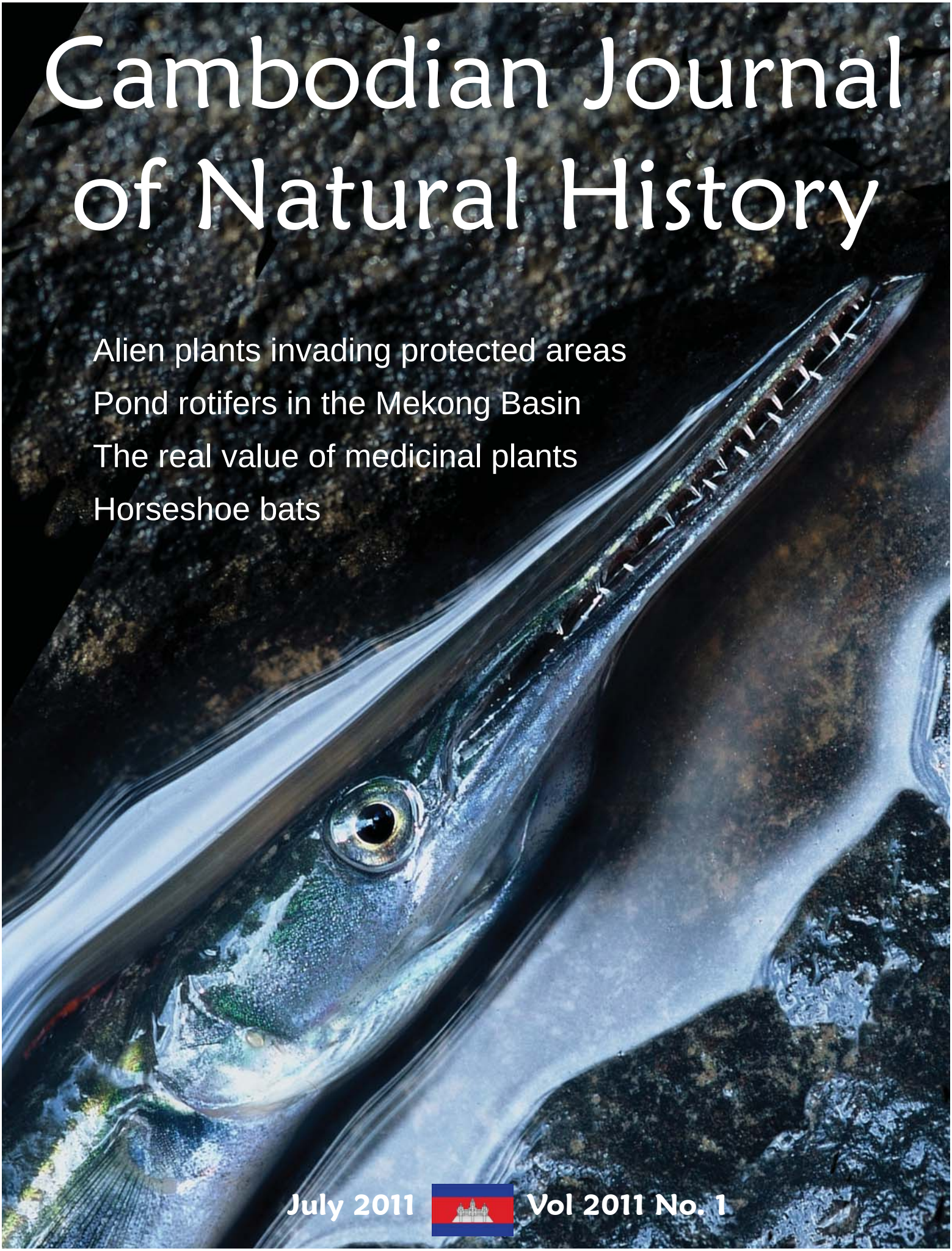
Cambodian Journal of Natural History



Alien plants invading protected areas

Pond rotifers in the Mekong Basin

The real value of medicinal plants

Horseshoe bats

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Cover photo: A male freshwater needlefish or 'trey phtong' *Xenentodon canciloides* from the Pramaoy River, Phnom Samkos Wildlife Sanctuary (© Jeremy Holden/ Fauna & Flora International). The management of fisheries is explored in this issue's Editorial.

Editorial - A new point of view for Cambodian aquatic natural resources

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A relatively small number of people in Cambodia see *fish as income only*. Fish as an extractive resource, caught and traded in the market for cash, disproportionately benefit only a minority of Cambodia's wealthy elite. To most Cambodians *fish are food and income*. Fish are also *culture*. Fish, combined with rice and vegetables, provide *essential nutrition*, and ultimately *survival* for Cambodia's rural poor (McKenney & Prom, 2002).

Yet conventional fisheries management in Cambodia focuses on the state's commitment to improving commercial catch production. Fish are treated as an important tradable national commodity and a target for more commercialisation, in spite of chronically poor monitoring and statistical analysis in Cambodia's freshwater, brackish and marine fisheries (but see Allebone-Webb & Clements, 2010, as a recent exception). This narrow focus, coupled with a lack of data, is especially problematic at Community Fisheries (CFi) levels. Currently, there are no readily available data on productivity or catches to empirically assess the contribution, if any, that the CFi management system makes to fish conservation or improving the lives of Cambodian fishers. Cambodia is not alone, as this is true of most small-scale fisheries in the Global South (Béné *et al*., 2006). Their biodiversity, productivity and socioeconomic importance is downplayed or ignored in national resource accounting (Degen *et al*., 2000).

A new framing or imaging of Cambodian fisheries governance is required (Jentoft *et al.,* 2010). A new viewpoint is needed to better understand how the world's fourth largest freshwater fishery (Van Zalinge *et al.,* 2001), a dynamic and historical social-ecological system, fits into local, regional and global aquatic value chains. We need to look at Cambodian and the broader Mekong fisheries as part of an increasingly globalized fish commodity market, with many influences fundamentally originating from outside the region and impacting across multiple and different scales on harvesting levels and trade (Taylor *et al*., 2007). Conventional quantitative assessments do not capture the nuanced social-ecological and cultural factors of how local communities view their resources and the resulting impacts and declines (Bush & Hirsch, 2008). This is essentially how we currently look at all fisheries - as extractive resources for those who catch and possess them. Even after they are caught, fish continue to move from the South to the North, from developing to developed countries, from rural to urban areas, and from the poor to the rich. Transboundary trade patterns show the Mekong region is no exception.

The alternative point of view is to see fish and fisheries as part of the broader natural history of Cambodia, and aquatic resources as intimately connected to people and place. Aquatic resource systems co-evolved with people, intricately connected in time and space, and responding to changes in Mekong hydrology and geomorphology, resulting in high biodiversity and fish yields.

Perhaps we now need to see fish divorced from their primary role of contributor to Gross Domestic Product (GDP) and export earnings. The true value of Cambodian fisheries to its peoples has never been adequately calculated in any national accounting process (Hap & Bhattarai, 2009). It is already acknowledged that the Food & Agriculture Organization and official catch data grossly underestimate the actual catch of fish, let alone account for the small-scale, family-level contributions that common, rural local fisheries make to overall population health, wellbeing and food security (Béné *et al.,* 2010). What is the true value of fisheries in preventing mass rural food insecurity in Cambodia?

A new fisheries paradigm for Cambodian CFis requires putting the conservation of fish and their ecosystem support services first (Berkes, 2010). At the same time CFis should develop measures of local livelihoods governance. The Community Fisheries Law must be reformed or made flexible enough to account for the diversity of local, community-based innovations in resource governance, which may come to oversee the conservation and management within CFis. The Fishery

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Law is a commitment to decentralisation and deconcentration, as the legal framework of fisheries co-management. The Community Fisheries Law is now encoded in the Fisheries Administration 10-year Strategic Planning Framework (FiA, 2010).

But I fear this discussion may be too late, not just here in Cambodia, but in other heavily stressed commercial-subsistence freshwater systems in the Global South. Without the willingness and commitment of manpower and other resources to develop and enforce effective community-based fisheries legislation - both in freshwater and coastal areas - we can only hope that our piecemeal approaches to management and advocacy will delay the massive collapses that are coming. These collapses will happen, even without the impacts from Mekong mainstream dams (Barlow *et al.*, 2008).

So I put this question forward. Under the many current fisheries governance environments found in the Global South, *can any freshwater capture fishery sustainably contribute to GDP growth?* The new paradigm suggests that continued reliance on small-scale fisheries to contribute to exports is unrealistic under current management practices. The role of freshwater fisheries in developing countries is better served in contributing to local wellbeing and thus human security. However, success is often the result of political decisions. Cambodian fisheries, like agriculture, are primarily viewed as production crops, and placed in the Ministry of Agriculture, Forestry and Fisheries. Even in Cambodia, fisheries are not seen as essential to national sustainable development.

Questions, conflicts and case studies in Cambodian freshwater fisheries still primarily centre on who has the right to catch certain fish in certain territories. For example, Fishing Lot lessees locked in long term conflicts with the local CFi or community-base organisation alliances, or disputes between neighbouring CFis and provincial fisheries cantonments. Such conflicts are primarily about harvest access and benefits, and take a property rights approach to settling exclusionary problems in the commons. This is about cross-scale power and influence in controlling the mapping and enforcement of fisheries territories and thus access rights. It is about networks of fishers standing up for their rights to fish and combat 'illegal fishing'. It is about NGOs and the government designing co-management approaches to better harvest fisheries resources, and struggles by FiA to enforce the law. The Cambodian fisheries narrative is never about the conservation of fish and their habitats to ensure sustained ecological production and maximize biological diversity. Fish are seen by the state as a product; a commodity to be harvested with maximum efficiency and returns to their 'rightful' owner under law. Cambodia's researchers and conservationists need to increase their presence in the political discourse of Cambodian fisheries co-management. Who is speaking for the fish in these formal and often informal negotiations? Fisheries conservation and sustainable livelihoods need not be incompatible.

The Mekong Basin, its people, livelihoods and cultures are changing under a number of multiple and cross scale drivers. Mekong fisheries will also change, and the trajectories do not look good. Mekong fisheries must no longer be taken for granted as a historical birthright, always there and always providing (Friend *et al.*, 2009). We have hopefully learned about the results of such hubris and mismanagement from the massive collapse of the Northern cod *Gadus morhua* stocks off Newfoundland, Canada, in the 1990s. Stocks that supplied vast amounts of fish for over 300 years were gone in 30! International fisheries governance organizations failed to prevent the collapse of these stocks. It required the governments and scientists to listen and pay attention to fishers whose lives depended on sustaining the fish. This example took place in a wealthy, informed, well-connected, developed country with little or none of the socioeconomic problems the Mekong faces. So again, *who speaks for the fish?* Whose knowledge and voices actually count in Mekong fisheries decision-making arenas?

All stakeholders need to begin by taking a more integrated conservation and development approach to managing fisheries (Berkes, 2006). This would include an open and accountable national government commitment to adaptive co-management based on the unique attributes of each CFi. This will require devolving effective decision-making powers to the commune councils. Local fisheries knowledge should be integrated in a systematic way into CFi planning and management. The locally elected commune councils should be provided with adequate financial resources and enforcement powers to manage their CFi, and given the powers to develop their own income streams, including aquaculture. The natural resource and conservation NGO sector should make a firm commitment to building up cross-scale capacities to integrate local knowledge into integrated conservation and development planning strategies. Local people and their legitimate representatives should have both the rights and responsibilities to use and protect aquatic resources. The multiple levels of assistance available in Cambodia should be mobilized to create realistic, integrated approaches to conservation and fisheries management. This would include a commitment by all parties to a binding third party dispute-resolution mechanism to resolve any territorial disputes. It also means devolving real power to commune councils to enforce the fisher-

ies legislation, whether the problem is illegal fishing by foreign trawlers or the local use of destructive and illegal gear. This requires all actors to look at holistic approaches to aquatic biodiversity conservation and management. It means working with integrated farming systems, rice-fish aquaculture and field refuge systems to improve rice field capture fisheries. It means working with indigenous and isolated communities to protect the fisheries linked to the remaining valuable forested watersheds in such areas as the '3S' (Sesan, Sekan and Srepok Rivers), Cardamom Mountains and coastal mangroves.

It means seeing through a new pair of glasses that our health and wellbeing are critically dependent on the goods and services that aquatic systems provide (Baron *et al*., 2002).

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News

Cambodian Reef Conservation Project scholarships from Coral Cay Conservation

Coral Cay Conservation (CCC) is an award-winning non-profit organization working for the protection of coral reef resources by working closely with local communities. CCC has helped to establish numerous marine reserves and sanctuaries worldwide. This team was invited by the Cambodian Fisheries Administration in 2009 to lead a long term monitoring project around Koh Rong's coral reefs and produce global information system 'hot spot' maps and marine protected area management plans.

CCC projects work closely with local communities to raise awareness of the plight coral reefs. One method of achieving this goal is through CCC's Scholarship Award Programme. Applications are now being accepted from Cambodian citizens wishing to make an active contribution towards the protection and sustainable use of their coral reefs. CCC offers four scholarship places every month with three awards available:

1. CCC Snorkelling Reef Awareness Awards

   A three-day scholarship that includes snorkel training and a short course in reef biology, awareness and conservation.

2. CCC SCUBA Reef Awareness Awards

   A six-day scholarship that provides training in scuba diving (to PADI Open Water certification), reef biology, awareness and conservation.

3. CCC SCUBA Reef Conservation Awards

   A four-week intensive residential scholarship course. Participants will obtain SCUBA training certification (to PADI Advanced Open Water certification) and certification under the CCC Skills Development Training Programme and Reef Check.

Scholarship candidates receive full board and lodging at the project base on Koh Rong Island.

The scholarship is a great opportunity for international volunteers and Cambodian citizens to learn about new cultures. It is also a crucial step towards the ultimate goal of the project, eventually handing over the Cambodian Reef Conservation Project to the Cambodian people to continue monitoring and conserving their valuable ecosystem. For a scholarship application please visit http://www.coralcay.org/content/view/104/423/

SAM HOPE, Coral Reef Conservation Project, Coral Cay Conservation, Sihanoukville, Cambodia. Email samb.hope@gmail.com

A new website for orchid research in Cambodia

The first rank in Cambodian flora is most likely held by the orchid family due to its rich diversity of species: over 500 species are estimated to occur here. The documentation of local wild orchids goes back over 700 years, as bas-reliefs of orchids are seen in Bantey Srey and in Angkor Wat. Yet scientific information about the 'kesorkol' (the Cambodian name for orchids) is still limited.

Unfortunately, much of the data from modern research on Cambodian orchids were lost during the Khmer Rouge regime. Explorations made during the last decade by French, American, British and Cambodian botanists are revealing once again the rich diversity of orchids in the mountains and humid tropical forests, and in the unique Tonle Sap swamp forest. The distribution of orchids varies across these different biogeographical zones. According to Dr Marpha Telepova, approximately 35% of Cambodia's species are found in the coastal region, 40% in the Cardamom Mountains range, more than 13% in the dry forest savannah and 10% in the Mekong Confluence.

A new website, www.orchidcambodia.com, provides detailed information on the Cambodian discoveries. This site is intended to share information and promote the conservation of wild orchids. To alleviate the plundering of wild orchids, it also highlights "market orchids" (mostly hybrids) and explains how these are better suited for non-specialists. The site provides a first checklist of documented orchids, with over 53 genera and 170 species listed to date. The main genera present are *Bulbophyllum, Eria, Dendrobium, Cleisostoma* and *Coelogyne*.

Today, habitat destruction (the clearing of forests to create agricultural or pasture lands) and the illegal trade of these protected species are on the rise. There is an urgent need to promote the research and understanding of what exists before it disappears in the wild.

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Short Communication

First record of dusky thrush *Turdus eunomus* for Cambodia

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The dusky thrush *Turdus eunomus* is a migratory bird belonging to the family Turdidae. It has recently been recognised as a separate species from Naumann's thrush *T. naumanni (*Knox *et al*., 2008), although the IUCN Red List still treats them as the same species (BirdLife International, 2009). In older literature, the scientific name of dusky thrush was *T. naumanni* ssp. *eunomus*.

On 17 November 2010, a dusky thrush was located and photographed in Preah Vihear Province in the northern plains of Cambodia (Fig. 1a-c). The site was near Tmatboey, an eco-tourism destination that sees regular visits from birders throughout the winter months (December to March). Tmatboey is in the Kulen Promtep Wildlife Sanctuary. The habitat is predominantly deciduous, dipterocarp forest. It is home to a small community-run eco-lodge on the edge of the village. Behind the lodge is a small pond that has a few large trees on its perimeter. The thrush was observed perched on a treetop approximately 20 m in height.

The bird was seen and identified by Sam Veasna Center guide Duong Nara and three bird tour participants: Tom Fiore, Kristine Wallstrom and Mike Moore. All present agreed with the identification.

The bird was a fat-bellied, small perching bird with a relatively small head and short, slim bill. A large white eye-brow extended to the nape. Its ear coverts were dark and the throat and chin were white with a dark malar stripe. The breast had a dark band and the flanks showed white scales. The wings were rufous. Its upper parts were brownish-grey. It had black eyes, a bicoloured bill and pinkish legs. The bird appeared to be an adult male.

As the bird perched, it flapped its wings and flicked its tail in a manner reminiscent of a taiga flycatcher *Ficedula albicilla*. It repeated its call notes 'chuk-chuk-chuk' every few seconds while perched.

The bird was observed for five minutes from a distance of 25 metres with the aid of binoculars and a Nikon spotting scope. The bird was discovered around 1530h and was observed against a clear sky with the sun behind the observers. The scope was employed by Nara for digi-scoping purposes, a technique that places a digital camera on the scope's eyepiece to get a telephoto image (Fig. 1a-c).

The eye-browed thrush *Turdus obscurus* and white-throated rock thrush *Monticola gularis* are both regular winter visitors to Cambodia. These two species were considered, but eliminated as possibilities. Neither species has a rusty wing panel nor the combination of large, white supercilium and blackish ear coverts. Robson's (2008) *A Field Guide to the Birds of South-East Asia* was the reference used on site.

The preferred breeding habitat for both the dusky thrush and Naumann's thrush is open woodland in Siberia, from the taiga to the edge of lowland tundra. The breeding range for the dusky thrush is generally north of, and extends farther west and east, than that of Naumann's thrush. Where they are sympatric, the dusky thrush prefers higher elevations (Brazil, 2009).

Both species can be found together in migratory flocks, but the dusky thrush winters farther east, with large numbers passing through eastern China, Japan and Korea. Its wintering range is eastern China (Brazil, 2009). According to Robson (2008), the dusky thrush can be a rare to locally common winter visitor across northern Southeast Asia (northern Myanmar, northern Thailand and the Tonkin region of Vietnam).

Prior to this observation in Cambodia, the most southerly record of a dusky thrush came from Bach Ma National Park in Vietnam (R. Craik, Birding Vietnam, pers. comm.). This represented the only dusky thrush sighting south of the Tonkin region. Bach Ma is approxi-

Fig. 1a-c. Digi-scope photographs of the dusky thrush *Turdus eunomus* in Preah Vihear Province (© Duong Nara).

mately 420 km to the northeast of Tmatboey, with the northerly latitudinal distance being approximately 240 km.

The dusky thrush has shown a degree of vagrancy with recent records from Leigh, Manchester, UK, on 8 December 2010 (McKercher, 2011), from Erezée, Belgium on 3 January 2009 (Lijster, 2011), and another from the opposite direction on 27 June 2002 on Mount Vernon, Washington, USA (Seattle Audobon Society, undated). The British Trust for Ornithology website claims nine records for the UK, dating back to 1905. It has also been recorded in Oman, Saudi Arabia, Kuwait and the Northern Marianas.

Given this species' history of vagrancy, it is not entirely unexpected that this bird has been found in Cambodia, especially given the general low level of coverage that Cambodia has received from ornithologists until recently. Nevertheless, this appears to be a first country record and the dusky thrush must be assumed to be a vagrant here, until more field work revises this assessment.

The Sam Veasna Center for Wildlife Conservation in Siem Reap Cambodia organizes birdwatching trips to Tmatboey and throughout the country and provides trained bird guides for these trips, including Duong Nara. Howie Nielsen is the guide trainer for Sam Veasna Center and helped Mr Duong to organize the information for this article.

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Short Communication

First record of *Psammophis indochinensis* Smith, 1943 from Cambodia, within the context of a distributional species account

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Until 1999, the Indochinese sand snake *Psammophis indochinensis* Smith, 1943, was treated as a subspecies of *Psammophis condanarus* (Merrem, 1820). Herein, we follow Hughes (1999) in regarding *P. indochinensis* as a full species due to the substantial differences in dorsal microdermatoglyphic characters pointed out by Brandstätter (1995), which warrant distinct specific status. The former nominotypic subspecies *P. condanarus* occurs in Pakistan, Nepal and North India as far east as 86° East (Boulenger, 1890; Brandstätter, 1996; Smith, 1943; Taylor, 1965). *Psammophis indochinensis* is thus the only member of Psammophiid snakes occurring in mainland Southeast Asia. So far, it has been recorded from Myanmar, Thailand, Laos and Vietnam (for details see Fig. 1).

Besides these mainland records, Ineich & Deuve (1990) reported on a specimen from Bali, Indonesia, and Mertens (1957) mentioned one specimen from eastern Java, Indonesia. Hence, *P. indochinensis* has a highly disjunct distribution, which is strikingly analogous to that of the viper *Daboia siamensis* (Smith, 1917). *Daboia siamensis* is known from Myanmar, Thailand, Cambodia, southern China, Taiwan and Indonesia (eastern Java and several of the Lesser Sunda Islands) (Wüster, 1998; Thorpe *et al*., 2007). Mertens (1927) recognized the Indonesian populations as a distinct subspecies of *Daboia russelii* (Shaw & Nodder, 1797) (*D. r. limitis*), which was rejected by Wüster (1998). Molecular analyses by Thorpe *et al*. (2007) showed that the Indonesian populations do not represent a distinct taxon and must be assigned to *D. siamensis*. Still, molecular studies are needed to resolve the taxonomic status of the Indonesian populations of *P. indochinensis*.

In February 2010, during ornithological work in the seasonally inundated grasslands of the Tonle Sap floodplain, at Krous Kraom in Kampong Thom Province (approximately UTM P48 482000E 1391000N) at 1500h, a series of photographs was taken of a single live specimen of *P. indochinensis* (Fig. 2). Driving by truck on a recently established dam for dry season rice growing, we spotted the snake on the dirt track in front of the vehicle where it remained 'frozen', thus allowing us to examine it from a close distance and take photographs. Eventually the snake fled quickly into the adjacent ditch where it dived into the water and disappeared from sight.

In addition to this record, in February 2008 in Chikraeng District, Siem Reap Province (approximately UTM P48 436000E 1434000N) at about 1400h, another specimen of *P. indochinensis* was found trapped and immobilized in an old fishing net by M. Handschuh. The snake was photographed and released (Fig 3.). Our two records indicate that the species may be widely distributed in the Tonle Sap floodplain.

Both of our observations of *P. indochinensis* are consistent with Pauwels *et al*.'s (2003) suggestion of an activity peak at the beginning of the year, based on their observations in Phetchaburi Province, Thailand.

Through the combination of the following characters the photographed individuals can be assigned to *P. indochinensis*: body slender, head scarcely distinct from the neck, loreal region distinctly concave, large eye, pupil rounded, dorsal scales smooth, four brownish dorsolateral and lateral stripes (no vertebral stripe), lateral stripes continue on to the head through the eye and terminate at the snout, two dark ventral hairlines at the outer edge of the ventral scutes (Figs 2 & 3).

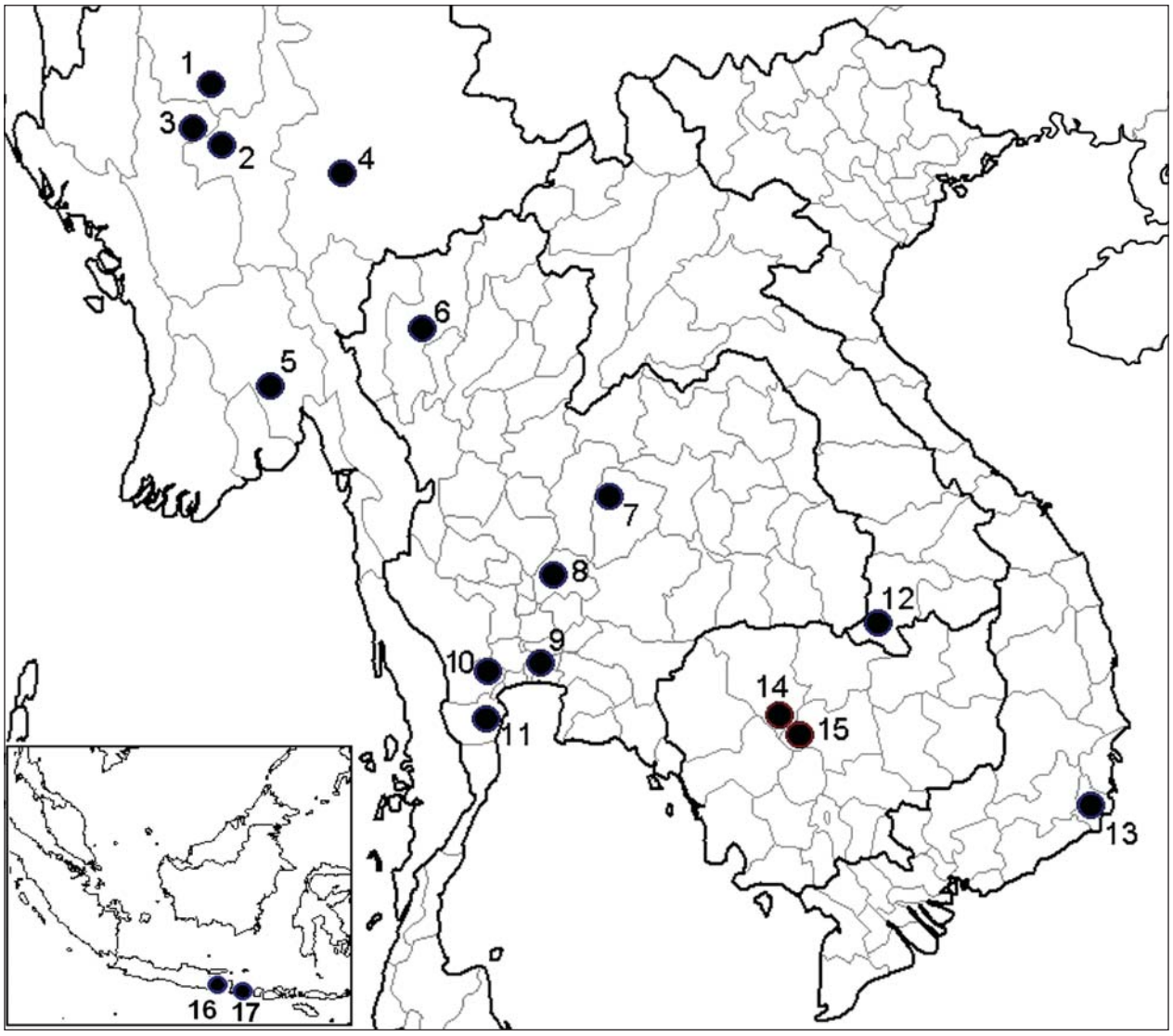

Fig. 1 Map showing records of *Psammophis indochinensis*. MYANMAR: (1) Monywa District, Sagaing Division (Wogan *et al.*, 2008); (2) Myingyan District, Mandalay Division (*ibid*); (3) Pakokku District, Magwe Division (*ibid*); (4) Taunggyi, Shan State (Boulenger, 1896); (5) Bago Division (Boulenger, 1890); THAILAND: (6) Doi Suthep, Chiang Mai Province (Taylor, 1965); (7) Phu Khieo, Chaiyaphum Province (Das, 2010); (8) Lopburi Province (Smith, 1943); (9) Bangkok (*ibid*; ZFMK 16 658); (10) Photharam, Ratchaburi Province (Chan-Ard *et al.*, 1999); (11) Tha Yang & Muang District, Phetchaburi Province (Pauwels *et al.*, 2003); LAOS: (12) Dong Khantung, Champasak Province (Stuart, 1998; Teynié *et al.*, 2004); VIETNAM: (13) Phan Rang, Ninh Thuan Province (Smith, 1943; Nguyen *et al.*, 2009; ZFMK 88 831); CAMBODIA: (14) Chikreang District, Siem Reap Province (this paper); (15) Kruos Kraom, Kampong Thom Province (*ibid*); INDONESIA: (16) Gresik, Eastern Java (Mertens, 1957); (17) Near Mount Merbuk, Bali (Ineich & Deuve, 1990).

Pauwels *et al.* (2003) listed *P. indochinensis* as occurring in Cambodia, but without giving any further information. They referred to Saint Girons (1972), David & Ineich (1999) and Daltry & Chheang (2000) for the Cambodian snake records, but none of the quoted works mentions *P. indochinensis*. Therefore, our photographs represent the first documented record of *P. indochinensis* for Cambodia.

Acknowledgements

We thank Charlotte Packman and Son Virak for the 2010 fieldwork during which the 2010 photographs were taken, the Sam Veasna Center for the 2008 field trip and Jürgen Müller for providing the 2008 photograph, Neang Thy for providing literature and Flora Ihlow for preparing a draft map.

Fig. 2 (top) *Psammophis indochinensis*, Krous Kraom, Kampong Thom Province, central Cambodia; (below) Lateral view of the same individual's head, 6 February 2010 (© Markus Handschuh).

Fig. 3 *Psammophis indochinensis* trapped in an old fishing net. Chikraeng District, Siem Reap Province, central Cambodia, 18 February 2008 (© Jürgen Müller).

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Short Communication

Notes on the trade of orchids in the Cardamom Mountains, Pursat and Koh Kong Provinces

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The current number of orchid species known from Cambodia is around 188, including five endemics (Govaerts *et al*., 2006), although the estimated total number may be around 500 species (www.orchidcambodia.com). The Cardamom Mountains offer some of the greatest variety of habitats for orchids in the country, but very little information is available about orchids in this area because botanical research was not possible for many years (Holden, 2010). The forests of the Cardamom Mountains were a final stronghold of the Khmer Rouge, and along with the large numbers of unexploded landmines, this meant that the area was inaccessible for a long time (Davis, 2005). Lack of research led to the orchid flora of the Cardamom Mountains being described as "nearly unexplored" (Seidenfaden, 1992) and that of Cambodia being among the least known in Southeast Asia (Schuiteman & de Vogel, 2000). This knowledge gap is slowly changing as botanical surveys are beginning to occur, bringing with them a number of new plant species discoveries and re-discoveries (Telepova-Texier, 2009; Holden, 2010).

Little research has been carried out on the collection of orchids for trade in Cambodia. Species that may be in high demand include three species of slipper orchid (a group favoured by collectors) - *Paphiopedilum appletonianum*, *P. callosum* and *P. concolor* - which are listed on Appendix I of the Convention on International Trade in Endangered Species (CITES) (McGough *et al*., 2006). Cambodia's proximity to Thailand, the world's biggest exporter of orchids (Thammasiri, 2005), also puts it at risk, and trade in orchids for both the national and international markets could become a significant conservation issue. Examples from neighbouring countries demonstrate this risk well. For example, *P. vietnamense*, first discovered in Vietnam in 1997 and once locally common in the wild in Thai Nguyen Province, was over collected for sale to dealers, resulting in it being classified as Extinct in the Wild within four years of its discovery (Averyanov *et al*., 2003). This is not an isolated case: *P. canhii* was described in 2010 (Averyanov *et al*., 2010) and was quickly targeted by international collectors within weeks of its publication in the scientific literature (David Roberts, pers. comm.).

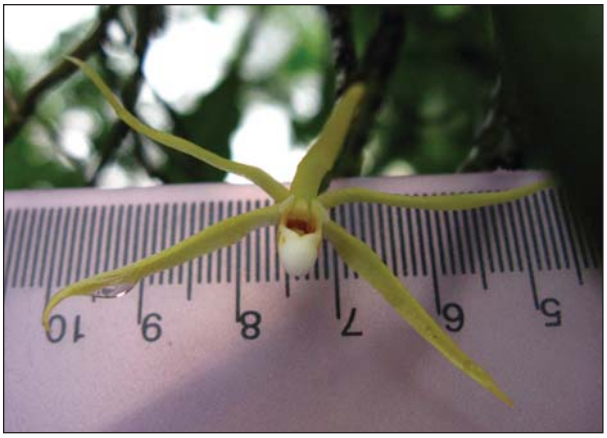
This Short Communication describes the findings of a study by the author in 2008 with the aim of investigating the collection, use and trade of orchids in villages around the Central Cardamoms Protected Forest. Social surveys of 77 households were conducted in two areas of the protected forest: 38 in Rovieng Village in Pursat Province in the north and 39 in Thma Bang Village in Koh Kong Province in the south.

This study found that collection of orchids from the forest occurred in both villages. Medicinal use was reported by eight households (10.4%) with most using part of an orchid plant to treat women who had just given birth. Almost half (47%) of households interviewed used orchids for decoration, with wild-collected plants grown in pots or on trees around the home. Many of the species used for decoration were not in flower and remain unidentified by the author, but those that were in flower included *Staurochilus fasciatus, Thrixspermum* sp., *Pholidota articulata, Dendrobium aloifolium, D. draconis, D. hercoglossum, D. friedricksianum* and, in several cases, the pigeon orchid *D. crumenatum* (see Fig. 1).

During the survey in Rovieng Village, two wild-collected plants were identified as *D. hercoglossum* and *D. friedricksianum.* These species were new country records for Cambodia (Hinsley, 2010), and both species are also found in forest just across the border in Southeast Thailand (Vaddhanaphuti, 2005). Although *D. hercoglossum* is relatively widespread in Asia, *D. friedricksianum* was previously thought to be endemic to Thailand (Govaerts *et al*., 2006), but has recently been recorded from Laos as

(a) *Dendrobium hercoglossum* at a house in Rovieng, Pursat Province.

(b) *Dendrobium friedricksianum* at a house in Rovieng.



(c) *Thrixspermum* sp. at a house in Thma Bang, Koh Kong Province.

(d) *Dendrobium draconis* at a house in Rovieng.

(e) *Pholidota articulata* at a house in Thma Bang.

Fig. 1 Some orchids found during the survey, all wild-collected and all observed being used to decorate village houses (© Amy Hinsley).

well (Schuiteman *et al.*, 2008). The person who had collected them stated that he had found them growing on trees in forest far from the village.

When asked about trade, people in both villages acknowledged that orchids were collected and sold for between 5,000-13,000 riels (US$1.25-4.25) per kg to dealers or between 100 riels ($0.025) per stem to $10 per plant when sold to individuals visiting the village. In Thma Bang, one type of orchid that could not be identified (see description below) fetched particularly high prices, with one man claiming he had been offered up

to 50,000 riels ($12.50) for each plant in flower. Although several people acknowledged that this collection was illegal, many stated that they did not think they would be punished unless they were caught taking very large numbers of plants out of the village. In Rovieng Village, almost one quarter (23%) of households sold orchids on a regular basis, usually in the wet season. Orchids were collected to order, with buyers coming from Thailand or Phnom Penh for certain types or colours of orchid, often in large numbers. Forestry Administration rangers stated that they had observed people leaving the forest with "cart-loads" of orchid plants and, on one occasion, had confiscated three 20-kg bundles of orchid plants in a group of vehicles seized for carrying illegally logged wood.

In Thma Bang, a similar number of people (21%) stated that collecting orchids for trade had been important in the past, and at least two men had made a good living from full-time orchid collecting until late 2007. However, when asked if this still occurred, most people stated that improved access to markets for farm produce following the completion of National Route 48 in 2007 (linking the village to Phnom Penh and Koh Kong) had changed this. This was best summed up by one respondent who stated that "Every family in the village used to sell orchids to buy food. Now nobody does, or very few do, because they can make money from farming instead". The 2% of people interviewed who still collected orchids for trade stated that they only sold a particular type that fetches high prices from buyers from Thailand. This orchid was described as a terrestrial species with flowers that looked like a lady's shoe, most likely referring to one of the three species of slipper orchid (genus *Paphiopedilum*) mentioned above.

This study was limited to two communities so it is not possible to draw any general conclusions for the whole region. However, it is clear that orchid trade is taking place and warrants more investigation, especially in areas with few alternative livelihood options. The new country records found are a good indication of the need to continue to build on the botanical work that has recently begun to take place. Cambodia has a great opportunity to prevent the loss of orchids from what are, when compared to nearby forests in Thailand, relatively intact forest areas. This is important not just to protect the species that are already known from these forests, but also the species which may not have yet been discovered. The examples of *Paphiopedilum vietnamense* and, more recently, *P. canhii* from Vietnam illustrate the imminent threat from collection to orchids in South East Asia, especially those that are rare or newly discovered.

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Rotifer fauna in pond samples from the upper Cambodian Mekong River Basin

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មូលន័យសង្ខេប

ការសិក្សាអំពីរ៉ូទីហ្វ៊ែរនៅក្នុងប្រទេសកម្ពុជាមានតិចតួចណាស់ និងមិនទាន់មានការសិក្សាណាមួយត្រូវបានបង្ហាញពីប្រភេទរ៉ូទីហ្វ៊ែរនៅក្នុងទឹកស្រះនៃតំបន់ដងទន្លេមេគង្គនៅផ្នែកខាងលើនៃប្រទេសកម្ពុជានៅឡើយ។ នៅតំបន់នេះ សំណាកចំនួន១០កន្លែងត្រូវបានប្រមូលពីថ្ងៃទី២៥ ដល់ ៣០ខែមេសា ឆ្នាំ២០១០។ ចំនួនប្រភេទរ៉ូទីហ្វ៊ែរនៅក្នុងសំណាកនីមួយៗមានពី៣ទៅ៤៤។ រ៉ូទីហ្វ៊ែរទាំង៧៩ប្រភេទស្ថិតក្នុង២២ពូក និង១៥អំបូរត្រូវបានរកឃើញ ដែល២១ប្រភេទស្ថិតនៅក្នុងអំបូរ Lecanidae។ ក្នុងចំណោម ១៦ប្រភេទ (ស្ថិតក្នុង៨អំបូរ) ជាកំណត់ត្រាប្រភេទថ្មីសម្រាប់ប្រទេសកម្ពុជា ដែលរួមមានទាំងកំណត់ត្រាពូកថ្មីមួយផងគឺ *Encentrum felis*។ ប្រភេទសំបូរជាងគេគឺ *Brachionus falcatus* និង *Keratella tropica* ដែលត្រូវបានប្រទះឃើញក្នុងសំណាក៨ក្នុងចំណោមសំណាកទាំង១០។ យើងបានគណនាភាពសំបូរបែបនៃប្រភេទរ៉ូទីហ្វ៊ែរ (តាម Chao2-bc) ក្នុងស្រះដែលត្រូវបានប្រមូលសំណាកសរុបបានគឺមាន ចំនួន ១៧១ប្រភេទ លើយគ្មានប្រព័ន្ធទំនាក់ទំនងសំខាន់ត្រូវបានរកឃើញរវាងចំនួនប្រភេទក្នុងសំណាកនិមួយៗនិងប៉ារ៉ាម៉ែតបរិស្ថានដែលបានវាស់វែងនោះទេ។ ភាពសំបូរបែបនៃប្រភេទខ្ពស់ណាស់ បើប្រៀបធៀបជាមួយការសិក្សាពីរលើកកន្លងមកក្នុងទឹកស្រះនៅផ្នែកខាងក្រោមនៃតំបន់ទន្លេមេគង្គ។ ក្នុងចំណោម២៥ប្រភេទដែលប្រទះឃើញក្នុងទិន្នន័យនៃការសិក្សាទាំងបីលើក មាន២៤ ប្រភេទទំនងជាប្រភេទច្រើន ជួបប្រទះនិងបិតថេរ ពីព្រោះវាត្រូវបានប្រទះឃើញនៅក្នុងសំណាកមុនៗពីតំបន់ កន្លែងរស់នៅ និងរដូវខុសៗគ្នាពីឆ្នាំ២០០៤ដល់២០០៧។ ប្រភេទទាំងនោះអាចជាប្រភេទតួយ៉ាងដ៏ល្អសម្រាប់ការសិក្សានៅពេលក្រោយទៀតសម្រាប់អភិវឌ្ឍប្រព័ន្ធអាំងទីកាទ័រជីវសាស្ត្រសម្រាប់បរិស្ថានទឹកសាបនៅក្នុងប្រទេសកម្ពុជា។

Abstract

There have been few studies of rotifers in Cambodia and no survey has been previously been reported from ponds in the upper Cambodian Mekong River Basin, where 10 samples were collected during 25-30 April 2010. The number of species in each sample ranged from three to 44. A total of 79 species belonging to 22 genera and 15 families of Rotifera were found, of which 21 species belonged to the family Lecanidae. Among our findings were 16 species (belonging to eight families) that were new records for Cambodia, including the first record of the genus *Encentrum* (*E. felis*). The commonest species were *Brachionus falcatus* and *Keratella tropica*, which were found in eight of the 10 sampled localities. We calculated the total rotifer species richness (Chao2-bc estimator) in the sampled ponds to be 171 species, and no significant correlations were found between the number of species in each sample and the environmental parameters measured. Species richness was very high in comparison to two earlier surveys of ponds in the lower Cambodian Mekong River Basin. Of the 25 species found in all three data sets, 24 appeared to be common and persistent species because

they were found in previous samples from different areas, habitats or seasons from 2004-2007. These 'persistent' species may be good candidates for further studies to develop a bioindicator system for freshwater environments in Cambodia.

Keywords

Cambodia, Monogononta rotifers, new records, species richness, zooplankton.

Introduction

The Rotifera is a phylum of microscopic aquatic and multicellular invertebrates, many of which are planktonic. Members of this phylum can be found in freshwater environments, brackish water and the sea, and some survive in moist soil, on mushrooms, on mosses or lichens growing on the bark of trees or on rocks, or as parasites on aquatic vertebrates (Wallace *et al*., 2006). Some species play important roles in natural and artificial aquatic systems because they serve as food for larval animals in natural environments or in culture, or serve as indicators of water quality (Mäemet, 1983; Pejler, 1983; Sládeček, 1983; Duggan *et al*., 2001; Yúfera, 2001). To develop a strategy to use rotifer species as bioindicators, an improved knowledge of their incidence and persistence among habitats and seasons would aid the selection of species worthy of more detailed evaluations of their association with environmental factors, including habitat quality.

Cambodia is a Southeast Asian country that depends greatly on the natural resources provided by the Mekong River Basin (Pech & Sunada, 2008). The basin crosses the country from north to south, and includes the Tonle Sap Great Lake that serves as a natural reservoir that is filled and drained by reversible flow of the Tonle Sap River (Kummu *et al*., 2008). The diversity of different taxonomic groups continues to be studied in the region, with many new species recently discovered and more remaining to be discovered (Gephart *et al*., 2009; Giam *et al*., 2010). More work to characterize the biological and ecological systems in the region is required to provide supporting information for Cambodia's sustainable development.

Rotifers in Cambodia were first reported by Bērziņš (1973), who described four species from river samples. Seventy-four species of rotifers were subsequently recorded in 30 samples from various rivers in the Cambodian Mekong River Basin, which were collected in March (during the dry season) over a period of four years (Davison *et al*., 2006; MRC, 2008; Vongsombath *et al*., 2009). One hundred and forty-three species of rotifers were recorded in 200 samples collected from different freshwater habitats in the lower part of the Cambodian Mekong River Basin during three collection periods, of which 102 species were new country records (Meas & Sanoamuang, 2010), and 91 species were found in 20 ponds (Meas, 2008). Based on the Chao-2 bc estimator, which considers the relative frequency of rare species (Chao & Shen, 2003), Meas & Sanoamuang (2010) estimated that a total of 223 species (95% CI = 199-276) could be expected to occur in Cambodia, and that rotifer species richness was significantly higher in the late rainy season (October) than the early dry season (December) or the early rainy season (June).

There have therefore been relatively few studies on rotifer distribution in Cambodia, with no new species described since Bērziņš (1973) and probably many species yet to be recorded. The present study examined ponds in the upper part of the Cambodian Mekong River Basin, a habitat type that has been shown to be relatively rich in rotifer species, but which has not yet been sampled in northern Cambodia. The primary objectives of this study included the search for rotifer species not previously recorded in Cambodia, the comparison of species found to those recorded earlier in ponds by Meas (2008), and the preliminary assessment of species that could be used as bioindicators in Cambodia.

Methods

Ten samples were collected from ponds (standing water bodies smaller than eight hectares) in northeastern Cambodia during the late dry season (25-30 April, 2010), of which eight were from Stung Treng Province and two were from Ratanakiri Province. All but one of the ponds were located in agricultural land, had steep banks and appeared to be artificially maintained; the exception being site S4 (Table 1), which was beside an unsealed road through a forested area. During the dry season, most of the ponds appeared to be isolated with the exception of sites S4, S9 and S10, where at least one channel of slow flowing water was observed. Samples were collected by tossing a 30-µm mesh net into the pond from its edge, and pulling the net near the surface of the water. The sample for each pond was pooled from 15 'pulls' and preserved immediately by adding a small volume of 5% formaldehyde solution. Temperature, *p*H, electroconductivity (Hanna DiST WP 4), turbidity (Hach 2100P) and dissolved oxygen (Hach HQ20) were measured from a 25-litre water sample collected near the edge of

Table 1 Water quality properties, geographic location and species count of the ponds sampled.

Site code	Temperature (°C)	*p*H	Dissolved oxygen (mg L^{-1})	Conductivity (mS cm^{-1})	Turbidity (NTU*)	UTM (Zone = 48P)		Altitude (m)	Number of species
						Easting (m)	Northing (m)		
S1	37.2	8.38	8.6	0.52	90.6	607307	1497715	59	17
S2	34.2	8.54	7.8	0.11	105.0	608287	1495442	51	16
S3	31.9	8.56	9.8	0.20	170.0	642445	1487418	80	14
S4	29.6	7.76	4.3	0.01	17.9	715298	1527067	254	3
S5	33.3	8.85	9.6	0.06	192.0	679340	1499377	104	12
S6	31.8	7.89	4.5	0.19	n/a	599580	1493085	47	15
S7	31.7	6.94	2.6	0.32	320.0	609610	1496515	49	16
S8	29.6	7.43	6.1	0.11	556.0	606872	1492900	65	7
S9	32.3	8.65	7.3	0.02	12.8	606710	1492917	67	14
S10	34.2	8.47	8.9	0.02	13.1	611363	1489857	85	44

* Nephelometric Turbidity Unit.

the pond. Altitude and georeference coordinates (using the Universal Transverse Mercator system or UTM) were recorded for each sampled locality. Some of the results were compared with those obtained from pond samples collected by Meas (2008) from southern Cambodia using a 60-µm plankton mesh net.

Rotifers were examined under a compound microscope (Olympus CX21) and identified using the following references: Nogrady *et al*. (1995); Segers (1995); De Smet & Pourriot (1997); and Nogrady & Segers (2002). Photographs of rotifers were taken using a digital camera (Olympus BX51) on the microscope. The nomenclature of this research follows Segers (2007).

Species richness was estimated using SPADE v. 4 (Chao & Shen, 2003). The Chao2-bc estimator of species richness was used in this study because it is reported to be reliable for incidence data from small sample sizes (Hortal *et al*., 2006). Bivariate correlations of environmental parameters with number of species, and non-parametric comparisons of medians (Mann-Whitney U test), were performed using SPSS v. 17.0.

Results

Rotifer species found

Seventy-nine species belonging to 22 genera and 15 families were recorded in this investigation, of which 16 species were new records for Cambodia (Table 2) and 61, 26 and 2 species were the same as those reported by Meas & Sanoamuang (2010), MRC (2009) and Bērziņš (1973), respectively. One of these new records, *Encentrum felis* (Müller, 1773) was the first member of this genus to be recorded in Cambodia (Figs 1c, 1e, 1f) and only a few specimens were found in one pond in Chke Hot Village, Trapeang Kraham Commune, Koun Mom District, Ratanakiri Province (site S5, Table 1). Twelve of the new records are considered cosmopolitan species (Table 2). However, most of the new records could be considered infrequent species for Cambodia because they were found in only one or two of the 10 pond samples in this study. The exceptions were *Lecane arcuata* (Bryce, 1891) and *L. inopinata* Harring & Myers, 1926, which were found in three and five samples, respectively.

The commonest species were *Brachionus falcatus* Zacharias, 1898, and *Keratella tropica* (Apstein, 1907), which were found in eight of the 10 ponds, followed by *Anuraeopsis coelata* de Beauchamp, 1932, in seven of the 10 ponds. One specimen appeared to be an unusual form of *B. falcatus,* with a peculiar tip to each foot (Figure 1h), and this was found in one pond in Reacheanukoul Village, Samaki Commune, Stung Treng District, Stung Treng Province (site S8) along with other specimens of the same species. The rarest species, which were found in only one of the 10 samples, included 11 of the new country records (Table 2). A further 37 species (one species each of *Colurella, Euchlanis, Filinia, Hexarthra, Keratella, Lophocharis, Mytilina* and *Scaridium*, two species each of *Brachionus, Dicranophoroides, Macrochaetus* and *Testudinella*, three species of *Lepadella*, eight species of *Trichocerca* and 10 species of *Lecane*) were also each found in only one of the 10 ponds sampled.

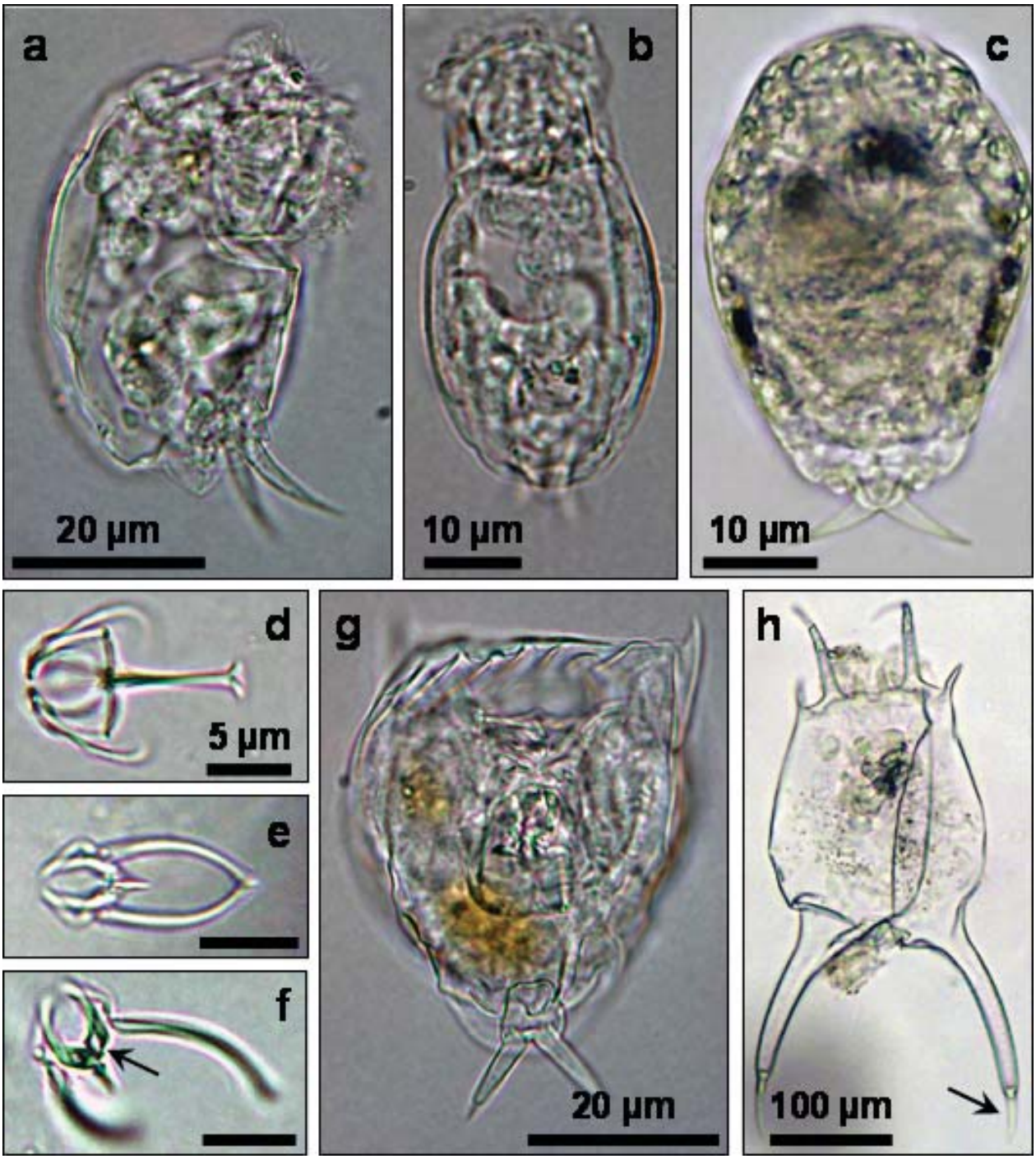

Fig. 1 A selection of rotifers collected during the present survey (© Min M.): **(a)** *Cephalodella ventripes* (Dixon-Nuttall, 1901), lateral view; **(b)** *Cephalodella ventripes*, dorsal view; **(c)** *Encentrum felis* (Müller, 1773); **(d)** *Cephalodella ventripes,* trophi; **(e)**,**(f)** *Encentrum felis,* trophi; **(g)** *Lecane flexilis* (Gosse, 1886); **(h)** *Brachionus falcatus* Zacharias, 1898: unusual form with a peculiar tip on each foot (indicated with an arrow).

Lecanidae was the most diverse family found, with 21 species. The second most diverse family was Brachionidae with four genera and 15 species. Only one species was found in each of the families Hexarthridae, Ituridae, and Synchaetidae. These were *Hexarthra intermedia* (Wiszniewski, 1929), *Itura aurita* (Ehrenburg, 1830) and *Synchaeta oblonga* Ehrenberg, 1832, respectively.

The number of species in each pond sample ranged from three to 44 species. The highest number of species (44) was found in a pond in Reacheanukoul Village, Samaki Commune, Stung Treng District, Stung Treng Province (site S10, Table 1), while the lowest number (three) was in a pond in Tharang Svay Village, Ou Chum Commune, Ou Chum District, Ratanakiri Province (site S4). Sites S10 and S7 (Srae Pou Village, Sarh Ruessei

Table 2 New records of Rotifera in Cambodia from 10 pond samples.

New record	Sample[a]	Records elsewhere[b]
Cephalodella ventripes (Dixon-Nuttall, 1901)	S5, S6	Cosmopolitan[c]; Thailand (Sanoamuang *et al*., 1995)
Colurella hindenburgi Steinecke, 1917	S7	Cosmopolitan
Colurella obtusa (Gosse, 1886)	S10	Cosmopolitan; Thailand (Pholpunthin, 1997)
Encentrum felis (Müller, 1773)	S5	AUS, NEA, NEO, PAL; Laos (Segers & Sanoamuang, 2007)
Itura aurita (Ehrenberg, 1830)	S7	Cosmopolitan; Thailand (Sanoamuang *et al*., 1995)
Lecane arcuata (Bryce, 1891)	S1, S2, S10	Cosmopolitan; Thailand (Chittapun & Pholpunthin, 2001)
Lecane aspasia Myers, 1917	S1, S2	NEA, NEO, ORI, PAL; Thailand (Sanoamuang *et al*., 1995)
Lecane batillifer (Murray, 1913)	S10	AUS, ORI; Thailand (Segers & Pholpunthin, 1997)
Lecane flexilis (Gosse, 1986)	S10	Cosmopolitan; Thailand (Sanoamuang *et al*., 1995)
Lecane inopinata Harring & Myers, 1926	S3, S5, S6, S8, S10	Cosmopolitan; Thailand (Sanoamuang *et al*., 1995)
Lecane tenuiseta Harring, 1914	S7	Cosmopolitan; Thailand (Sanoamuang *et al*., 1995)
Lepadella punctata Wulfert, 1939	S7	ORI, PAL; Thailand (Chittapun *et al*., 2003)
Macrochaetus longipes Myers, 1934	S10	Cosmopolitan; Thailand (Sanoamuang *et al*., 1995)
Synchaeta oblonga Ehrenberg, 1832	S10	Cosmopolitan
Trichocerca iernis (Gosse, 1887)	S7	Cosmopolitan; Laos (Segers & Sanoamuang, 2007)
Trichocerca scipio (Gosse, 1886)	S6, S10	Cosmopolitan; Laos (Segers & Sanoamuang, 2007), Thailand (Segers *et al*., 2004)

[a] Site numbers correspond to those in Table 1.

[b] Cosmopolitan, i.e. occurs in at least five of the eight biogeographic regions of the world (Afrotropical, AFR; Antarctic, ANT; Australian, AUS; Nearctic, NEA; Neotropical, NEO; Oriental, ORI; Pacific, PAC; Palearctic, PAL) according to Segers (2007).

[c] Although considered cosmopolitan, this species was not listed in ORI by Segers (2007).

Table 3 Species richness and shared species of ponds sampled in the present study (LDS 2010 - late dry season, 25-30 April 2010, upper Cambodian Mekong Basin) and an earlier study in which ponds were sampled during two collection periods (Meas, 2008: ERS 2006 - early rainy season, 11-17 June 2006, lower Cambodian Mekong Basin; LRS 2006 - late rainy season, 16-19 October 2006, lower Cambodian Mekong basin). Figures in parentheses show the 95% confidence interval.

		LDS 2010	ERS 2006	LRS 2006
Number of samples		10	10	10
Number of species collected		79	41	81
Total number of species present, estimated using Chao2-bc estimator		171 (120-285)	49 (43-71)	108 (92-144)
Number of shared species	LDS 2010	–	30	46
	ERS 2006	30	–	31

Commune, Stung Treng District, Stung Treng Province) had the highest number of new records, totalling eight and five species, respectively (Table 2). There was no significant correlation between the environmental parameters measured at each sampled locality and the number of species collected (Pearson correlation, $p > 0.05$).

Comparison of species richness and sample sets

This study sampled 10 ponds in the upper Cambodian Mekong River Basin during the late dry season (LDS 2010). An earlier study by Meas (2008) sampled different habitats in the lower Cambodian Mekong River Basin during three collection periods, including 10 ponds that were sampled during the early rainy season (ERS 2006) and late rainy season (LRS 2006) in 2006. A total of 79, 41 and 81 species were found in the LDS 2010, ERS 2006 and LRS 2006 samples, respectively. Using the Chao2-bc estimator (Chao & Shen, 2003), which is a non-parametric method that estimates the number of unseen species from the observed frequency of rare species, we calculated the total species richness of these three groups to be 171, 49 and 108, respectively (Table 3).

The samples from the present study (LDS 2010) shared 46 species with the LRS 2006 samples, while the ERS 2006 samples shared only 30-31 species with the other two sets of samples (Table 3). A total of 25 species were found to be common to all three sets of pond samples (Table 4), which we will call 'persistent' species. Out of the total of 240 samples examined in this study and reported by Davidson *et al*. (2006), Meas (2008), MRC (2008) and Vongsombath *et al*. (2009), all but one of these 'persistent' species were relatively common, as they occurred in 12-61% of the samples (median = 41%). The exception was *Trichocerca chattoni* (de Beauchamp, 1907), which was found in only four samples. Of the 200 samples collected by Meas (2008), 194 contained at least one species and, of these, 192 samples contained at least one of the 'persistent' species, while the remaining two samples contained only one species each. The earlier data also indicated that 23 of the 'persistent' species were found during all three sampling periods between December 2005 and October 2006 (Meas & Sanoamuang, 2010), 21 of which occurred in all seven types of habitats sampled (Meas, 2008). Four of these species also occurred in the four sample sets collected in Cambodia from 2004-2007 by MRC (Table 4): *Brachionus angularis, Keratella cochlearis* (Gosse, 1851), *Lecane hastata* (Murray, 1913) and *L. luna* (Müller, 1776).

For each 'persistent' species, statistical comparisons were made of the LDS 2010 ponds in which each species was present and the ponds from which it was absent, using the non-parametric Mann-Whitney U test:

- Species found in significantly warmer ponds were *Anuraeopsis fissa* Gosse, 1851 (median of 33.8°C vs 30.6°C, $p = 0.032$) and *Plationus patulus* (Müller, 1786) (33.8°C vs 31.8°C, $p = 0.042$).
- *Anuraeopsis fissa* also occurred in ponds with significantly higher dissolved oxygen (8.8 vs 5.2 mg/L, $p = 0.033$).
- *Brachionus quadridentatus* Hermann, 1783 was found in ponds with significantly lower turbidity (13 vs 170 NTU, $p = 0.040$).

Discussion

With the 16 new species records obtained during the present study, a total of 196 rotifer species has now been confirmed in Cambodia. When the data from all published reports are combined for the Chao2-bc estimator, the national rotifer species richness is estimated to be 234 (95% CI = 214-277). This indicates that approximately 40 more species could be expected from additional surveys in this country.

One of the new records that was found in one pond sample, *Encentrum felis*, is the first record of this genus in Cambodia. Very little appears to have been published on the biology of this rotifer, although it has been reported to be either oligosaprobic or beta-saprobic (Sládeček, 1983). Another new record, *Cephalodella ventripes* (Dixon-Nuttall, 1901), is not commonly expected in the Oriental zone (Segers, 2007), but is considered to be a cosmopolitan species and has been reported in Thailand (Sanoamuang *et al*., 1995). In Cambodia, this species was found in two ponds, sites S5 and S6 (Anlong Svay Village, Ou Rai Commune, Thala Barivat District, Stung Treng Province). *Cephalodella ventripes* is also reported to be either oligosaprobic or beta-saprobic (Sládeček, 1983), as well as associated with a moderately high trophic degree (Bērziņš & Pejler, 1989). It occurs in littoral, pelagic or psammon habitats (Muirhead *et al*., 2006).

The results from this study indicate that rotifer species richness in ponds in northern Cambodia during the dry season (Chao2-bc estimator, 95% CI = 120-285) is as high as has been estimated in ponds in southern Cambodia during the late rainy season (92-144), and significantly higher than during the early rainy season (43-71). The likely explanation for the large number of species found in this study is the use of a net with finer mesh (30 μm instead of 60 μm). Rotifer species richness may therefore have been substantially underestimated in Cambodia, particularly as the previous work found fewer species during the early dry season and early rainy season (Meas & Sanoamuang, 2010). Future surveys should focus on

the rainy season and evaluate year-to-year variation, which could be substantially larger than seasonal variation (Muirhead *et al*., 2006; Walsh *et al*., 2007).

Of the 21 species common to the LDS 2010 and LRS 2006 samples, but absent from the ERS 2006 samples, 17 are considered to be cosmopolitan species. Their absence would likely be due to environmental and biological factors at a local scale rather than a regional scale. Of the five species that were absent from the LDS 2010 and LRS 2006 samples but present in the ERS 2006 samples, two are considered cosmopolitan (*Ascomorpha ecaudis* Perty, 1850 and *Lecane stenroosi* (Meissner, 1908)), two are considered endemic to the Oriental biogeographic region (*Brachionus murphyi* Sudzuki, 1989; *Keratella edmondsoni* Ahlstrom, 1943) and one is not commonly expected in the Oriental region (*Ploesoma hudsoni* (Imhof, 1891)). The presence of two species typically associated with oligotrophy, *A. ecaudis* (Bērziņš & Pejler, 1989) and *P. hudsoni* (Mäemets, 1983; Peljer, 1983; Bērziņš & Pejler, 1989), in the ERS 2006 samples suggests that these ponds were low in nutrients, which could be due to the lack of input from run-off or disturbance from rain before the rainy season. This explanation would mean that the LDS 2010 samples, collected during the late dry season, could also represent a low nutrient environment. We hypothesize more rotifer species could be expected after nutrients have been replenished in the early rainy season.

There are different approaches to using rotifers and other organisms as bioindicators. Certain species could indicate water quality; for example, *B. angularis* Gosse, 1851, *Cephalodella gibba* (Ehrenberg, 1830), *Filinia longiseta* (Ehrenberg, 1834), *K. cochlearis* and *Lepadella patella* (Müller, 1773), found in the present study, are associated with eutrophy (Bērziņš & Pejler, 1989). Systems have also been used to rank rotifer species according to the trophic status of water bodies (Bērziņš & Pejler, 1989; Duggan *et al*., 2001), saprobicity of wastewater (Sládeček, 1983) and disturbance from human activities (Vongsombath *et al*., 2009). As the incidence of any species is also dependent on the mode of their introduction and other factors, reliance on a single species to serve as a bioindicator is not recommended. A variety of common and persistent species could be very useful for quantitative comparisons based on their abundance (Radwan & Popiolek, 1989; Duggan *et al*., 2001; May & O'Hare, 2005) or morphology (Green, 2007; Sarma *et al*., 2008). The present study has identified *B. angularis, K. cochlearis, L. hastata* and *L. luna*, as four of the 25 'persistent' species that are potential candidates for this approach. All four have moderate tolerance of site disturbance, with *K. cochlearis* showing the least tolerance in the group and *B. angularis* showing the greatest (Vongsombath *et al*., 2009). Both *B. angularis* and *K. cochlearis* rank relatively high in trophic degree (Bērziņš & Pejler, 1989; Bielańska-Grajner & Gładysz, 2010), and the latter is considered to be a K-strategist while the former is an r-strategist (Walz, 1987). *Brachionus angularis* also has a moderately high saprobic index, while *K. cochlearis* and *L. luna* have moderate indices (Sládeček, 1983), and all three have been found in littoral, pelagic and psammon habitats (Muirhead *et al*., 2006). The preliminary evaluations in the present study, based on a small sample size of 10 ponds, suggest that a few rotifer species occupy ponds that significantly differ in some property from those ponds from which they are absent. These examples illustrate how the 'persistent' species may occur in a range of habitat conditions and provide a range of responses. More extensive studies could reveal robust patterns that are related to various measures of habitat quality.

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Table 4 Rotifer species found in all three sets of pond samples. The incidence number shown is the number of samples in each period that contained the specified species.

	Pond samples[a]			Meas[b]	MRC[c]
	LDS 2010	ERS 2006	LRS 2006		
Total number of samples	10	10	10	200	30
Anuraeopsis fissa Gosse, 1851	6	3	5	41*	4
Brachionus angularis Gosse, 1851	6	4	2	107*†	15[x]
Brachionus falcatus Zacharias, 1898	8	4	4	123*†	5
Brachionus quadridentatus Hermann, 1783	2	2	6	102*†	3
Dicranophoroides caudatus (Ehrenberg, 1834)	1	3	2	34	0
Filinia camasecla Myers, 1938[d]	1	1	2	68*†	0
Filinia longiseta (Ehrenberg, 1834)	3	4	1	62*†	10
Filinia opoliensis (Zacharias, 1898)	4	8	7	128*†	3
Hexarthra intermedia (Wiszniewski, 1929)	1	8	4	85*†	0
Keratella cochlearis (Gosse, 1851)	3	3	2	81*†	28[x]
Keratella lenzi Hauer, 1953	1	2	2	90*†	0
Keratella tropica (Apstein, 1907)	8	4	5	119*†	0
Lecane bulla (Gosse, 1851)	1	3	9	137*†	9
Lecane crepida Harring, 1914	3	2	2	27*	0
Lecane curvicornis (Murray, 1913)	4	5	8	109*†	2
Lecane hastata (Murray, 1913)	3	5	1	66*†	7[x]
Lecane leontina (Turner, 1892)	1	2	9	110*†	3
Lecane luna (Müller, 1776)	2	1	2	59*†	10[x]
Lecane papuana (Murray, 1913)	3	7	4	108*†	0
Lepadella rhomboides (Gosse, 1886)	1	3	4	55*†	0
Plationus patulus (Müller, 1786)	4	3	8	110*†	4
Testudinella patina (Hermann, 1783)	1	2	8	86*†	3
Testudinella tridentata Smirnov, 1931	1	1	2	27*†	0
Trichocerca chattoni (de Beauchamp, 1907)	1	1	1	3	0
Trichocerca similis (Wierzejski, 1893)	1	4	5	96*†	12

[a] See footnotes for Table 3.

[b] Data from different habitats (canals, floodplains, lakes, ponds, rice fields, rivers and streams) sampled in the lower Cambodian Mekong Basin by Meas (2008), which included the ERS 2006 and LRS 2006 samples, and samples collected during the early dry season from 10-14 December 2005.

* = Species found during all three sampling periods. *Dicranophoroides caudatus* and *Trichocerca chattoni* were not found during the early dry season;

† = Species found in all seven habitat types. *Anuraeopsis fissa* was not found in rivers or streams, *D. caudatus* was not found in lakes, rivers or streams, *Lecane crepida* was not found in lakes or rivers, and *T. chattoni* was found only in ponds and one lake.

[c] Data from rivers sampled during four surveys conducted by Davidson *et al*. (2006), MRC (2008) and Vongsombath *et al*. (2009), in which samples were collected during 17-23 March 2004, 24-27 March 2005, 6-19 March 2006 and 17-21 March 2007.

[x] = Species found during all four sampling periods.

[d] This species was also reported by Bērziņš (1973).

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A method for identifying the sex of lesser adjutant storks *Leptoptilos javanicus* using digital photographs

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មូលន័យសង្ខេប

ចំពោះសត្វស្លាបជាច្រើន ការកំណត់អត្តសញ្ញាណភេទទាមទារការធ្វើតេស្តDNA ឬការសង្កេតពីឥរិយាបថ។ ឯកសារស្រាវជ្រាវនេះពិពណ៌នាពីវិធីសាស្ត្រថ្មីសម្រាប់កំណត់អត្តសញ្ញាណភេទនៃសត្វត្រដក់តូច (*Leptoptilos javanicus*) ដោយប្រើរូបថតឌីជីថល។ រូបថតត្រូវបានថតសត្វត្រដក់តូចចំនួន២០ (ឈ្មោល១១ ញី៩) នៅមជ្ឈមណ្ឌលអភិរក្សជីវៈចម្រុះអង្គរនៅប្រទេសកម្ពុជា និងវិភាគលក្ខណៈក្បាលពីចំហៀងដោយប្រើកម្មវិធី Adobe Photoshop CS2 ។ លក្ខណៈខុសគ្នារវាងភេទត្រូវបានគេរកឃើញដោយកំរិតនៃការវាស់ក្បាលតាមអក្សរឈររបស់វា ដែលត្រូវបានប្រើដើម្បីបង្កើតមុខងារខុសៗគ្នា។ មុខងារនេះចែកជាភេទត្រឹមត្រូវបាន៩០ភាគរយនៃក្រុមសិក្សា។ យើងសន្និដ្ឋានថា រូបភាពឌីជីថលអាចជួយកំណត់អត្តសញ្ញាណភេទរបស់ត្រដក់តូចបាន។

Abstract

For many birds, gender identification requires DNA tests or behavioural observations. This paper describes a new method of identifying the sex of lesser adjutant storks *Leptoptilos javanicus* using digital photographs. Photographs were taken of 20 captive lesser adjutant storks (11 males, nine females) at the Angkor Centre for Conservation of Biodiversity in Cambodia, and lateral head features analysed using Adobe Photoshop CS2. Differences between the sexes were found in their vertical head measurement ratios which were used to generate a discriminant function. This function correctly classified the genders of 90% of the study group. We conclude that digital photographs can aid the gender identification of lesser adjutant storks.

Keywords

Cambodia, discriminant function, gender identification.

Introduction

The lesser adjutant stork *Leptoptilos javanicus* is currently classified as globally Vulnerable (BirdLife International, 2011). Current conservation efforts for the species include, amongst others, nest protection measures (Visal & Clements, 2008; Clements *et al*., 2009; BirdLife International, 2011) as well as small-scale captive breeding programmes (Salakij *et al*., 2004; Maust *et al*., 2007; ACCB, unpubl. data). Such programmes may benefit from researchers being able to identify the gender of the individuals involved without having to capture the birds or do extensive behavioural observations, which might not be reliable (Dorr *et al*., 2005; Cwiertnia *et al*., 2006; Cheong *et al*., 2007; ACCB, unpubl. data). Reliable sex identification in this species is currently possible only through DNA analysis of blood or feathers, or laparoscopy. These are techniques that usually involve handling or even anaesthetizing the birds (Greenwood, 1983; Harvey *et al*., 2006; Maust *et al*., 2007).

For other waterbird species, sex identification using morphometrics has been reported (e.g. Cwiertnia *et al*., 2006; Cheong *et al*., 2007; Dorr *et al*., 2005). Cheong *et al*. (2007) showed that in the Oriental white stork *Ciconia boyciana*, lateral head features derived from digital photographs could reliably distinguish the sexes. Following this method, we investigated whether or not the same method could be applied to lesser adjutant storks.

Methods

Study Species

The lesser adjutant stork belongs to the order Ciconiiformes, suborder Ciconiae, family Ciconiidae, and tribe Leptoptilini (giant storks) (Elliot *et al*., 1994). This large stork (122-129 cm tall) is primarily dark grey-black above with a white underside, a largely naked head and neck, and a large, horn-coloured bill (Wells, 1999; BirdLife International, 2011). The global population is currently estimated at 6,500–8,000 individuals, but suspected to be declining rapidly. Cambodia holds 2,500–4,000 individuals (BirdLife International, 2011). This species inhabits both open and forested wetlands, where it nests colonially in large trees. Major threats include habitat loss through the felling of nest trees and the conversion of wetlands, agricultural intensification and increased pesticide use, collection of eggs and chicks, hunting of adults and, especially in Cambodia and Nepal, incidental mortality from the practice of poisoning pools to catch fish (BirdLife International, 2011).

Study location

The study was carried out at the Angkor Centre for Conservation of Biodiversity (ACCB), a wildlife rescue and environmental education centre in Siem Reap Province, Cambodia. The lesser adjutant storks were housed in a 1.1 ha paddock that consists of a main enclosure (approximately 0.9 ha) with a pond and seven smaller compartments for separate individuals or pairs.

Study population

The sample group contained 20 DNA-sexed birds including 11 males (two adults, six subadults, three juveniles) and nine females (three adults, two subadults, four juveniles). These birds were considered to be juvenile up to two years old, subadult from two to five years old and adult when over five years old, based on the estimated age of first breeding (ACCB, unpubl. data). All of the birds originated from confiscations or donations and were not fit for release, so they are part of ACCB's breeding programme for selected globally threatened species.

Data collection and analysis

The study was conducted from August to December 2009. Digital photographs were taken of the sides of the storks' heads during daylight using a Canon PowerShot A610 digital camera. The photographs were taken from a distance of 5-15 metres with an image resolution of 180 dpi. Reference points were defined (Fig. 1), adapted from Cheong *et al*. (2007), and distances between reference points were measured using Adobe Photoshop CS2, with an accuracy of ± 1 mm. Because not all of the storks had been photographed from exactly the same distance and angle, the horizontal and vertical measurements were not absolute values, and therefore ratios were generated. In total, 28 horizontal and 55 vertical measurement ratios were calculated (Table 1).

Horizontal measurements

H1 Tip of the bill to commissural point (corner of the gape where maxilla and mandible meet).

H2 Tip of the bill to beginning of skin flap.

H3 Tip of the bill to beginning of skull (i.e. exposed culmen).

H4 Tip of the bill through commissural point to occiput.

H5 Commissural point to occiput (= H4-H1).

H6 Length of nostril.

H7 Tip of bill to anterior edge of nostril.

H8 Beginning of skull tangential to upper edge of eyeball to occiput.

Vertical measurements

V1 Proximal bill height (beginning of skin flap to beginning of skull).

V2 Proximal maxilla height (at beginning of skull).

V3 Proximal mandible height (= V1-V2).

V4 Bill height at distal edge of nostril, perpendicular to H1.

V5 Maxilla height at distal edge of nostril, perpendicular to H1.

V6 Mandible height at distal edge of nostril (= V4-V5).

V7 Commissural point to crown, tangential to posterior baso-lateral edge of the eyeball.

V8 Commissural point to crown, tangential to anterior edge of the eyeball.

V9 Beginning of skin flap tangential to posterior edge of eyeball to crown.

V10 Beginning of skin flap tangential to anterior edge of eyeball to crown.

V11 Head height perpendicular to H5 and tangential to posterior edge of eyeball.

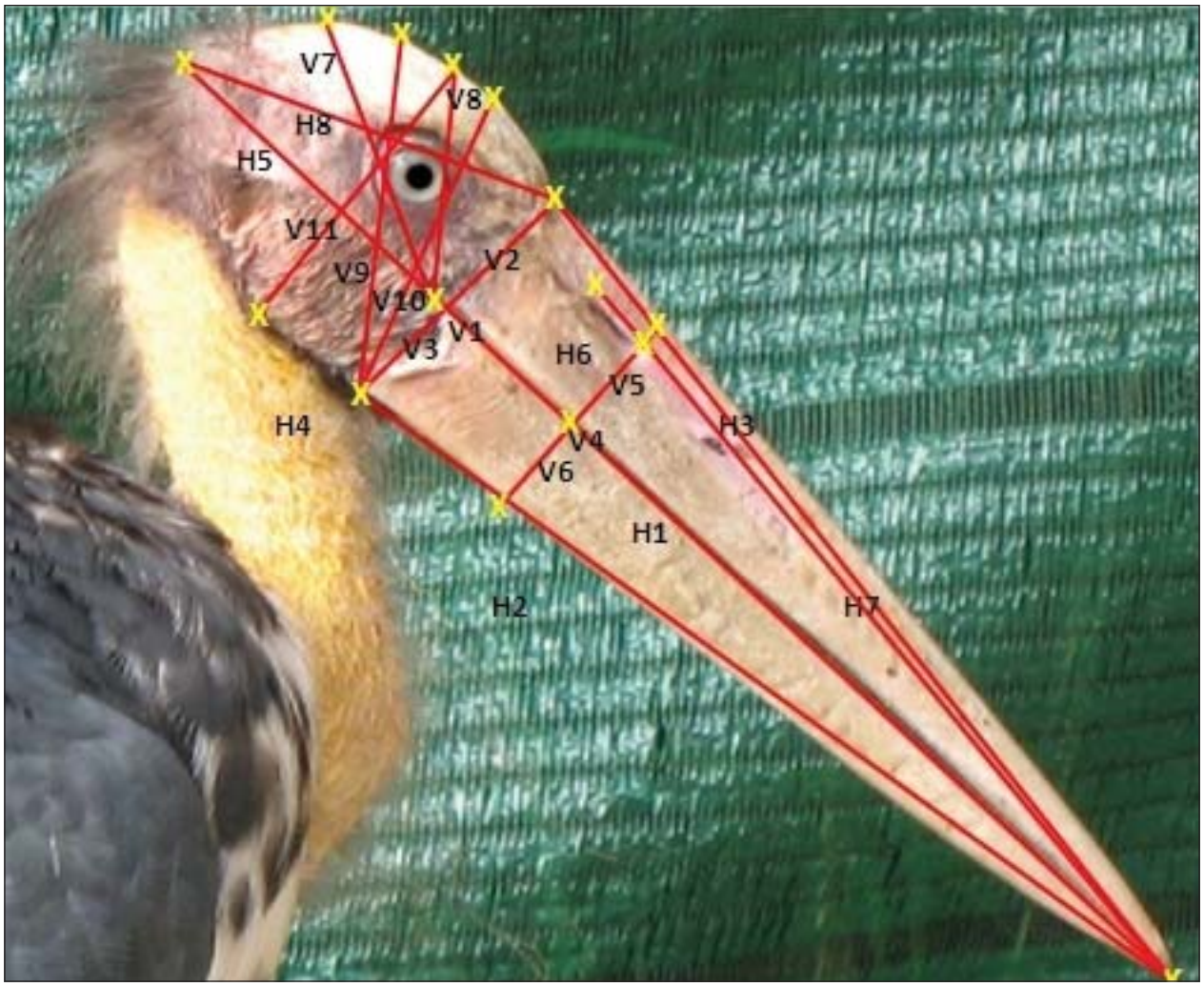

Fig. 1 Reference points (crosses) and measurements (lines) on the head of a lesser adjutant stork. H indicates a horizontal measurement, V indicates a vertical measurement.

Table 1 Horizontal and vertical measurement ratios used to compare the lateral head features of male (n = 11) and female (n = 9) lesser adjutant storks.

Horizontal measurement ratios									
H1/H2	H1/H3	H1/H4	H1/H5	H1/H6	H1/H7	H1/H8	H2/H3	H2/H4	H2/H5
H2/H6	H2/H7	H2/H8	H3/H4	H3/H5	H3/H6	H3/H7	H3/H8	H4/H5	H4/H6
H4/H7	H4/H8	H5/H6	H5/H7	H5/H8	H6/H7	H6/H8	H7/H8		
Vertical measurement ratios									
V1/V2	V1/V3	V1/V4	V1/V5	V1/V6	V1/V7	V1/V8	V1/V9	V1/V10	V1/V11
V2/V3	V2/V4	V2/V5	V2/V6	V2/V7	V2/V8	V2/V9	V2/V10	V2/V11	V3/V4
V3/V5	V3/V6	V3/V7	V3/V8	V3/V9	V3/V10	V3/V11	V4/V5	V4/V6	V4/V7
V4/V8	V4/V9	V4/V10	V4/V11	V5/V6	V5/V7	V5/V8	V5/V9	V5/V10	V5/V11
V6/V7	V6/V8	V6/V9	V6/V10	V6/V11	V7/V8	V7/V9	V7/V10	V7/V11	V8/V9
V8/V10	V8/V11	V9/V10	V9/V11	V10/V11					

Table 2 Vertical measurement ratios showing significant differences in lateral head features between male (n = 11) and female

	V1/V7	V1/V8	V1/V9	V1/V10	V1/V11	V3/V7	V3/V8	V3/V9
Males	0.95 ± 0.04	1.27 ± 0.04	0.77 ± 0.03	0.85 ± 0.03	0.87 ± 0.02	0.44 ± 0.02	0.59 ± 0.03	0.36 ± 0.02
Females	0.89 ± 0.05	1.18 ± 0.09	0.73 ± 0.04	0.81 ± 0.05	0.83 ± 0.04	0.41 ± 0.03	0.54 ± 0.06	0.33 ± 0.03
t	2.62	2.55	2.60	2.29	2.81	2.70	2.30	2.45
p	0.017*	0.020*	0.018*	0.034*	0.011*	0.015*	0.034*	0.025*

To test for significant differences between the lateral head measurement ratios of males and females, independent samples t-tests were conducted using SPSS 16 (the data were normally distributed), and ratios that differed significantly were included in a discriminant function analysis. The same test was used to examine differences between measurement ratios of the age classes 'subadult' and 'adult'. Juveniles were not included into this test because they are often still growing and thus their features may differ naturally to a larger extent.

In addition, six individuals (one adult male, one adult female, one subadult male, one subadult female, one juvenile male and one juvenile female) from the study group of 20 birds were captured and horizontal measurements were taken directly using a calliper and a ruler. To test whether ratios obtained from digital measurements differ significantly from those taken from direct measurements, the measurements from every individual were compared using paired t-tests in Microsoft Office Excel 2007.

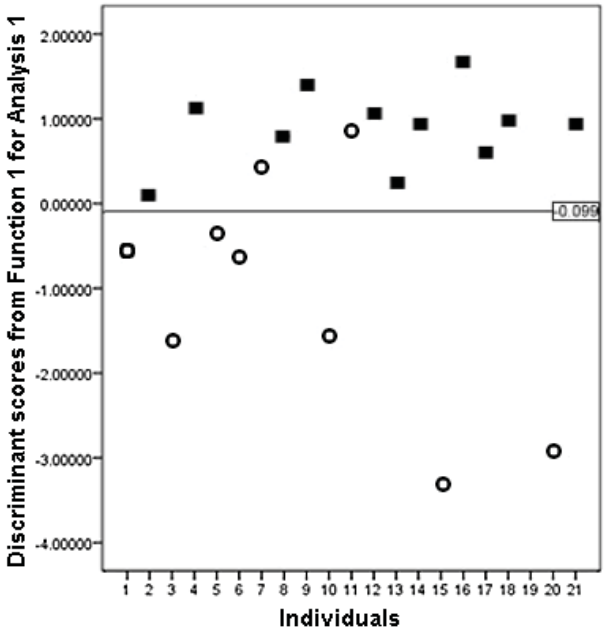

Fig. 2 The discriminant scores (D) obtained for 20 lesser adjutant storks predicting the sex of every individual. Males are indicated with a black rectangle, females with an open circle.

Results

Independent samples t-tests showed a significant difference between males and females in 17 of the 55 vertical measurement ratios calculated, but in none of the 28 horizontal measurement ratios (Table 2).

Using these 17 significant vertical measurement ratios, the discriminant function analysis yielded a Wilks' Lambda = 0.481. The discriminant function used to calculate the discriminant score (D) is:

D = (-0.942*V1/V7) + (0.324*V1/V8) + (-1.013*V1/V9) + (0.292*V1/V10) + (0.478*V1/V11) + (-1.824*V3/V7) + (1.277*V3/V9) + (2.797*V4/V7) + (-0.413*V5/V8) + (0.036*V6/V7)

This discriminant function correctly classified the gender of 90% (n = 18) of the individuals in the study group (n = 20). The group centroids were 0.892 for males and -1.090 for females, and thus the 'cut score' was (-1.090+0.892)/2 = -0.099. If a stork's score (D) is above -0.099, there is 90% certainty it is a male. If D is below -0.099, there is 90% certainty the bird is a female. The scatter plot in Fig. 2 illustrates the predicted sexes using the discriminant scores (D) obtained for every individual.

A stepwise discriminant function analysis showed that the ratio of the bill height (V4) and the distance from the commissural point to the crown (V7) was the best single predictor to distinguish between male and female, being larger in male storks than in female storks. This led to the simplified function D = (2.797*V4/V7). This function correctly classified the gender of 15 (75%) individuals in the study group (n = 20). Figure 3 illustrates this morphological difference with a stylised visualisation of

(n = 9) lesser adjutant storks: * indicates a significant result (p <0.05); ** indicates a highly significant result (p <0.01).

V3/V11	V4/V7	V4/V10	V4/V11	V5/V8	V6/V7	V6/V8	V6/V9	V6/V10
0.40 ± 0.02	0.87 ± 0.03	0.78 ± 0.02	0.80 ± 0.02	0.62 ± 0.03	0.39 ± 0.02	0.52 ± 0.03	0.31 ± 0.02	0.35 ± 0.02
0.38 ± 0.03	0.82 ± 0.04	0.74 ± 0.04	0.76 ± 0.03	0.59 ± 0.04	0.36 ± 0.02	0.48 ± 0.04	0.30 ± 0.02	0.33 ± 0.02
2.17	3.32	2.89	3.31	2.27	2.97	2.70	2.30	2.45
0.044*	0.004**	0.010*	0.004**	0.036*	0.08*	0.015*	0.034*	0.025*

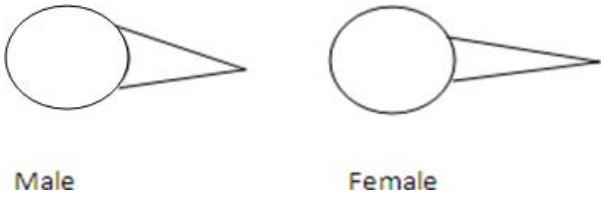

Fig. 3 Stylised head and bill proportions in male and female lesser adjutant storks as suggested by this study.

the proportions of the head and bill of male and female storks.

The comparisons of lateral head ratios of adults (n = 5) and subadults (n = 8) showed that seven of the 28 horizontal measurement ratios and eight of the 55 vertical measurement ratios differed significantly between age classes. When adults and subadults were tested separately for differences between the genders, only one vertical ratio (V4/V9) was found to significantly differ between subadult males (n = 6) and subadult females (n = 2). Of the 17 vertical measurement ratios that significantly differed between males and females in the entire sample group (n = 20), 15 were significantly different between the adult males (n = 2) and adult females (n = 3).

Overall, ratios taken from the eight direct horizontal measurements (taken with a calliper and ruler on six captured birds) did not differ significantly from those derived from photographs (t-test: paired two samples for means, average p = 0.365). The only exception was H6 (length of the nostrils), which differed in four of the six birds (one subadult male, one adult female, one juvenile male and one juvenile female).

Discussion

The results show that there is a significant difference between the lateral head features, derived from digital photographs, of male and female lesser adjutant storks. Previously, only behavioural differences had been reported as a noninvasive method of identifying the sexes in this species (Maust *et al*., 2007): a method that may be unreliable (ACCB, unpubl. data).

Our results suggest that the method we describe in this paper is suitable for identifying the genders of lesser adjutant storks with a high level of reliability. However, it must be noted that the study was carried out by a single observer, thus minimizing potential bias with regards to defining reference points and taking measurements. Although taking measurements in digital photographs on a computer screen using Adobe Photoshop CS2 was found to be reliable when tested against direct measurements, some of the reference points were hard to define due to variation between individuals' head features. It should also to be kept in mind that the study was carried out on a relatively small sample of 20 individuals, all of Cambodian origin, and the results might therefore have to be treated with caution when applied to populations from other geographical regions. Additional individuals from Cambodia and elsewhere need to be tested to determine whether head features are consistent within the study region and whether the species exhibits geographical variation.

None of the horizontal measurement ratios differed significantly between males and females. However, horizontal measurements were used to compare the ratios taken from direct measurements and indirect measurements (derived from photographs) because they were easier to measure and therefore required less time for handling the storks. This comparison showed that the ratios of measurements derived from photos accurately match the ratios derived from direct measurements.

Among the significantly different vertical measurement ratios, the ratio of the bill height to the distance from the commissural point to the crown (V4/V7) was found to be the best predictor of gender in a stepwise discriminant function analysis. The ratio is larger in male storks than in female storks: i.e. the difference between these two measurements is smaller in males.

Using the discriminant function obtained, the gender of 90% of individuals in the study group was classified correctly, with 75% of individuals sexed correctly using a simpler form of the function. Two female birds were classified incorrectly, but both were small and not much is known about their origin, i.e. there might have been food shortages or other problems during their growth and development at an early age. Furthermore, since both females were still subadult, repeating the measurements when they have reached adulthood might yield different results. Fewer measurement ratios differed between the sexes in the subadult age class than in the adults, and therefore sex identification using this method is not as reliable in the younger age classes.

Conclusions

1. We have demonstrated a new method for gender identification of lesser adjutant storks with a high level of accuracy (90%) using digital photographs.
2. There is a significant difference between the ratios of vertical lateral head measurements of male and female lesser adjutant storks.
3. Analogous horizontal head features are not suitable for gender identification in this species.

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The contribution of wild medicinal plants towards poverty alleviation and health improvements: a case study in two villages in Mondulkiri Province, Cambodia

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មូលន័យសង្ខេប

សេវាកម្មសុខភាពសាធារណៈក្នុងខេត្តមណ្ឌលគីរីនៅទន់ខ្សោយនៅឡើយ ដោយសារខ្វះហេដ្ឋារចនាសម្ព័ន្ធដើម្បីភ្ជាប់ទៅភូមិដាច់ស្រយាល។ ខេត្តនេះមានជីវៈចម្រុះកំរិតខ្ពស់ ដែលរួមមានរុក្ខជាតិឱសថដែលប្រជាជនប្រើសម្រាប់ព្យាបាលជំងឺសំខាន់ៗ និងជំងឺបន្ទាប់បន្សំនានា។ ប៉ុន្តែការកាប់បំផ្លាញព្រៃឈើនាពេលបច្ចុប្បន្ននេះ គំរាមកំហែងដល់ធនធានធម្មជាតិទាំងនោះ។ ឯកសារស្រាវជ្រាវនេះវិភាគពីសារៈសំខាន់នៃរុក្ខជាតិឱសថ និងការប្រើប្រាស់របស់វាសម្រាប់ព្យាបាលជំងឺផ្សេងៗនៅក្នុងភូមិពីរក្នុងខេត្តមណ្ឌលគីរី។ បន្ទាប់មក យើងសិក្សាពីតម្លៃសេដ្ឋកិច្ចនៃរុក្ខជាតិឱសថតាមរយៈការវិភាគការចំណាយរបស់ក្រុមគ្រួសារលើការថែទាំសុខភាព។ លទ្ធផលបង្ហាញថា ការប្រើប្រាស់រុក្ខជាតិឱសថជួយអ្នកភូមិយ៉ាងច្រើនក្នុងការកាត់បន្ថយថ្លៃចំណាយលើជំងឺក្រពះ ការឈឺចាប់ក្រោយពេលសម្រាលកូន ជំងឺរាករូស និងជំងឺផ្តាសាយ។ ដោយការស្តារសុខភាពរូបកាយ និងសកម្មភាពសេដ្ឋកិច្ចក្នុងតម្លៃទាបជាងថ្នាំពេទ្យ ឬជម្រើសព្យាបាលផ្សេងទៀត រុក្ខជាតិឱសថជួយប្រជាជនងាយរងគ្រោះដើម្បី កាត់បន្ថយ ឬជៀសវាងភាពក្រីក្របាន។

Abstract

Public health services remain weak in Mondulkiri due to the lack of infrastructure connecting remote villages. This province contains a high level of biodiversity, including medicinal plants that people use to treat diseases and ailments, but deforestation now threatens these natural resources. This paper analyses the importance of medicinal plants and their different therapeutic uses in two villages in Mondulkiri. Then, we study the economic value of these plants through analysing household expenditure on health care. The results show that the use of medicinal plants helps villagers to significantly reduce the costs incurred from stomach aches, post partum pains, diarrhoea and colds. By restoring physical health and economic activity at a lower cost than synthetic drugs or other alternatives, medicinal plants help vulnerable people to alleviate or avoid poverty.

Keywords

Ethnobotany, health economics, medicinal plants, regression analysis, traditional knowledge.

Introduction

According to Rao *et al.* (2006), 80% of the population in developing countries use medicinal plants for health care. Cambodia definitely meets this description, but so far there have been very few empirical assessments of the importance of medicinal plants for primary health care. Linddal & Outey (2004) wrote that "the socio-economic importance of medicinal plants for livelihoods and health care in Cambodia may have been underestimated by Government and the donor community". Indeed, around 1,000 different plant species are used regularly, with an average of 100 different plant species used by each village (Linddal & Outey, 2004).

It is hard to obtain robust evidence to demonstrate that conserving biodiversity alleviates poverty. Mondulkiri Province illustrates this challenge. The province is rich in terms of biodiversity, but its population remains one of the poorest in the country (CDHS, 2006). Since the 1990s, the Cambodian government, encouraged and facilitated by NGOs, has progressively established protected areas to conserve this biodiversity. Eighty percent of the province is now within a network of protected areas known as Mondulkiri Protected Forest (429,438 ha), Seima Biodiversity Conservation Area (305,440 ha) and Phnom Prich Wildlife Sanctuary (222,500 ha).

Despite these measures, these ecosystems have been under the threat of deforestation since the end of the 1990s. The deforestation rate in Mondulkiri was stated to be around 6% per year between 1996 and 2002 (McKenney *et al.*, 2004). Massive land-clearing is still taking place due to multiple factors: high immigration, logging, cash crop farming and agro-industrial plantations. Kamnap & Sambat (2009) estimated that a total of 126,700 hectares had been allocated for land concessions in Mondulkiri, mostly for rubber plantations. Most of these concessions are in protected areas. As a result of this deforestation, more than 50% of native medicinal plants and 14% of the known flora in Mondulkiri Province could be under threat in the long term (IOM, 2009). These species exhibit "a significant level of endemism, relatively narrow ecological amplitude and/or are dense forest species" (Ashwell & Walston, 2008).

Although important economic and social gains have been made over the past decade, public health conditions are still poor in the province, where people recurrently face various diseases such as malaria. Poor medical infrastructure, low availability of reliable drugs and the problem of transport, especially in the rainy season, do not encourage villagers to choose to attend public health facilities. According to Schmitt (2004), 50% of villages are more than 10 km from a health centre. Consequently, local solutions, such as medicinal plants, continue to play an important role in primary health care practice and everyday life (Schmitt, 2004). Medicinal plants are commonly used by villagers to treat diseases and pains such as stomach aches, diarrhoea, colds and headaches. Villagers consult various kinds of traditional healers, usually called 'Kruu Boran'. They treat a large variety of illnesses and injuries with a range of medicinal plants, touching and praying over the area of the body that is hurt or sick. Medicinal plants also play important roles in health issues related to spiritual beliefs, especially during the numerous ceremonies led by Mondulkiri's indigenous people to appease the spirits.

Nevertheless, substituting medicinal plants for synthetic drugs is not a panacea, especially for dangerous diseases such as the human immunodeficiency virus (HIV), malaria or tuberculosis, because the safety and efficacy of medicinal plants is often not known or well-understood. Indeed, most ethno-pharmacological studies focus on isolating only one active ingredient from medicinal plants to understand their mechanism of action on a pathogen and to produce a safe and efficient drug. Very few studies examine the whole traditional remedy, in which a complex mixture of components may act synergistically to produce therapeutic effects (Palombo, 2006). Furthermore, the concept of traditional medicine efficacy can be contentious for medical anthropologists. As explained by Waldram (2000), no consensus has yet been found on the nature of efficacy of traditional medicine as a result of too many divergent views leading to researchers studying "very different things in very different ways and for very different purposes".

Accordingly, three main questions are to be asked in this paper: (1) What is the role of medicinal plants? (2) Can a comparison be made between the economic impact of medicinal plants versus that of synthetic drugs? (3) Does the conservation of biodiversity meaningfully help to alleviate poverty? If this is the case, then the results need to be measured, the process at work needs to be understood, and we need to identify which target groups benefit most.

Pearce & Puroshothaman (1993) quote several ways to approach the economic valuation of medicinal plants: (a) the actual market value of the plants when traded (Murphy *et al.*, 2005); (b) the market value of drugs which are a material source, especially for bio-prospecting (Artuso, 1999); and (c) the value of drugs in terms of their life-saving properties with the value of a "statistical life" (Farnsworth & Soejarto, 1985). The two first methods are inapplicable in Mondulkiri because medicinal plants are consumed directly by households and are rarely traded. The price of medicinal plants sold in the market is there-

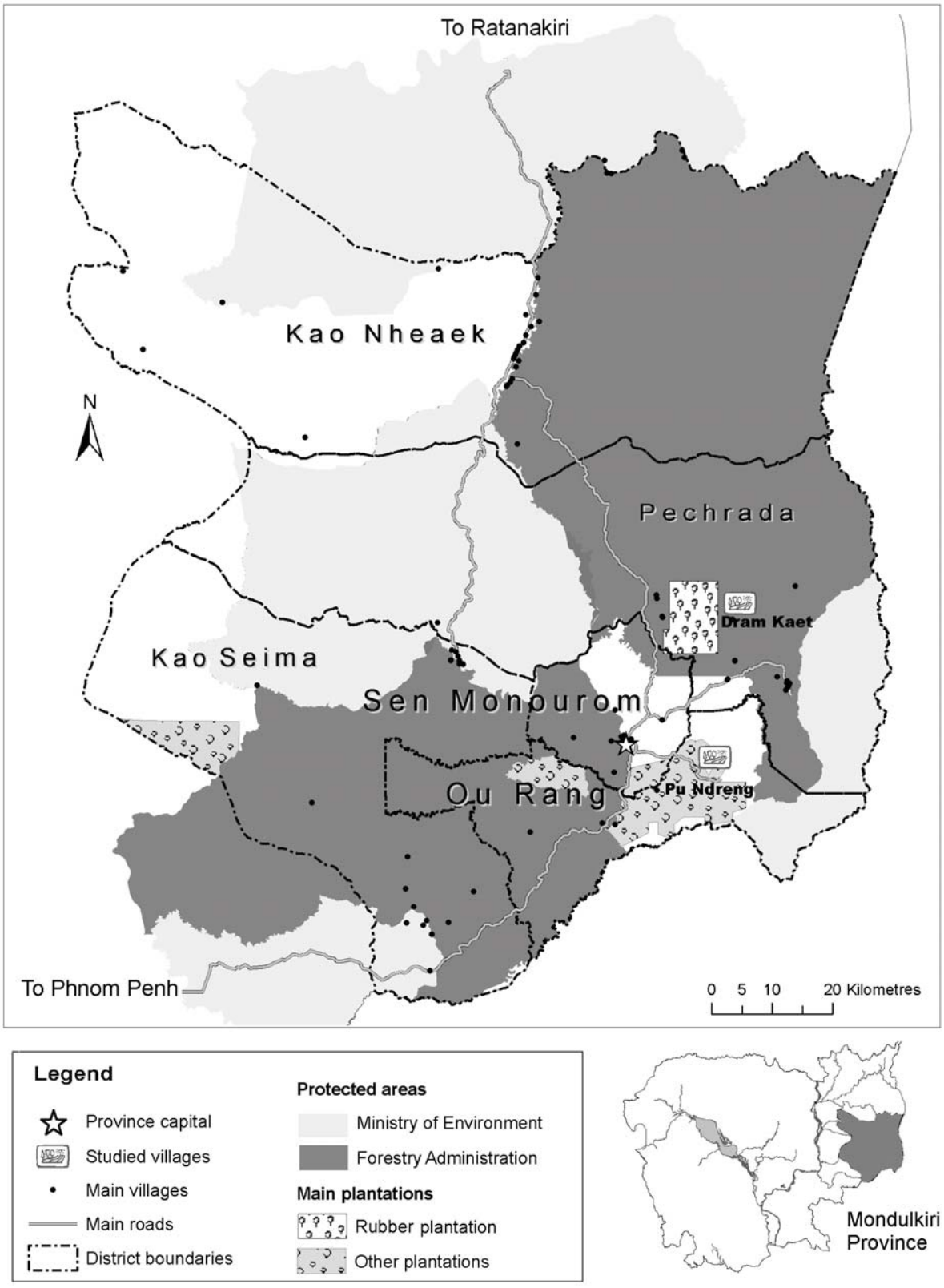

Fig. 1 Map showing Mondulkiri Province and the location of the two villages studied. The main protected areas are highlighted, together with the boundaries of land concessions. Note that the number and size of concessions are likely to have increased by the time this paper goes to press.

fore low and there is no bio-prospecting near such sites. For example, the plant called Tarm Djan *Smilax glabra* Roxb., collected in Pu Ndreng village, is sold in Senmonorom for only 500 to 2,000 riel/kg (approximately US$ 0.12 to 0.48/kg).

Thus, the third method above will be used in this paper, but even then we will focus on the 'present' values of medicinal plants rather than 'future' ones, by using statistical life values. Farnsworth & Soejarto (1985) calculated the value of medicinal plants in the USA expected to disappear by the year 2000. Their method consisted of multiplying the probability of finding active substances in medicinal plants by 1/125 the annual expenditure on health. They estimated the total value of medicinal plants was US$ 203 billion in 1980. Farnsworth & Soejarto's study is a standard reference on the economic value of medicinal plants and was, for example, quoted by Kumar (2004). In this approach: (i) The *market value* of a natural resource is its price when exchanged in a market place. The *economic value* includes the market value, but also the value of the drug in terms of wellbeing (potential life-saving, reducing work stoppages due to illness, furnishing food and feed crops, etc.) and intrinsic values (willingness to pay for their future use or to transmit this heritage to the next generation). (ii) The demand for drugs is not elastic, the share of health care depends on household income. However, some precautions must be taken when transferring this approach from the USA, a developed country. In Cambodia, the molecules in medicinal plants are not well known and the probability of finding active substances is uncertain.

To assess the economic value of medicinal plants, this paper begins by describing their different uses by local people. Then, we look at the economic value of medicinal plants by using a substitute approach with synthetic drugs. We hypothesize that the presence of natural remedies is advantageous for villagers, but this hypothesis depends on other socioeconomic characteristics of households (for example, consumption of unhealthy water and malnutrition may reduce the efficiency of medicinal plants). The comparison between the values of medicinal plants and synthetic drugs is made through a regression analysis which allows an analysis of the real variation in health care expenditure.m

Methods

The study area

The research was conducted in two villages in Mondulkiri Province (Fig. 1): Dram Kaet in Krang Teh Commune, Pechrada District and Pu Ndreng in Dak Dam Commune, O'Reang District. The two villages represent two different biogeographic regions of Mondulkiri (Maurice, 1993; Schmitt, 2004), with different levels of biodiversity and different species of medicinal plants.

Dram Kaet village is located in the foothills, near the lowlands, between 370 m and 450 m above sea level. The ecosystem here is made up of semi-evergreen and deciduous forest. In 2007, the average annual temperature in this area was 26.4°C, and the annual rainfall was 1,788 mm, with the maximum rainfall in August of 458 mm (Nomad, 2007). 90% of the 300 inhabitants of the village are indigenous and belong to the Bunong ethnic minority. Krang Teh Commune contains a further three similar villages along the same road. A health post is available in the next village, 3 km away. The main public health facility, the referral hospital, is in the provincial capital Senmonorom, 35 km from the village.

Pu Ndreng village is on the top of the plateau, 840 m above sea level. The main ecosystem of this zone is mainly savannah, with dense forest in the small valleys. In 2007, the average annual temperature was 24.3 °C, and the annual rainfall was very high, at 4,341 mm, with the highest monthly rainfall in August (1,800 mm) (Nomad, 2007). The village is part of Dak Dam Commune, which contains a further two similar villages. It consists of 600 inhabitants, of whom 90% are Bunong. The commune health post is 1 km from the village whereas the referral hospital is 25 km away. However, when they have a serious health problem, people often opt to go to Dalat in Vietnam.

These villages were selected because of their high proportion of Bunong inhabitants. The Bunong mainly live in the north-eastern highland areas. They form one of Cambodia's largest indigenous groups and have remained culturally distinct from lowland and the main state (Khmer) societies. Their language, religious beliefs and practices, agricultural production and forms of social organisation differ in significant ways from those of lowlanders. Indigenous people generally speak languages that do not have written scripts and their belief systems and religious practices can be described as 'animist'. Their agricultural production system is traditionally based on shifting cultivation (Backstrom *et al.*, 2007) and they strongly rely on forest resources for food, construction materials, cash income and medicine. As a result, the Bunong, as well as other indigenous groups in the region, are highly sensitive and vulnerable to external factors such as climate change, the decline of forest resources and to loss of land and other pressures placed on its use. The Nomad Recherche et Soutien International (Nomad RSI) team has worked with traditional healers in

these villages since 2004, which facilitated the fieldwork for the present study. This research is part of a Nomad RSI programme aimed at the preservation of traditional medical knowledge and medicinal plants in Mondulkiri Province.

Data collection

Data were collected between July and December 2009 by Pauline Laval, the lead researcher, and Vanny Tuon, Bunong facilitator and research assistant. Semi-structured interviews were conducted in Dram Kaet and Pu Ndreng villages with a questionnaire covering the following subjects: access to land and forest, management of farming systems, responses to illness, collection of medicinal plants, perceptions of the evolution and availability of wild medicinal plants, and coping strategies if wild plants decline.

The required sample size was calculated on the basis of the proportion of people using medicinal plants in the two study villages. The first interviews showed that 96% of villagers use medicinal plants. The required sample size was then obtained using the follow equation:

$$n = t^2 * p * (1-p) / m^2$$ (Bartlett, Kotrlik & Higgins, 2001)

Where n is the required sample size; t is the Student statistic value (at 95% of confidence level, its value is 1.96); p is the estimated probability of medicinal plants use in the studied area and m is the margin of error at 5% (standard value of 0.05). The result was a required sample size of 59 households, which were distributed in proportion to the number of households in each village: 20 in Dram Kaet, 39 in Pu Ndreng. One house in three was sampled and only one adult was interviewed in each household (to avoid a direct duplication between answers), ensuring a balance of gender and ethnicity according to the available data from the Cambodian National Census of 2008.

The regression model

To compare the socioeconomic impacts of medicinal plants and synthetic drugs, we developed a linear regression model that explains the relationship between the direct costs of illness (money spent by a family per disease) with the uses of medicinal plants and other socioeconomic and environmental variables. The regression equation can be formally written in the following way:

$$y_i = aX_{1i} + bX_{2i} + cX_{3i} + dX_{4i} + e + \varepsilon_i$$

Where y_i is the variation in expenditure to cure one disease by a household in national currency (riel); X_{1i} is a vector containing the social characteristics of the household explicating the variation of health expenditure; and X_{2i} is a vector comprising the economic variables that, because the majority of the population in Mondulkiri is rural, take into account the characteristics of the farm system to estimate the household income (e.g. number of animals, area of land used, types of crops, market access). X_{3i} describes the types of diseases (malaria, cold, stomach ache) and the types of treatments. X_{4i} is a vector that combines environmental factors (village, medicinal plants used, perception of deforestation). a, b, c and d are the coefficients of each parameter and e is the constant term, which means the basic expenditure for any household whatever their characteristics. Finally, ε_i is the error vector, which captures the variation in heath expenditure that is not explicated by the model. This one is particularly important due to the unpredictable characteristics of health care demands.

To explain the variation in health care expenditure among households, we considered nine demographic variables: sex, age, number of people in the household, the arrival date in the region and the origin of people (indigenous people or migrants). The use of medicinal plants was analysed with a dummy variable 'Synthetic Drugs/ Medicinal Plants': a qualitative variable that was coded 1 when the person used medicinal plants and 0 elsewhere. Nine types of diseases and seven forms of treatment were introduced into the model to explain the variation of health care expenditure.

To estimate this multiple regression, we used XLSTAT-Pro, statistical software produced by Addinsoft. After comparing the coefficient of determination, the root mean square of model's error, the Akaike and the Schwarz criteria, a simple ordinary least squares model was selected. We applied a Jarque-Bera test to verify the normality of errors.

Results

Village demographics

Our sample represented the social characteristics of the population in this area. The sex ratio was respected as 50% of the persons interviewed were women. The distribution of ethnicity was composed of 90% Bunong, 9% Khmer and 1% other ethnicities. Their average age was 44.5 years (standard deviation 18 years). The average size of household was 6.29 persons (standard deviation 3.00). The interviewees had been settled in these villages for 23 years on average (standard deviation 9 years).

Table 1 The main medicinal plants in both study villages, and the percentage of households that reported using them.

Main plants used in Dram Kaet Village			Main plants used in Pu Ndreng Village		
Vernacular name	Scientific name	Use	Vernacular name	Scientific name	Use
Tarm Kap	*Flacourtia indica*	40%	Tarm Kap	*Flacourtia indica*	31%
Tarm Ko Mouy	*Euonymus cochinchinensis*	30%	Tarm Djan	*Smilax glabra*	26%
Tarm Mang Lang	*Chromolaena odorata*	25%	Tarm Tang Yang	*Helicteres angustifolia*	23%
Tarm Marr	Not identified	21%	Tarm Gong	Not identified	23%
Tarm Rova Kong	*Hiptage benghalensis*	20%	Ratao Plaï Tchi	*Willughbeia edulis*	21%
Tarm Rungaï	*Dendrolobium lanceolatum*	20%	Tarm Rova Kong	*Hiptage benghalensis*	21%
Tarm Tro Bek	*Psidium guajava*	20%			

Economic activities

Because the study took place in a rural area, agricultural variables were used to describe household capital. Our findings show that the households own, on average, 1.75 ± 1.65 ha of crop land (paddy fields, swidden fields, gardens) and 7.2 ± 7.2 animals (cattle, pigs, etc.). Agricultural land is considered to be natural capital whereas the number of animals is a form of savings, because villagers set their wealth on cattle. They walk an average of 6 ± 4 km to their crop fields. 41% of villagers require additional income from external activities such as resin tapping and collection of other forest products. All these variables can influence the income of the household and the cost of health care.

The uses of medicinal plants

In both villages, more than 96% of the interviewees reported using medicinal plants: 81% of households use them to treat diseases, 71% drink them every day to prevent illness, 64% use them to treat pains linked with pregnancy and childbirth, 15% apply them to treat animals and, finally, 12% of villagers sell medicinal plants. Some medicinal plants are also used for traditional Bunong ceremonies.

In total, 94 plants were recorded during the interviews in the two villages. The most commonly reported are shown in Table 1. The most frequently reported medicinal plant is Tarm Kap *Flacourtia indica* (Burm. f.) Merr. In Dram Kaet, two other plants are also well known: Tarm Ko Mouy *Euonymus cochinchinensis* Pierre, and Tarm Mang Lang *Chromolaena odorata* (L.) R.M. King & H. Rob. In Pu Ndreng, Tarm Djan *Smilax glabra* Roxb. is also very frequently used.

Treatment of diseases, and the role of medicinal plants

The most frequently reported diseases (as described by the people, not using medical terminology) in both villages were malaria, stomach aches, common colds and headaches (Table 2). Different forms of treatment are chosen by the villagers: going to a public health facility; buying medicine in a private store without prescription; self-medication using medicinal plants; and consulting a private doctor or a traditional healer. The distance from one's house to the place of medical care and the price of treatment are the main factors that determine the people's health treatment-seeking behaviour (according to 11% and 5% of interviewees respectively). For some families, the reputation of the healer is also important when deciding where to go.

The difference between the two villages in their responses to malaria can be explained by the presence of a malaria clinic in Dram Kaet village, which provides free malaria testing and treatments. To treat malaria, villagers usually go to the health post or the malaria clinic, or both. Their therapeutic path is usually complex and, in 65% of cases, the people use more than one health facility. However, the use of medicinal plants in malaria treatment is of relatively low importance. This is probably due to the fact that NGOs and governmental agencies deliver health messages regarding the treatment of malaria and encourage people to consult a health post or centre as soon as first symptoms of malaria appear. In contrast, around 67% of the villagers use medicinal plants to treat stomach ache. The most frequently used medicinal plants are Tarm Tang Yang *Helicteres angustifolia* L. and Tarm Marr (species scientific name not identified). Half of the villagers use medicinal plants to cure colds. The most commonly used medicinal plants are Tarm Mang Lang *Chromolaena odorata* (L.) R.M. King & H. Rob. and Tarm Ko *Ceiba pentadra* (L.) Gaertn. To cure headaches, most interviewees prefer synthetic drugs.

Villager perceptions of the impacts of deforestation

The interview findings indicate that deforestation threatens the availability of medicinal plants in Mondulkiri.

Table 2 The main diseases and associated use of medicinal plant treatments in the study villages.

	Frequency of medicinal plant use		Major medicinal plants in Dram Kaet		Major medicinal plants in Pu Ndreng	
Disease/ ailment	Dram Kaet	Pu Ndreng	Vernacular name	Scientific name	Vernacular name	Scientific name
Malaria	65%	83%	Tarm Rungaï Tarm Bandol Pech Tarm Yao	*Dendrolobium lanceolatum* *Tinospora crispa* *Zingiber zerumbet*	Ratao Dung Warr Tarm Tang Yang	*Coscinium usitatum* *Helicteres angustifolia*
Cold	30%	46%	Tarm Mang Lang Tarm Ach Kra	*Chromolaena odorata* *Hyptis suavolens*	Tarm Ko Tarm Mang Lang	*Ceiba pentadra* *Chromolaena odorata*
Stomach ache	25%	49%	Tarm Trobek Tarm Marr	*Psidium guajava* Not identified	Tarm Tang Yang Tarm Eu Greng Tarm Roya Tarm Gong	*Helicteres angustifolia* *Antidesma ghaesembilla* *Terminalia bialata* Not identified
Headache	20%	26%	Tarm Yao Tarm Rungaï Tarm Ko Tarm Pum Gom	*Zingiber zerumbet* *Dendrolobium lanceolatum* *Ceiba pentadra* *Blumea balsamifera*	Tarm Nahing	*Euodia lepta*

Table 3 Multivariate regression analysis of household expenditure on health care. *t* represents the Student parameter statistic. *** = significant at 1% ($p < 0.01$); ** significant at 5% ($p < 0.05$).

Group of variables	Variable	Coefficient value	Standard deviation	*t*	Probability
	Constant	-9.073	68.405	-0.133	0.895
Socioeconomic variables	Sex of interviewee	0.278	0.540	0.514	0.611
	Age of interviewee	-0.011	0.017	-0.615	0.543
	Length of time resident in the study village	0.011	0.034	0.335	0.740
	Number of people in the household	-0.144	0.123	-1.170	0.251
	Whether the interviewee is paid to work on other farms	-0.372	0.534	-0.697	0.491
	Average distance from household to fields	-0.090	0.068	-1.318	0.197
	Area of land owned	-0.254	0.196	-1.294	0.205
	Number of animals owned by household	0.057	0.039	1.473	0.151
Medicinal plants	Synthetic medicine / medicinal plants	-1.497	0.817	-1.832	0.076
Diseases and ailments	Malaria	0.547	1.339	0.409	0.686
	Arthritis	0.042	2.635	0.016	0.987
	Stomach ache	-0.460	1.492	-0.308	0.760
	Cold	-0.572	1.361	-0.420	0.677
	Headache	0.007	1.429	0.005	0.996
	Aching	-0.610	1.576	-0.387	0.701
	Pain in uterus	**-4.792****	2.098	-2.284	0.029
	Fever	**6.066*****	1.614	3.758	0.001
Method of treating disease	Nothing	**-6.112****	2.380	-2.568	0.015
	Self-medication	**-8.871*****	1.661	-5.339	< 0.001
	Health post	**-4.070****	1.627	-2.501	0.018
	Malaria centre	**-12.818*****	1.963	-6.529	< 0.001
	Private doctor	-1.646	1.823	-0.903	0.373
	Kruu boran	-3.975	1.974	-2.013	0.053
	Hospital in Phnom Penh	0.000	0.000	-	-

Between 41% and 65% of villagers consider that some species are becoming increasingly more difficult to find. 31% think that some medicinal plants are or have been overexploited. For example, a plant locally called Tarm Puk Pu *Hydnophytum formicarum* Jack was reportedly collected in Dram Kaet for commercial purposes from 2004 to 2007 and consequently disappeared.

Regression analysis of treatment costs

A household spends 40,000 riel on average on each of the most frequent diseases and ailments (standard deviation 17,000 riel), corresponding to US$ 10.00 ± 4.10. Villagers who use medicinal plants spend only 1,200 riel ($ 0.30 US$) per disease or ailment, whereas those using synthetic drugs spend 50,000 riel (US$ 12.50) on average. This result shows the potential value of these natural resources, but a direct substitute approach is not easy due to the variation of the type of diseases and the other socioeconomic characteristics of the households. The multivariate regression results are detailed in Table 3. The R^2 obtained was 0.9 and the Fisher test $F = 12.629$ is significant at $p < 0.01$, showing that the model is robust.

Table 3 shows that the use of medicinal plants significantly reduces health care costs for villagers. The coefficient value of medicinal plants is negative and statistically significant at an error risk of 7.6%. When a household decides to use medicinal plants to cure the most frequent disease, the total cost is reduced by 1,497 riel on average per disease or ailment, without taking into account the other variables. However, the types of disease and the ways of treating them can greatly influence expenditure.

Table 3 indicates that the most expensive type of disease for villagers is 'fever'. Villagers frequently use synthetic drugs to treat this and therefore incur high costs. The least expensive ailment was 'uterus pain', which can be treated with medicinal plants such as Tarm Tang Yang *Helicteres angustifolia* and Tarm Eu Greng *Antidesma ghaesembilla* Gaertn.

The last qualitative group of variables - the method of treating diseases - explains why villagers usually do not go to hospital or a private doctor. In fact, all the other ways of treatment mentioned by villagers were less expensive. The malaria clinic and the health post offer good services for fair prices. The use of medicinal plants for self-medication and the consultation of a Kruu Boran (Fig. 2) reduce health care costs significantly.

It is important to note that none of the socioeconomic variables tested in the model were statistically significant. This suggests that were no differences in health care costs according to the person's origin, sex, age or wealth.

Discussion

This paper analyses the importance of medicinal plants for villagers of Mondulkiri to treat and prevent various diseases and ailments. Measuring the economic value of such medicinal plants is not easy because they are directly consumed by villagers and rarely sold in the market. Our analysis suggests that medicinal plants taken in self-medication are a cheaper alternative to other forms of health care and thus contribute to reducing the financial burdens of households in rural areas of Mondulkiri.

Because deforestation has been implicated as a cause of some medicinal plants becoming less abundant, the loss of forests could increase health care costs, especially for stomach ache and uterus pain. It will give less opportunity for people to choose medicinal plants as a way of treating diseases and therefore would increase their expenditures because the alternatives are more costly. This is an important result of this study, showing that medicinal plants reduce health care costs for the commonest diseases in those villages.

We did not analyse the indirect effects of the decline in medicinal plants reported by the villagers. However, we anticipate that deforestation around the village areas will increase both the number of working days lost (due the high frequency of untreated diseases and ailments), and the number of hours needed to collect medicinal plants at greater distances from the villages. Indeed, this trend is already happening in the village of Dram Kaet, where two rubber tree companies (Khou Chouly and DTC group) have recently established a large concession (the exact size is not known, but the entire forest between Krang the and Pu Chri has been planted with rubber trees). Accordingly, the forest that used to be the main area from which villagers collected non timber forest products (NTFPs) does not exist anymore. As stated above, 41% of families rely on resin tapping and collection of other forest products. People have therefore changed their collection areas to a more distant forest, three to four hours away on foot. This adds considerable time and physical effort, compared to the former 30 minutes' or less walk to their traditional collection area. There is no guarantee that the more distant collection areas will continue to be available to them because rubber tree concessions are being awarded in protected areas.

The decreasing access to forests to obtain medicinal plants and to supplement income and food is affecting indigenous culture. As medicinal plants are frequently used during ceremonies, they have cultural and spiritual values for the Bunong. Important ceremonies require specific plants to be held, such as the rice ceremony where

Fig. 2 While collecting the field data, the researchers spent time with traditional healers to obtain accurate information on medicinal plants and their uses. In this picture, the Kruu Boran (traditional healer) of Dram Kaet Village is boiling Tarm Rangay *Dendrolobium lanceolatum* Schindl. to prepare a remedy for diarrhoea (© P. Laval).

the plant Puk Pu *Hydnophytum formicarum* is used to bless the rice spirits. In addition, there is a risk of losing the knowledge of plants that is transmitted between generations while collecting them in the forest. Around 70% of villagers in Pu Ndreng and 45% in Dram Kaet reported receiving their knowledge from their parents and grandparents. If a plant can no longer be found or collected, families will have no opportunity to pass on its properties and the knowledge of its use. This will be a serious loss for future generations.

Even though 40% (Dram Kaet) or 12% (Pu Ndreng) of households can now grow medicinal plants, most of these are fruit trees or aromatic plants whose medicinal properties, even if known, are not the reason for their cultivation. The main conservation technique reported occurs during the practice of swidden agriculture, which happens in forest areas. When they clear the forest, people who know about medicinal plants will consciously keep some forested parts inside or at the edge of their field to provide medicinal plants. Farmers therefore actively conserve some natural plants while they prepare their fields and grow crops. However, this practice is limited to people who are aware of medicinal plants, especially the traditional healers.

Cultivating medicinal plants is not a normal practice for the villagers, most of whom have never considered growing them. Among the medicinal plants with specialised ecological requirements some, like lianas, are difficult for villagers to grow away from their natural forest habitats. Nomad RSI has started some experimental gardens in forest areas close to villages, but still asserts that the natural wild plant populations are critical for regeneration. However, cultivation of some medicinal plants is recommended to alleviate poverty through the potential development of a sustainable market chain for some medicinal plant species. This option cannot of

course be a substitute for natural forests, but may be practical where accessible natural land is permanently lost. More research is needed to find out about the potential plants and market opportunities. Even then, there can be no guarantees because the market prices of medicinal plants are often too low and too unstable to develop sustainable practices. Collectors tend to be opportunistic in their behaviour.

The sustainable use of the remaining forest is the most appropriate solution to ensure the continued availability of medicinal plants. It is therefore important to promote the community-based management of natural resources, especially for medicinal plants, in the natural forest areas. Nomad RSI acknowledges the importance of medicinal plants in the local health systems and has recognised the potential threats that medicinal plants are facing in Mondulkiri Province. Nowadays, the organisation encourages the sustainable use, conservation and cultivation of medicinal plants in the province through the development of Community Medicinal Plants Committees. These committees are composed of key actors in the village for medicinal plants, e.g. the Kruu Boran, village elder, village chief and medicinal plant collectors. They are intended to monitor medicinal plants, raise awareness of sustainable collection practices, help to transmit knowledge and eventually develop income-generating activities. The development of self-supporting community-based organisations to do this is also key to achieving the sustainable use of all important forest products, most essentially the medicinal plants. It is especially important to raise awareness of medicinal plants and advocate their role in the livelihoods, traditions and beliefs of villagers, not only in Mondulkiri, but in many rural areas of Cambodia.

This study has shown the value of medicinal plants for the health care of villagers, which is crucial in persuading key policy and decision-makers, and others able to exert influence, of the importance of a resource whose value is very difficult to identify and quantify. Moreover, medicinal plants are only some of the forest resources that Cambodian villagers derive real benefits from. Resin from dipterocarp trees, honey, bamboo, rattan and timber are also important products for local livelihoods. The total value of all these forest products, together with the intrinsic value of the forest biodiversity, should be weighed up by decision-makers against the gains from granting concessions to private companies. The socio-economic costs and benefits of such concessions should be compared with those of the indigenous villagers who have lived there for thousands of years. This is not a purely economic analysis - more incalculable is the loss of ancient and rich traditional cultures.

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Observations on the spread and extent of alien invasive plant species in six protected areas in Cambodia

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មូលន័យសង្ខេប

រុក្ខជាតិក្រៅស្រុកទន្ទ្រានទីជារុក្ខជាតិគំរាមកំហែងដល់ជីវៈចម្រុះ ប៉ុន្តែមានការយកចិត្តទុកដាក់តិចតួចពីអ្នកស្រាវជ្រាវក្នុងប្រទេសកម្ពុជា។ យើងបានជ្រើសរើសសំណាកពីរបាយរបស់ប្រភេទរុក្ខជាតិទន្ទ្រានទីនៅភាគនិរតីនិងភាគឥសានប្រទេសកម្ពុជា ដោយកំណត់បែងចែកជាឡូត៍ ១០X១០ ម៉ែត្រក្នុងព្រៃ ឬនៅជាប់តំបន់ការពារទាំងប្រាំមួយ។ ក្នុងតំបន់ការពារនីមួយៗ យើងបង្កើតយ៉ាងហោចណាស់ ឡូត៍បីតាមជម្រាលរវាងព្រំដែននិងចំណុចកណ្តាលរបស់វា ដើម្បីវាយតម្លៃពីការរីករាលដាលរុក្ខជាតិក្រៅស្រុកទន្ទ្រានទី។ យើងបានវាស់វែងនិងធ្វើផែនទីនៃការគ្របដណ្តប់របស់រុក្ខជាតិក្រៅស្រុកទន្ទ្រានទីប្រាំពីរប្រភេទ (*Cassia alata, C. occidentalis, Chromolaena odorata, Pennisetum polystachion, Mimosa invisa, M. pudica* និង *Solanum torvum*) ក្នុងឡូត៍នីមួយៗយ៉ាងជាក់លាក់បំផុត។ ក្នុងឡូត៍សរុបទាំង២០ ភាគរយដែលគ្របដណ្តប់ដោយរុក្ខជាតិក្រៅស្រុកទន្ទ្រានទីគឺពី០ ភាគរយដល់១០០ភាគរយ។ ចំណែកតំបន់ភូមិសាស្ត្រស្នូលនៃតំបន់ការពារត្រូវបានរកឃើញថាហាក់ដូចជាពុំមានប្រភេទរុក្ខជាតិក្រៅស្រុកទន្ទ្រានទីទេ ប៉ុន្តែច្រើនប្រភេទបានជ្រៀតចូលក្នុងព្រំដែនរបស់វា។ ការសិក្សារបស់យើងបង្ហាញថា ប្រភេទរុក្ខជាតិក្រៅស្រុកទន្ទ្រានទីគឺជារុក្ខជាតិគំរាមកំហែងដល់តំបន់ការពារក្នុងប្រទេសកម្ពុជា ជាពិសេសតំបន់ដែលប្រជាជនអាចធ្វើដំណើរទៅដល់តាមរយៈផ្លូវគោក ឬផ្លូវទឹក។

Abstract

Alien invasive plants are a threat to biodiversity, but have received little attention from researchers in Cambodia. We sampled the distribution of alien plant species in Southwest and Northeast Cambodia by using 10 x 10 metre plots in forests in or adjacent to six forested protected areas. In every protected area, we established at least three plots along a gradient between its boundary and its centre to evaluate the spread of alien invasive plant species. We measured and mapped the coverage of seven alien plant species (*Cassia alata*, *C. occidentalis*, *Chromolaena odorata*, *Pennisetum polystachion*, *Mimosa invisa*, *M. pudica* and *Solanum torvum*) in every plot as precisely as possible. In the total of 20 plots, the percentage cover of alien invasive plants ranged from zero to 100%. While the geographic core areas of the protected areas were found to be relatively free of alien plants, several species have penetrated their borders. Our study indicates that alien invasive plants are a threat to protected areas in Cambodia, especially sites with good access to people via roads or waterways.

Keywords

Conservation management, habitat alteration, habitat loss, land cover change, Southeast Asia.

Introduction

Worldwide, many plants have been transported to areas where they are not native (Sakai *et al*., 2001). In many cases the translocation was performed for a reason: many plants from the tropics have been exported to temperate areas because of their economic importance (Sakai *et al*., 2001), while other species were transported from temperate Eurasia to provide early settlers and colonists with livestock and food. However, alien plant species can also be dispersed unintentionally and may grow where they are not wanted and are regarded as pests, including protected areas (Callaway & Aschehougdagger, 2000; Sakai *et al*., 2001; Waterhouse 2003). Alien invasive plant species have a high potential to affect natural plant communities because they can spread rapidly and compete with native species (e.g. Williamson, 1996; Wilcove *et al*., 1998; Parker *et al*., 1999; Sala *et al*., 2000; Stein *et al*., 2000).

The spread of alien invasive plant species is facilitated through trade, transportation and travel (Poorter *et al*., 2007). In a first approximation, alien invasive plant species typically penetrate agricultural areas because they tend to be more highly competitive in open areas and along waterways (e.g., Bakar, 2004; Queensland Department of Natural Resources and Mines, 2007). Farmers have to spend a lot of money and labour to clear invaded fields (Bakar, 2004). It is often easier to clear more forest than face the impenetrable thickets of alien invasive plant species (own observation and interviews with several local farmers in Cambodia). Alien invasive plant species are therefore an *indirect* threat to natural forests, by causing the locals cut down the forest for new farmland to replace their invaded fields. However, some species can also invade and alter natural habitats by covering the ground in natural forest gaps and, through competition, prevent native species from regenerating (Queensland Department of Natural Resources and Mines, 2007).

Several alien invasive plant species are known to occur in Cambodia, but very little is known about their distribution and ecology in comparison to other countries, such as Vietnam (Triet, 2000; Triet *et al*., 2001). Some of these alien invasive plant species are spreading and penetrating remote areas, particularly *Mimosa pigra* (Seng & Tan, 2007). Alien plants mostly grow along roadsides, on agricultural land, unused or fallow land and deforested areas, but are also invading ecologically sensitive sites in Cambodia, especially sites that are connected via roads or waterways with frequent traffic (e.g. Levine *et al*., 2003; von der Lippe & Kowarik, 2007). The real extent of the spread and pressure of alien invasive plants on protected areas in Cambodia has not been quantified so far.

Here we provide baseline information on the coverage of seven alien invasive plant species in forested protected areas in Southwest and Northeast Cambodia. We test whether the species composition and abundance of alien plants varies in different parts of the protected areas. Our study provides a first assessment of alien invasive plant species and delivers preliminary results, but further detailed studies are needed to draw more profound conclusions for conservation.

Methods

We surveyed alien invasive plant species in Southwest and Northeast Cambodia, in the Cardamom Mountains and Elephant Mountains and the Eastern Plains respectively (Fig. 1). Specifically, we sampled 20 plots in or near the following protected areas:

i. The Central Cardamoms Protected Forest covers 401,300 ha. In 2006, evergreen forest dominated the area (87.7%), followed by semi-evergreen forest (3.1%), scrubland (4.7%) and bamboo forest (>0.1%) (Forestry Administration, 2008).

ii. Kirirom National Park covers 35,000 ha and is famous for its 13,000-ha *Pinus merkusii* forest (37.1% of the park), the largest pine forest in Cambodia (ICEM, 2003). Lowland evergreen, lowland deciduous forest, and medium-altitude evergreen forests cover about 60% of Kirirom National Park (ICEM, 2003). Anthropogenic areas include a tea plantation (1,500 ha; <0.1%) as well as a hydroelectric power dam.

iii. Bokor National Park covers 140,000 ha. About 97 % of the land is considered to be natural or near-natural forest and just 3% has been transformed. Bokor National Park covers a sandstone massif, rising north from the coast to over 1,100 m. It contains a wide range of habitats, including both low and medium altitude, and numerous waterfalls (ICEM, 2003).

iv. The Seima Biodiversity Conservation Area covers 303,400 ha, of which 155,000 ha are regarded as 'core zone'. The forests are classified into four main types: evergreen, semi-evergreen, mixed deciduous and deciduous dipterocarp forests. Bamboo thickets are another important vegetation type found in the Seima Biodiversity Conservation Area (Pollard *et al*., 2007).

v. Phnom Prich Wildlife Sanctuary covers 222,500 ha (World Database on Protected Areas, 2009). The forest is comprised of semi-evergreen forest, mixed deciduous forest, and open deciduous dipterocarp forest (Claassen *et al*., 2007).

vi. The Mondulkiri Protected Forest covers 429,462 ha. Mondulkiri is considered an important sample of the Lower Mekong Dry Forest EcoRegion, one of WWF's

[*Editor's note: Seima Biodiversity Conservation Area (area iv) became Seima Protected Forest in 2009, and covers 292,600 ha*].

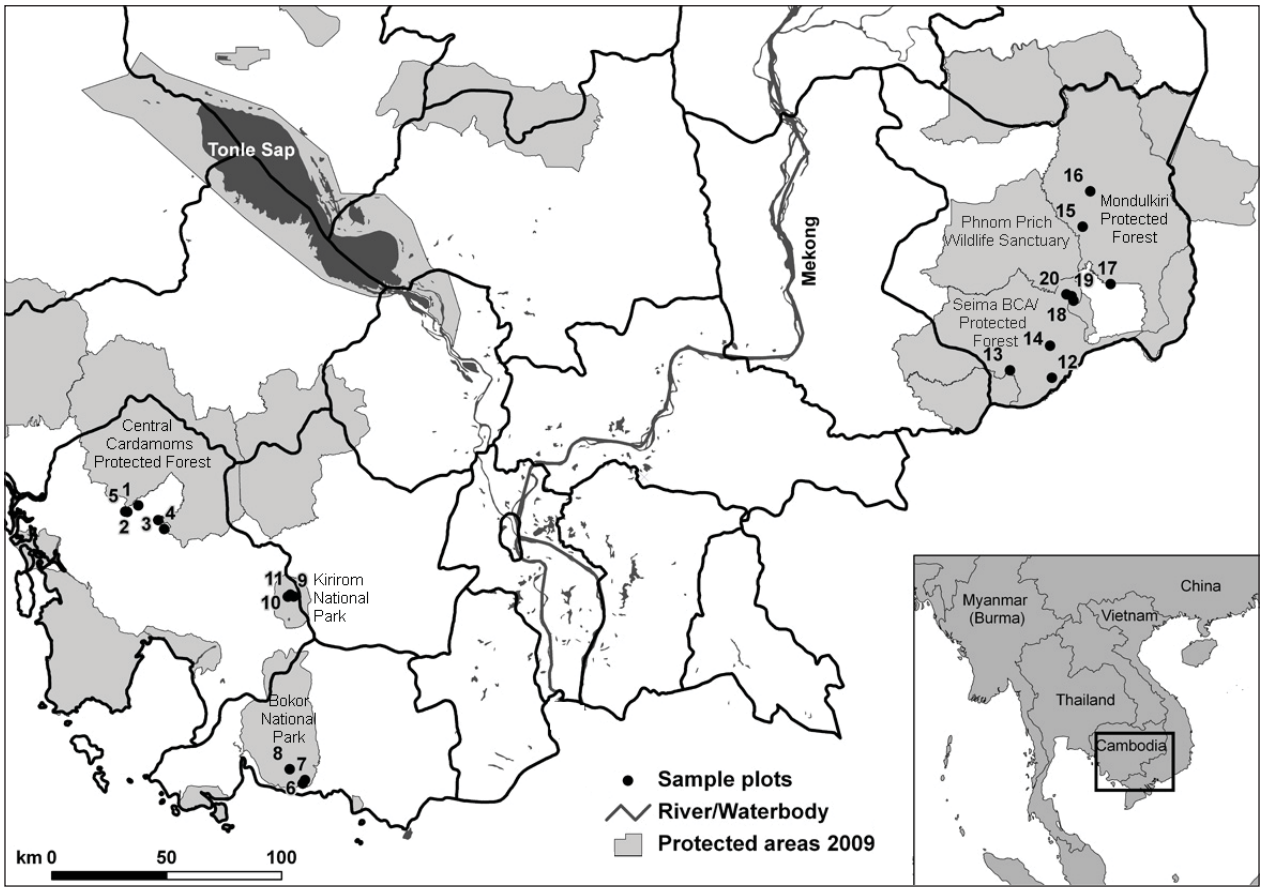

Fig. 1 Map with localities of each sample plot (plot numbers are referenced to Tables 1 and 3). Protected areas are indicated in grey shading, rivers and wetlands are dark grey, and bold lines indicate provincial boundaries.

Global 200 Priority EcoRegions (No. 54, Diggle 2006). The dry forests are generally open, dominated by deciduous dipterocarp forest and resembling savannah rather than forest (Diggle, 2006).

We surveyed alien invasive plant species between December 2008 and May 2009 in areas with considerable forest cover. Twenty survey plots were established: 11 in Southwest Cambodia and nine in the Eastern Plains (Table 1). We visited every plot during the dry season (December to May). Every plot was a 10 x 10 metre square.

In general, we followed the vegetation survey methods of Kuebler (2008), but changed the procedures slightly to address our objectives better. We selected the plots (Table 1) through stratified random sampling. First, we selected forested areas with protected status (under the jurisdiction of the Ministry of Environment or Forestry Administration). Then, in each area, we selected at least three plots between the boundary and centre of the forest (labelled 'edge', 'midway' and 'core' in Table 1). The distance to the nearest road ranged between 10 and 5,000 metres (Table 1), but every plot was within 10 metres of a frequently used foot trail. The plots were well vegetated, and bare soil was visible in only two plots (in both cases covering less than 5% of the plot area).

We mapped the occurrence and extent of seven invasive alien plant species (Table 2) within every plot and estimated their cover as a percentage of the total plot area. First, we delineated the 10 x 10 metre study plot with red marking tape. Then we mapped individual alien invasive plant shoots (measuring their distance to the nearest 5 cm from the plot's x and y axes), and treated every sapling as covering an area of 100 cm^2. However, if there were more then 10 visible shoots in a 10 x 10 cm area and if distinguishing individual shoots was difficult, we measured and mapped their actual area. (The latter method proved to be essential for plots with a high density of alien invasive plants). A summary of the target alien invasive plant species and their origins are given in Table 2.

In each of the six protected areas, at least three plots (five for the Central Cardamoms Protected Forest) were

Table 1 Sampling plot dates and locations.

Protected area	Plot #	Date when sampled	Distance to road (m)	Distance to forest (m)[a]	Position of plot[b]	IUCN category[c]	Elevation (m)	Strategy to manage alien invasive plants
Central Cardamoms Protected Forest	1	16 Dec 08	150	20	Edge	IV	595	Management plan drafted, but does not address invasive species.
	2	16 Dec 08	180	20	Edge	IV	480	
	3	17 Dec 08	5	300	Core[e]	IV	613	
	4	17 Dec 08	10	800	Core[e]	IV	279	
	5	16 Dec 08	100	30	Edge	IV	365	
Bokor National Park	6	07 May 09	15	0	Edge	II	133	Management plan being implemented, but does not address invasive species.
	7	07 May 09	40	0	Midway	II	461	
	8	07 May 09	0	0	Core	II	918	
Kirirom National Park	9	08 May 09	10	0[d]	Midway	II	675	No management plan.
	10	08 May 09	8	0[d]	Core	II	622	
	11	08 May 09	2	0[d]	Edge	II	691	
Seima Biodiversity Conservation Area	12	23 Feb 09	1,000	0	Edge	n/a	332	No management plan.
	13	24 Feb 09	2,000	0	Midway	n/a	162	
	14	25 Feb 09	5,000	0	Core	n/a	343	
Mondulkiri Protected Forest	15	26 Feb 09	2,000	0	Midway	IV	262	Management plan drafted, addresses invasive species.
	16	26 Feb 09	5	0	Core	IV	208	
	17	26 Feb 09	5	0	Edge	IV	426	
Phnom Prich Wildlife Sanctuary	18	27 Feb 09	5	0	Edge	IV	421	No management plan.
	19	27 Feb 09	10	0	Midway	IV	415	
	20	27 Feb 09	15	0	Core	IV	397	

[a] Estimates. '0' indicates areas less than 5 metres from the forest edge.

[b] If the park has not been formally zoned, the location is in relation to its main forested area.

[c] IUCN categories adopted from the World Database on Protected Areas (2009) and explained by IUCN (2004) and Dudley *et al.* (in press).

[d] Plots in *Pinus merkusii* woodland. 'Edge' refers to the boundary with a different forest type.

[e] Not inside the protected area, but within a large tract of forest close to a settlement.

placed in different parts of the protected area (Table 1). These were defined as: *Core* - located towards the centre of the protected area (not necessarily congruent with the management 'core zone'), *Edge* - at the boundary of the protected area, and *Midway* - halfway between the Edge and the Core plots (Fig. 1, Table 2). As a proxy for the centre, we established the core plots as far inside each forest as allowed and as possible (the shortest distances to roads and the forest edge are given in Table 1). The locations of each of the three plots were chosen to indicate how far alien invasive plant species had penetrated the protected areas.

Using our plot data, we tested whether the mean relative abundance of each alien invasive plant species varied according to their locations within the protected areas. The null hypothesis (H_0) was that there was no difference between the edge, midway and core plots:

$$H_0: A_e = A_m = A_c$$

where A_e is the abundance (area in square metres per plot) of invasive species in edge plots, A_m is the abundance of invasive species in midway plots, and A_c is the abundance of invasive species in core plots.

The alternative hypothesis (H_1) was that the abundance of invasive plants would be highest at the edges of the protected areas (where we assume there is easier access for humans and therefore greater opportunities for the dispersal of alien plant species), lowest in core areas (due to lower opportunities for seed transportation), and intermediate in the midway plots:

Table 2 Alien invasive plant species found in Cambodia and our study sites, with their origin and a general description. Plot numbers refer to Table 1 and Fig. 1.

Scientific name, English name, ឈ្មោះខ្មែរ Khmer name	Area of origin	Remarks
Cassia alata Ringworm cassia ឌុង្គិត	South America	A small shrub, about 1.5 m tall. Cultivated near houses for ornamental and utilitarian reasons. The clusters of large yellow saffron flowers bloom during rainy season and fall during dry season. Considered to be toxic but used as medicine (Dy Phon, 2000).
Cassia occidentalis Coffee weed សណ្តែកខ្មោច	South America (U Kyaw Tun & U Pe Than, 2006)	Hard herb with yellow flowers eaten as vegetables. Plant used in traditional medicine. In Cambodia, along most roads and in uncultivated places (Dy Phon, 2000).
Chromolaena odorata Siam weed ទន្ទ្រានខេត្រ	Tropical America	Herb, 1-2 m tall. Grows as a pioneer in deforested places. All parts of the plant are used as green manure (Dy Phon, 2000).
Pennisetum polystachion Mission grass ស្មៅកន្ទុយដំរី	Tropical Africa (Bakar, 2004)	A coarse, erect and gregarious grass. Culms slender to moderately stout, up to 2 m tall, usually 1-2 m, simple or few-branched. Blades 50-400 mm long, 5-18 mm wide, glabrous or pubescent. Spike dense, yellow brown, 50-250 mm long, 13-26 mm wide. Spikelets surrounded by bristles, these densely hairy at base, unequal, one longer than the others but not greatly exceeding the next one or two shorter ones, 12-25 mm long; spikelets 2-flowered c. 5 mm long, upper floret perfect.
Mimosa invisa Giant false sensitive plant ព្រះខួបឪរី	Tropical America	Slender and thorny climbing shrub. Growing in forest clearings, undergrowth, and along roads (Barneby, 1987, 1991). Used in traditional medicine (Dy Phon, 2000).
Mimosa pudica Giant sensitive plant ព្រះខួបសំពះ	Tropical America	Shrub or strong herb. In some counties, the plant has a high potential of invasion and is counteracted. In Cambodia, this species spreads along the roads and in cultivated places. Used in traditional medicine (Dy Phon, 2000).
Solanum torvum Turkey berry ត្របែតត់លំញង	Caribbean islands (Irawan *et al*., 2006)	Small shrub, 1-3 m tall. Escaped from cultivation and found in undergrowth of forests up to 1,200 m above sea level. The small fruits are a supplementary food (Dy Phon, 2000).

$$H_1: A_e > A_m > A_c$$

We tested these data using Analysis of Variance (ANOVA), with the plots grouped into the three location categories: edge, midway and core.

In addition, we tested whether alien invasive plants species richness varies between the edge, core, and midway sites. Again, the null hypothesis (H_0) was that there would be no significant difference between these locations:

$$H_0: S_e = S_m = S_c$$

where S_e is the number of alien invasive plant species counted in edge plots, S_m is the number of alien invasive plant species in midway plots and S_c is the number of alien invasive plant species in core plots. For our alternative hypothesis (H_1), we postulated that species diversity would be highest in edge plots and lowest in core plots:

$$H_1: S_e > S_m > S_c$$

We used a non-parametric test (Wilcoxon signed-rank test) to compare the number of species in edge, midway and core plots, and set our confidence interval to 0.90 ($p = 0.1$).

Results

A total of seven alien invasive plants were found in the 20 plots surveyed. All seven are considered to be alien because they originate from the Americas or Africa and have been dispersed throughout Southeast Asia relatively recently (Table 2).

The distribution of each species varied between plots and between protected areas (Table 3). We found the highest diversity of alien invasive plant species in plots in Bokor National Park, and the highest abundance (in terms of percentage cover of the plots) in plots near the Central Cardamoms Protected Forest. Kirirom National Park and Mondulkiri Protected Forest appeared almost unaffected, with only one species and low coverage in plots close to the core.

Central Cardamoms Protected Forest ($n = 5$)

We recorded six alien invasive plant species covering up to three-quarters of the plot areas (Table 3). Coverage varied considerably between plots and species. *Chromolaena odorata* and *P. polystachion* were the dominant

Table 3 Percentage cover of alien invasive plants species in study plots in or near protected areas in Cambodia.

Protected area	Plot #	*Cassia alata*	*Cassia occidentalis*	*Chromolaena odorata*	*Mimosa invisa*	*Mimosa pudica*	*Pennisetum polystachion*	*Solanum torvum*	Total cover of plot (%)
Central Cardamoms Protected Forest	1	-	-	66.9	-	-	4.0	-	70.9
	2	0.3	-	-	-	-	73.0	0.6	73.9
	3	-	20.0	-	-	51.8	-	-	71.8
	4	-	-	27.2	-	-	-	-	27.2
	5	-	-	10.2	-	-	-	-	10.2
Bokor National Park	6	-	-	8.0	-	2.8	8.6	-	19.4
	7	-	-	2.5	-	-	2.2	-	4.7
	8	-	-	5.0	1.2	1.6	-	-	7.8
Kirirom National Park	9	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-
	11	-	-	70.2	-	-	-	-	70.2
Seima Biodiversity Conservation Area	12	0.6	-	72.6	-	-	4.9	-	78.1
	13	-	-	5.4	-	-	-	-	5.4
	14	-	-	-	-	-	-	-	-
Mondulkiri Protected Forest	15	-	-	92.3	-	-	-	-	92.3
	16	-	-	-	-	-	-	-	-
	17	-	-	0.6	-	-	-	-	0.6
Phnom Prich Wildlife Sanctuary	18	-	-	72.0	28.0	-	-	-	100.0
	19	-	-	68.3	-	-	-	-	68.3
	20	-	-	56.1	-	-	-	-	56.1

species in all five plots in or near the Central Cardamoms Protected Forest, while *Solanum torvum* and *Cassia alata* were almost negligible (Table 3).

All five plots were near (within 2 km) the boundary of the Central Cardamoms Protected Forest and none were far inside the reserve. Nevertheless, the five plots varied in their distance from the forest edge (Table 1).

Bokor National Park (*n* = 3)

Four alien invasive plant species were detected in Bokor National Park (Table 3), but their relative abundance was below 10 % and much lower than in the Central Cardamoms Protected Forest plots. Alien invasive plant species were more common towards the gate of the park (Plot 6) and the former French hill station (Plot 8; Table 3).

Kirirom National Park (*n* = 3)

Only *Chromolaena odorata* was found in one plot in Kirirom National Park. We observed no alien invasive plant species in Plots 9 and 10 (Table 3). This suggests that alien invasive plant species have barely reached the edge of the national park (Plot 11) and have not yet penetrated the core area.

Seima Biodiversity Conservation Area (*n* = 3)

We recorded *P. polystachion*, *C. odorata* and *Cassia alata* in the Seima Biodiversity Conservation Area. *Chromolaena odorata* was dominant in Plot 12, but less abundant in Plot 13 and absent from Plot 14. We recorded no alien invasive plant species in Plot 14 in the core of Seima Biodiversity Conservation Area (Table 3).

Mondulkiri Protected Forest (*n* = 3)

We recorded one alien invasive plant species in Mondulkiri Protected Forest. *Chromolaena odorata* covered most of Plot 15 (core area) and was present in Plot 17 (edge), but no alien invasive plant species were found in Plot 16 (midway) (Table 3).

Phnom Prich Wildlife Sanctuary (*n* = 3)

We recorded two alien invasive plant species in Phnom Prich Wildlife Sanctuary: *C. odorata* and *Mimosa invisa*. *Chromolaena odorata* was present in all three plots, while the remainder of the plot was covered by *M. invisa* nested inside *C. odorata*. In addition, *C. odorata* covered large parts of Plots 19 and 20 (Table 3).

Assessment of relative abundance and species composition

With regard to the three distance classes – Core, Midway and Edge – we found all seven species at the edges of protected areas and few alien invasive plant species (both in terms of total abundance and species diversity) in the core plots. We found a clear negative relationship between the number of species in the plots and their distance from the forest edges ($p = 0.056$, Wilcoxon signed-rank test with continuity correction. The data were not normally distributed) (Fig. 2). This indicates there is a greater diversity of alien invasive plant species outside the forests/ protected areas, but with a trend of the plants spreading towards the core area.

Across all of the alien invasive plant species detected, *C. odorata* was the most abundant (covering a total of 572 m² of the 20 plots), followed by *P. polystachion* (141 m²). All other alien invasive plant species covered less than 7% of the total area sampled. We suggest priority be given to *Chromolaena odorata* and *P. polystachion* in management plans, to reduce their further spread towards the centres of forested areas.

Discussion

This study found seven alien invasive plant species (Table 2). Each species varied in its distribution and abundance among the 20 plots sampled. While several forests and core areas of protected areas appear to be relatively free from these alien invasive plants, the trend and spread potential, as well as current distribution derived from our data, suggests that alien invasive plants may continue to spread further into the inner reaches of protected areas in Cambodia.

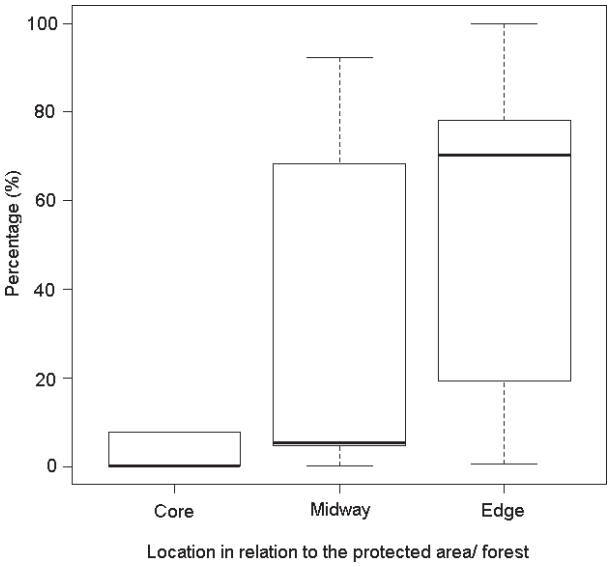

Fig. 2 Percentage cover of alien invasive species at Core, Edge, and Midway plots ($n = 20$) in Cambodia. Their abundance was higher at the boundaries of the protected areas.

Chromolaena odorata is the most aggressive and successful invader over all locations, especially along frequently used paths and roads (e.g. Plot 10). Seeds of *C. odorata* are dispersed by humans and wind. Ossom *et al*. (2007) found that *C. odorata* produces thousand of seeds in one season, dispersed both by wind and clinging to animal fur, human hair or clothes. Hence, *C. odorata* is likely to spread further towards the core areas along paths frequented by tourists or local traffic.

Our observations indicate that alien invasive plant species can be a threat to forest areas, even if a low percentage of the area is covered. One of the main threats is indirect, according to land users close to the Central Cardamoms Protected Forest and Seima Biodiversity Conservation Area. Alien invasive plant species first invade agricultural areas on the forest fringes, dispersed through wind and traffic, etc., making it difficult for the small farmers to cultivate these areas. This forces the farmers to seek new farmland, and they often have no choice but to clear more forests.

Spread towards core areas

Many of the sites visited had fewer alien invasive plant species in the core forest plots than the edge plots. Unfortunately, in some cases (e.g., Plot 8), we found alien invasive plant species in the centre of some large forest tracts, probably facilitated through human transportation. While interviewing locals, many confirmed that *C. odorata* in particular has already infested large areas in

the Cardamom Mountains. Through the high dispersing potential of most alien invasive plants and their competitive advantages (e.g. Williamson, 1996; Wilcove *et al*., 1998; Parker *et al*., 1999; Sala *et al*., 2000; Stein *et al*., 2000; Callaway & Aschehougdagger, 2000; Sakai *et al*., 2001), it is likely that all species will continue to spread and infest more areas. For instance, the construction of the highway into Bokor National Park is anticipated to increase the dispersal of alien invasive plant species in the future.

Management of alien invasive plants

Only half of the six protected areas in our study have a management plan. Of these, only one addresses the spread of alien invasive plant species by suggesting monitoring the extent of invasive species and controlling alien invasive plants. This is clearly insufficient to address the spread of alien invasive plants in Cambodia. All sites need to address alien invasive plant species to limit their further spread towards core areas. Effective invasive species control will ultimately help to maintain sufficient areas for agricultural use outside of the forests, by reducing the need for subsistence farmers to abandon infested fields and clear more forest.

The need for improved management is especially urgent in the southern parts of Bokor National Park. Construction of a four-line motorway started in early 2009, soon to be followed by a resort and a casino. Damage from road construction has penetrated up to 500 metres into the forest on both sides of the road (own observations, 6 and 7 April 2009). This road, and the likely increased traffic, could facilitate the spread of alien invasive plant species into this park.

There are currently almost no organized efforts to control the spread of alien invasive plant species in Cambodia. The only case we identified was an ongoing attempt by BirdLife International to eradicate *Mimosa pigra* from Bueong Prek Lapouv Sarus Crane Reserve. The need to address the spread of invasive alien plant species has been identified in Mondulkiri Protected Forest (Table 1) and local work plans are currently being drafted for the Central Cardamoms Protected Forest and Bokor National Park (Table 1). However, management plans for areas without any protected status or beyond protected area boundaries do not exist and are not being prepared. Hence, buffer zones and corridors should be the main focus for future activities to prevent the colonization of protected areas by alien invasive plants.

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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

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មូលន័យសង្ខេប

នៅចន្លោះឆ្នាំ១៩៩៩និង២០១១ ប្រភេទ *Rhinolophus affinis* ត្រូវបានគេប្រមូលនៅទីតាំងបួនកន្លែងនៃភាគខាងជើងប្រទេសកម្ពុជា។ នេះគឺជាឯកសារកំណត់ត្រាដំបូងនៃសត្វប្រចៀវក្រចកជើងសេះពីប្រទេសកម្ពុជា និងធ្វើឲ្យចំនួនប្រភេទសត្វប្រចៀវរកឃើញនៅប្រទេសកម្ពុជាកើនឡើងរហូតដល់៥០ប្រភេទ ដែលបញ្ជីឈ្មោះប្រភេទត្រូវបានផ្តល់ជូន។ ទិន្នន័យថ្មីៗត្រូវបានគេផ្តល់ជូនអំពីលក្ខណៈសំលេង និងអេកូឡូស៊ីរបស់ *R. affinis* នៅក្នុងប្រទេសកម្ពុជា ថៃ និងវៀតណាម និងអំពីរបាយរបស់វាក្នុងតំបន់ដីគោកនៃអាស៊ីអគ្នេយ៍។

Abstract

Between 1999 and 2011, *Rhinolophus affinis* was collected from four localities in northern Cambodia. These are the first documented records of the intermediate horseshoe bat from this country and increase the number of bat species known from Cambodia to 50, a list of which is provided. New data are provided on the acoustic characteristics and ecology of *R. affinis* in Cambodia, Thailand and Vietnam, and on its distribution in mainland Southeast Asia.

Keywords

Acoustics, Cambodia, distribution, ecology, *Rhinolophus affinis*, species list.

Introduction

Until recently there had been little bat research in Cambodia. A preliminary checklist was published by Kock (2000) and this was updated by Hendrichsen *et al*. (2001) who included 10 new country records resulting from a field survey conducted by Fauna & Flora International in Phnom Samkos Wildlife Sanctuary (Daltry & Momberg, 2000a,b). Further records were added by Matveev (2005) who collected specimens between 2000 and 2002 in a variety of locations, mostly in the north-eastern and south-western parts of the country. Other *ad hoc* field studies led to some additions to the bat fauna including: two species new to science, *Murina harrisoni* Csorba & Bates, 2005 and *Kerivoula titania* Bates *et al*., 2007; others that were rare and/or little known such as *Otomops wroughtoni* (Walston & Bates, 2001) and *Kerivoula kachinensis* (Soisook *et al*., 2007); and one that resulted from a taxonomic revision, *Rhinolophus microglobosus* (Soisook *et al*., 2008). Ith *et al*. (2011) clarified the status of *R. shameli*. Today, based on the literature cited above and including the current paper, the known bat fauna of Cambodia has reached 50 species, of which eight are *Rhinolophus* species (horseshoe bats): *Rhinolophus acuminatus*; *R. affinis, R. chaseni, R. luctus, R. malayanus, R. microglobosus, R. pusillus* and *R. shameli* (Table 1).

In contrast, there have been 190 years of bat research in Thailand and 126 species have been recorded from that country (Bumrungsri *et al*., 2006; Thong *et al*., 2006; Bates *et al*., 2007; Soisook *et al*., 2007, 2008, 2010; Wu *et al*., 2009; Douangboupha *et al*., 2010), including 21 species of *Rhinolophus*: *R. acuminatus, R. affinis, R. beddomei, R. coelophyllus, R. lepidus, R. luctus, R. macrotis, R. malayanus, R. microglobosus, R. marshalli, R. megaphyllus, R. paradoxolophus, R. pearsonii, R. pusillus, R. shameli, R. siamensis, R. stheno, R. thailandensis, R. thomasi, R. trifoliatus* and *R. yunanensis*.

In Vietnam, Hendrichsen *et al*. (2001) recognised 85 species of bats for which there were confirmed records. However, with as many as 110 species subsequently listed by Can *et al*. (2008), the total number reliably recorded is not clear and needs further revision, particularly in relation to taxa that have been misidentified (Thong, 2011). On the basis of Csorba *et al*. (2003), Thong *et al*. (2006), Soisook *et al*. (2008), Francis (2008) and Furey *et al*. (2009), 16 species of *Rhinolophus* are known from Vietnam: *R. affinis, R. chaseni, R. luctus, R. malayanus, R. megaphyllus, R. macrotis, R. marshalli, R. microglobosus, R. paradoxolophus, R. pearsonii, R. pusillus, R. shameli, R. sinicus, R. stheno, R. thomasi* and *R. yunanensis*. A further three, *R. rouxii, R. siamensis* and *R. subbadius*, were included for Vietnam by Simmons (2005), but their status remains unclear. Following Francis (2008), specimens previously referred to *R. borneensis* by Csorba *et al*. (2003) are here included in *R. chaseni*.

In Thailand and Vietnam, the intermediate horseshoe bat, *Rhinolophus affinis* Horsfield, 1823, is a common and widespread species (Fig. 1), but its status in Cambodia has been unclear. Some authors, such as Corbet & Hill (1992) and Francis (2008), included the species throughout the country on distribution maps without explanation. Others, such as Kock (2000) and Hendrichsen *et al*. (2001), specifically rejected its inclusion because of the lack of supporting evidence; a view followed by Csorba *et al*. (2003) and Simmons (2005).

This paper presents the first documented evidence for the presence of *R. affinis* in Cambodia, summarises the diagnostic characters of this species in Cambodia, provides new information on its echolocation and ecology in Cambodia, Thailand and Vietnam and maps its distribution in mainland Southeast Asia.

Methods

The new data from Cambodia result from a series of short surveys. These were conducted by Joe Walston of the Wildlife Conservation Society in Preah Vihear Province, northern Cambodia (March, 1999; August and December, 2000); by Annette Olsson in Virachey National Park, Northeast Cambodia (June, 2006); by Ben Hayes, Phauk Sophany and Phen Sarith in Phnom Kulen National Park, Northwest Cambodia (November, 2009; April, June and July, 2010); and by Neil Furey, Ith Saveng and Gabor Csorba in Preah Vihear Protected Forest, northern Cambodia (February, 2011). New data on the distribution and ecology of this species in Thailand are based on field research carried out primarily between 2003 and 2007 by the bat team of the Prince of Songkla University, Thailand, in conjunction with colleagues from the National University of Laos, Lao PDR, and the Royal University of Phnom Penh, Cambodia. New data from Vietnam were collected on a series of field surveys between 2005 and 2010 by Vu Dinh Thong.

For the field surveys undertaken in Cambodia, Thailand and Vietnam, bats were captured from caves and forests using a combination of hand nets, four bank harp

Table 1 Bat species currently recognised in the peer-reviewed literature for Cambodia. Status follows IUCN (2011) for species that have been evaluated: LC = Least Concern; NT = Near Threatened; DD = Data Deficient.

Family/ Species	IUCN status	First record
Pteropodidae		
Cynopterus brachyotis	LC	Matveev (1999)
Cynopterus sphinx	LC	Kock ((2000))
Eonycteris spelaea	LC	Kock (2000)
Macroglossus sobrinus	LC	Kock (2000)
Megaerops niphanae	LC	Klein (1971)
Pteropus hypomelanus	LC	Kock (2000)
Pteropus lylei	LC	Dobson (1880)
Rousettus amplexicaudatus	LC	Kock (2000)
Rousettus leschenaultii	LC	Kock (2000)
Emballonuridae		
Taphozous longimanus	LC	Kock (2000)
Taphozous melanopogon	LC	Kock (2000)
Taphozous theobaldi	LC	Matveev (2005)
Megadermatidae		
Megaderma lyra	LC	Kock (2000)
Megaderma spasma	LC	Kock (2000)
Rhinolophidae		
Rhinolophus acuminatus	LC	Kock (2000)
Rhinolophus affinis	LC	This paper
*Rhinolophus chaseni**	LC	Hill & Thonglongya (1972)
Rhinolophus luctus	LC	Hendrichsen *et al*. (2001)
Rhinolophus malayanus	LC	Kock (2000)
Rhinolophus microglobosus	LC	Soisook *et al*. (2008)
Rhinolophus pusillus	LC	Matveev (2005)
Rhinolophus shameli	LC	Kock (2000)
Molossidae		
Chaerephon plicata	LC	Yoshiyuki (1966)
Otomops wroughtoni	DD	Walston & Bates (2001)
Hipposideridae		
Hipposideros armiger	LC	Kock (2000)
Hipposideros cineraceus	LC	Matveev (2005)
Hipposideros galeritus	LC	Matveev (2005)
Hipposideros larvatus	LC	Klein (1969)
Hipposideros pomona	LC	Kock (2000)
Vespertilionidae		
Arielulus circumdatus	LC	Hendrichsen *et al*. (2001)
Harpiocephalus harpia	LC	Matveev (2005)
Hesperoptenus blanfordi	LC	Hendrichsen *et al*. (2001)
Hesperoptenus tickelli	LC	Hendrichsen *et al*. (2001)
Kerivoula hardwickii	LC	Kock (2000)
Kerivoula kachinensis	LC	Soisook *et al*. (2007)
Kerivoula papillosa	LC	Kock (2000)
Kerivoula titania	LC	Bates *et al*. (2007)
Murina harrisoni	DD	Csorba & Bates (2005)
Myotis annectans	LC	Hendrichsen *et al*. (2001)
Myotis hasseltii	LC	Kock (2000)
Myotis muricola	LC	Matveev (1999)
Myotis rosseti	LC	Oey (1951)
Pipistrellus coromandra	LC	Hendrichsen *et al*. (2001)
Pipistrellus tenuis	LC	Kock (2000)
Scotophilus heathii	LC	Hendrichsen *et al*. (2001)
Scotophilus kuhlii	LC	Kock (2000)
Tylonycteris pachypus	LC	Hendrichsen *et al*. (2001)
Tylonycteris robustula	LC	Hendrichsen *et al*. (2001)
Miniopteridae		
Miniopterus schreibersii	NT	Matveev (2005)
Miniopterus sp.	n/a	Matveev (2005)

* As *R. borneensis*.

traps (Francis, 1989) and mist nets. Voucher specimens were preserved in 70% ethanol.

In Cambodia and Thailand, time-expanded (x10) echolocation calls were recorded from hand-held bats using D 240x utrasound detectors (Pettersson Elektronik, Sweden), stored using digital recorders and analysed with Batsound software (version 3.31, Pettersson Elektronik, Sweden). In Vietnam, real time recordings of calls were collected from hand-held bats with custom-made equipment (PC Tape, University of Tübingen, Germany) at a sampling rate of 480 kHz. For every bat, the selected sound sequence was analysed and displayed using Selena software (University of Tübingen, Germany). Acoustic data reported in this paper refer to the frequency of maximum energy (FMAXE). In Cam-

bodia and Thailand, FMAXE was extracted from spectograms using 1024 samples Fast Fourier Transform (FFT) with a Hanning window. The Constant Frequency (CF) portions of at least five calls from each individual were analysed.

Morphological measurements were taken with a digital calliper. They included: FA: forearm length from the extremity of the elbow to the extremity of the carpus with the wings folded; TAIL: tail length from the tip of the tail to its base adjacent to the anus; TIBIA: tibia length from the knee joint to the extremity of the heel behind the os calcis; FOOT: foot length from the extremity of the heel behind the os calcis to the extremity of the longest digit, not including the hairs or claws; EAR: ear length from the lower border of the external auditory meatus to the tip of the pinna; 3MT, 4MT, 5MT: third, fourth and fifth metacarpal lengths, respectively, from the extremity of the carpus to the distal extremity of the third, fourth and fifth metacarpals, respectively; 3D1P, 3D2P: lengths of the first and second phalanges, respectively, of the third digit; 3D1P/33D2P: length of the second phalanx of the third digit divided by the length of the first phalanx, relative to its metacarpal; SL: skull length from the projecting posterior part of the skull to the anterior alveolus of the canine; CCL: condylo-canine length from the exoccipital condyle to the anterior alveolus of the canine; ZB: zygomatic breadth – the greatest width of the skull across the zygomata; MW: mastoid width – the greatest distance across the mastoid region; PC: postorbital constriction – the narrowest width across the constriction posterior to the orbits; C-M^3: upper toothrow length from the front of the upper canine to the back of the crown of the third upper molar; M^3-M^3: posterior palatal width taken across the outer borders of the third upper molar; C^1-C^1: anterior palatal width taken across the outer borders of the upper canine; PL: length of the bony palate; PL/C-M^3x 100: palatal length divided by upper toothrow length multiplied by 100; C-M_3: lower toothrow length– from the front of the lower canine to the back of the crown of the third lower molar; ML: mandible length from the most posterior part of the condyle to the most anterior part of the mandible, including the lower incisors.

Results

Systematics

Rhinolophus affinis

Intermediate horseshoe bat

Rhinolophus affinis Horsfield, 1823 [1821-1824]: (6), pl.; figs a,b; Java; (lectotype [BMNH 79.11.21.70] designated by Csorba *et al*., 2002, deposited in the Natural History Museum, London).

Rhinolophus a. macrurus Andersen, 1905: 103; Taho, 'Karennee', SE Myanmar.

Rhinolophus a. superans Andersen, 1905: 104; Pahang, Malaysia.

Diagnostic characters: *Rhinolophus affinis* is a medium-sized horseshoe bat (FA= 45.1-51.3 mm, Table 2; all observations and measurements based on material from Cambodia). The ears are not greatly enlarged. In the noseleaf, the lancet is straight-sided with a pointed tip; the connecting process, in lateral view, is rounded and typical of the *megaphyllus* group (*sensu* Csorba *et al*., 2003); and the sella is slightly concave (Fig. 2). In the wing, the second phalanx of the third digit is long, usually more than x1.7 the length of the first phalanx. The fifth metacarpal is longer than the third and fourth. The tibia, on average, slightly exceeds the length of the tail. Pelage colour is variable, ranging from mid- to orange-brown; the belly is slightly paler than the back. In the single baculum we examined from Cambodia, the shaft was thin and curved ventrally, the base had a deep notch and was expanded, and the total length was 2.3 mm (Fig. 3). This is slightly longer than for three specimens from India included in Thomas (1997) which averaged 1.8 mm in length, with a range of 1.5 to 2.1 mm.

The skull is robust (SL= 21.5-23.7 mm, Table 2); the zygomata exceed the mastoids in width. In the rostrum, the anterior median compartments are not greatly inflated and are only slightly superior to the posterior ones when viewed in lateral profile (Fig. 4). The sagittal crest is variably developed. The frontal depression is bordered by well-defined ridges. The bony palate is short, averaging about one quarter of the upper toothrow length (PL/C-M^3x100 = 22.4-26.3). In the dentition, the upper canine is usually well developed. In contrast, the first upper premolar (P^2) is minute, situated in the toothrow or slightly displaced internally. The canine and the second (large) premolar (P^4) are not in contact. In the

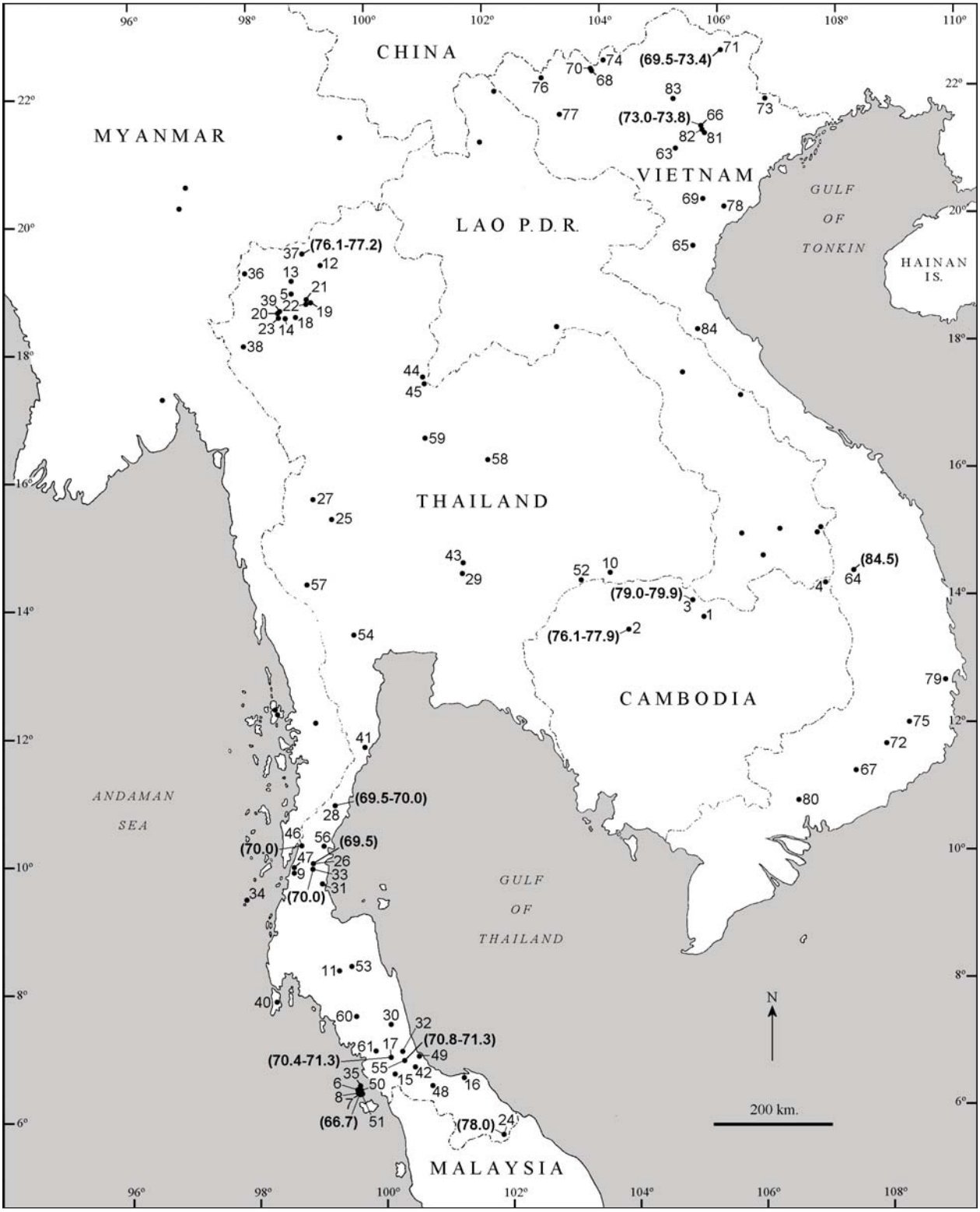

Fig. 1 Distribution of *Rhinolophus affinis* in mainland Southeast Asia, excluding Malaysia. Localities for Cambodia, Thailand, and Vietnam are based on data in Appendix 1; for Myanmar and Laos are based on references listed in 'Conservation status and distribution'. Figures in bold (in parentheses) are FMAXE readings in kHz for specimen(s) from the particular locality

Table 2 External, cranial, and dental measurements (in mm) and echolocation frequency (in kHz) of *Rhinolophus affinis* from Cambodia, for the definitions see the Methods section. Measurements are presented as mean, standard deviation, minimum-maximum, and number of specimens. Sample sizes are in parentheses when different to *n*.

External measurements													
n	sex	FMAXE	FA	TAIL	TIBIA	FOOT	EAR	3MT	4MT	5MT	3D1P	3D2P	3D2P/ 3D1P
11	♂	77.2, 1.0	48.0, 1.5	22.7, 1.1	22.9, 0.5	9.4, 0.6	18.4, 1.3	37.0, 0.9	37.8, 1.0	38.8, 1.2	13.8, 0.8	24.7, 0.9	1.79, 0.10
		76.1-79.0 (7)	45.1-50.0	20.2-24.1	22.1-23.9	8.5-10.7	16.7-20.9	35.9-39.0	36.3-40.0	37.0-41.0	12.5-15.1	23.0-26.1	1.68-2.00
3	♀	79.9	48.2, 2.8	21.6, 3.1	22.6, 2.5	9.2, 1.1	19.9, 2.9	37.3, 0.8	38.3, 1.3	38.9, 2.5	14.5, 0.6	25.2, 2.2	1.74, 0.09
		(1)	46.1-51.3	18.8-25.0	21.8-23.8	8.0-10.0	17.0-22.8	36.5-38.0	37.0-39.7	37.3-41.8	13.9-15.2	22.7-26.9	1.63-1.80
Cranial and dental measurements													
n	sex	SL	CCL	ZB	MW	PC	C-M^3	M^3-M^3	C^1-C^1	PL	PL/C-M^3x100	C-M_3	ML
11	♂	22.9, 0.7	19.4, 0.5	11.1, 0.3	10.4, 0.2	2.2, 0.1	9.0, 0.1	8.5, 0.3	6.0, 0.3	2.2, 0.1	24.3, 1.5	9.5, 0.3	15.8, 0.3
		21.8-23.7	18.4-20.0	10.8-11.6 (10)	10.2-10.8 (10)	2.0-2.5	8.7-9.2	8.2-8.9	5.5-6.4	2.0-2.5	22.4-26.3	8.9-9.9	15.2-16.1
3	♀	22.0, 0.5	19.2, 0.3	10.7, 0.0	10.2, 0.3	9.5, 0.4	8.8, 0.2	8.4, 0.3	5.9, 0.3	2.2, 0.1	24.8, 1.2	9.2, 0.3	15.3, 0.5
		21.5-22.5	18.9-19.6	10.7-10.8	10.0-10.5	9.1-9.8	8.6-9.0	8.1-8.7	5.6-6.1	2.1-2.3	23.8-26.2	9.0-9.5	14.8-15.9

lower toothrow, the second premolar (P_3) is minute; in all the material examined from Cambodia, it is extruded or partially displaced externally.

Echolocation

Every call of *Rhinolophus affinis* comprises an initial upward Frequency Modulated (FM) component, followed by a CF component, and ending with a downwards FM component. In Cambodia, FMAXE ranged from 76.1 to 79.9 kHz (Table 2). This is essentially similar to calls of *R. affinis* from northern Thailand and Laos (70.0 to 76.1 kHz) (Fig. 1) (Francis, 2008). It is in contrast to individuals from Peninsular Thailand to the north of 7°00′N which have a lower frequency, ranging from 66.7 to 71.3 kHz. However, one record from Hala-Bala Wildlife Sanctuary, Narathiwat, to the south of this latitude, is 78.0 kHz, which is comparable to those obtained in Peninsular Malaysia (77.0 to 78.0 kHz) (Francis, 2008). In Vietnam, FMAXE ranged between 69.5 and 73.8 kHz for *R. affinis* collected in the north of the country (Furey *et al*., 2009; Thong, 2011). One further individual provisionally assigned to this species from central Vietnam had a higher frequency of 84.5 kHz (Thong, 2011).

Taxonomic variation

Based on current understanding, specimens from Thailand north of the peninsula, Cambodia and Vietnam are provisionally referred to *R. a. macrurus* Andersen, 1905, which was described from eastern Myanmar. Those from Peninsular Thailand, on account of their average larger size, are referable to *R. a. superans* Andersen, 1905, which was described from Pahang in Malaysia.

Ecology

In Cambodia, *R. affinis* was collected in February, 2011 in dry dipterocarp and semi-evergreen forest at an elevation of 110 metres in Preah Vihear Protected Forest. It was also found in forest areas in Phnom Kulen National Park in April, June, July and November at elevations ranging from 80 to 177 metres. Of the four specimens collected from Virachey National Park in June, two were

Fig. 2 *Rhinolophus affinis.* PSUZC-MM2006.117, ♂, Khao Kram, Pathiew, Chumphon Province, Thailand (not to scale). (© Pipat Soisook).

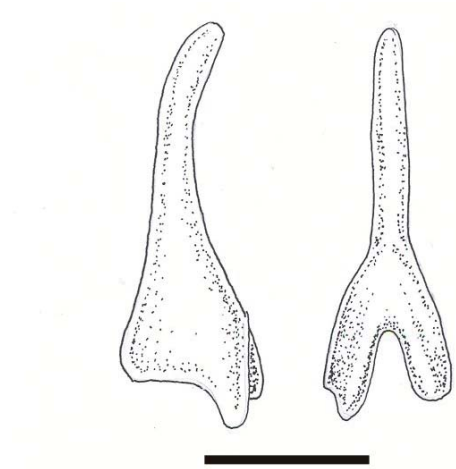

Fig. 3 Baculum of *Rhinolophus affinis.* HZM.76.39872, ♂, Virachey National Park, Cambodia. Scale = 1 mm

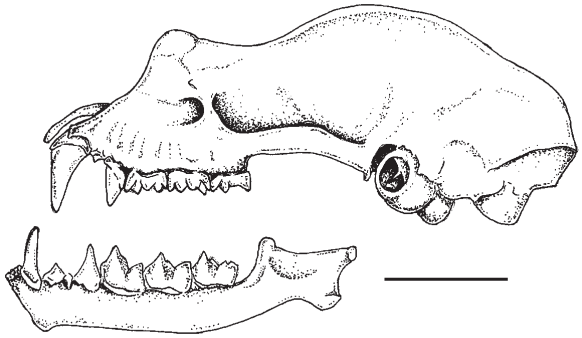

Fig. 4 Lateral view of the skull of *Rhinolophus affinis*. HZM.77.39873, ♀, Virachey National Park, Cambodia. Scale = 5 mm.

subadults, based on the unfused epiphyses of their wing bones. In Thailand, *R. affinis* is an adaptable species that has been found in the following forest types: deciduous, bamboo, dry evergreen, mixed deciduous, hill evergreen and dipterocarp. It is also frequently found in agricultural areas, including orchards and rubber plantations, and is often observed roosting in limestone caves. In Vietnam, *R. affinis* is found almost throughout the country, including mountainous areas. It frequently roosts in limestone caves and inhabits tunnels, and has been recorded foraging within various vegetation types ranging from degraded to primary forests. The species is commonly found in medium-sized colonies of up to approximately 400 individuals (Vu Dinh Thong, pers. obs.). In a detailed study in Kim Hy Nature Reserve, northern Vietnam, it was most

commonly found in disturbed forest, which according to Furey *et al*. (2010), it frequents more often than primary forest, agricultural land or degraded forest.

Distribution and conservation status

Rhinolophus affinis is currently known from India (including the Andaman Islands), Nepal to southern China, mainland Southeast Asia, Borneo and the Lesser Sunda Islands (Simmons, 2005). Its distribution in Cambodia (Fig. 1) is based on the new material listed in Appendix 1. Localities in Thailand and Vietnam are based on new material and literature records (Appendix 1), localities in Myanmar are from Bates *et al*. (2004) and the collections of the Harrison Institute, UK, and those in Laos are from Francis *et al*. (1996); Francis *et al*. (1997); Francis & Khoonmy (1998); Francis *et al*. (1999), Ruedi & Kirsch (2005) and the collections of Muséum National d'Histoire Naturelle, Paris, France.

This species is currently listed by IUCN as Least Concern (Walston *et al*., 2008), although Francis *et al*., (1999) suggested this species could be potentially at risk in Laos because of human hunting pressure.

Discussion

Rhinolophus affinis is currently considered to be a common and widespread species, albeit one that exhibits considerable variation in size. The taxonomic significance of this intraspecific variation is not clearly understood (Andersen, 1907; Bergmans & van Bree, 1986; Csorba *et al*., 2003). The echolocation data presented in this study also show considerable intraspecific variation and, again, the significance of this is not clear.

Perhaps, as Soisook *et al*. (2008) observed in their study of *R. stheno*, this variation is indicative of the presence of cryptic species. However, as Soisook *et al*. (2008) also observed for *R. malayanus* and Thabah *et al*. (2006) for the intermediate leaf-nosed bat *Hipposideros larvatus*, acoustic differences are not always good indicators of speciation or evolutionary history. It is clear that further research evaluating geographical variation in echolocation, morphometrics and genetics within *R. affinis* in mainland Southeast Asia would be of considerable interest, especially in the light of recent studies by Francis *et al*. (2010) which show that widespread taxa display considerable geographic variation in their DNA barcode sequences.

In terms of bat species diversity, data from Thailand and Vietnam suggest that there is still considerable scope for discovering new country records and possibly undescribed taxa in Cambodia. In particular, detailed surveys in the Southern Annamite montane rainforests of Northeast Cambodia, the Central Indochina dry forests of north-western Cambodia and the Cardamom Mountains rainforests of south-western Cambodia would be of interest.

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Appendix 1

Numbers in [ ] refer to localities on Fig. 1. Collection codes: HZM = Harrison Institute; CSO, CBC = Zoological Museum, Royal University of Phnom Penh; PSU, MM = Zoological Collections, Prince of Songkla University.

Material: Cambodia: Preah Vihear Province: M'Lou Prey (13°48'N 105°17E) [1]; 2♂, 1♀ (HZM.25. 34147; HZM26.34175; HZM.27.34176); Preah Vihear Protected Forest (14°04'N 105°17'E) [3]; 1♂, 1♀ (CSOCA220; CBC01233); Ratanakiri Province: Virachey National Park (14°21'N 107°22'E) [4]; 1♂, 3♀ (HZM.75.39871; HZM.76.39872; HZM.77.39873; HZM.78.39874); Siem Reap Province: Phnom Kbal Spean, Banteay Srei District, Phnom Kulen National Park (13°40'N 104°01'E) [2]; 7♂ (CBC00587; CBC00927; CBC00942; CBC00943; CBC00947-949).

Material: Thailand: Chiang Mai Province: Mae Ja cave, Chiang Dao Wildlife Sanctuary, Chiang Dao District (19°31'55" N 98°50'26"E; 864 m a.s.l) [37]; 3♂, 3♀ (PSUZC-MM2005.105; 111; 119; 120; 121; 122); Tak Province: Kavackee, East Thung Yai Naresuan Wildlife Sanctuary (15°42'26''N 98°59'28''E) [27]; 1♂ (PSUZC-MM2005.85); Loei Province: Phu Suan Sai National Park, Na Haeo District (17°30'19"N 100°56'18"E, 620 m, 975 m a.s.l) [44, 45]; 3♂ (PSUZC-MM2006.108-110); Thung Sa Lang Luang National Park, Nhong Mae Na (16.34'17''N 100.52'35''E) [59]; 1♀ (PSU-M05.107); Chaiyapum Province: Thung Kamang, Phukieo Wildlife Sanctuary, Khon San District (16°18'N 101°52'E) [58]; 1♀ (PSUZC-MM2005.86); Surin Province: Ta Muen Thom, Huai Thap Than-Huay Sumran Wildlife Sanctuary (14°21'08''N 103°15'54''E) [52]; 1♂(PSU-M05.82); Chumphon Province: Khao Kram cave, Patiew District (10°55'08"N 99°22'26"E, 67 m a.s.l) [28]; 3♂, 3♀ (PSUZC-MM2006.113-118); Huay Wang Cave, T. Khao Talu, Sawi District (10°10'00''N 98°55'11''E) [26]; 1♂ (PSU-SB070110.4); Klao Plu Cave, Lamae District (09°43'36''N 99°06'30''E) [31]; 1♂ 1♀ (PSU-SB070109.4); Pra Kayang Cave, T. Lum Lieng, A. Kraburi (10°19'34''N 98°45'55''E) [46]; 1♀ (PSU-SB070113.6); Ranong Province: Knad Dai Cave, A. La-Aun (10°01'55''N 98°55'11''E) [33]; 1♀ (PSU-SB070112.13); Satun Province: Wang Saithong waterfall, Manang District (07°05'25"N 99°54'35"E) [61]; 1♀ (PSUZC-MM2006.84); Boripatr Waterfall, Ton Nga-chang Wildlife Sanctuary (07°00'03''N 100°08'32''E) [17]; 4♂, 2♀ (PSU-M05.100-104; PSU-M05.106); Songkhla Province: Tham Khao Tieb cave, Ratthaphum District (06°59'59"N 100°17'52"E, 18 m a.s.l) [55]; 3♂, 3♀ (PSUZC-MM2006.94-99); Klao Rak Kiet, Rattaphum District (07°04'16''N 100°15'59''E) [32]; 1♂ (PSU-SB061216.18); Narathiwat Province: Hala-Bala Wildlife Sanctuary (05°47'54''N 101°49'30''E) [24]; 2♂, 1♀ (PSU-CP1, CP2, CP4); Tarutao Islands: Ao Son-Ao Chak Road (06°39'38''N 99°38'2''E) [6, 7]; 3♂, 1♀ (PSU-M07.128; PSU-M07.129; PSU-M05.83; PSU-M05.91); Ou Rang Road, Tarow (06°36'16''N 99.40'31''E) [51]; 1♀ (PSU-M07.130); Ao Son Road, Tarutao NP (06°39'32"N 99°37'58"E) [8]; 1♂ (PSU-M07.12).

Literature records for Thailand: Chiang Rai Province: Doi Chang Kieng [19] (Sawada & Harada, 1985); Chiangmai Province: Mount Angka (Doi Intanon) [39] (Allen & Coolidge, 1940); Doi Chang Khien, Muang District [19]; Doi Pui, Muang District [21]; Doi Suthep, Muang District [22]; Doi Inthanon, Chom Tong District [20]; Ban Sop Hat, Chom Thong District [14]; Dong Tak Ten, Chom Tong District [23]; Ban Prong Yang Nok, Huai Nam-Un, Mae Taeng District [13]; Ban Pa Hin, Phrao District [12] (Yenbutra & Felton, 1986); Amphoe Mae Rim [5] (Sawada & Harada, 1985); Chom Thong (BMNH) [18]; Mae Hong Son Province: Mae Hong Son [36]; Mae Sariang [38] (Lekagul & McNeely, 1977); Phetchabun Province: Thung Salang Luang, Lom Kao District [59] (Yenbutra & Felton, 1986); Nakhon Ratchasima Province: Khao Yai National Park, Pak Chong District [29]; Pak Chong Station, Pak Chong District [43] (Yenbutra & Felton, 1986); Surin Province: Ban Dan, Ban Huai Sing, Kap Choeng District [10] (Yenbutra & Felton, 1986); Kanchanaburi Province: Tham Wang Phra, Sai Yok District [57] (Yenbutra & Felton, 1986); Huai Kha Khang [25] (Hood *et al*., 1988); Ratchaburi Province: Tham Khao Bin, Chom Bung District [54] (Yenbutra & Felton, 1986); Prachap Khiri Khan Province: Muang District [41] (Yenbutra & Felton, 1986); Chumphon District: Tham Khuan Muang, Na Pho, Sawi District [56] (Yenbutra & Felton, 1986); Ranong Province: Ban Bang Non, Muang District [9] (Yenbutra & Felton, 1986); Surat Thani Province: Pak Chalue, Ban Ao Ko, Tha Chang District (Yenbutra & Felton, 1986); Ranong (BMNH) [47]; Phang Nga Province: Koh Surin Nua [34] (Yenbutra & Felton, 1986); Phuket Province: Muang District [40] (Yenbutra & Felton, 1986); Nakhon Si Thammarat Province: Tham Jom, Chawang District [53]; Ban Khuan Chang, Thung Yai District [11] (Yenbutra & Felton, 1986); Trang Province: Trang [60] (Miller, 1898; Andersen, 1905); Phatthalung Province: Khuan Kut, Muang District [30] (Yenbutra & Felton, 1986); Satun Province: Ban Wang Bla Chan, Muang District [15]; Koh Tarutao [35] (Yenbutra & Felton, 1986); Songkhla Province: Nam Tok Ton Nga Chang, Hat Yai District [42]; Saba Yoi District [48] (Yenbutra & Felton, 1986); Songkhla [49] (Sawada & Harada, 1985); Pattani Province: Biserat, Jalor [16] (Bonhote, 1903).

Material: Vietnam: Bac Kan Province: Kim Hy Nature Reserve [71]; 2♂, 3♀ Vinh Phuc Province: Road to Rung Rinh Mountain Peak, Tam Dao National Park [66]; 8♂, 1♀ Tam Dao Town, Tam Dao National Park [82]; 1♂, 1 unsexed Kon Tum Province: Bar Gok Ranger Station Raea, Chu Mom Ray National Park [64].

Literature records for Vietnam: Lai Chau Province: Muong Boum [76]; Lao Cai Province: Chapa [68]; Houang Lien Nature Reserve [70]; Lao Cai [74]; Dien Bien Province: Muong Boum [76]; Tuyen Quang Province: Tuyen Quang [83]; Lang Son Province: Lang Son [73]; Vinh Phuc Province: Tam Dao [81]; Ha Tay Province: Ba Vi National Park [63]; Ninh Binh Province: Cuc Phuong [69]; Ninh Binh [78]; Thanh Hoa Province: Ben En National Park [65] (Csorba *et al*, 2003); Ha Tinh Province: Vu Quang National Park [84] (Borissenko & Kruskop, 2003); Bak Kan Province: Quang Chu [79]; Lam Dong Province: Mt. Lang Bian, Da Lat Plateau [75]; Lam Dong [72]; Caryu Danar [67]; Ho Chi Minh Province: Saigon [80] (Csorba *et al*., 2003).

Recent Master's Theses

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

A taxonomic review of Cambodian amphibians in the genus *Rana* (*Hylarana*), with comparisons between similar species

Khom Sokkhea

With over 60 species in five families currently known, the order Anura (frogs and toads) is a major group compared to other amphibian orders in Cambodia. These 60 species include 10 within the *Rana* genus, which can be viewed as including two subgenera (*Rana* and *Hylarana*) according to DNA evidence. Within these two subgenera, eight species are included in *Hylarana* (*H. attigua, H. erythraea, H. faber, H. macrodactyla, H. milleti, H. mortenseni, H. nigrovittata* and *H. taipehensis*) and two in *Rana* (*R. johnsi* and *R. lateralis*).

As studies of Cambodian amphibians are limited, my study aimed to develop an identification key for these ten species using external morphology and to compile information on their distribution and habitat preferences. In doing so, I aimed to (i) identify external features which can be used to identify each species; (ii) clarify their distribution and habitat preferences in Cambodia; and, (iii) present this information through an identification key and detailed species accounts for all ten species. Molecular and acoustic data were not included in the study.

Although limited by relatively small sample sizes, my results suggest that these ten species are rather similar and difficult to identify by external morphology alone, with *H. mortenseni* and *H. nigrovittata* being especially problematic. Some biometric measurements such as the depth of the head and distance from the eye to the tympanum do differ between these two species however, being typically greater in *H. mortenseni* compared to *H. nigrovittata*, although the same measurements for females of another similar species, *H. faber*, exceed those of *H. mortenseni*.

Of the ten species in my study, I suggest that one be considered as data-deficient: *H. faber*, which is endemic to Cambodia and appears to have a localized distribution. To promote taxonomic understanding of Cambodian representatives of the *Rana* (*Hylarana*) genus, I also recommend further sampling to improve collections of *H. faber* and several other species including *H. attigua, R. lateralis, H. macrodactyla, R. johnsi, H. milleti* and *H. erythraea.*

Food preferences of the Vulnerable smooth-coated otter *Lutrogale perspicillata*, inferred by analysis of spraint from wild and captive animals

Lim Sotheary

The food preferences of the Vulnerable smooth-coated otter *Lutrogale perspicillata* were studied from October to November 2010 at the Phnom Tamao Zoo and Wildlife Rescue Centre. The aim of my study was to determine (i) the feeding preferences of captive otters in terms of crabs, fish, frogs and snakes; (ii) the relationship between proportions of food consumed and those remaining in their spraint (faeces); and (iii) to estimate the relative proportion of food types consumed by wild otters through application of the previous relationship in analysis of their spraint.

Following feeding choice experiments, three methods were used to estimate the proportions of different prey consumed by captive otters: weight and ratio, frequency of occurrence and score bull-estimate. In spraint analysis, weight and ratio data were used to determine the relationship between food proportions consumed by the captive otters and those remaining in their spraint. This was then used to calculate food proportions consumed by wild otters following collection and analysis of their spraint.

My results suggest that fish is the preferred food of captive otters, followed by snakes, frogs and crab. Of the four fish species made available in the choice experi-

ments, two appeared to be preferred most: chhpin *Hypsibarbus wetmorei* and andenh *Clarias gariepinus*. There appeared to be no difference between the food preferences of captive male and female otters. In my analysis of spraint from wild otters, fish were also found to be the major diet item, followed by snakes, frogs and lastly a small amount of crab.

In addition to indicating that fish is the preferred food of both captive-bred and wild otters, my choice experiments also suggest that food consumption may not be related to its accessibility. However, as data from my study was collected over a short period, it remains unclear whether food consumption may vary in different seasons. Notwithstanding this, my results suggest that estimating the relationship between food consumed and that remaining in spraint is a useful method to determine the diet of otter species in the wild.

A systematic review of selected Cambodian dipterocarps (*Dipterocarpus*, *Hopea* and *Shorea*), with an identification key and notes on their conservation status

Peou Youleang

The Dipterocarpaceae comprises the main timber trees in the tropical rain forests of Southeast Asia. All dipterocarp species are large trees with alternative entire leaves and pentamerous flowers. Due to their economic importance, they account for the largest volume of timber harvested in the region. The aims of my study were to i) undertake a systematic review of Cambodian dipterocarp species; ii) develop a key for their identification; and, iii) compile information on their conservation status.

Over the course of two field trips in Northwest and Northeast Cambodia, three to four specimens were collected of each species encountered, including branches, leaves, inflorescences, flowers and fruit. All specimens collected were examined using a stereomicroscope to confirm their identity. Specimens of dipterocarp species collected by botanists in the early 19th Century and later deposited at the Royal University of Phnom Penh herbarium were similarly reviewed.

My results indicate that specimens collected from field work comprise 12 species (and two varieties), including one new to science: *Hopea* sp. nov, and one new country record: *Shorea henryana* Pierre. Review of herbarium material revealed four species, and seven species (and one variety) mentioned by Smitinand *et al.*, (1990) were also included in my study. Taken together, my work reviews a total of 23 species (and three varieties) in the *Dipterocarpus, Hopea* and *Shorea* genera, and provides keys for their identification and notes on their conservation status.

The limited number of species in my study is likely due to the fact that sampling was completed in a short period and because limited sampling effort has been undertaken in southeast and southwest Cambodia. Many forest areas in Cambodia have yet to be properly surveyed by botanists. Such work needs to be undertaken to determine the Dipterocarpaceae species that may occur in these and other parts of the country.

The utility of bat (ultrasound) detectors in identifying bat species: a case study from Phnom Kulen National Park, Cambodia

Phauk Sophany

Echolocating bats are a highly successful group that use a biological sonar system to orient and forage in three dimensional space. As existing capture techniques such as harp traps and mist nets are less effective at capturing bats that habitually fly in open areas and above the forest canopy, acoustic sampling with bat detectors may provide an effective method for inventorying and monitoring bat populations. The aim of my study was to assess the utility of this technique for bat research in Cambodia by (i) providing the first description of time-expanded echolocation calls from Cambodian bat populations; and, (ii) determining the extent to which species recorded can be identified by their echolocation calls.

Between April and July 2010, echolocation calls were recorded from a total of 17 bat species belonging to the Megadermatidae (two species), Rhinolophidae (five), Hipposideridae (five) and Vespertilionidae (five) at Phnom Kulen National Park. Descriptions of the echolocation calls produced by each species were developed based upon a series of measurements, including three in the frequency domain (start, end and peak frequency), two in the time domain (call duration and inter-pulse

interval) and two derived measurements (duty cycle and pulse repetition rate). The presence and number of call harmonics was also noted, as was position of the harmonic containing the greatest energy.

As acoustic identification of bat species is best approached using quantitative analysis, I undertook a discriminant function analysis of 444 echolocation calls produced by the 17 species using cross validation. This indicated that acoustic identification is feasible using the above measurements by correctly classifying 82.8% of these calls to the true species. In addition, multivariate analysis (MANOVA) indicated that the discriminant analysis models were significant for bats that emit calls with a constant frequency component (hipposiderid and rhinolophid species, p <0.001) and other bats (megadermatid and vespertilionid species, p <0.001). As a consequence, I recommend the inclusion of acoustic sampling methods in future inventories and monitoring of bat assemblages in Cambodia and Southeast Asia.

Over the course of the study, a total of 642 bats representing 20 species in six families were captured, including three bat species which appear to be new records for Cambodia. Hipposideridae accounted for most captures (37.23%), followed by Rhinolophidae (36.76%), Pteropodidae (21.81%), Vespertilionidae (2.65%), Megadermatidae (1.4%) and lastly Miniopteridae (0.16%). Species richness levels were similar between forest types with 18 species recorded in each, although Simpson's Index values for species diversity were higher for good quality forest. Capture rates in mist nets were also similar between forest types, although overall numbers of bats captured were much greater in good quality forest compared to highly disturbed forest (449 vs 193 bats respectively) due to marked differences in harp trap capture rates.

In summary, my results suggest that highly disturbed forests may support similar numbers of species to less disturbed forest areas, but at somewhat lower abundances. Further work is needed to confirm this finding, however, and will likely reveal the existence of additional bat species in Phnom Kulen National Park.

The effects of forest disturbance on the species richness and abundance of bat assemblages at Phnom Kulen National Park, Cambodia

Phen Sarith

Bats form a major component of mammal diversity in Southeast Asia (ca. 30%), but are believed to be threatened by forest degradation and loss in this region. The overall aim of my study was to determine the influence of forest condition on bat assemblages at Phnom Kulen National Park, Siem Reap Province, Cambodia.

Live trapping of bat assemblages was undertaken in the Kbal Spean area of the national park over a four-month period from April to July 2010. During this period, bats were captured using mist nets and harp traps in two forest types broadly identified as good quality forest and highly disturbed forest. To ensure valid comparisons could be made, sampling methods and effort were standardised in each forest type and sampling was undertaken from 1800h to 2100h each night. Sixteen nights of sampling were completed in each forest type, giving 32 sampling nights in total, equalling 2,880 m^2mnh (mist-net-hours) and 230.4 m^2hth (harp-trap-hours).

Papilionidae butterflies in Cambodia: does maternal host plant choice influence larval food preferences and survivorship?

Sett Sophak

Butterfly farming has been established in many tropical countries as an alternative livelihood source, with one initiative recently established in Cambodia: the Banteay Srey Butterfly Centre in Siem Reap Province. Female oviposition plays an important role in determining the host plant of larvae. Identifying preferred host plants can help increase the survivorship of larvae which can result in improved yields for butterfly farmers. Such information can also help avoid larval damage to plantations through the provision of preferred host plants in such areas.

My study focussed on the lime butterfly *Papilio demoleus* and aimed to determine (i) the oviposition preferences of *P. demoleus* among three known host plants: *Citrus* spp., *Feroniella lucida* and *Micromelum minutum*; (ii) the food preferences of *P. demoleus* larvae between these three host plants; and to assess (iii) the influence of maternal host plant choice on larval growth rates and survivorship. To achieve these aims, I carried a series of

experiments at the Angkor Centre for Conservation of Biodiversity at Phnom Kulen National Park from May to July, 2010.

My results suggest that adult female *P. demoleus* tend to lay their eggs on *F. lucida* rather than *M. minutum* and *Citrus* spp., although the differences were not statistically significant. Larvae of *P. demoleus* also consumed greater amounts of *F. lucida*, although again the differences were not statistically significant. Host plant choice was shown to have a statistically significant effect on the growth rate and survivorship of larvae however, as larvae feeding on *F. lucida* exhibited higher weight gains, shorter pupation periods and faster development.

Despite the lack of statistical support, my results suggest that *F. lucida* is the preferred oviposition plant for *P. demoleus*, this leading to improved larval survivorship and growth rates. For pest control, it might therefore prove useful to intercrop *F. lucida* in *Citrus* plantations to provide feeding alternatives for *P. demoleus* larvae. Butterfly farmers should use a mixture of *Citrus* spp., *F. lucida* and *M. minutum* or at least one of these as food plants for *P. demoleus* larvae. Further studies could focus on the effectiveness of intercropping *F. lucida* in Citrus plantations for pest control and undertake similar experiments with other commercial butterfly species.

Recent literature from Cambodia

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

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

If you or your organisation have recently published a technical paper or report that you wish 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

Csorba, G. (2011) A new species of *Glischropus* from the Indochinese Subregion (Mammalia: Chiroptera: Vespertilionidae). *Zootaxa,* **2925,** 41-48.

A new species of bat is described from Cambodia: the Indochinese thick-thumbed bat *Glischropus bucephalus* sp. nov. The author suggests that all specimens of *G. tylopus* previously collected in the Indochinese zoogeographical subregion belong to the new species (while, on mainland Southeast Asia, *G. tylopus* is restricted to areas south of the Isthmus of Kra). Author: csorba@nhmus.hu

Furey, N.M., Ith S., Bates, P.J.J. & Csorba, G. (2011) Cambodian bat research: past and present. *Paper presented to the Second International Southeast Asian Bat Conference, 6-9 June 2011, Bogor, Indonesia.*

Only 49 bat species have been confirmed in Cambodia; far fewer than in neighbouring countries. Since 2005, the authors and their associates have published two species new to science (*Murina harrisoni* and *Kerivoula titania*) and one new country record (*K. kachinensis*). A further 16 new records await publication (one of which has now been described by Csorba, 2011, above), to bring Cambodia's bat list to 65 species. This paper also describes recent progress to build capacity to study and conserve the bats of Cambodia. Author: n.furey.ffi@gmail.com

Gorochov, A.V. (2011) Contribution to the fauna and systematics of the Stenopelmatoidea (Orthoptera) of Indochina and some other territories: IX. *Entomological Review,* **91,** 71-89.

This paper includes the description of a new cricket, *Stonychophora khmerica* sp. nov., which may be endemic to Bokor National Park. Online: http://www.springerlink.com/content/yn42214588397647/fulltext.pdf

Handschuh, M., van Zalinge, R.N., Olsson, U., Phok S., Hong C. & Evans, T.D. (2011) First confirmed record and first breeding record of Indian spotted eagle *Aquila hastata* in Indochina. *Bulletin of the British Ornithologists' Club,* **131,** 118-122.

Genetic tests prove that a juvenile bird discovered in Kampong Thom Province in 2008 was an Indian spotted eagle *Aquila hastata*. This is the first confirmed record of this globally Vulnerable species in Indochina. In the field, this species could be easily confused with the greater spotted eagle *A. clanga*, which also occurs in Cambodia. Author: markus.handschuh@accb-cambodia.org

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

New data are presented on the taxonomy, call characters, distribution and ecology of two very similar bat species. This study found that the bats can be distinguished on the basis of skull morphology, size and echolocation call frequency. To date, only *Rhinolophus shameli* has been confirmed in Cambodia, where it appears to be widespread. Author: ithsaveng@yahoo.com

Mahony, S. (2011) Two new species of *Megophrys* Kuhl & van Hasselt (Amphibia: Megophryidae), from western Thailand and southern Cambodia. *Zootaxa,* **2734,** 23-39.

Both new species of frog were discovered among ancient specimens in the Natural History Museum, London, where they had previously been misidentified as *Megophrys parva*. The new species from Cambodia, *Megophrys damrei* sp. nov., was collected on the Bokor Plateau in southern Cambodia in 1914. Its present status in the wild is unknown. Author: stephenmahony2@gmail.com

Malhotra, A., Thorpe, R.S., Mrinalini & Stuart, B.S. (2011) Two new species of pitviper of the genus *Cryptelytrops* Cope 1860 (Squamata: Viperidae: Crotalinae) from Southeast Asia. *Zootaxa,* **2757,** 1-23.

Two new green pitvipers are described: *Cryptelytrops cardamomensis* sp. nov. from Southeast Thailand and the Cardamom Mountains of Southwest Cambodia, and

Cryptelytrops rubeus sp. nov. from southern Vietnam and eastern Cambodia. Both snakes are superficially similar to *C. macrops*, which occurs in northern Cambodia. Author: a.malhotra@bangor.ac.uk; Online: http://www.mapress.com/zootaxa/2011/f/zt02757p023.pdf

Neang T., Holden, J., Eastoe, T., Seng R., Ith S. & Grismer, L.L. (2011) A new species of *Dibamus* (Squamata: Dibamidae) from Phnom Samkos Wildlife Sanctuary, southwestern Cardamom Mountains, Cambodia. *Zootaxa,* **2828,** 58-68.

This new species of legless lizard, *Dibamus dalaiensis* sp. nov. is the first member of this genus and family to be recorded in Cambodia. It was discovered on Phnom Dalai in Phnom Samkos Wildlife Sanctuary. Author: nthymoeffi@gmail.com

Ng, H.H., Dang K.H. & Nguyan V.T. (2011) *Clarias gracilentus*, a new walking catfish (Teleostei: Clariidae) from Vietnam and Cambodia. *Zootaxa,* **2823,** 61-68.

A walking catfish is described from mainland southeastern Cambodia and the nearby Phu Quoc Island (Vietnam). The new species is superficially similar to *C. nieuhofii*. Author: heokhee@nus.edu.sg

Reddy, S. & Moyle, R.G. (2011) Systematics of the scimitar babblers (*Pomatorhinus*: Timaliidae): phylogeny, biogeography, and species-limits of four species complexes. *Biological Journal of the Linnean Society,* **102,** 846-869, doi: 10.1111/j.1095-8312.2010.01611.x

This paper examines the taxonomic relationships of all known birds in the scimitar babbler genus, including Cambodia's *Pomatorhinus hypoleucos, P. ochraceiceps* and *P. schisticeps.* Author: sreddy6@luc.edu

Roberts, T.E, Lanier, H.C., Sargis, E.J. & Olson, L.E. (2011) Molecular phylogeny of treeshrews (Mammalia: Scandentia) and the timescale of diversification in Southeast Asia. *Molecular Phylogenetics and Evolution*, **60,** 358-372.

The authors used genetic techniques to resolve the relationships of treeshrew species, including Cambodia's *Tupaia belangeri* and *Dendrogale murina*. Author: trina.roberts@nescent.org

Schaefer, H. & Renner, S.S. (2011) Phylogenetic relationships in the order Cucurbitales and a new classification of the gourd family (Cucurbitaceae). *Taxon*, **60,** 122-138.

The plant order Curcurbitales is reorganised on phylogenetic grounds. Cambodian species were included in the genetic analysis, apart from the newly described *Khmeriosicyos harmandii* W.J. de Wilde & Duyfjes 2006 (Cucurbitaceae). This endemic species already appears to be extinct in its type locality in Preah Vihear Province. Author: hschaef@fas.harvard.edu

Somboon, P., Thongwat, D. & Harbach, R.E. (2011) *Anopheles (Cellia) rampae* n. sp., alias chromosomal form K of the Oriental *maculatus* group (Diptera: Culicidae) in Southeast Asia. *Zootaxa*, **2810,** 47-55.

A new mosquito, *Anopheles rampae* sp. nov., is described from northern Cambodia (Ratanakiri and Vihear Provinces), northeastern Thailand, Laos and central Vietnam. The new species was previously considered to belong to *A. maculatus,* which also occurs in Cambodia. Author: psomboon@med.cmu.ac.th; Online: http://www.afrims.org/media/news-drrampa-somboon.pdf

Takagi, A.P., Ishikawa, S., Nao T, Song S.L., Hort S., Thammavong, K., Saphakdy, B., Phomsouvanhm, A., Nishida, M. & Kurokura, H. (2011) Genetic differentiation of *Macrognathus siamensis* within the Mekong River between Laos and Cambodia. *Journal of Applied Ichthyology*. Article first published online 7 June 2011, doi: 10.1111/j.1439-0426-.2011.01774.x

Mitochondrial DNA sequences of the eel *Macrognathus siamensis* indicate its Laotian and Cambodian populations separated approximately four million years ago. This study may have implications for the management and conservation of this species. Author: akirapt@mail.ecc.u-tokyo.ac.jp

Yata, O., Chainey, J.E. & Vane-Wright, R.I. (2010) The golden and mariana albatrosses, new species of pierid butterflies, with a review of subgenus *Appias* (*Catophaga*) (Lepidoptera). *Systematic Entomology,* ***35,*** 764–800, doi: 10.1111/j.1365-3113.2010.00535.x

A review and key of the butterflies in the subgenus *Appias* (*Catophaga*). Taxa listed in Cambodia are *Appias (Catophaga) albina darada* and *Appias (Catophaga) paulina adamsoni,* Author: euremayata@gmail.com; Online: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-3113.2010.00535.x/full

Guides and monographs

Hepburn, H.R. & Radloff, S.E. (eds) (2011) *Honeybees of Asia*. Springer-Verlag, Berlin, Germany.

The systematics, ecology and behaviour of Asian honeybees, including Cambodia's giant honey bee *Apis dorsata*, the medium-sized *A. cerana* and the dwarf honeybees *A. andreniformis* and *A. florea*. Author: s.radloff@ru.ac.ze

Biodiversity inventories

Evans, T. & Goes, F. (2011) *Cambodia Recent Bird Reports.* Http://www.samveasna.org/report [accessed 1 July 2011].

Part of a continuing series of monthly or bi-monthly reports, compiling bird counts and unusual records across Cambodia. The latest report covers January and February 2011. Author: tevans@wcs.org

Hartmann, T., Handschuh, M. & Sovath S. (2010) Amphibien- und Reptilienfauna im Nordwesten Kambodschas *ZGAP Mitteilungen,* **26,** 20-22. ["Amphibian and reptile fauna of northwestern Cambodia". In German with English summary].

Surveys in the Phnom Kulen National Park in 2008 and 2009 resulted in the identification of 24 amphibian species and 37 reptiles. This relatively high diversity is threatened by rapid deforestation within the park. Author: t.hartmann.zfmk@uni-bonn.de; Online: http://www.accb-cambodia.org/en/26_2c.pdf

Neang T. & Furey, N. (2011) Recent research initiatives: preliminary results from herpetological studies in the Cardamom Mountains of southwest Cambodia. *Paper presented to the Association for Tropical Biology and Conservation's Asia Pacific Chapter Annual Meeting, 12-15 March 2011, Bangkok, Thailand.*

The recent discovery of three new forest species raises the number of known Cambodian endemic reptiles and amphibians to 12. Of these, nine are thought to be locally endemic to the Cardamom Mountains. Further surveys could lead to more species being discovered in Cambodia. Author: nthymoeffi@gmail.com

Ohler, A. & Goutte, S. (2011) *Anuran Amphibians From Preah Vihear Province, Cambodia: Preliminary Report.* Département de Systématique et Evolution, Muséum National d'Histoire Naturelle, Paris, France.

A three-week survey in December 2010 found 24 species of amphibians near the Preah Vihear Temple and other parts of this province. This report contains descriptions and high quality photographs of the amphibians. Author: annemarie.ohler@gmail.com

Ouk V., So N., Lim P. & Pich S.W. (2010) Seagrass diversity and distribution in coastal area of Kampot Province, Cambodia. *International Journal of Environmental and Rural Development,* **1,** *112-117.*

Twelve seagrass species were identified, of which *Holdule uninervis* was the most abundant. Most species were observed in a water depth of 1-3 metres, and none were seen at depths greater than 7 metres. Author: ouk.vibol@online.com.kh; Online: http://int-erd.org/images/IJERD-vol1_2/1_2_112.pdf

Roland, H.-J. (2011) *Dragonflies of Cambodia.* Http://www.dragonflies-cambodia.com/ [accessed 1 July 2011].

A new website to share information on the dragonflies and damselflies (Odonata) of Cambodia. Author: Hjuergenroland@aol.com

Species ecology and status

Daltry, J.C. & Starr, A. (2010) Development of a re-introduction and reinforcement programme for Siamese crocodiles in Cambodia. In *Global Re-introduction Perspectives: 2010* (ed. P. Soorae), pp. 118-123. IUCN/SSC Re-introduction Specialist Group and Environment Agency, Abu Dhabi, United Arab Emirates.

A short paper from the Cambodian Crocodile Conservation Programme, outlining the rationale and steps for restocking Cambodian waterways with Critically Endangered Siamese crocodiles. Author: jenny.daltry@fauna-flora.org; Online: www.iucnsscrsg.org/download/Global%20Reintro%20Perspectives.pdf or http://data.iucn.org/dbtw-wpd/edocs/2010-076.pdf#page=131

Ferguson, J.W., Healey, M., Dugan, P. & Barlow, C. (2011) Potential effects of dams on migratory fish in the Mekong River: lessons from salmon in the Fraser and Columbia Rivers. *Environmental Management*, **47,** 141-159.

Drawing on experiences from the USA, the authors infer that the multitude of new and planned dams in the Mekong Basin will have a catastrophic impact on its >135 migratory fish species. "Minimizing impacts will require decades to design specialized fish passage facilities, dam operations, and artificial production, and is complicated by the Mekong's high diversity and productivity." Author: john.w.ferguson@noaa.gov; Online: http://www.springerlink.com/content/5561301gr88q6m37/fulltext.pdf

Goetz, S. (2010) Wie hieß die Kuh? Hochbetrieb im Geierrestaurant. *ZGAP Mitteilungen,* **26,** 8-14. ["What was the cow? Rush at the vulture restaurant". In German with English summary].

Photographs and observations made in the Preah Vihear Protected Forest at a 'vulture restaurant', where animal carcasses are provided to vultures as part of a conservation programme. Online: http://www.accb-cambodia.org/en/26_2a.pdf

Handschuh, M. & Packman, C. (2010) First nest record of Mekong wagtail *Motacilla samveasnae. BirdingAsia,* **14,** 84.

Paper not seen. Author: markus.handschuh@accb-cambodia.org

Handschuh, M. (2010) Javanische Schuppentiere im Angkor Centre for Conservation of Biodiversity in Kambodscha. *ZGAP Mitteilungen,* **26,** 18-20. ["Sunda pangolins at the Angkor Centre for Conservation of Biodiversity in Cambodia". In German with English summary].

The experiences of the Angkor Centre for Conservation of Biodiversity in keeping, breeding and rearing Sunda pangolins *Manis javanica* - a species that is notoriously difficult to keep in captivity. Author: markus.hands-

chuh@accb-cambodia.org; Online: http://www.accb-cambodia.org/en/26_2b.pdf

Ingalls, T. (2011) *Variation in dental morphology in four species of bovids: applications for Southeast Asian archaeology and the Angkor Borei site, Cambodia.* Masters thesis, University of Hawai'i at Manoa, Hawai'i, USA.

Statistical analyses were used to identify the diagnostic traits of the bones and teeth from water buffalo *Bubalus bubalis,* banteng *Bos javanicus*, gaur *Bos gaurus* and zebu cattle *Bos indicus*. Results were tested at an archaeological site in Cambodia, Angkor Borei. Author: teresa@bishop-museum.org

Jennings, A.P. & Veron, G. (2011) Predicted distributions and ecological niches of 8 civet and mongoose species in Southeast Asia. *Journal of Mammalogy,* **92,** 316-327.

Full paper not seen, but the abstract refers to several species that occur in Cambodia. Author: smallcarnivores@yahoo.com

Kim, S.K., Carbone, L., Becquet, C., Mootnick, A.R, Li, D.J., de Jong, P.J. & Wall, J.D. (2011) Patterns of genetic variation within and between gibbon species. *Molecular Biology and Evolution.* Article first published online 2 March 2011, doi: 10.1093/molbev/msr033

Incorporating gibbon species from Cambodia, this study found high levels of genetic diversity within the species, indicative of large historical population sizes. It also revealed low genetic differentiation between species in the same genus, which could indicate occasional hybridization. Author: wallj@humgen.ucsf.edu; Online: http://mbe.oxfordjournals.org/content/early/2011/03/02/molbev.msr033.full.pdf+html

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

A forum held by the Southeast Asian Bat Conservation Research Unit (SEABCRU) identified four conservation research priorities in this region: flying fox conservation and monitoring, taxonomy, conservation of cave-dependent bats, and conservation of forest-dependent bats. Author: tigga.kingston@ttu.edu; Online: http://www.springerlink.com/content/b6516306312l687k/fulltext.pdf

Lee, B.P.Y.-H. (2011) A possible decline in population of the long-tailed macaque (*Macaca fascicularis*) in northeastern Cambodia. In *Monkeys on the Edge: Ecology and Management of Long-Tailed Macaques and Their Interface with Humans* (eds Michael Gumert, Agustin Fuentes), p. 83-87. Cambridge University Press, Cambridge, U.K.

Surveys in 2008 achieved few sightings of long-tailed macaques, even in areas of apparently suitable habitat in Northeast Cambodia. The author presents circumstantial evidence that their populations have been severely depleted by hunting, especially the organised capture and trade of live monkeys for export. Author: Benjamin_LEE@nparks.gov.sg

Morton, B. (2010) Colonization of Asian freshwaters by the Mytilidae (Bivalvia): a comparison of *Sinomytilus harmandi* from the Tonle-Sap River, Phnom Penh, Cambodia, with *Limnoperna fortunei. Molluscan Research,* **30,** 57-72.

The mussel *Sinomytilus harmandi* inhabits lakes and rivers of Indochina and probably originated in the Mekong River. Another mussel, the highly opportunistic *Limnoperna fortunei*, was probably introduced to tropical Indochina from China. Author: gdi@aqua.dtu.dk

O'Kelly, H. & Hor N.M. (2010) *Monitoring of Key Wildlife Populations in Seima Protection Forest, Cambodia, 2005-2010.* Wildlife Conservation Society and Forestry Administration, Phnom Penh, Cambodia.

Surveys of primate and ungulate populations have been conducted in the Seima Protection Forest (previously the Seima Biodiversity Conservation Area) annually or biennially since 2005. Additional priority species have been recently added to this monitoring programme. This report explores the emerging trends in wildlife numbers. Author: hokelly@wcs.org; Online: http://www.wcscambodia.org/resources/reports/seima/seima-wildlife-monitoring-report-2005-2020.pdf

Ouk V., Dove, V. & Congdon, G. (2010) Review of the conservation and establishment of protected areas for the Irrawaddy dolphin, *Orcaella brevirostris* in the Mekong River, Cambodia. In *Final Workshop Report: Establishing Protected Areas for Asian Freshwater Cetaceans* (eds D. Kreb, R.R. Reeves, P.O. Thomas, G.T. Braulik & B.D. Smith), pp. 73-84. Yayasan Konservasi RASI, Samarinda, Indonesia.

In 2008, an estimated 70 Mekong dolphins remained in Cambodia, fewer than previous estimates. At least 92 dolphins died between 2003-2009 from gill nets and other, unverified causes. WWF and the Fisheries Administration are working with local communities to protect nine main dolphin pools and to prevent the use of gill nets and reduce overall fishing pressure in these areas. Author: ouk.vibol@online.com.kh; Online: http://www.ykrasi.110mb.com/final_asian_freshwater_dolphin_workshop_report.pdf#page=77

Ryan, G.E., Dove, V., Trujillo, F. & Doherty Jr., P.F. (2011) Irrawaddy dolphin demography in the Mekong River: an application of mark–resight models. *Ecosphere,* **2,** 1-15.

Eleven surveys conducted over three years have revealing that the Mekong population comprised approximately 77 dolphins in Cambodia and seven or eight in Laos. Although population size appeared to be stable during this period, the authors inferred that recruitment is very low, its population is ageing, and the species is in

serious danger of extirpation. Author: gryan@wwfgreatermekong.org; Online: http://www.esajournals.org/doi/pdf/10.1890/ES10-00171.1

Starr, C., Nekaris, K.A.I., Streicher, U. & Leung, L.K.-P. (2011) Field surveys of the Vulnerable pygmy slow loris *Nycticebus pygmaeus* using local knowledge in Mondulkiri Province, Cambodia. *Oryx,* **45,** 135-142.

The pygmy slow loris inhabits Vietnam, Laos, southern China and eastern Cambodia. In Cambodia, mean encounter rates were 0.40/km in Seima Protection Forest, 0.10/km in Phnom Prich Wildlife Sanctuary and 0.00/km in Mondulkiri Protected Forest. Widespread declines have been reported and linked to high hunting pressure over the past decade. The authors call for urgent actions to safeguard pygmy lorises throughout eastern Cambodia. Author: c.starr@uq.edu.au

Steinmetz, R., Garshelis, D.L, Chutipong, W. & Seuaturien, N. (2011) The shared preference niche of sympatric Asiatic black bears and sun bears in a tropical forest mosaic. *PLoS ONE,* **6,** e14509, doi:10.1371/journal.pone.0014509

In Thailand, both bear species were found to inhabit the same forests and use largely the same resources. However, Asiatic black bears *Ursus thibetanus* dominate habitats with more fruit, while the smaller sun bears *Helarctos malayanus* use the less-preferred insects. Author: roberts@wwfgreatermekong.org; Online: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0014509#aff1

Sukumasavin, N. (2010) Sixth meeting of Mekong Giant Catfish Working Group held in Thailand. *Catch and Culture*, **16,** 33-35.

A summary of the issues and resolutions discussed by Cambodian and other regional representatives to conserve the Mekong giant catfish *Pangasianodon gigas*. Online: http://www.mrcmekong.org/download/programmes/fisheries/catch_culture_Vol16.2-with-insert.pdf#page=37

Van N.T., Hallam, C., Roos, C. & Hammerschmidt, K. (2011) Concordance between vocal and genetic diversity in crested gibbons. *BMC Evolutionary Biology,* **11,** 36, doi:10.1186/1471-2148-11-36

Acoustic analyses of gibbon duets confirm that it is possible to distinguish between crested gibbon species (including Cambodia's *N. annamensis* and *N. gabriellae*), and, furthermore, gibbon calls can be used to verify phylogenetic relatedness and geographic origin. Author: vanthinhngoc@yahoo.com

van Zalinge, R., Sun V., Sorn P. & Evans, T. (2011) *The Status and Distribution of Large Waterbirds in the Tonle Sap Biosphere Reserve, 2010 Update.* Wildlife Conservation Society Cambodia Program, Phnom Penh, Cambodia.

This review examines records collected from July 2009 to June 2010 through regular monitoring work in and around several sites including Prek Toal, Boeung Tonle Chhmar and Stung Sen Core Areas (inner flooded forest zone), and Veal Srongai and the Bengal Florican Conservation Areas (floodplain grasslands). Author: robertvanzalinge@yahoo.com; Online: http://www.wcscambodia.org/resources/reports/tonlesap/full-2010-waterbird-report.pdf

Webber, C.E., Tuy S., Maltby, M.P. & Lee, P.L. (2011) Elephant crop-raiding and human–elephant conflict in Cambodia: crop selection and seasonal timings of raids. *Oryx,* **45,** 243-251, doi:10.1017/S0030605310000335

Using a four-year database of events, this study investigated the most frequently raided crops and patterns of raids over time and by location. Peak raiding season was between October and December, and bananas, sugar cane and pineapples were disproportionately affected. Rates of damage decreased after mitigation strategies were implemented, including observation towers, deterrents and fences. Author: cw35@stir.ac.uk

Coasts, wetlands and aquatic resources

Anonymous (2010) Integrating data from fisheries monitoring programmes in the Lower Mekong Basin. *Catch and Culture*, **16,** 10-12.

The Mekong River Commission Fisheries Programme is supporting national fisheries monitoring programmes within this region. The monitoring includes fish catches using different types of fishing gear in various habitats and the abundance of fish larvae from spawning areas. In 2010, a regional workshop was held to enable Cambodian, Laotian, Thai and Vietnamese scientists to integrate their data and quantify basin-wide changes over time. Online: http://www.mrcmekong.org/download/programmes/fisheries/catch_culture_Vol16.2-with-insert.pdf#page=37

Anonymous (2010) A restaurant with rods, a garden of dreams. *Catch and Culture*, **16,** 36-40.

Examples of innovative recreational fishing businesses in Cambodia and Vietnam. Online: http://www.mrcmekong.org/download/programmes/fisheries/catch_culture_Vol16.2-with-insert.pdf#page=37

Anonymous (2010) Cambodian fish yield estimate rises in 2009. *Catch and Culture*, **16,** 41-40.

Cambodia's yield from freshwater capture fisheries was approximately 390,000 tonnes in 2009, up from 365,000 tonnes in 2008, in spite of declining catches of small cyprinid fish. Aquaculture production rose from 40,000

tonnes to around 50,000 tonnes during the same period, while the 2009 yield from marine capture fisheries was estimated to be 75,000 tonnes. Cambodia currently has more than 55,000 households engaged in farming fish and other aquatic animals. Online: http://www.mrcmekong.org/download/programmes/fisheries/catch_culture_Vol16.2-with-insert.pdf#page=37

Chum N., Baran, E., Chervier, C., Leng S.V. & Emmett, D. (2010) Contribution of Kampong Preak Fish Sanctuary (Tonle Sap Lake, Cambodia) to livelihoods in two adjacent floating villages. *International Journal of Environmental and Rural Development*, **1,** 119-124.

Data from 60 households revealed that the fish sanctuary contributed revenue and food to all households. Fish, snakes, water birds, turtles, edible wild plants and firewood are essential for poor households. However, rich households made significantly more money from these resources because they had more capital to invest in fishing equipment and to bribe law enforcers. Author: panit_chum@yahoo.com; Online: http://int-erd.org/images/IJERDvol1_1/119-124.pdf

Cochrane, T.A., Arias, M.E., Teasley, R.L. & Killeen, T.J. (2010) Simulated changes in water flows of the Mekong River from potential dam development and operations on the Se San and Sre Pok tributaries. *Paper presented to the IWA World Water Congress and Exhibition, 19-24 September 2010, Montreal, Canada.*

Computer-based modelling shows that the planned development of multiple dams on the Sesan and Srepok Rivers will affect flows in the Mekong River by approximately 8%. Dry season flows could almost double whereas wet season peak flows would be significantly reduced. Author: tom.cochrane@canterbury.ac.nz

Dugan, P.J., Barlow, C.B., Agostinho, A.A., Baran, E., Cada, G.F., Chen, D., Cowx, I.G., Ferguson, J.W., Jutagate, T., Mallen-Cooper, M., Marmulla, G., Nestler, J., Petrere, M., Welcomme, R.L. & Winemiller, K.O. (2010) Fish migration, dams, and loss of ecosystem services in the Mekong Basin, *AMBIO,* **39,** 344-348.

Some of the world's leading fisheries scientists call for an urgent actions to avoid the major social and economic impacts that are predicted from mainstream dam development in the Lower Mekong Basin. Author: p.dugan@cgiar.org; Online: http://wfsc.tamu.edu/winemiller/lab/PDFs/2010%20Dugan%20et%20al.%20Fish%20migration,%20dams%20and%20loss%20of%20services%20in%20the%20Mekong.pdf

Hortle, K.G. (2010) Basin development plan and fisheries. *Catch and Culture*, **16,** 4-8.

As part of the Mekong River Commission's process to prepare a Basin Development Plan, this study was conducted into the predicted effects of dams and flood mitigation projects. "The most damaging dams are likely to be those on the mainstream in Cambodia itself as they directly impact migration routes and spawning grounds of many of the fishery species in the river-floodplain catches... leading to very large nett losses even under the best-case assumptions by 2030." Online: http://www.mrcmekong.org/download/programmes/fisheries/catch_culture_Vol16.2-with-insert.pdf#page=37

Jensen, H.K., Konradsen, F., Jørs, E., Petersen, J.H. & Dalsgaard, A. (2011) Pesticide use and self-reported symptoms of acute pesticide poisoning among aquatic farmers in Phnom Penh, Cambodia. *Journal of Toxicology,* **2011,** Article ID 639814, 8 pages doi:10.1155/2011/639814

Interviews with farmers around Boeung Cheung Ek Lake, Phnom Penh, found 50% of their pesticides belonged to WHO classes I and II, personal protection was inadequate and 88% of farmers had experienced symptoms of acute pesticide poisoning. The use of organophosphates and carbamates was inferred to be especially hazardous, and better controls and training are needed. Author: hklith@gmail.com

Keskinen, M. (2010) *Bringing back the common sense? Integrated approaches in water management: Lessons learnt from the Mekong*. Doctorate thesis, Aalto University, Espoo, Finland.

This thesis identifies weaknesses in water management practices in the Mekong River Basin, including the Tonle Sap Lake. "What really matters are... not only the technical methods for integration, but also the ways the management and research teams in specific management contexts communicate, collaborate and interact with their various stakeholders as well as – an issue that is frequently forgotten – internally within their teams". Author: marko.keskinen@aalto.fi

Mam K., Ouk V., Dubois, M. & Dyna, E. (2010) Innovations in fisheries co-management - experiences in linking state, civil society and villager led research. *Paper presented to the First ICERD-International Conference on Environmental and Rural Development, March 2010, Phnom Penh, Cambodia.*

Focusing on the deep pools that are important dry season fish refuges in Northeast Cambodia, this paper examines how local villagers share and use their research findings, the roles of the state and other actors, and the potential for fisheries co-management. Author: d.eam@cgiar.org; Online: http://e-archive.criced.tsukuba.ac.jp/data/doc/pdf/2010/03/1st%20ICERD-abstracts.pdf

Ministry of Interior (2010) *Lessons Learned Report*. Tonle Sap Sustainable Livelihoods Project, Royal Government of Cambodia, Phnom Penh, Cambodia.

The Tonle Sap Sustainable Livelihoods Project (June 2006 to December 2010) aimed to reduce pressure on natural resources by improving livelihood opportunities in

provinces that adjoin the Tonle Sap. Author: ptownsley@fastwebnet.it; Online: http://www.adb.org/Documents/Produced-Under-TA/39603/39603-01-cam-dpta-02.pdf

Ministry of Interior (2010) *Internal Assessment of Social, Economic and Environmental Impacts: Final Report*. Tonle Sap Sustainable Livelihoods Project, Royal Government of Cambodia, Phnom Penh, Cambodia.

Online: http://www.adb.org/Documents/Produced-Under-TA/39603/39603-01-cam-dpta-03.pdf

Nasuchona, N. & Charles, A. (2010) Community involvement in fisheries management: experiences in the Gulf of Thailand countries. *Marine Policy,* **34,** 163-169.

There are signs of increasing involvement by coastal communities in fisheries management in Malaysia, Vietnam, Cambodia and Thailand. In Cambodia, there needs to be stronger legislation to control fisheries operations and greater clarity of the role of communities in management. Author: nasuchon@yahoo.com

Pomeroy, R.S. & Andrew, N. (eds) (2011) *Small-Scale Fisheries Management: Frameworks and Approaches for the Developing World.* CABI, Wallingford, U.K.

Includes original fisheries data from Cambodia. Author: robert.pomeroy@uconn.edu

Sar S., Chervier, C., Lim P., Warrender, C., Warrender, G.W. & Gilbert, R.S. (2010) Seasonal direct-use value of Cheung Ek peri-urban lake, Phnom Penh, Cambodia. *International Journal of Environmental and Rural Development*, **1,** 113-118.

Cheung Ek Lake receives 80% of Phnom Penh's urban wastewater. Interviews with local households found the lake generates more than US$ 1 million annually (including 65% from water spinach, 20% fishing, 13% from water mimosa), benefitting nearly 1,000 residents. The lake also generates immeasurable indirect values, including health benefits and tourism. Author: sar_seila2005@yahoo.com; Online: http://int-erd.org/images/IJERDvol1_1/113-118.pdf

Schneider, H. (2011) Development at the expense of the environment and the poor: The conflict for Boeng Kak lake in Phnom Penh, Cambodia. *Pacific News*, **36,** 4-10.

Author: helmut.schneider@uni-due.de; Online: Http://www.pacific-news.de/pn36/PN36_Schneider.pdf

Senaratna, S.S., Mith, S., Hoanh, C.T., Johnston, R., Baran, E., Dubois, M., Soeun, M., Craig, I., Nam, S. & Smith, L. (2010) *Commune Agroecosystem Analysis to Support Decision Making for Water Allocation for Fisheries and Agriculture in the Tonle Sap Wetland System.* Challenge Program for Water and Food, Colombo, Sri Lanka.

Commune Agroecosystem Analysis is a participatory approach to improve decision-making at commune level, and has been applied to agricultural issues in Cambodia for many years. This paper considers how to apply it to fisheries management. Author: s.senaratnasellamuttu@cgiar.org

Sok S., Lebel, L., Bastakoti, R.C. Thau S. & Samath S. (2011) Role of villagers in building community resilience through disaster risk management: a case study of a flood-prone village on the banks of the Mekong River in Cambodia. In *Environmental Change and Agricultural Sustainability in the Mekong Delta* (eds M.A. Stewart & P.A. Coclanis), pp. 241-255. Advances in Global Change Research, No. 45, Springer, New York, USA, doi: 10.1007/978-94-007-0934-8_14

Describes the impacts of flooding in Angkor Ang Village in Prey Veng Province, and the obstacles to action by villagers and others working at community and other levels. Author: sereyhawaii@yahoo.com

Whittingham, E.W. (2010) *Sites of practice: negotiating sustainability and livelihoods in rural Cambodia.* PhD thesis, University of Exeter, Exeter, U.K.

An analysis of two projects implementing community fisheries in Cambodia: the first supported by the Culture and Environment Preservation Association (CEPA) in Stung Treng Province, the other by the Ministry of Environment in Koh Kong Province. Online: https://eric.exeter.ac.uk/repository/handle/10036/107420

Vouen V. (2010) Late prehistoric site in Cambodia yields thousands of fish bones from 18 families. *Catch and Culture*, **16,** 13-17.

Recent government research indicates that people living near the Tonle Sap Lake have been engaged in fish processing for more than 2,000 years. This illustrated article summarises the findings from analysing thousands of fish bones from middens near the Great Lake. Online: http://www.mrcmekong.org/download/programmes/fisheries/catch_culture_Vol16.2-with-insert.pdf#page=37

Forests and forest resources

Barney, K. (2010) *Large Acquisition of Rights on Forest Lands: Focus on Cambodia and Lao PDR.* Rights and Resources Initiative, International Land Coalition, Rome, Italy.

Report not seen. Author: kbarney@yorku.ca

Evans, T. (2011) *Progress Towards Indigenous Land Titling in the Seima Protection Forest, Mondulkiri: Briefing Note May 2011.* Wildlife Conservation Society, Phnom Penh, Cambodia.

A short progress report from a programme that has already enabled one community to obtain communal land title - among the first of its kind in Cambodia. Author: tevans@wcs.org; Online: http://www.wcscambodia.org/resources/reports/seima/indigenous-land-titling-progress-in-spf-may-2011.pdf

Fox, J. & Castella, J.C. (2010) Expansion of rubber (*Hevea brasiliensis*) in mainland Southeast Asia: what are the

prospects for small holders? *Paper presented to the Regional Center for Social Science and Sustainable Development (RCSD) Revisiting Agrarian Transformations in Southeast Asia: Empirical, Theoretical and Applied Perspectives Conference, 13-15 May 2010, Chiang Mai, Thailand.*

World demand for natural rubber is growing. In the uplands of mainland Southeast Asia, including Cambodia, this is likely to drive the continued expansion of rubber plantations. Author: foxj@eastwestcenter.org; Online: http://rcsd.soc.cmu.ac.th/InterConf/paper/paper-pdf1_367.pdf

Horm C., Bampton, J.F.R., Kelley, L.C. & Brofeldt, S. (2010) Whose land is this anyway? The role of collective action in maintaining community rights to the land in Kratie, Cambodia. *Paper presented to the CAPRi Workshop on Collective Action, Property Rights, and Conflict in Natural Resources Management, 28 June - 1 July 2010, Siem Reap, Cambodia.*

This paper examines a conflict that began after a economic land concession company was awarded land on which a community in Kratie Province had applied for a community forest. Online: http://www.capri.cgiar.org/pdf/CAPRi_Conflict_Chandet.pdf

Hun R., Saur, E., Mak S., Chervier, C. & Gilbert, R.(2010) Negative impact of forest land use change on household income, Kratie, Cambodia. *Paper presented to the First International Conference on Environmental and Rural Development, March 2010, Phnom Penh, Cambodia.*

Findings from questionnaires with residents in Kratie Province indicate that one of the most severe effects of forest loss (due to economic land concessions, conversion to agriculture and illegal logging) is the loss of income from tapping resin trees. Author: smeygidar@yahoo.com; Online: http://e-archive.criced.tsukuba.ac.jp/data/doc/pdf/2010/03/1st%20ICERD-abstracts.pdf

Kiernan, K. (2010) Environmental degradation in karst areas of Cambodia: A legacy of war? *Land Degradation & Development,* **21,** 503–519, doi: 10.1002/ldr.988

Karst areas in Kampot Province, Southwest Cambodia, show evidence of soil erosion, resulting in the partial infilling of caves. While this is especially severe in areas subject to intensive human use, the unusually widespread damage may be linked to aerial bombardment between 1965 and 1973. Author: kevin.kiernan@utas.edu.au

Rainey, H.J., Heng B. & Evans, T.E. (2010) *Forest Cover Trends in the Northern Plains of Cambodia, 2002-2010.* Wildlife Conservation Society, Phnom Penh, Cambodia.

Using satellite imagery, the mean annual rate of deforestation across the study area during 2002-2010 was 0.79%. Rates of loss were considerably higher in buffer areas than in the CALM protected areas. Author: hrainey@wcs.org; Online: http://www.wcscambodia.org/resources/reports/northern/northern-plains-forest-cover-report-email-version

Schneider, A.E. (2011) What will we do without our land? Land grabs and resistance in rural Cambodia. *Paper presented at the International Conference on Global Land Grabbing, 6-8 April 2011, Brighton, U.K.*

Approximately 15-20% of the Cambodian population is landless or 'near landless'. At least 27 forced evictions took place in 2009, affecting 23,000 people. There are signs the rural poor are beginning to use political and other means to prevent further loss of land and access to forest resources. (The author completed a thesis in 2010 with the same title). Online: http://www.future-agricultures.org/index.php?option=com_docman&task=doc_download&gid=1264&Itemid=971

Suon S. & Khorn S. (2010) Forest law enforcement and governance in Cambodia. In *Forest Law Enforcement and Governance: Progress in Asia and the Pacific* (eds M.J. Pescott, P.B. Durst & R.N. Leslie), pp. 69-84. Food and Agriculture Organization of the United Nations: Regional Office for Asia and the Pacific, Bangkok, Thailand.

The Royal Government of Cambodia has been implementing in-depth forestry reform, including legislation, national forest policy, specific strategies, a National Forest Programme and strengthening forest law enforcement and governance. The authors conclude this reform has made progress in spite of multiple challenges. Online: http://www.profor.info/profor/sites/profor.info/files/docs/FLEG-ASEAN.pdf#page=79

Theilade, I., Schmidt, L., Chang, P. & McDonald, J.A. (2011) Evergreen swamp forest in Cambodia: floristic composition, ecological characteristics, and conservation status. *Nordic Journal of Botany,* **28,** 1-10, doi: 10.1111/j.1756-1051-.2010.01003.x

A rare new type of evergreen freshwater swamp forest has been discovered in at least six sites in Stung Treng Province. This forest is dominated by hydrophytic trees with pneumatophores, stilt roots or aerial roots (e.g. *Macaranga riloba, Myristica iners*, *Pternandra caerulescens*) and is also notable for the emergent *Livistona saribus* and dense stands of other palms and tree ferns in the understory. Author: idat@life.ku.dk; Online: http://onlinelibrary.wiley.com/doi/10.1111/j.1756-1051.2010.01003.x/full

Southworth, J., Nagendra, H. & Cassidy, L. (2011) Forest transition pathways in Asia - studies from Nepal, India, Thailand, and Cambodia. *Journal of Land Use Science,* doi: 10.1080/1747423X.2010.520342

This study draws on data from Nepal, India, Thailand, and Cambodia to examine patterns of deforestation and forest regeneration. Author: jsouthwo@geog.ufl.edu; Online: http://ithuteng.ub.bw:8080/bitstream/handle/10311/826/

Forest%20transition%20pathways%20in%20Asia-studies%20from%20Nepal%2c%20India%2c%20Thailand%20and%20Cambodia.pdf?sequence=1

Payments for conservation services, including carbon

Ty, S., Sasaki, N., Ahmad, A.H. & Ahmad, Z.A. (2011) REDD development in Cambodia: potential carbon emission reductions in a REDD project. *FORMATH,* **10,** 1–23.

The methods and findings from a REDD project established in 2007 by the Forestry Administration, Community Forestry International and Terra Global Capital for community forests in Oddar Meanchey Province. Multiple causes of forest loss and degradation were identified and addressed, and changes in deforestation, carbon stocks, and project emissions were estimated. The authors conclude this project will save approximately 8.6 million tonnes of CO_2 over 30 years. Online: http://www.formath.jp/book/Vol10/Vol10_1-23Sokhun.pdf

Kiyono, T., Furuya, N., Sum T., Umemiya, C., Itoh, E., Araki, M. & Matsumoto, M. (2010) Carbon stock estimation by forest measurement contributing to sustainable forest management in Cambodia. *Japan Agricultural Research Quarterly,* **44,** 81-92.

The authors tested a simplified method for estimating CO_2 emissions from deforestation by monitoring forest land and periodically summing up the land area and its averaged carbon stock for important forest types in Cambodia. Author: kiono@affrc.go.jp; Online: http://www.jircas.affrc.go.jp/english/publication/jarq/44-1/44-01-12.pdf

Westeröd, C. (2010) *Everything must go – a Cambodia for sale. How the Cambodian legal system is allowing extralegal land acquisitions*. Master's thesis, University of Gotheburg, Sweden.

The causes and effects of land-grabbing in Cambodia, in both urban and rural areas. Online: http://gupea.ub.gu.se/bitstream/2077/25521/1/gupea_2077_25521_1.pdf

Climate change

D'Agostino, A.L. & Sovacool, B.K. (2011) Sewing climate-resilient seeds: implementing climate change adaptation best practices in rural Cambodia. *Mitigation and Adaptation Strategies for Global Change,* doi: 10.1007/s11027-011-9289-7

Cambodia's decentralisation reforms offer an opportunity to incorporate climate change planning into government operations. The authors believe that water resources infrastructure and agricultural practices could be designed to effectively withstand climate variability. However, climate change planning costs have to compete with more immediate funding priorities, such as education, roads, and health care. Author: sppald@nus.edu.sg

Kingston, D.G., Thompson, J.R. & Kite, G. (2011) Uncertainty in climate change projections of discharge for the Mekong River Basin. *Hydrology and Earth System Science,* **15,** 1459–1471.

This paper models the potential impacts of climate change on freshwater resources within the river basin. Author: daniel.kingston@geography.otago.ac.nz; Online: http://www.hydrol-earth-syst-sci.net/15/1459/2011/hess-15-1459-2011.pdf

Magnan, N. & Thomas, T.S. (2011) *Food Security and Climate Change to 2050: Cambodia: A Policy Discussion Paper.* International Food Policy Research Institute, Washington, DC, USA.

Using computer simulations, this report predicts that world prices for rice and maize - two crops that Cambodia currently exports - will rise, maize production will increase, and the cultivated area of rice will decrease. The trend in per capita food availability for Cambodians is uncertain, however, with either a significant increase or decrease depending on the climate change variables used. Author: n.magnan@cgiar.org; Online: www.cdri.org.kh/webdata/download/sr/fscc11e.pdf

Capacity building

Bates, P.J.J., Satasook, C., Bumrungsri, S., Soisook, P., Douangboubpha, B., Ith S., Furey, N.M., Moe Moe Aung, Vu Dinh Thong, Kingston, T., Pearch, M.J. & Thomas, N.M. (2011) Enhancing taxonomic capacity to underpin biodiversity conservation in Southeast Asia. *Paper presented to the Second International Southeast Asian Bat Conference, 6-9 June 2011, Bogor, Indonesia.*

Recent analyses suggest that many more species of bats remain to be discovered in Southeast Asia. To address this and other information gaps, the Harrison Institute (UK) has a programme to train and support taxonomists in Cambodia, Laos, Myanmar, Thailand and Vietnam. Author: pjjbates2@hotmail.com

Rath S. & Furey, N. (2011) Building capacity to train and support a new generation of Cambodian conservationists. *Paper presented to the Association for Tropical Biology and Conservation - Asia Pacific Chapter Annual Meeting 2011, 12-15 March 2011, Bangkok, Thailand.*

Since 2005, the Royal University of Phnom Penh and Fauna & Flora International have worked together to raise technical conservation capacity through developing a postgraduate course, reference collections, publications, and opportunities for Cambodian scholars to

develop original projects. Author: biodiversity.conservation.1@gmail.com

Miscellaneous

Ecker, O. & Diao, X. (2011) *Food Security and Nutrition in Cambodia: Pattern and Pathways: A Policy Discussion Paper*. International Food Policy Research Institute, Washington, DC, USA.

An overview of the food security and nutrition situation in Cambodia. Average GDP per capita remains low and one-in-four Cambodians is undernourished. Nonetheless, progress has been made, e.g. staple food production has more than doubled since 1995, and poverty has dropped by more than a third. The authors call for more effective policies, research, investments, and programs to accelerate progress. Online: http://www.cdri.org.kh/webdata/download/sr/foodSecuNutrition10e.pdf

Richman, M.J., Nawabi, S., Patty, L. & Ziment, I. (2010) Traditional Cambodian medicine. *Journal of Complementary and Integrative Medicine*, **7,** Article 28.

The traditional health care practices identified from a survey in Siem Reap. Because recent studies have demonstrated several promising medicinal plants in Cambodia, the authors call for further investigations to identify the scientific names and properties of herbal medicines in this country.

Woodruff, D. (2010) Biogeography and conservation in Southeast Asia: how 2.7 million years of repeated environmental fluctuations affect today's patterns and the future of the remaining refugial-phase biodiversity. *Biodiversity Conservation*, **19,** 919–941.

How climatic and other changes have shaped the distribution of biodiversity in Southeast Asia. The author predicts that tens of millions of people who depend on protected area forests, riverine ecosystems and coastal habitats will become "environmental refugees". In Cambodia, the creation of dams is anticipated to destroy the Tonle Sap by 2030. Author: dwoodruff@ucsd.edu; Online: http://www.springerlink.com/content/19077r646877v761/

The Recent Literature section was compiled by JENNY C. DALTRY, with additional contributions from Neil Furey, Fredéric Goes, Markus Handschuh, Stephen Mahony, Matt Maltby, Neang Thy, Hanns-Jürgen Roland and Ida Theilade. All Internet addresses were correct at the time of publication. Please send contributions (published or grey literature, including project technical reports and conference abstracts not more than 18 months old) by email to: Editor.CJNH@gmail.com

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- Research on the status or ecology of habitats.
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- Reviews of conservation policy and legislation in Cambodia.
- Conservation management plans for species, habitats or areas.
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Concise reports (<300 words) on news of general interest to the study and management of Cambodia's biodiversity. News items may include, for example:

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

Preparation of Manuscripts

Authors should consult examples in this issue for general style. Contributions should be in English, with UK English spelling (if in doubt, Microsoft Word and similar software should be set to check spelling and grammar for 'English (UK)' language). Lines should be double-spaced. Submissions can be in 'doc', 'docx', 'rtf' or 'wpd' format, preferably as a single file attached to one covering email. The order of the sections of the manuscript should be: cover page, main text, references, short biography of each author, tables, figures and plates (photographs). The cover page should contain the title and full mailing address and email address of the Lead Author and the addresses of all co-authors. All pages should be numbered consecutively.

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

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

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

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

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

The titles of articles and journals should be written in full.

The following are examples of house style:

Papers:

Berzins, B. (1973) Some rotifers from Cambodia. *Hydrobiologia,* **41,** 453-459.

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

Tanaka, S. & Ohtaka, A. (2010) Freshwater Cladocera (Crustacea, Branchiopoda) in Lake Tonle Sap and its adjacent waters in Cambodia. *Limnology,* **11,** 171-178.

Books and chapters:

Khou E.H. (2010) *A Field Guide to the Rattans of Cambodia.* WWF Greater Mekong Cambodia Country Programme, Phnom Penh, Cambodia.

MacArthur, R.H. & Wilson, E.O. (1967) *The Theory of Island Biogeography*. Princeton University Press, Princeton, USA.

Rawson, B. (2010) The status of Cambodia's primates. In *Conservation of Primates in Indochina* (eds T Nadler, B. Rawson & Van N.T.), pp. 17-25. Frankfurt Zoological Society, Frankfurt, Germany, and Conservation International, Hanoi, Vietnam.

Reports:

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

Theses:

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

Websites:

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

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

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

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

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

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

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

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Contents