorbird *Orthotomus chaktomuk*, sp. nov. is described from dense humid lowland scrub in the floodplain of the Mekong, Tonle Sap and Bassac rivers of Cambodia. The new species is genetically similar to *O. atrogularis*, but the two tailorbirds occur sympatrically without apparent hybridization. Although the new species is locally abundant in a number of locations (including within the city limits of Phnom Penh), the authors recommend it be classified as Near Threatened. Author: smahood@wcs.org; Online: http://orientalbirdclub.org/wp-content/uploads/2013/06/TAILORBIRD_Forktail_29pp1-14.pdf

Neang T. & Hun S. (2013) First record of *Oligodon annamensis* Leviton, 1953 (Squamata: Colubridae) from the Cardamom Mountains of Southwest Cambodia. *Herpetology Notes,* **6,** 271–273.

A single juvenile *O. annamensis* was collected in evergreen forest at 916 metres above sea level in Phnom Samkos Wildlife Sanctuary in 2012. This snake was previously known only from two specimens collected in Lam Dong Province, South Vietnam. This discovery invalidates previous suggestions that the species is endemic to Vietnam and adds a new snake to the Cambodian fauna. Author: Thy.Neang@fauna-flora.org; Online: http://www.herpetologynotes.seh-herpetology.org/Volume6_PDFs/Neang_Herpetology_Notes_Volume6_page271-273.pdf

Park, K.-T., Bae, Y.-S. Kim S. & Heppner, J.B. (2013) Genus *Torodora* Meyrick in Cambodia (Lepidoptera: Lecithoceridae: Torodorinae), with descriptions of three new species. *Journal of Natural History*, doi: 10.1080/00222933.2012.759285

A review of the long-horned moth genus *Torodora* (Lepidoptera: Lecithoceridae) in Cambodia, using material collected by the authors in 2009–2011. Eight species are recognised, including three new species: *T. osamensis* Park, sp. nov., *T. occidentalis* Park, sp. nov. and *T. cambodiana* Park, sp. nov. In addition, five species of the genus; *T. parotidosa*, *T. nabiella*, *T. aritai*, *T. sagmaria* and *T. pentagona*, are reported in Cambodia for the first time. A key and descriptions of the new species are provided, together with illustrations of adults and genitalia. Author: ktpark02@gmail.com

Park, K.-T., Heppner, J.B. & Lee, S. (2013) New genus, *Lepidozonates* Park, gen. nov. (Lepidoptera: Lecithoceridae) with description of three new species. *Journal of Entomological Science,* **16,** 222–226.

A new genus of long-horned moths, *Lepidozonates* gen. nov., is presented, together with descriptions of three new species: *L. viciniolus* Park, sp. nov. from Thailand, *L. tenebrosellus* Park, sp. nov. from Taiwan and *L. prominens* Park, sp. nov. from Cambodia and Thailand. Author: ktpark02@gmail.com

Veciana, M., Chaisiri, K., Morand, S., Miquel, J. & Ribas, A. (2013) New biogeographical and morphological information on *Physaloptera ngoci* Le-Van-Hoa, 1961 (Nematoda: Physalopteridae) in South-east Asian rodents. *Parasite*, **20,** 23.

During a study of the parasitic worms of 1,643 rodents trapped along the Mekong River in 2008–2011, the spirurid nematode *Physaloptera ngoci* Le-Van-Hoa, 1961 was recorded for the first time in Cambodia, Laos and Thailand. Online: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3718517/

Biodiversity inventories and monitoring

Boulakia, S., Seguy, L., Tantachasatid, P., Thanisawanyankura, S., Vira L. & Boyer, J. (2012) Diversity and structure of soil macrofauna communities under plant cover in a no-till system in Cambodia. In *Proceedings of the 3rd International Conference on Conservation Agriculture in Southeast Asia, 10–15 December 2012, Hanoi, Vietnam*, pp. 234–235. CIRAD—Agricultural Research for Development, France, NOMAFSI—Northern Mountainous Agriculture and Forestry Science Institute, Vietnam, and University of Queensland, Australia.

Soil invertebrates were sampled in the Bos Khnor seed station in Chamcar Loeu District, Kampong Cham Province. All invertebrates visible to the naked eye were identified (Oligochaeta, Coleoptera larvae, Diptera larvae, Lepidoptera larvae, Formicidae, Diplopoda, Chilopoda, Isopoda, Isoptera, Araneidae, Coleoptera, Diptera, Dictyoptera, Heteroptera, Dermaptera, Gastropoda, Orthoptera, and "other"), counted and weighed. Samples from plots using conventional tillage (bare soil tilled with disc harrows and herbicide) were compared with four direct-sown no-tillage systems under plant cover—the legume *Stylosanthes guianensis*; the grass *Brachiaria ruziziensis*; mixed *B. ruziziensis* and the legume *Cajanus cajan;* and the grass *Eleusine coracana*. All four no-till treatments had significantly higher macrofauna density and biomass than the tilled plot. Author: johnny.boyer@cirad.fr

Chanthy, P. Martin, R.J., Gunning, R.Y. & Andrew, N.R. (2013) Arthropod survey on soybean crops in Cambodia: a comparison of the sweep netting and beat sheeting collection methods for estimating arthropod diversity and species richness. *Australian Journal of Entomology*, doi: 10.1111/aen.12035

Sweep netting and beat sheeting collection methods were employed in the first assessment of insect assemblages on soybean crops in Cambodia. The two methods produced substantially different results—Sweep netting caught significantly higher numbers of most insect orders, but beat sheeting caught more Acari and proved more effective for sampling *Nezara viridula*, a major invertebrate pest of soybean. The use of different sampling methods to assess pests, predators and parasitoids in crops is crucial for assessing Integrated Pest Management strategies. Author: nigel.andrew@une.edu.au

Goes, F. (2012) *Cambodia Recent Bird Reports, October–December 2012*. Http://www.samveasna.org/userfiles/cambodia_rr_oct-dec2012.pdf

Quarterly round-up of unusual and important bird sightings in Cambodia. Includes the first country record of rufous-throated fulvetta *Alcippe rufogularis* from Phnom Samkos Wildlife Sanctuary. Author: fredbaksey@yahoo.com

Hartmann, T., Ihlow, F., Edwards, S., Sovath S., Handschuh, M. & W. Böhme (2013) A preliminary annotated checklist of the amphibians and reptiles of the Kulen Promtep Wildlife Sanctuary in northern Cambodia. *Asian Herpetological Research*, **4,** 36–55.

The first herpetological checklist for the Kulen Promtep Wildlife Sanctuary contains 22 species of amphibians and 33 species of reptiles. The checklist includes three species (*Ingerophrynus macrotis, Micryletta inornata, Scincella melanosticta*) that in Cambodia were formerly known to occur only in the Cardamom Mountains. Author: t.hartmann.zfmk@uni-bonn.de; Online: http://www.ahr-journal.com/index.php?module=case&act=Dwon&id=112&Pid=0

Hosoishi, S., Ngoc, A.L., Yamane, S. & Ogata, K. (2013) Ant diversity in rubber plantations (*Hevea brasiliensis*) of Cambodia. *Ant Myrmecology*, **5,** 69–77.

Arboreal and ground ants were sampled in rubber plantations in Kampong Cham Province, Cambodia. A total of 41 species of Formicidae, belonging to 28 genera in seven subfamilies, were collected. The commonest ant species was the native *Oecophylla smaragdina,* followed by the exotic invaders *Tapinoma melanocephalum* and *Anoplolepis gracilipes*. Total species richness did not vary significantly between rubber plantations of different ages (from six years to more than 50 years), but the oldest plantation notably had some rarer more cryptic ant genera, e.g. *Calyptomyrmex, Pyramica* and *Discothyrea*. Author: hosoishi@agr.kyushu-u.ac.jp; Online: http://www.asian-myrmecology.org/publications/am05_69-77_hosoishi-etal_2013.pdf

Kano, Y., Adnan, M.S., Grudpan, C., Grudpan, J., Magtoon, W., Musikasinthorn, P., Natori,Y., Ottomanski, S., Praxaysonbath, B., Phongsa, K., Rangsiruji, A., Shibukawa, K., Shimatani, Y., Nam S, Suvarnaraksha, A., Thach, P., Thanh, P.N., Tran, D.D., Utsugi, K., Yamashita, T. (2013) An online database on freshwater fish diversity and distribution in Mainland Southeast Asia. *Ichthyological Research,* **60,** 293–295.

An account of the website http://ffish.asia/ that was created by the Nagao Natural Environment Foundation, Japan,

to document and map the freshwater fish biodiversity of Southeast Asia. More than 700 species have been uploaded to date, and the search function operates in several major languages, including Khmer script. Author: kano@species.jp

Species ecology and status

Ayouba, A., Duval, L., Liégeois, F., Ngin S., Ahuka-Mundeke, S., Switzer, W.M., Delaporte, E., Ariey, F., Peeters, M. & Nerrienet (2013) Nonhuman primate retroviruses from Cambodia: high simian foamy virus prevalence, identification of divergent STLV-1 strains and no evidence of SIV infection. *Infection, Genetics and Evolution*, **18,** 325–334.

Blood samples from 118 individuals consisting of six species "from Cambodia" (identified in this paper as *Macaca fascicularis, M. leonina, Presbytis cristata, Nycticebus coucang, Hylobates pileatus* and a Bornean orangutan *Pongo pygmaeus*) were screened for retroviruses. Nearly 45% of individuals tested positive for simian foamy viruses by serology and 3.3% (*M. fascicularis, P. cristata* and *H. pileatus*) for simian T-cell lymphotropic viruses. No evidence of simian immunodeficiency viruses was found. Author: ahidjo.ayouba@ird.fr

Bickford, D., Gilbert, M., Clark, L., Johnson, A., Joyner, P.H., Ogg Keats, L., Khammavong, K., Nguyen Van L., Newton, A., Seow, T.P.W., Roberton, S., Silithammavong, S., Singhalath, S., Yang, A. & Seimon, T.A. (2013) Amphibian pathogens in Southeast Asian frog trade. *Paper presented to 50th Anniversary Meeting of the Association for Tropical Biology and Conservation (ATBC) 23-27 June 2013, San Jose, Costa Rica*.

The health of amphibians traded in Southeast Asia for food or as pets was examined, focusing on *Batrachochytrium dendrobatidis*, ranavirus and general clinical condition. Samples were collected from 2,389 individuals in 51 sites in Laos, Cambodia, Vietnam and Singapore for *Batrachochytrium dendrobatidis* screening, and 74 individuals in Cambodia and Vietnam were sampled for ranavirus screening. The parasitic fungus *Batrachochytrium dendrobatidis* was found on one frog in Cambodia (n = 347) and 13 in Singapore, but none in Laos or Vietnam. No ranavirus was found in Cambodia (n = 70) or Vietnam. Skin lesions were observed in all East Asian bullfrogs *Hoplobatrachus rugolosus* sampled in farms in Vietnam, caused by mycobacteria. These results confirm that *B. dendrobatidis* is still fairly rare among traded amphibians in Southeast Asia. The presence of bacterial disease in farmed *H. rugolosus* is a cause for concern because it may have public health implications. This indicates the need for improved biosecurity in amphibian farming and trade. Author: rokrok@nus.edu.sg

Blair, P.J., Putnam, S.D., Krueger, W.S., Chum C., Wierzba, T.F., Heil, G.L., Yasuda, C.Y., Williams, M., Kasper, M.R., Friary, J.A., Capuano, A.W., Vonthanak S., Peiris, M., Shao, H., Perez, D.R. & Gray, G.C (2013) Evidence for avian H9N2 influenza virus infections among rural villagers in Cambodia. *Journal of Infection and Public Health*, **6,** 69–79.

In 2008, 800 adult Cambodians were enrolled in a study of avian influenza virus transmission in eight sites where highly pathogenic avian influenza (HPAI) H5N1 virus had been reported in humans and poultry from 2006 to 2008. Serologic assays revealed no evidence of previous infection with 13 different low-pathogenic avian influenza viruses or with HPAI avian-like A/Cambodia/R0404050/2007(H5N1). However, 21 participants had elevated antibodies against avian-like A/Hong Kong/1073/1999(H9N2), suggesting they were previously infected with this virus. Author: gcgray@phhp.ufl.edu

Durkin, L., Kim C. & Handschuh, M. (2013) Conservation relevant basic research upon Asian leaf turtles (*Cyclemys*) in Northwest Cambodia. *ZGAP Mitteilungen*, **29,** 10–11.

Article in German. Author: markus.handschuh@gmx.de; Online: http://www.accb-cambodia.org/en/29_1a.pdf

Elwing, S. (2013) *Zoonotic pathogens at the interface between humans and animals in Cambodia, a rural approach.* MSc thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Areas where wild animals, domestic animals and humans live in close proximity favour the transmission of diseases between animals and humans. This study examined three villages in Kampong Cham Province where, as is typical in Cambodia, livestock is free-ranging and not always penned at night. The local farmers exhibited limited knowledge of the route of disease transmission between animals and humans or how to protect themselves against disease. Online: http://stud.epsilon.slu.se/5544/7/elwing_s_130430.pdf

Foley, K.E., Stengel, C.J. & Shepherd, C.R. (2011) *Pills, Powders, Vials and Flakes: the Bear Bile Trade in Asia*. TRAFFIC Southeast Asia, Petaling Jaya, Selangor, Malaysia.

The trade of bear gall bladders and bear bile is a major threat to Asian bear species and cross-border trade of bear bile products is prohibited by the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES). Surveys were conducted in traditional medicine outlets in 13 countries and territories including Cambodia, one of the source countries for wild Asiatic black bears and sunbears. Most of the trade in bear bile was found to be illegal, violating national laws and CITES, and bear farms appeared to offer no conservation role because pressures on wild populations persist. The report contains a series of recommendations to tackle illegal, unsustainable trade. Online: http://cmsdata.iucn.org/downloads/traffic_species_mammals65.pdf

Handschuh, M. (2013) The Bengal florican in Cambodia: a dark chapter for conservation or an example for saved in

the nick of time? *ZGAP Mitteilungen*, **29,** 12–15.

Article in German. Author: markus.handschuh@gmx.de; Online: http://www.accb-cambodia.org/en/29_1b.pdf

Iida, S., Ito, E., Shimizu, A., Nobuhiro, T., Shimizu, T., Kabeya, N., Tamai, K., Araki, M., Chann S. & Keth N. (2013) Year-to-year differences in sap flow and crown-level stomatal conductance of two species in a lowland evergreen forest, Central Cambodia. *Japan Agricultural Research Quarterly*, **47,** 319–327.

This paper describes transpiration and crown-level stomatal conductance in *Calophyllum inophyllum* (which undergoes successive leaf exchange) and *Drypetes* sp. (which performs irregular leaf exchange) in lowland evergreen forest in Kampong Thom Province. Rates of transpiration and stomatal conductances varied in both *Calophyllum* and *Drypetes*, but the former displayed the more constant physiological activity, maintained by successive leaf fall and flushing of new leaves. The data imply that leaf phenology is one of the most important factors affecting transpiration. Author: iishin@ffpri.affrc.go.jp; Online: http://www.jircas.affrc.go.jp/english/publication/jarq/47-3/47-03-10.pdf

Iida, S., Shimizu, T., Tamai, K., Ito, E., Kabeya, N., Shimizu, A., Ohnuki, Y., Keth N. & Chann S. (2013) Intra- and interspecies differences in transpiration in a lowland deciduous forest in Cambodia. In (ed. K. Steppe) *Proceedings of the Ninth International Workshop on Sap Flow,* pp. 417–423. International Society for Horticultural Science, Gent, Belgium.

The Granier method was used to measure single-tree transpiration by four species of trees in a lowland deciduous forest in Cambodia. Greater intra- and interspecific variation in transpiration was observed during leaf fall and foliation during the dry season. The trees began their leaf flush during the driest part of the year, at least one month before the first monsoon rains. Transpiration rates were linearly related to the crown projection area that was not shaded by the crowns of other trees. Author: iishin@ffpri.affrc.go.jp

Khieu V., Schär, F., Marti, H., Sayasone S., Duong S., Muth S., Odermatt, P. (2013) Diagnosis, treatment and risk factors of *Strongyloides stercoralis* in schoolchildren in Cambodia. *PLoS Neglected Tropical Diseases,* 7(2): e2035; doi:10.1371/journal.pntd.0002035

Strongyloides stercoralis is a soil-transmitted parasitic threadworm. A study of 458 Cambodian schoolchildren in Saang District, Kandal Province, found one quarter of the children were infected. Ivermectin proved to be highly efficacious against *S. stercoralis*, with a cure rate of over 98%. Author: peter.odermatt@unibas.ch

Nakanishi, Y., Yamashita, H., Yoshikawa, T., Tominaga, T., Nojiri, K., Sunaga, Y., Muneoka, A., Iwasaki, K., Utoh, M., Nakamura, C., Yamazaki, H. & Uno, Y (2013) Cytochrome P450 metabolic activities in the small intestine of cynomolgus macaques bred in Cambodia, China, and Indonesia. *Drug Metabolism and Pharmacokinetics*, doi: 10.2133/dmpk.DMPK-13-NT-031.

The cynomolgus (also called crab-eating or long-tailed) macaques *Macaca fascicularis* used in drug metabolism studies are mainly sourced from Asian countries. The cytochrome P450 superfamily comprises enzymes in the liver and small intestine that can metabolize drugs. This study found no significant differences in the P450 metabolic activity of the small intestine of *M. fascicularis* procured from Cambodia, China and Indonesia. Author: no-yasuhiro@snbl.co.jp; Online: https://www.jstage.jst.go.jp/article/dmpk/advpub/0/advpub_DMPK-13-NT-031/_pdf

Oi, T., Thao S., Meas S. & Hamada, Y. (2012) Present status and conservation of primates in the Kingdom of Cambodia. *Primate Research*, **28,** 49-60. [In Japanese].

A survey of the distribution of primates at 73 sites in Cambodia—primarily in the Rattanakiri Highlands and the Cardamom, Elephant, and Dangrek Mountains—was conducted in 2008 and 2010 using interviews with local residents and observations of pet primates, wild primates, and monkeys fed at temples. In the Rattanakiri Highlands, information on *Nycticebus pygmaeus, N. bengalensis, Macaca fascicularis, M. leonina, M. assamensis, M. mulatta, M. arctoides, Pygathrix nigripes, Nomascus gabriellae* and *Trachypithecus margarita* was obtained, although the presence of *M. mulatta* and *M. assamensis* was unconfirmed. In the Cardamom Mountains, the authors obtained information on *N. pygmaeus, N. bengalensis, M. fascicularis, M. leonina, M. assamensis, M. mulatta, M. arctoides, T. germaini* and *Hylobates pileatus*, but *N. pygmaeus, M. assamensis, M. mulatta,* and *M. arctoides* were unconfirmed. In the Dangrek Mountains, the presence of *N. bengalensis, M. fascicularis* and *M. leonina* was recorded. Habitat loss and degradation by large timber concessions, agricultural concessions and illegal hunting are major threats to primates in Cambodia. Although primates are protected by the Forest Law of 2002, local residents are often unaware of this law and continue to consume and trade wild meat and animal parts. Captive breeding of *M. fascicularis* for international use in pharmaceutical testing and biomedical experiments might also threaten the wild populations. Author: toruoi@affrc.go.jp Online: https://www.jstage.jst.go.jp/article/psj/28/1/28_28.004/_pdf

Orjuela-Sánchez, P., Sá, J.M., Brandi, M.C., Rodrigues, P.T., Bastos, M.S., Amaratunga, C., Duong S., Fairhurst, R.M. & Ferreira, M.U. (2013) Higher microsatellite diversity in *Plasmodium vivax* than in sympatric *Plasmodium falciparum* populations in Pursat, Western Cambodia. *Experimental Parasitology,* **134,** 318–326.

Using 10 microsatellites for *Plasmodium falciparum* and 13 for sympatric *P. vivax* in Pursat Province, the *P. vivax*

population was found to be significantly more diverse, with more multiple-clone infections and more alleles per marker. Higher genetic diversity in *P. vivax* may reflect differences in population history or increased mutation rates. Author: muferrei@usp.br

Srivilai, P., Prommetta, A. & Prathapa, P. (2013) Initiation of fruiting body development of the medicinal mushroom *Phellinus linteus* from Cambodia *African Journal of Microbiology Research*, **7,** 2885–2892.

Biological compounds from the widely distributed *P. linteus* are used in the treatment of tumours, cancer, arthritis and liver damage, and are reported to have antiviral and antibacterial properties. Fungal crossing analysis revealed that Cambodian *P. linteus* is a heterothallic basidiomycete with a bipolar mating system. Fruiting bodies were observed on wood (the mushroom's natural substrate in Cambodian forests) and malt extract agar, but failed to develop further, possibly due to inadequate humidity. The authors highlight the difficulty of cultivating this species, and add that "Cambodian *P. linteus* has a high risk of extinction due to several factors such as deforestation, poor forest management, forest fire, in discriminate harvesting and climate change". Author: prayook.s@msu.ac.th; Online: http://www.academicjournals.org/ajmr/PDF/pdf2013/4Jun/Srivilai%20et%20al.pdf

Touch S., Yoonuan, T., Nuamtanong, S., Homsuwan, N., Phuphisut, O., Thaenkham, U. & Waikagul, J. (2013) Seasonal variation of *Opisthorchis viverrini* metacercarial infection in cyprinid fish from southern Cambodia. *Journal of Tropical Medicine and Parasitology*, **36,** 1–7.

Small liverfluke infections are caused by fish-borne trematodes, the main cause of cholangiocarcinoma in the Greater Mekong Subregion. The authors sampled 1,874 fish, comprising 17 different species from eight sites in Kandal Province. Opisthorchid metacercariae were found among all species of fish tested, ranging from 5.6% of *Crossocheilus reticulates* (Cambodian name: Trey Changwa Chunh Chuak) to 100% of *Amblyrhynchichthys truncates* (Trey Kambot Chramos). Overall prevalence of *Opisthorchis viverrini* among Kandal Province fish was 34.3%. Infection levels peaked in March and were lowest in July, and were significantly negatively correlated with water level. Author: jitra.wai@mahidol.ac.th; Online: http://www.tm.mahidol.ac.th/tropmed-parasitology/2013-36-1/36-1-2013-e1-Seasonal-Variation.pdf

Wright, H.L., Collar, N.J., Lake, I.R., Net N., Sum P. & Dolman, P.M. (2013) Research upon nesting success in the white-shouldered ibis. *ZGAP Mitteilungen*, **28,** 15.

Article in German. Author: wright@uea.ac.uk; Online: http://www.accb-cambodia.org/en/28_2.pdf

Yen, A.L. & Ro S. (2013) The sale of tarantulas in Cambodia for food or medicine: is it sustainable? *Journal of Threatened Taxa,* **5,** 3548–3551.

The increasing number of foreign tourists visiting Cambodia is placing greater demand on fried female tarantulas *Haplopelma* sp. or spp. (locally called 'a-ping'). The main outlet is Skun, a town in Kompong Cham Province, where tarantulas were originally consumed for medicinal purposes. A skilled collector can dig up several hundred spiders daily, and a vendor selling 100–200 defanged spiders daily could earn 15,000–30,000 Riel. As the spider populations around Skun are reported to have declined, spiders are being sourced from other provinces. Some sellers blame the destruction of the rainforests for the decline in spider numbers, although some sources indicate that the spiders thrive in cashew nut plantations. Online: http://threatenedtaxa.org/ZooPrintJournal/2013/January/o314926i133548-3551.pdf

Coasts, wetlands and aquatic resources

Amano, A. & Kazama, S. (2012) Relationship between discharge and nutrient concentration in inundation areas in Cambodia. *Journal of Water and Environment Technology,* **10,** 165–175.

Analysis of monthly discharge, ammonium, phosphorus, and potassium in the lower Mekong River found no correlation between discharge and these water quality parameters. Author: kazama@kaigan.civil.tohoku.ac.jp; Online: https://www.jstage.jst.go.jp/article/jwet/10/2/10_165/_pdf

Heng S. & Suetsugi, T. (2013) Using artificial neural network to estimate sediment load in ungauged catchments of the Tonle Sap River Basin, Cambodia. *Journal of Water Resource and Protection*, **5,** 111–123.

Modelling revealed that the suspended sediment load of the three catchments in the Tonle Sap River Basin ranged between 159,281 and 723,580 tonnes per year. Planned dam reservoirs are predicted to reduce this annual suspended sediment load by as much as 47–68%, with implications for food production and the lifespan of the proposed dams. Author: heng_sokchhay@yahoo.com; Online: http://scholar.google.co.uk/scholar_url?hl=en&q=http://www.scirp.org/journal/PaperDownload.aspx%3FpaperID%3D27680&sa=X&scisig=AAGBfm0lB3QN7BH5zLH3HI-wrjs5tFMdxQ&oi=scholaralrt

Holtgrieve, G.W., Arias, M.E., Irvine, K.N., Lamberts, D., Ward, E.J. *et al.* (2013) Patterns of ecosystem metabolism in the Tonle Sap Lake, Cambodia with links to capture fisheries. *PLoS ONE,* **8,** e71395. doi:10.1371/journal.pone.0071395

Every year, the Tonle Sap Lake's surface area expands from approximately 2,500 km^2 to over 12,500 km^2, driven by seasonal flooding by the Mekong River. Using a state-space oxygen mass balance model and continuous dissolved oxygen measurements from four locations, this

study found that gross primary productivity averaged 4.1±2.3 g O_2 m^{-3} d^{-1} and ecosystem respiration averaged 24.9±20.0 g O_2 m^{-3} d^{-1}. Aquatic net primary production was predicted to be 2.4±0.2 million tonnes of carbon per year, of which the fisheries harvest the equivalent of up to 69%—substantially higher than global average for marine and freshwater systems. Author: gholt@uw.edu

Kanchanaroek, Y. (2013) Property rights regimes in complex fishery management systems: a case of the Tonle Sap wetlands, Cambodia. *Paper presented to ESEE 2013 Conference—Ecological Economics and Institutional Dynamics: 10th Biennial Conference of the European Society for Ecological Economics, 18–21 June 2013, Lille, France*.

Article not seen. Author: eeyk@leeds.ac.uk

Nagumo, N., Sugai, T. & Kubo, S. (2013) Late Quaternary floodplain development along the Stung Sen River in the Lower Mekong Basin, Cambodia. *Geomorphology*, **198,** 84–95.

The Stung Sen River, the biggest tributary to Lake Tonle Sap, is characterized by large seasonal changes of water discharge, with water levels fluctuating by at least 7 metres. The river floodplain consists of two geomorphic units: a meander belt along the river channel and the backmarsh. Backmarsh sediments at sites in Kampong Chheuteal and Kampong Thom showed a constant accumulation rate of about 0.5 mm per year during the Holocene, but only 0.1 mm per year during the late Pleistocene. Around 11,000 years ago, a sand layer was deposited over the entire valley around Kampong Chheuteal and larger wetlands developed around Kampong Thom, which suggests a period of increased rainfall. Author: nnagumo@nenv.k.u-tokyo.ac.jp

O'Neill, A., Phillips, D.H., Kok S., Chea E., Seng B. & Sen Gupta, B. (2013) Arsenic in groundwater and its influence on exposure risks through traditionally cooked rice in Prey Vêng Province, Cambodia. *Journal of Hazardous Materials*, in press.

This study of arsenic-contaminated groundwater in Prey Veng Province found high risk zones along the Mekong River plain. Households in this area consume up to 24 times more inorganic arsenic than the maximum daily amount recommended by the World Health Organisation. Cooking rice in rainwater significantly reduced exposure to arsenic. Author: B.Sengupta@qub.ac.uk

Ong, L.T.J. & Smith, R.A. (2013) Perception and reality of managing sustainable coastal tourism in emerging destinations: the case of Sihanoukville, Cambodia. *Journal of Sustainable Tourism*, doi: 10.1080/09669582.2013.809091.

Sihanoukville emerged as a tourist destination at a time when the global community was calling for sustainable practices. The Cambodian Government has partnered with international agencies to develop plans and incorporate practices to render this coastal destination more sustainable. This study found a generally good level of alignment between the perceptions and the reality of sustainable tourism practices among the various stakeholder groups, but points to the challenges ahead in managing coastal tourist areas sustainably. Author: jackie.ong@uqconnect.edu.au

Pedersen, L.J. (2013) *The climate effect of land use changes related to hydroelectric development: developing a method to discuss good site selection for hydropower dams*. MSc thesis, Roskilde University, Trekroner, Roskilde County, Denmark.

While some large dams are relatively benign from a climate standpoint, others appear to release substantial amount of greenhouse gases to the atmosphere due to their direct human-induced land use changes. This paper provides a simple methodology for comparing proposed hydroelectric project sites in terms of their climate impacts. Land-use changes tend to be more significant in the tropical region than elsewhere, and hence bear a much higher degree of risk. The proposed Sambor hydropower dam reservoir in Cambodia is estimated to release greenhouse gases to the equivalent of between 153.17 and 204.41 million tonnes in CO_2 over a 100 year timeframe: an energy ratio of 205 to 274 tCO_2 pr. GWh. This is substantially worse than other alternative energy solutions, but still less than conventional thermal energy sources. Online: http://rudar.ruc.dk:8080/bitstream/1800/10490/1/The%20Climate%20Effect%20of%20Land%20Use%20Changes%20related%20to%20Hydropower%20Development.pdf

Phan K., Phan S., Huoy L., Suy B., Wong, M.H., Hashim, J.H., Mohamed Yasin, M.S., Aljunid, S.M., Sthiannopkao, S. & Kim K.W. (2013) Assessing mixed trace elements in groundwater and their health risk of residents living in the Mekong River basin of Cambodia. *Environmental Pollution*, **182,** 111–119.

Groundwater and hair samples were collected from three provinces and analysed. Groundwater from Kandal and Kratie was polluted with arsenic, manganese, barium and iron, whereas none of tube wells in Kampong Cham had trace elements higher than permissible concentrations. An estimated 98.7%, 12.4% and 0% of residents in the study areas of Kandal, Kratie and Kampong Cham respectively are calculated to be at risk from non-carcinogenic effects from exposure to multiple elements, most notably arsenic. Appropriate treatment technologies are required for Cambodian groundwater to be used as drinking water. Author: kongkeaphan@gmail.com

Tsujimoto, K. & Koike, T. (2013) Land-lake breezes at low latitudes: the case of Tonle Sap Lake in Cambodia. *Journal of Geophysical Research: Atmospheres*, **118,** doi: 10.1002/jgrd.50547.

During the post-monsoon season, a small linear cloud system has been observed over the Tonle Sap Lake in the early morning, while the sky above the surrounding land is clear. Numerical simulations show a linear updraft system

forms along the southwest lake shore around 22:00 h and moves northeast to the middle of the lake. The heavier air mass from the land meets the extraordinarily warm and humid air mass that forms over this relatively shallow lake, triggering updrafts. This unique feature generates a distinct nocturnal land breeze circulation over the lake, in spite of its low latitude. Author: tsujimoto@hydra.t.u-tokyo.ac.jp

Grasslands

Packman, C.E., Gray, T.N.E., Collar, N.J., Evans, T.D., Van Zalinge, R.N., Son V., Lovett, A.A. & Dolman, P.M. (2013) Rapid loss of Cambodia's grasslands. *Conservation Biology*, **27,** 245–247.

The Tonle Sap Lake contains the largest remaining seasonally inundated grassland in Southeast Asia. Some 1.1 million people in its immediate surroundings depend on it for pastoralism, traditional low-intensity rice cultivation, and fisheries. The grassland is also used by endemic and rare species, including water snakes and 11 globally threatened birds. Aerial photographs, topographic maps and satellite images indicate there has been a 46% drop in grassland cover from 3,349 km^2 in 1995 to 1,817 km^2 in 2005. Most of this loss is attributed to dry-season rice cultivation and associated reservoirs. The loss of native large herbivores and changing pastoral farming practices may account for the loss of some grassland areas to encroaching scrub. Only a strong political commitment to protection and restoration can prevent the impending loss of the last major flooded grassland in Southeast Asia. Online: http://www.birdlife.org/community/wp-content/uploads/2013/05/Rapid-Loss-of-Cambodias-Grasslands-1.pdf

Forests and forest resources

Bruce, C. (2013) Creating options for long-term resource use and conservation in the Eastern Plains dry forest landscape of Cambodia. In *Evidence-based Conservation: Lessons from the Lower Mekong* (eds T.C.H. Sunderland, J.A. Sayer & Hoang M.-H.), pp. 145–156. Earthscan, London, United Kingdom.

This is a brief account of the 363,177-hectare Mondulkiri Protected Forest, which was established in 2002 and actively managed by the Forestry Administration and WWF since 2004. Challenges to the protected forest include rapid in-migration, unchecked population growth, forest clearance due to lack of land management frameworks, and unplanned development activities. The protected forest management strategy envisions reduced community dependence on forest products through alternative livelihood activities, including ecotourism. Author: craigwbruce@gmail.com

Bugalski, N. & Pred, D. (2013) Safeguarding tenure: lessons from Cambodia and Papua New Guinea for the World Bank Safeguards review. *Paper presented to Annual World Bank Conference on Land and Poverty, 8–11 April, 2013, Washington DC, USA.*

With reference to the *Voluntary Guidelines on the Responsible Governance of Tenure of Land, Forests and Fisheries* approved by the UN Committee on Food Security in 2012, this paper identifies gaps in existing World Bank safeguard policies with respect to tenure. Vulnerable groups suffered from the World Bank-supported Land Management and Administration Project in Cambodia and oil palm projects in Papua New Guinea because the Bank's safeguard policies failed to avoid and mitigate adverse impacts on their tenure. To avoid similar dangers in future projects, the paper outlines new safeguard measures proposed by Oxfam and Inclusive Development International to: (i) Ensure that World Bank-financed operations do not infringe tenure rights to land, housing and natural resources in a manner that violates the human right to an adequate standard of living, including the right to adequate housing and the right to food; (ii) Strengthen, secure and prioritise the tenure of vulnerable and marginalised people so that they enjoy, at minimum, legal protection against forced eviction and illegitimate use by others of their land and natural resources; (iii) Make every effort to ensure that Bank-financed operations do not instigate or exacerbate conflict over land and natural resources; and (iv) Promote more equitable use of, access to and control over land, housing and natural resources. Online: http://www.inclusivedevelopment.net/wp-content/uploads/2013/04/Safeguarding-Tenure.pdf

Evans, T.D., O'Kelly, H.J., Men S., Nut M.H., Pet P., Sorn P. & Pollard, E.H.B. (2013) Seima Protection Forest. In *Evidence-based Conservation: Lessons from the Lower Mekong* (eds T.C.H. Sunderland, J.A. Sayer & Hoang M.-H.), pp. 157–186. Earthscan, London, United Kingdom.

The 292,690-hectare Seima Protection Forest in eastern Cambodia was established in 2009 through an upgrading of the Seima Biodiversity Conservation Area. This area is the focus of a conservation project implemented by the Forestry Administration and Wildlife Conservation Society comprising political support, law enforcement, community natural resource management and developing alternative livelihoods. This chapter explores some of the lessons learned and future needs. Importantly, the authors note that the protected forest is likely to require joint government/NGO management for at least another 10 years. Author: tevans@wcs.org

Khem R.D. & Chou S. (2013) Virachey National Park. In *Evidence-based Conservation: Lessons from the Lower Mekong* (eds T.C.H. Sunderland, J.A. Sayer & Hoang M.-H.), pp. 216–224. Earthscan, London, United Kingdom.

The 332,500-hectare Virachey National Park was created by Royal Decree in 1999 and is managed by the Ministry of Environment. Between 2000 and 2006, it was the focus of the Biodiversity and Protected Area Management Project, with the aim of developing, testing and learning management methods that might be applied to other protected areas in Cambodia. Elements of the park's management programme include community development, ecotourism development and regional cooperation (with Laos and Vietnam). Author: khemrongden007@yahoo.com

Khou E.-H. (2013) Phnom Samkos Wildlife Sanctuary. In *Evidence-based Conservation: Lessons from the Lower Mekong* (eds T.C.H. Sunderland, J.A. Sayer & Hoang M.-H.), pp. 201–215. Earthscan, London, United Kingdom.

The 332,566-hectare Phnom Samkos Wildlife Sanctuary was established by Royal Decree in 1999. The protected area is managed by the Ministry of Environment with support from Fauna & Flora International, and faces multiple threats, including a large and rapidly growing human population living in the central bowl of the sanctuary. The main concern for the future management of this area is securing funding for law enforcement. Author: khou_eanghourt@yahoo.com

Kumagai, T., Mudd, R.G., Miyazawa, Y., Liu, W., Giambelluca, T.W., Kobayashi, N., Lim T.K., Jomura, M., Matsumoto, K., Huang, M., Chen, O., Ziegler, A. & Yin, S. (2013) Simulation of canopy CO_2/H_2O fluxes for a rubber (*Hevea brasiliensis*) plantation in central Cambodia: The effect of the regular spacing of planted trees. *Ecological Modelling*, **265,** 124–135.

Rubber tree plantations are rapidly expanding throughout mainland Southeast Asia, commonly replacing evergreen forest and secondary swidden forests and transforming the carbon dioxide and water dynamics of these areas. A soil-vegetation-atmosphere transfer model was developed, supported with measurements collected at a field site in central Cambodia, to simulate carbon dioxide and water fluxes from the canopies of rubber plantations. The results suggest there is a potentially optimal spacing of rubber trees to produce high primary productivity and water use efficiency. Author: tomoomikumagai@gmail.com; Online: http://homepage1.nifty.com/kumabox/em1301.pdf

Michinaka, T., Miyamoto, M., Yokota, Y., Sokh H., Lao S. & Ma V. (2013) Factors affecting forest area changes in Cambodia: an econometric approach. *Journal of Sustainable Development*, **6,** 12–25.

Elucidating the factors that affect forest cover is critical for implementing REDD+ schemes. This study analysed a variety of socioeconomic factors and their relationships with deforestation in Cambodia in 18 forested provinces for the period 2002–2010. The results showed that population, gross agricultural production and large-scale plantation development drive forest loss. On the other hand, the impacts of rice cultivation, gross industrial production, household income and house floor area by household were not significantly associated with changes in forest cover. Forests in Cambodia still face severe pressures. Intensifying agriculture could be beneficial, by making better use of current agricultural land and lessening the pressure on forest. Industry and other economic ventures must also be developed to bolster the national economy without imposing further pressures on forest land. The authors remind decision makers to use discretion when developing large-scale plantations. Author: zhangyf@affrc.go.jp; Online: http://scholar.google.co.uk/scholar_url?hl=en&q=http://ccsenet.org/journal/index.php/jsd/article/download/26492/16190&sa=X&scisig=AAGBfm0oHXxQ4bxoksec58i_gufPDuh5FQ&oi=scholaralrt

Münke, C., Chhoun C., Lach T., Ao V., Roos, N. & Hjortsø, C.N. (2013) The informal market of edible crickets and spiders in Cambodia: potentials of a traditional food source. *Paper presented to Resilience of Agricultural Systems against Crises, Tropentag 2012, 19–21 September, Göttingen, Germany*.

A market assessment in six provinces, including Phnom Penh, was coupled with a review of existing policies and stakeholders in the management and use of invertebrates as food. The authors conclude there is potential to develop a larger domestic and export market for crickets, through domestication and scaled up collection practices. On the other hand, wild populations of edible tarantulas face overexploitation due to increased market demand. Edible invertebrates can contribute to resilience of agricultural systems to supply food, but their sustainable use requires the development of appropriate natural resource governance structures. Author: cm@ifro.ku.dk

Ouk K. & Chay C. (2013) Central Cardamom Conservation Program. In *Evidence-based Conservation: Lessons from the Lower Mekong* (eds T.C.H. Sunderland, J.A. Sayer & Hoang M.-H.), pp. 187–201. Earthscan, London, United Kingdom.

Logging concessions in the Central Cardamom Mountains were formally suspended in 2001, and the 401,313-hectare Central Cardamoms Protected Forest was established by Forestry Administration in 2004, with support from Conservation International. The Central Cardamom Conservation Program comprises law enforcement, community engagement, research and monitoring, and education and communication. Additional support is provided by other partners including Care International, Wildlife Alliance and Fauna & Flora International. Forthcoming challenges include the proposed hydroelectric power dam development in the Areng Valley. Author: oukkimsan@yahoo.com

Neef, A., Touch S. & Chiengthong, J. (2013) The politics and ethics of land concessions in rural Cambodia. *Journal of Agricultural and Environmental Ethics*, doi: 10.1007/s10806-013-9446-y

The allocation of state land to Economic Land Concessions (ELCs)—estimated to cover an area equivalent to more than 50% of the country's arable land—is associated with encroachment on farmland, community forests and indigenous territories, contributing to a rapid increase of rural landlessness. By contrast, less than 7,000 hectares of land have been allotted to land-poor and landless farmers under a pilot project for Social Land Concessions (SLCs) supported by various donor agencies. Drawing on fieldwork conducted in two research sites in Kratie Province, findings suggest that large-scale and often non-transparent ELCs are discursively justified as land policy measures supporting national development, creating employment opportunities in rural areas and restoring "degraded" and "non-use" land, while SLCs are presented as a complementary policy to reduce landlessness, alleviate rural poverty, and ensure a more equitable land distribution. The authors argue that the SLC project is a deliberate ploy to engage international aid agencies to smooth the adverse social impacts of ELCs and thereby minimise resistance by dispossessed rural people. Author: neef.andreas.4n@kyoto-u.ac.jp; Online: http://link.springer.com/content/pdf/10.1007%2Fs10806-013-9446-y.pdf

Peters, C.M., Thammavong, B., Mekaloun, B., Neak P., Ou R. & Ledecq, T. (2013) Growth of wild rattans in Cambodia and Laos: implications for management. *Forest Ecology and Management*, **306,** 23–30.

Annual stem growth of six species of wild rattans was studied over four years in permanent plots in Prek Thnot, Cambodia, and Ban Sopphouane, Laos. Rattan species studied in Cambodia included *Calamus palustris, C. tetradactylus, C. viminalis, Myrialepis paradoxa,* and *Plectocomia pierreana.* Of these, *M. paradoxa* and *P. pierreana* exhibited the fastest growth (averaging 229.7 cm and 221.5 cm per year respectively), while *C. tetradactylus* exhibited the slowest (averaging 78.3 cm per year). The time required to produce a commercial cane varied from two to eight years. The results show that a reasonable estimate of wild rattan growth can be obtained by marking and measuring 50–60 sample plants of which more than half are of pre-commercial size. Author: cpeters@nybg.org

Scheidel, A., Giampietro, M. & Ramos-Martin, J. (2013) Self-sufficiency or surplus: conflicting local and national rural development goals in Cambodia. *Land Use Policy*, **34,** 342–352.

This article explores two contrasting visions of land use in Cambodia: the aim of the government to foster surplus-producing rural areas for overall economic growth versus the attempts of smallholders to maintain and create livelihoods based on largely self-sufficient rural systems. These two pathways are largely incompatible in the long term. Cambodia's rural labour force is expected to increase enormously over the next decades, but available land for smallholders has become scarce due to the granting of Economic Land Concessions, which offer relatively few employment opportunities. Increased rural–urban migration is anticipated, accompanied by a transition from self-employed smallholders to employment-dependent labourers. Author: arnim.scheidel@gmail.com

Wyatt, T. (2013) From the Cardamom Mountains of Southwest Cambodia to the forests of the world: an exploration of the illegal charcoal trade. *International Journal of Comparative and Applied Criminal Justice*, **37,** 15–19.

Charcoal is used by rural and urban people for cooking, but contributes to deforestation, desertification and climate change. Using a literature review and data from Wildlife Alliance and the Forestry Administration, this study predicts dire consequences for the environment and people until and unless illegal charcoal trade is treated as a serious crime. Author: tanya.wyatt@northumbria.ac.uk

Yen H.M., Preece, L., Nguyen N.L. & Colfer, C.J.P. (2013) A review of conservation area governance in Cambodia, Laos and Vietnam. In *Evidence-based Conservation: Lessons from the Lower Mekong* (eds T.C.H. Sunderland, J.A. Sayer & Hoang M.-H.), pp. 273–308. Earthscan, London, United Kingdom.

This review summarises the management of conservation areas in Indochina based on an appraisal of 15 sites, including five in Cambodia. The authors compare the activities, progress and constraints to managing conservation areas in Cambodia, Laos and Vietnam. For example, Cambodia is distinguished for having a greater focus on development activities (education, training, healthcare, etc.) within its conservation areas, but exhibits poorer inter-organisational collaboration than seen in the other countries. While NGOs play a major role in area governance in Cambodia, they are criticised for competing for scarce qualified personnel and paying significantly more than the standard government salaries. Author: lukepreece@gmail.com

Payments for conservation services, including carbon

Avtar, R., Sawada, H. & Kumar, P. (2013) Role of remote sensing and community forestry to manage forests for the effective implementation of REDD+ mechanism: a case study on Cambodia. *Environment, Development and Sustainability*, doi: 10.1007/s10668-013-9448-y

Curbing deforestation is necessary for the effective implementation of Reducing Emissions from Deforestation and forest Degradation (REDD+). Updated information on forest cover and biomass, obtained using advanced remote sensing techniques, can be useful for selecting suitable sites for planned thinning, reforestation, community forestry, and concession land. To overcome the limitations of remote sensing, the authors advocate an

integrated approach of remote sensing and ground-based monitoring of forests. Author: ram.envjnu@gmail.com

Brewster, J., Bradley, A. & Yeang D. (2012) *Community-based Monitoring, Reporting and Verification (MRV): an assessment in the Oddar Meanchey Community Forestry REDD+ Site, Cambodia*. PACT and UNDP Cambodia, Phnom Penh, Cambodia.

The Oddar Meanchey REDD+ project is the most advanced REDD+ project in Cambodia and the first community based mosaic REDD+ project in Asia to achieve Verified Carbon Standard registration and Climate, Community and Biodiversity Standards validation. In this project, Community-based monitoring has involved a variety of activities including: building capacity in participatory monitoring; community participation in forest inventories, biodiversity assessments and forest patrolling; community patrol reporting through the use of the Frontline SMS mobile phone reporting system; and participatory analysis of data. Data gathered by local communities and grassroots NGOs can provide detailed information on the effectiveness, efficiency and equity of REDD+ on the ground; help enhance local ownership over the REDD+ process; and support local livelihoods through employment and capacity building. However, if not implemented correctly, there are also a potential risks and disadvantages, related to data accuracy and social exclusion. Correct procedures need to be put in place at sub-national and national levels to allow local communities to contribute to and inform the implementation of monitoring, reporting and verification activities in Cambodia. Online: http://www.theredddesk.org/sites/default/files/community_based_mrv_-_lessons_learned_report_2.pdf

Clements, T., Rainey, H., An D., Rours V., Tan S., Thong S., Sutherland, W.J. & Milner-Gullan, E.J. (2013) An evaluation of the effectiveness of a direct payment for biodiversity conservation: the Bird Nest Protection Program in the Northern Plains of Cambodia. *Biological Conservation*, **157,** 50–59.

Direct payments for biodiversity protection have been proposed as an means of delivering both conservation outcomes and benefits to local people. This paper analyses the effectiveness of a direct payment scheme for nine globally threatened bird species in the Northern Plains of Cambodia. Conditional payments have been made to local people to protect nests since 2003, entailing the protection of a total of >2,700 nests at a cost of $30,000 annually, with 71–78% of the costs paid directly to local people. Payments were found to significantly improve the success rates of protected nests in comparison with control sites, leading to population increases for at least three species. However, payments did not influence other threats to species, such as land clearance, and have failed to arrest declines in at least one species. The scheme benefited only a small proportion of people, causing some jealous individuals to deliberately disturb nesting birds. This case study demonstrates that direct payments can be an effective conservation tool where payments correctly target the cause of biodiversity loss, but it is important to consider how decisions over beneficiaries are made, especially where property rights over biodiversity are unclear. Author: tclements@wcs.org

Colas, C., Neang M. & Yoeu A. (2013) Development of ecosystem-services-based policy tools in Cambodia. *Paper presented to ESEE 2013 Conference—Ecological Economics and Institutional Dynamics: 10th Biennial Conference of the European Society for Ecological Economics, 18–21 June 2013, Lille, France*.

Article not seen. Author: colas.chervier@gmail.com

Pasgaard, M. (2013) The challenge of assessing social dimensions of avoided deforestation: examples from Cambodia. *Environmental Impact Assessment Review*, **38,** 64–72.

In developing countries, Reduced Emissions from Deforestation and forest Degradation (REDD) has been promoted as a win-win strategy to reduce greenhouse gas emissions and mitigate climate change. To be successful in reducing emissions while also providing social and environmental benefits, REDD+ must overcome challenges of insecure forest tenure and inequity in the distribution of benefits. This paper considers how to assess the social dimensions of REDD+ using examples from Cambodia. Author: mase@life.ku.dk

Yeang D., Khiev S., Net C., Chhun D., Brewster, J. & Sherchan, K. (2013) Local community engagement in an early stage of REDD+ project development: lessons learned from Siem Reap Community Forestry REDD+ project in Cambodia. *Paper presented to the Cambodian AgriNatura Research Workshop on Integrated Agriculture and Natural Resource Management for Sustainable Development, 4 January 2013, Royal University of Agriculture, Phnom Penh, Cambodia*.

Reducing Emission from Deforestation and Forest Degradation (REDD+) is a policy mechanism to reduce carbon dioxide emission from developing countries through forest conservation, sustainable forest management and enhancement of forest carbon stocks. Implementation challenges include measuring, reporting and verifying forest area change, carbon stocks and the social and environmental impacts of REDD+ projects. A study of the Siem Reap Community Forestry REDD+ project found that local communities can help to measure forest carbon stock and gather social and environmental data. Methods include a basic measurement of biomass stock parameters in the sample plots such as circumference at breast height, standing and fallen deadwood, and tree stump, but the survey community were poor at using hand-held Global Positioning Systems and compasses. Household surveys of natural resource use could be conducted by literate local community members. Engaging and empowering local communities during the

early stages of REDD+ project development could build a sense of trust and responsibility that local communities have towards the project. In addition, community based measuring, reporting and verifying could provide a rapid and cost-effective way to gather necessary data for REDD+ project development. Author: donal.yeang@fauna-flora.org

Climate change

Murphy, T., Irvine, K. & Sampson, M. (2013) The stress of climate change on water management in Cambodia with a focus on rice production. *Climate and Development*, **5,** 77–92.

This article uses existing publications to examine the potential impact of climate change on water resources, and considers possible adaptation and mitigation strategies. Agriculture and hydropower are developing rapidly in Cambodia, and the intensity of storms and droughts appears to be increasing. Infrastructure must be adapted to withstand more extreme weather events. A more resilient option for growing rice includes using less water, which incurs reduced release of methane, a greenhouse gas. The required changes could be implemented more quickly by the mitigation approach of carbon trading of modified rice culture, which could augment food production, reduce greenhouse gases, and help poor rice farmers to make a better living. Author: tompatmurphy@gmail.com; Online: http://geography.buffalostate.edu/sites/geography.buffalostate.edu/files/uploads/Documents/Climate%20Change%20Cambodia_2013.pdf

Other livelihoods initiatives

Palis, F.G., Sumalde, Z.M., Torres, C.S., Contreras, A.P. & Datar, F.A. (2013) *Impact pathway analysis of ACIAR's investment in rodent control in Vietnam, Lao PDR and Cambodia*. ACIAR Impact Assessment Series 83, Australian Centre for International Agricultural Research, Canberra, Australia.

The Australian Centre for International Agricultural Research has been supporting efforts to control rodents in Indochina through a suite of projects. Activities include research on rodent ecology (breeding, habitat) and species identification; training of trainers, extension workers and farmer leaders in rodent control and management; demonstrations of the community trap–barrier system; production and distribution of training/learning/communication/extension materials; and conducting village campaigns through the mass media and interpersonal sources. The uptake and impact of project methods proved much stronger and longer lasting in Vietnam and Laos than Cambodia. This is perhaps due to the shorter duration of support in Cambodia, but the authors also observed that Cambodian farmers view rodent infestation as a problem to be endured rather than tackled, even though their damage was severe (second only to insect infestation). It was also noted that Cambodian farmers can gain a supplementary income by catching live rodents for sale to crocodile farms. Online: http://aciar.gov.au/files/node/15303/ias083_impact_pathway_analysis_of_aciar_s_inves_19358.pdf

Reimer, J.K. & Walter, P. (2013) How do you know it when you see it? Community-based ecotourism in the Cardamom Mountains of southwestern Cambodia. *Tourism Management*, **34,** 122–132.

Honey's analytical framework for "authentic" ecotourism was applied to a case study of a community-based ecotourism project in Chi Phat, Koh Kong Province. Qualitative research methods included participant observation, interviews, focus groups and analysis of project documents. Findings for each of Honey's seven categories showed the complexity of community-based ecotourism in addressing often contradictory concerns of environmental conservation, local livelihoods and cultural preservation, and the importance of local context to ecotourism management. Gender, while not explicit in Honey's framework, was also seen to be an important analytical category for community-based ecotourism and sustainable development. Author: pierre.walter@ubc.ca

Regional Reviews

Duckworth, J.W., Batters, G., Belant, J.L., Bennett, E.L., Brunner, J., Burton, J., Challender, D.W.S., Cowling, V., Duplaix, N., Harris, J.D., Hedges, S., Long, B., Mahood, S.P., McGowan, P.J.K., McShea, W.J., Oliver, W.L.R., Perkin, S., Rawson, B.M., Shepherd, C.R., Stuart, S.N., Talukdar, B.K., van Dijk, P.P., Vié, J-C., Walston, J.L., Whitten, T. & Wirth, R. (2012) Why South-east Asia should be the world's priority for averting imminent species extinctions, and a call to join a developing cross-institutional programme to tackle this urgent issue. *Sapiens*, **5**, 77–95.

A new programme, "Action Asia", is being developed and coordinated by the IUCN Species Survival Commission to assist implementing agencies and their partners to tackle the impending extinctions among Southeast Asia's non-marine vertebrates. Author: will.duckworth@iucn.org; Online: http://sapiens.revues.org/1327

Koh, L.P., Kettle, C.J., Sheil, D., Lee, L.T., Giam, X., Gibson, L. & Clements, G.R. (2013) Biodiversity State and Trends in Southeast Asia. In *Encyclopedia of Biodiversity, Volume 1* (ed. S.A. Levin), 509–527. Elsevier Academic Press, Amsterdam, The Netherlands.

Southeast Asia, which encompasses four biodiversity hotspots (Indo-Burma, Sundaland, the Philippines, Wallacea), has a remarkably rich biodiversity, but has

experienced widespread and rapid deforestation and habitat degradation over recent decades. A summary and national statistics are provided on terrestrial and aquatic habitat loss, degradation and recovery; species diversity, status and trends; threats to biodiversity; and challenges and opportunities for conservation across Southeast Asia. Cambodia is highlighted for having the region's highest annual rate of primary forest loss (3.48%) between 2000 and 2010. Online: http://www.dbs.nus.edu.sg/lab/cons-lab/documents/Koh_etal_Ency_Biod_2013.pdf

Poffenberger, M., Soriaga, R. & Walpole, P. (2013) *Communities and Forest Stewardship: Regional Transitions in Southeast Asia*. Ateneo de Manila University Press, Manila, the Philippines.

A regional synthesis of trends in policies and projects on forest lands between the early 1980s and 2005, drawing on the experiences of the Asia Forest Network with forest-based communities in Cambodia, Indonesia, the Philippines, Thailand and Vietnam. Author: mpoffen@aol.com

Preece, L.D., Herrero-Cangas, B., Achidaiwan, R. & Stacey, N. (2013) Quantifying threats to forests in the Lower Mekong and assessing responses. In *Evidence-based Conservation: Lessons from the Lower Mekong* (eds T.C.H. Sunderland, J.A. Sayer & Hoang M.-H.), pp. 351–368. Earthscan, London, United Kingdom.

This chapter examines threats and conservation actions in 15 sites in Cambodia (specifically, Central Cardamom Protected Forest, Mondulkiri Protected Forest, Phnom Samkos Wildlife Sanctuary, Seima Protection Forest, Virachey National Park), Laos and Vietnam. Of 10 threats examined, logging and hunting were ranked as the primary threats across the 15 sites. Author: lukepreece@gmail.com

Slayback, D. & Sunderland, T.C.H. (2013) Forest degradation in the Lower Mekong and an assessment of protected area effectiveness *c.*1990–*c.*2009: a satellite perspective. In *Evidence-based Conservation: Lessons from the Lower Mekong* (eds T.C.H. Sunderland, J.A. Sayer & Hoang M.-H.), pp. 332–350. Earthscan, London, United Kingdom.

Satellite images were used to examine forest degradation in selected protected areas in Cambodia, Laos and Vietnam. During the 2000s, annual rates of forest degradation in five protected areas in Cambodia were: Central Cardamom Protected Forest 0.05%; Mondulkiri Protected Forest 0.04%; Phnom Samkos Wildlife Sanctuary 0.41%; Seima Protection Forest 0.16%; and Virachey National Park 0.00%. Rates of forest degradation tended to be worse in areas outside of the protected areas. There may be errors in interpreting satellite images, however, and ground data are required to verify these figures. Author: dan.slayback@nasa.gov

WWF (2013) *Ecosystems in the Greater Mekong: Past Trends, Current Status, Possible Futures*. WWF. Gland, Switzerland.

The report contains a series of maps showing the historical trends, current status and future projections of forests in Myanmar, Thailand, Cambodia, Laos and Vietnam. Future projections for the period 2009 to 2030 contrast two scenarios: an unsustainable growth scenario that assumes 2002–2009 deforestation rates continue unchecked (resulting in the loss of a further 34% of forest cover by 2030) versus a "green economy" scenario, which assumes a 50% reduction in deforestation rate and no further losses in important biodiversity areas. The four main drivers of change of the region's ecosystems are identified as: Human population growth and increasing population density, along with worsening income inequality; Unsustainable levels of resource use, increasingly driven by the demands of export-led growth; Unplanned and frequently unsustainable forms of infrastructure development (dams, roads, etc.); Government policies, along with lack of integrated planning, poor governance, corruption and wildlife crime on a massive scale. To enable these countries to achieve greener growth, a series of recommendations are provided, e.g. prevent further conversion of primary forest; prevent the construction of dams on major rivers, and support only sustainable hydropower projects on select tributaries; species-specific conservation and recovery actions for endemic species; and halt the illegal wildlife trade. Online: http://awsassets.panda.org/downloads/greater_mekong_ecosystems_report_020513.pdf

Miscellaneous

Lim P., Dek D., Try V., Eastman, R.T., Chy S., Sreng S., Suon S., Mao S., Sopha C., Sam B., Ashley, E.A., Miotto, O., Dondorp, A.M.,White, N.J., Su, X.-Z., Chuor C.M., Anderson, J.M., Amaratunga, C., Menard, D. & Fairhurst, R.M. (2013) Ex vivo susceptibility of *Plasmodium falciparum* to antimalarial drugs in western, northern, and eastern Cambodia, 2011-2012: association with molecular markers. *Antimicrobial Agents and Chemotherapy*, **57,** doi: 10.1128/AAC.00687-13

In light of the parasite's growing resistance to artemisinin, a combination of dihydroartemisinin and piperaquine has been the first-line treatment for *Plasmodium falciparum* malaria in western Cambodia since 2008. This treatment is not always effective, however. To monitor for resistance to piperaquine and other antimalarials, this study measured drug susceptibilities for *P. falciparum* collected from Pursat, Preah Vihear, and Ratanakiri. While multidrug-resistant *P. falciparum* was prevalent in western and northern Cambodia, no evidence was found for piperaquine resistance. This suggests that the failures of dihydroartemisinin–piperaquine treatments result mainly

from artemisinin resistance. Author: rfairhurst@niaid.nih.gov

Mohammed, E.Y., Wang, S. & Kawaguchi, G. (2013) *Making growth green and inclusive: the case of Cambodia*. OECD Green Growth Papers 2013-08, OECD Publishing, Paris, France.

Natural resources are a key contributor to Cambodia's development: three-quarters of the population are directly engaged in agriculture, and agriculture and forestry contribute nearly 40% of Gross Domestic Product. In 2009, the Royal Government established the Inter-Ministerial Green Growth Working Group (GGWG), chaired by the Ministry of Environment and with representatives from 19 ministries, which adopted a National Green Growth Roadmap in 2010 and finalised the National Strategic Plan on Green Growth. Consultation with multiple stakeholders revealed that greener growth was highly desirable, with poverty alleviation, institution building and economic growth benefits ranked as essential outcomes. Environmental protection, improved social well-being and investment opportunities were ranked as secondary outcomes. This report identifies the policies and other factors that will facilitate Cambodia's transition to greener growth, as well as a number of obstacles. The latter include a lack of public awareness of the implications of the current growth pathway for the Cambodia's environment and natural assets, limited institutional co-ordination to support coherent policy making, and insufficient investments in green sectors. Author: pythecanthro@gmail.com; Online: http://www.oecd-ilibrary.org/docserver/download/5k420651szzr.pdf?expires=1377329467&id=id&accname=guest&checksum=E1CFAB61CAFA946920AFBCB1ED6B1503

The Recent Literature section was compiled by JENNY C. DALTRY, with additional contributions from Angie Appel, Julien Brewster, Matthew Linkie, Frédéric Goes and Tran Thanh Huong. All Internet addresses were correct at the time of publication. Please send contributions (published or grey literature, including project technical reports and conference abstracts not more than 18 months old) by email to: Editor.CJNH@gmail.com

Instructions for Authors

Purpose and Scope

The *Cambodian Journal of Natural History* is a free journal that is published biannually by the Centre for Biodiversity Conservation at the Royal University of Phnom Penh. The Centre for Biodiversity Conservation is a non-profit making unit, dedicated to training Cambodian biologists and the study and conservation of Cambodia's biodiversity.

The *Cambodian Journal of Natural History* publishes original work by:

- Cambodian or foreign scientists on any aspect of Cambodian natural history, including fauna, flora, habitats, management policy and use of natural resources.
- Cambodian scientists on studies of natural history in any part of the world.

The Journal especially welcomes material that enhances understanding of conservation needs and has the potential to improve conservation management in Cambodia.

The primary language of the Journal is English. Authors are, however, encouraged to provide a Khmer translation of their abstract.

Readership

The Journal's readers include conservation professionals, academics, government departments, non-governmental organisations, students and interested members of the public, both in Cambodia and overseas. In addition to printed copies, the Journal is freely available online at: http://www.fauna-flora.org/publications/cambodian-journal-of-natural-history/

Papers and Short Communications

Full Papers (2,000–7,000 words) and Short Communications (300–2,000 words) are invited on topics relevant to the Journal's focus, including:

- Research on the status, ecology or behaviour of wild species.
- Research on the status or ecology of habitats.
- Checklists of species, whether nationally or for a specific area.
- Discoveries of new species records or range extensions.
- Reviews of conservation policy and legislation in Cambodia.
- Conservation management plans for species, habitats or areas.
- The nature and results of conservation initiatives, including case studies.
- Research on the sustainable use of wild species.
- Abstracts of student theses (Short Communications only).

The Journal does not normally accept formal descriptions of new species, new subspecies or other new taxa. If you wish to submit original taxonomic descriptions, please contact the editors in advance.

How to Submit a Manuscript

Manuscripts should be submitted by email to the Editors at **Editor.CJNH@gmail.com** In the covering email, the Lead (Corresponding) Author must confirm that:

- The submitted manuscript has not been published elsewhere,
- All of the authors have read the submitted manuscript and agreed to its submission, and
- All research was conducted with the necessary approval and permit from the appropriate authorities.

If you have any questions before or after submitting a manuscript, you are welcome to contact the Editors at any time.

Review and Editing

All contributors are strongly advised to ensure that their spelling and grammar is checked by a native English speaker before the manuscript is submitted to the Journal. The Editorial Team reserves the right to reject manuscripts that need extensive editing for spelling and grammar.

All manuscripts will be subject to rigorous peer review by a minimum of two qualified reviewers. Authors are welcome to suggest appropriate reviewers.

Proofs will be sent to authors as a portable document format (PDF) file attached to an email note. Acrobat Reader can be downloaded free of

charge from <www.adobe.com> to view the PDF files. Corrected proofs should be returned to the Editor within three working days of receipt. Minor corrections can be communicated by email.

The Editorial Team welcomes contributions to the journal, as follows:

News

Concise reports (<300 words) on news of general interest to the study and management of Cambodia's biodiversity. News items may include, for example:

- Announcements of new initiatives; for example, the launch of new projects, conferences or funding opportunities.
- Summaries of important news from an authoritative published source; for example, a new research technique, or a recent development in conservation.

Letters to the Editors

Informative contributions (<650 words), usually in response to material published in the Journal.

Recent Literature

Copies or links to recent (<18 months) scientific publications concerning Cambodian biodiversity and the management of natural resources. These may include journal papers, project technical reports, conference posters and student theses.

Preparation of Manuscripts

Authors should consult examples in this issue for general style. First-time authors are also advised to read the Editorial in the *Cambodian Journal of Natural History*, volume 2012, issue 2, entitled "How to write a winning paper" (freely available from http://www.fauna-flora.org/publications/cambodian-journal-of-natural-history/).

Contributions should be in English, with UK English spelling (if in doubt, Microsoft Word and similar software should be set to check spelling and grammar for 'English (UK)' language). Lines should be double-spaced.

Submissions can be in 'doc', 'docx', 'rtf' or 'wpd' format, preferably as a single file attached to one covering email. The order of the sections of the manuscript should be: cover page, main text, references, short biography of each author, tables, figures and plates (photographs).

The cover page should contain the title and full mailing address and email address of the Lead Author and the addresses of all co-authors. All pages should be numbered consecutively.

Title: A succinct description of the work, in no more than 20 words.

Abstract: (Full papers only). This should describe, in no more than 250 words, the aims, methods, major findings and conclusions. The abstract should be informative and intelligible without reference to the text, and should not contain any references or undefined abbreviations. Cambodian authors are strongly encouraged to submit a Khmer translation of the English abstract.

Keywords: (Full papers only). Up to eight pertinent words, in alphabetical order. There is no need to repeat words that are already in the title.

References: These should be cited in the text in the form of Stuart & Emmett (2006) or (Lay, 2000). For three or more authors, use the first author's surname followed by *et al.*; for example, Rab *et al.* (2006) or (Khou *et al.*, 2005). Multiple references should be in chronological order, for example, Holloway & Browne (2004); Kry & Chea (2004); Phan (2005); Farrow (2006).

The reference list should be presented in alphabetical order. Cambodian, Vietnamese and other authors who typically write their family name first are presented in the form <surname> <initials> without a comma (thus, Sin Sisamouth becomes Sin S.). Western author names are presented in the form <surname> <comma> <initials> (thus Charles Robert Darwin becomes Darwin, C.R.).

The titles of articles and journals are written in full.

The following are examples of house style:

Papers:

Amano, A. & Kazama, S. (2012) Relationship between discharge and nutrient concentration in inundation areas in Cambodia. *Journal of Water and Environment Technology,* **10,** 165–175.

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.

Miles, L., Newton, A.C., Defries R.S., Ravilious, I. May I., Blyth, S., Kapos, V. & Gordon, J.E. (2006) A global overview of the conservation status of tropical dry forests. *Journal of Biogeography,* **33,** 491–505.

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.

Koh, L.P., Kettle, C.J., Sheil, D., Lee, L.T., Giam, X., Gibson, L. & Clements, G.R. (2013) Biodiversity State and Trends in Southeast Asia. In *Encyclopedia of Biodiversity, Volume 1* (ed. S.A. Levin), 509–527. Elsevier Academic Press, Amsterdam, The Netherlands.

Reports:

Lic V., Sun H., Hing C. & Dioli, M. (1995) *A brief field visit to Mondolkiri Province to collect data on kouprey (*Bos sauveli*), rare wildlife and for field training.* Unpublished report to Canada Fund and IUCN, Phnom Penh, Cambodia.

Theses:

Yeang D. (2010) *Tenure rights and benefit sharing arrangements for REDD: a case study of two REDD pilot projects in Cambodia*. MSc thesis, Wageningen University, Wageningen, The Netherlands.

Websites:

IUCN (2010) 2*010 IUCN Red List of Threatened Species.* Http://www.redlist.org [accessed 1 December 2010].

About the Author(s): This section is optional for Full Papers and Short Communications. It should describe the main research interests of every author (<150 words each), apart from what is obvious from the subject of the manuscript and the authors' affiliations.

Tables, figures and plates: These should be self-explanatory, each on a separate page and with an appropriate caption. Figures, including maps, should ideally be in black and white. Plates (photographs) should be included only if they are of good quality and form part of evidence that is integral to the study (e.g. a camera trap photograph of a rare species).

Appendices: Long tables and other supporting materials, such as questionnaires, should be placed in Appendices.

Species names: The first time a species is mentioned, its scientific name should follow without intervening punctuation: e.g. Asian elephant *Elephas maximus*. English names should be in lower case throughout except where they incorporate a proper name (e.g. Asian flycatcher, Swinhoe's minivet, long-billed vulture).

Abbreviations: Full expansion should be given at first mention in the text.

Units of measurement: Use metric units for measurements of area, mass, height, etc.

Publisher: Centre for Biodiversity Conservation, Room 415, Main Campus, Faculty of Science, Royal University of Phnom Penh, Confederation of Russian Boulevard, Phnom Penh, Cambodia.

The journal online. All issues of this journal can be freely downloaded from:

http://www.fauna-flora.org/publications/cambodian-journal-of-natural-history/

Authors are permitted to post their papers on their personal and institutional webpages on condition that access is free and no changes are made to the content.

Cambodian Journal of Natural History

The preparation and printing of this volume was generously supported by:

Royal University of Phnom Penh – Centre for Biodiversity Conservation

RUPP is Cambodia's oldest university, with over 9,000 students and over 400 teachers. The Department of Biology founded the Centre for Biodiversity Conservation to provide training and support for national scientists. The Centre delivers a Masters of Science curriculum in Biodiversity Conservation and has established a library, classrooms, herbarium and zoological reference collection for use by students and scholars of Cambodian natural science.

Website: http://www.rupp.edu.kh/master/biodiversity/?page=cbc

Fauna & Flora International

FFI protects threatened species and ecosystems worldwide, choosing solutions that are sustainable, are based on sound science and take account of human needs. Operating in more than 40 developing countries worldwide, FFI saves species from extinction and habitats from destruction, while improving the livelihoods of local people. Founded in 1903, FFI is the world's longest established international conservation body. FFI has been active in Cambodia since 1996.

Website: www.fauna-flora.org

The present issue was also supported by a major foundation that chooses to remain anonymous.

The Cambodian Journal of Natural History does not charge subscription fees. The journal depends upon the generosity of its partner organisations and sponsors to be published and distributed free of charge to readers throughout Cambodia and worldwide.

If you or your organisation are interested in supporting the Cambodian Journal of Natural History or the Centre for Biodiversity Conservation, kindly contact the editors (Editor.CJNH@gmail.com) or the staff of the Centre for Biodiversity Conservation (mbiodiversity.info@rupp.edu.kh). The names and logos of all supporters will be published in the journal unless they wish to be anonymous.

The Editors are grateful to Ashish John, Phauk Sophany, Joe and Jade Heffernan, Jeremy Holden and Roger Ingle for their kind assistance with the production of this issue.

Cambodian Journal of Natural History

Volume 2013, Number 1

Contents