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Giant ibis census
Patterns of salt lick use
Protected area revisions
Economic contribution of NTFPs
New plants, bees and range extensions

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Cover image: This giant ibis *Thaumatibis gigantea* was photographed feeding at Western Siem Pang Wildlife Sanctuary on 3 May 2013 (© Jonathan C. Eames). The status of this Critically Endangered species in Cambodia is explored by Ty *et al.* in this issue (pages 51–59).

Editorial — Will the recent changes in protected area management and the creation of five new protected areas improve biodiversity conservation in Cambodia?

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Cambodia's forests are vital components of the highly threatened Indo-Burma biodiversity hotspot (Mittermeier *et al.*, 2004). They contain species found nowhere else on earth (Daltry, 2008), support important populations of some of the planet's most threatened large mammals and birds (Clements *et al.*, 2012; Gray *et al.*, 2012, 2014) and provide resources vital to the livelihoods of millions of rural Cambodians (Hansen & Top, 2006; Jiao *et al.*, 2015). Prior to changes within the Royal Government of Cambodia (RGC) in early 2016, the Ministry of Environment (MoE) and Ministry of Agriculture, Forestry and Fisheries (MAFF) were both responsible for forest management. MoE managed 23 protected areas (National Parks, Wildlife Sanctuaries, Protected Landscapes, Multiple Use Areas, Ramsar Sites, Biosphere Reserves and Natural Heritage Sites) under the 2008 Protected Areas Law; while under the 2002 Forestry Law, MAFF managed all other forests, including 13 protected forests and landscapes, and all wildlife outside of protected areas. Cambodia, on paper at least, had a comprehensive terrestrial protected area network with 26% of the country designated for conservation (World Bank, 2016). However having two agencies responsible for nature conservation often resulted in confusing jurisdictional overlap. Both ministries were also able to grant economic land concessions (ELCs) in protected areas. Between 2008 and 2012, MoE approved 113 ELCs within protected areas (ADHOC, 2012), allowing for some of the country's best forests to be cleared for agro-industrial cropping (Save Cambodia's Wildlife, 2014; Forest Trends, 2015). This, along with a focus on development over con-

servation even in protected areas (Gillson, 2007), one of the lowest expenditures on protected area management in the world (James *et al.*, 1999) and illegal extraction of high value timber species such as threatened rosewoods (*Dalbergia* spp.) (Singh, 2014), has resulted in extensive forest clearance. Between 2001–2014, acceleration of forest loss in Cambodia was the highest in the world with a 14.4% increase in annual forest loss rate per year (Petersen *et al.*, 2015). An estimated 60% of the country was forested in 2009, but this had reduced to 48% by 2014 (Open Development Cambodia, 2016a). Forests inside protected areas have disappeared as fast as forests elsewhere in the country (Peter & Pheap, 2015). In addition to this broad scale habitat loss, wildlife hunting is also a significant cause of forest biodiversity loss in Cambodia (Loucks *et al.*, 2009).

While Cambodia's protected area system covers a large land area, it was not comprehensive. Although 68% of Cambodia's most important areas of natural capital remained intact in 2014, only 48% were officially protected (McKinnon, in press). Many protected areas were separated by unprotected forests and none of the country's extensive and species-rich lowland evergreen forests had been protected: an ecosystem that has been extensively cleared throughout the Indo-Burma biodiversity hotspot (Tordoff *et al.*, 2011).

On 28th April 2016, the RGC transferred the management jurisdiction for protected forests and landscapes from MAFF to MoE. These areas are now protected under the 2008 Protected Areas Law, so MoE has sole

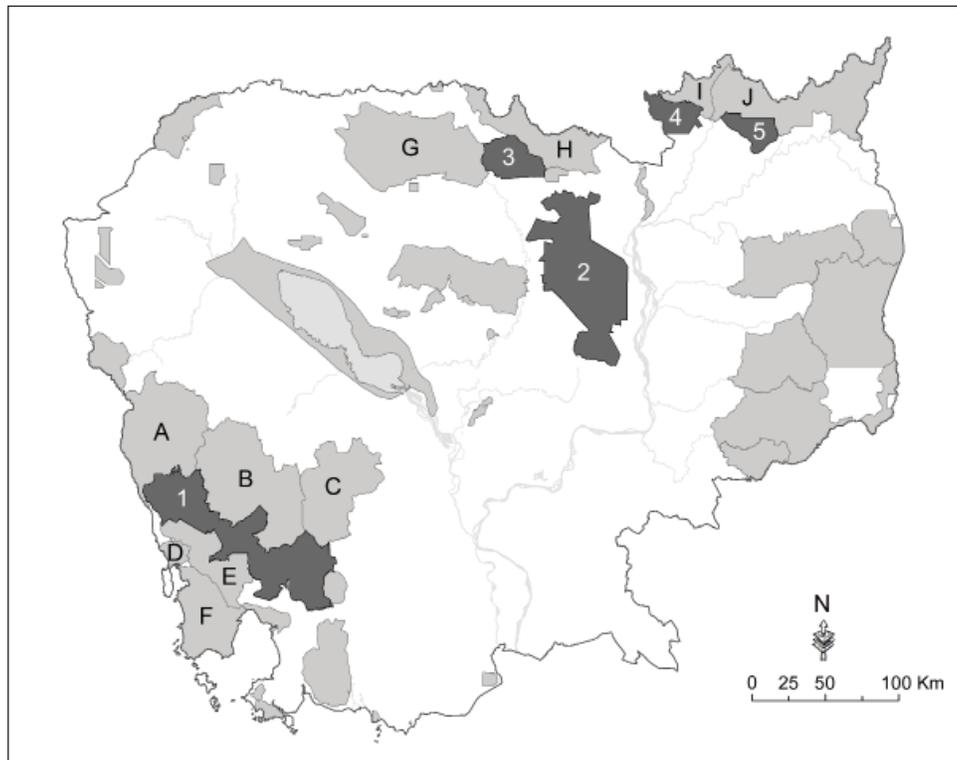


Fig. 1 Protected areas designated in Cambodia in 2016 (dark grey): 1) Chuo Phnom Kravanh Khang Tbong National Park; 2) Prey Lang Wildlife Sanctuary, 3) Preah Rokar Wildlife Sanctuary, 4) Prey Siem Pang Khang Lech Wildlife Sanctuary, 5) Veun Sai–Siem Pang National Park; and previously established protected areas (light grey): A) Phnom Samkos Wildlife Sanctuary, B) Central Cardamom Mountains National Park, C) Phnom Aural Wildlife Sanctuary, D) Peam Krasop Wildlife Sanctuary, E) Tatai Wildlife Sanctuary, F) Botum-Sakor National Park, G) Kulen Promtep Wildlife Sanctuary, H) Chheab Wildlife Sanctuary, I) Siem Pang Wildlife Sanctuary, J) Virachey National Park (Map produced by Ung Viset, Conservation International).

responsibility for all of Cambodia’s terrestrial protected areas (RGC sub-decree 69, 2016). All economic land concessions will be managed in future by MAFF. Community Forests will remain under the jurisdiction of MAFF, as will Conservation Areas and Community Fisheries which are managed by the Fisheries Administration within MAFF. MoE is working with MAFF to determine how staffing and equipment needs can be met for the newly acquired sites. The current plan is that MAFF staff working for sites now managed by MoE can volunteer for transfer to the latter, and these transfers will be handled on an individual basis by the ministries. It is important that assets and infrastructure previously donated to MAFF for the purpose of conserving the protected forests, such as headquarter buildings, are also transferred to MoE.

On the 9th of May 2016, the RGC declared five new protected areas which cover over one million ha of forest and grassland (Fig. 1):

1. Chuo Phnom Kravanh Khang Tbong National Park (410,392 ha; RGC sub-decree 89, 2016) is located in the Cardamom Mountains and links the Central Cardamom Mountains National Park and Tatai Wildlife Sanctuary. The site also connects the ridges of the Cardamom Mountains to the coastal mangroves at Peam Krasop Wildlife Sanctuary and Botum-Sakor National Park. Previously managed by MAFF and supported by Wildlife Alliance, the national park increases protection for 54 globally threatened species in the Cardamom Mountains (Killeen, 2012), particularly the region’s Endangered Asian elephants *Elephas maximus*, which are threatened by habitat fragmentation. The expansion of the Cardamom Mountains protected landscape should reduce this threat, improving the prospects for their long term survival. The national park has also been identified as one of the two priority sites for tiger (*Panthera tigris*) restoration in Cambodia (DWB/GTI, 2016) and recent camera-trapping has demonstrated a largely intact large mammal community (Wildlife Alliance, unpublished data). The

contiguous protected area network through and adjoining the Cardamom Mountains now covers nearly 2.4 million ha in Cambodia and Thailand: Botum-Sakor National Park, Kirirom National Park, Central Cardamom Mountains National Park, Kravanh Khang Tbhong National Park, Peam Krasop Wildlife Sanctuary, Phnom Aural Wildlife Sanctuary, Phnom Samkos Wildlife Sanctuary, Tatai Wildlife Sanctuary, Samlaut Multiple Use Area, Dong Peng Multiple Use Area, Koh Kapik and Associated Islets, Klong Khruo Wai Chalerm Pra Kiet and Klong Khruo Wai Chalerm Pra Kiet (Open Development Cambodia, 2016b,c). This strengthens justifications for designation of the area as a UNESCO Man and Biosphere Reserve.

2. Prey Lang Wildlife Sanctuary (431,683 ha; RGC sub-decree 74, 2016) formally protects Cambodia's largest remaining area of lowland evergreen forest (Olsson & Emmett, 2007). Previously the forest was protected from illegal logging by MAFF and self-organised community patrols. These patrols focused on preserving resin trees: valuable family assets that provide sustainable income and are spiritually significant to the forest's indigenous people. Prey Lang supports Asian elephants, several species of threatened primates and other mammals, 44% of Cambodia's known bird species and at least a third of its bats (Hayes *et al.*, 2015). It also has potential for inclusion in the UN REDD+ programme and is being considered by the Japanese government as a pilot site for REDD to implement the new Japanese credit mechanism.

3. Preah Rokar Wildlife Sanctuary (90,361 ha; RGC sub-decree 75, 2016) is the largest block of evergreen and semi-evergreen forest remaining in the northern central corridor landscape. The site forms a wildlife corridor between Kulen Promtep Wildlife Sanctuary and Chheab Wildlife Sanctuary. These were managed by MoE and MAFF respectively, but are now both managed by MoE with support from the Wildlife Conservation Society. Taken together, the area protected forms a critical part of the upper catchment for the Stung Sen and Tonle Sap Rivers. The Stung Sen River is the largest undammed tributary to Tonle Sap lake, which makes its head waters nationally important for climate resilience and food security. Preah Rokar Wildlife Sanctuary contains a diverse mosaic of habitats that support at least 28 threatened species on the IUCN Red List, including the Critically Endangered giant ibis *Thaumatibis gigantea* and white-shouldered ibis *Pseudibis davisoni*, two Critically Endangered tree species (*Aquilaria crassna* and *Dipterocarpus turbinatus*), and seven Endangered mammals (including pileated gibbon *Hylobates pileatus*, Eld's deer *Rucervus eldi* and banteng *Bos javanicus*) (Wildlife Conservation Society, unpublished data).

4. Prey Siem Pang Khang Lech Wildlife Sanctuary (65,389 ha; RGC sub-decree 76, 2016) connects Siem Pang Wildlife Sanctuary with Virachey National Park and Veun Sai National Park in Cambodia, Xe Pian National Protected Area in Laos and Chu Mom Ray National Park in Vietnam. Covering 483,942 ha, this is one of the largest protected landscapes in Indochina and a candidate for World Heritage Site nomination. BirdLife International supported MAFF to manage the adjacent Siem Pang Wildlife Sanctuary and worked for many years to secure the designation of Prey Siem Pang Khang Lech as a protected area. The deciduous dipterocarp and semi-evergreen forests of the new wildlife sanctuary support breeding populations of five Critically Endangered bird species (BirdLife International, 2012). These comprise 10% of the global giant ibis population, up to 50% of the global white-shouldered ibis population and red-headed vultures *Sacrogyaps calvus*, white-rumped vultures *Gyps bengalensis* and slender-billed vultures *Gyps tenuirostris* (BirdLife International, 2012; Loveridge & Ty, 2015; Hurrell, 2016). The site also supports populations of two Endangered bird species (green peafowl *Pavo muticus* and greater adjutant *Leptoptilus dubius*) and five endangered mammal species: Eld's deer *Rucervus eldi siamensis*, Indochinese silvered langur *Trachypithecus germaini*, red-shanked douc langur *Pygathrix nemaeus*, banteng and dhole *Cuon alpinus* (BirdLife International, 2012; Cox, 2016; Hurrell, 2016).

5. Veun Sai-Siem Pang National Park (55,000 ha; RGC sub-decree 77, 2016) comprises tall evergreen, semi-evergreen, deciduous and dry dipterocarp forests, natural grasslands and marshes. Connected to the much larger Virachey National Park, Veun Sai-Siem Pang was previously managed by MAFF with support from Conservation International and it was anticipated that the site would be designated as a protected forest. Veun Sai-Siem Pang is most notable for its population of northern yellow-cheeked crested gibbon *Nomascus annamensis*. Only described in 2010 (Thinh *et al.*, 2010), the species has yet to be assessed in the IUCN Red List, but because Veun Sai-Siem Pang supports approximately 500 groups (Rawson *et al.*, 2011), the site is likely to be important for its conservation.

The MoE now has an additional 2.6 million ha of land to manage, an almost 80% increase on its responsibilities at the beginning of 2016. However, there are no indications that it has received additional funding as yet. This represents a significant challenge to an already under-resourced ministry, considering that almost a third of the 156,000 ha of the forest cover that Cambodia lost in 2014 occurred within protected areas (Peter, 2015). Areas with a strong international NGO presence receive support for

patrolling and law enforcement, the costs of which range from 500,000–1,000,000 USD per area every year. Such funds are becoming harder to secure as donors increasingly consider the RGC to be responsible for law enforcement. The MoE, the Prime Minister, and other RGC Ministries are considering additional allocations from the central budget, the potential for taxes such as a tourism tax, supporting trust funds, REDD and other sustainable financing options for protected areas. However, based on regional experience, we do not recommend wildlife farming as a sustainable financing option, given the potential for extremely negative impacts on biodiversity (Brooks *et al.*, 2010, Livingstone & Shepherd, 2016).

The changes made by the RGC in early 2016 have increased coverage of the national protected area system to 34% of the Cambodian land surface (6,038,275 ha of protected areas vs. 17,651,500 ha national land surface; Central Intelligence Agency, 2016; Open Development Cambodia, 2016b) and placed their management under a single ministry, the MoE. These decisions can help direct resources and technical support towards areas of high biodiversity and promote other natural values and services such as clean water and carbon sequestration. As the protected area system remains severely underfunded, however, the RGC will need to commit the necessary resources if these encouraging developments are to translate into effective conservation, rather than the addition of more ‘paper parks’.

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News

36th Youth Debate presented by Save Cambodia's Wildlife (SCW)

Over 120 students joined the 36th Cambodian Youth Debate on 28 April in Phnom Penh, which was broadcast by TVK in May 2016. The event was sponsored by SCW in cooperation with Welthungerhilfe and organized by the Ministry of Environment. The famous singer songwriter Meas Soksopeha attended the debate as a guest judge and inspired participants with her commitment to the environment: "We don't have to wait for the future – everyone can act now to help save our environment. Thank you for today students".

The first round of the event debated the statement "Community-based natural resource management (NRM) is more effective than government-based NRM". Students from the Cambodian Mekong University argued for this and highlighted the strong interest of indigenous people in protecting their livelihood and cultural heritage. However, the student team from the Royal University of Law and Economics won the round by effectively arguing for government legislation and law enforcement.

The second round debated the statement "Livelihoods of indigenous people, which rely exclusively on non-timber forest products (NTFPs), are not sustainable". The main argument for this by the Royal University of Phnom Penh students was that NTFP use is unsustainable because their availability depends on climate and seasonality. However, arguments based on the growing economy for NTFPs such as rattan and bamboo by students from the Royal University of Agriculture convinced the judges otherwise.

The third round of the event debated the statement "Environmental education is more effective than laws to improve the waste situation in Cambodia". Students from the Royal University of Law and Economics argued against this by suggesting legislation and law enforcement are essential for change to occur in Cambodia. However, the Royal University of Agriculture student team won the round by arguing that education is a more sustainable and long-term way of changing behaviour.

Prizes were awarded to the top three teams: 1) Royal University of Law and Economics, 2) Royal University of Agriculture, and 3) Royal University of Phnom Penh.

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Investigating the risk of human disease from parasites of small mammals and bats

Emerging and re-emerging infectious diseases pose a significant public health challenge globally, with severe economic, social, and health consequences. It is estimated that the SARS outbreak alone cost over \$50 billion dollars in lost global economic activity. The frequency of epidemics caused by newly emerging and re-emerging pathogens and the likelihood of rapid global spread have increased dramatically in recent decades, with Southeast Asia considered a hot spot for future emergence events. Small mammals and bats play an important role in the maintenance and transmission of parasites that infect humans such as arenaviruses, coronaviruses, henipaviruses, rickettsial diseases, and tick-borne flaviviruses. The global distribution of several species of small mammals and bats, in addition to the ever-increasing interface between humans and wildlife, ensures that cross-species transmission events will continue to occur.

A kick-off meeting for a research project titled "Investigating the risk of human disease from parasites of small mammals and bats" was held recently in Phnom Penh. The project is supported by the Cooperative Biological Engagement Program of the United States Defense Threat Reduction Agency and will involve researchers from the Programme for Emerging Infectious Diseases, Duke–National University of Singapore Medical School, Singapore; the Department of Wildlife and Biodiversity, Forestry Administration, Cambodia; the National Veterinary Research Institute, Department of Animal Health and Production, Cambodia; the Naval Medical Research Center—Asia; the University of California—Davis; Fauna & Flora International; and the Commonwealth Scientific and Industrial Research Organization, Australia. The project will investigate the role of small mammals and bats as reservoirs for infectious agents with the ability to transmit to, and cause disease in, humans. Animal groups will be sampled across Cambodia to determine their presence and absence, in addition to their corresponding parasites. Our objective is to create a predictive map of high risk areas for cross-species transmission to inform future surveillance efforts.

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Short Communication

New records of Orchidaceae from Cambodia II

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In Schuiteman *et al.* (2015) we pointed out that the orchid flora of Cambodia is still inadequately known, implying that new records are to be expected as a result of increased exploration. Since then we have made another field trip, in April 2015, visiting the vicinity of Sen Monorom in Monduliri Province as well as, briefly, Bokor National Park in Kampot Province. The new records below also include some from our November 2013 trip to the southern Cardamom Mountains in Koh Kong Province.

As usual, only a small percentage of the orchid species seen in the field were found in flower. Of the 12 species reported below, only three were flowering during one of our trips (*Anoectochilus lylei*, *Eulophia flava*, and *Zeuxine nervosa*). Without taking the others into cultivation to observe them in flower, it would not have been possible to fully identify these. So far, two species new to science have turned up in our collections: *Nervilia mekongensis* S.W. Gale, Schuit. & Suddee (Gale *et al.*, 2016; Fig. 1), also known from all three neighbouring countries (the type is from Thailand); and *Porpax verrucosa* Schuit. (Schuiteman, 2016), apparently endemic to Cambodia. The following are new generic records for Cambodia: *Anoectochilus*, *Brachypeza*, *Nervilia* and *Porpax*.

In the interests of conservation we do not provide exact localities. Global distribution data follow Govaerts *et al.* (2016), unless indicated otherwise. Vouchers of all specimens mentioned are kept in the Kew spirit collection.

Species recorded

Anoectochilus lylei Rolfe ex Downie (Kew cult. 2013-1724; Figs 2–4)

This is one of the so-called jewel orchids, so named for their attractive foliage. The species of the genus *Anoectochilus* are highly in demand for traditional Chinese medicine; as a result they are unsustainably collected throughout Southeast Asia and China. The present species was found in flower in the Cardamom Mountains, growing in leaf litter in evergreen lower montane forest at 665 m asl (above sea level). It is recorded from Myanmar, Thailand, China (Yunnan) and Vietnam.

Arachnis labrosa (Lindl. & Paxton) Rchb.f. (Kew cult. 2013-1671; Fig. 5)

This species is known from all three neighbouring countries, therefore its occurrence in Cambodia is not unexpected. We found it in the foothills of the Cardamom Mountains as an epiphyte in disturbed primary evergreen forest on a ridge at 430 m asl. It is mainly a continental Asian species, distributed from Northeast India, Bhutan, Myanmar, Thailand, China, Laos (Schuiteman *et al.*, 2008), Vietnam and Taiwan to the Ryukyu Islands.

Brachypeza laotica (Seidenf.) Seidenf. (Kew cult. 2015-1144 & 2015-1282; Figs 6 & 7)

This species, with its *Phalaenopsis*-like habit, was found as an epiphyte on tree trunks in disturbed, evergreen dipterocarp forest within the Seima Wildlife Sanctuary

CITATION: Schuiteman, A., Ryan, C., Nut M., Nay S. & Att S. (2016) New records of Orchidaceae from Cambodia II. *Cambodian Journal of Natural History*, 2016, 7–14.



Fig. 1 *Nervilia mekongensis* S.W.Gale, Schuit. & Suddee. Flowers, photographed near Sen Monorom.



Fig. 2 *Anoectochilus lylei* Rolfe ex Downie. In situ, Caradammom Mountains.



Fig. 3 *Anoectochilus lylei* Rolfe ex Downie. Inflorescence. Kew cult. 2013-1724.



Fig. 4 *Anoectochilus lylei* Rolfe ex Downie. Leaf. Kew cult. 2013-1724.



Fig. 5 *Arachnis labrosa* (Lindl. & Paxton) Rchb.f. Flower. Kew cult. 2013-1671.



Fig. 6 *Brachypeza laotica* (Seidenf.) Seidenf. In situ, Seima Wildlife Sanctuary.



Fig. 7 *Brachypeza laotica* (Seidenf.) Seidenf. Inflorescence. Kew cult. 2015-1282.



Fig. 8 *Bulbophyllum lemniscatoides* Rolfe. Inflorescence. Kew cult. 2015-1288.



Fig. 9 *Bulbophyllum tridentatum* Kraenzl. Inflorescence. Kew cult. 2013-1746.



Fig. 10 *Coelogyne quadratiloba* Gagnep. Inflorescence. Kew cult. 2013-1689.



Fig. 11 *Dendrobium lagarum* Seidenf. Inflorescence. Kew cult. 2015-1155.



Fig. 13 *Eulophia flava* (Lindl.) Hook.f. In situ, near Sen Monorom.



Fig. 12 *Dendrobium stuposum* Lindl. Inflorescence. Kew cult. 2013-1747.



Fig. 14 *Eulophia flava* (Lindl.) Hook.f. In situ, Seima Wildlife Sanctuary.



Fig. 15 *Grosourdyia appendiculata* (Blume) Rchb.f. In situ, Cardamom Mountains.



Fig. 17 *Smitinandia helferi* (Hook.f.) Garay. Flowering plant. Kew cult. 2013-1590.



Fig. 16 *Grosourdyia appendiculata* (Blume) Rchb.f. Flowers. Kew cult. 2013-1585.



Fig. 18 *Smitinandia helferi* (Hook.f.) Garay. Inflorescence. Kew cult. 2013-1590.

southeast of Sen Monorom, Mondulhiri Province, at 340 m asl, and also in a remnant of evergreen forest near a waterfall south of Sen Monorom at 640 m asl. *Brachyepiza laotica* is also known from Thailand, Laos and Vietnam.

***Bulbophyllum lemniscatoides* Rolfe (Kew cult. 2015-1288; Fig. 8)**

This bizarre little orchid, noteworthy for the three rod-shaped, mobile appendages of the sepals, belongs to the section *Lemniscata*, which is a mainly continental Asian group with annually deciduous foliage. We found it growing on the lichen-covered trunks of thin trees on the edge of an evergreen forest remnant near a waterfall south of Sen Monorom at 640 m asl. This species is also recorded from Thailand, Laos (Schuiteman *et al.*, 2008), Vietnam, Peninsular Malaysia, Sumatra, Java, Borneo, and the Philippines (Cootes, 2011).

***Bulbophyllum tridentatum* Kraenzl. (Kew cult. 2013-1746; Fig. 9)**

Our specimen agrees well with the illustrations provided by Seidenfaden (1979), in part made after the type material. This species was only known from the Thai island of Koh Chang, which is close to South Cambodia, until it was recorded from Arunachal Pradesh (Rao, 2008). We found it in the foothills of the Cardamom Mountains as an epiphyte in disturbed evergreen, primary forest, at 390 m asl.

***Coelogyne quadratiloba* Gagnep. (Kew cult. 2013-1689; Fig. 10)**

This species was found as an epiphyte in the Cardamom Mountains, growing in rather dry primary montane forest with little undergrowth at 895 m asl. It was previously known from Thailand, Vietnam and the Andaman Islands.

***Dendrobium lagarum* Seidenf. (Kew cult. 2015-1155; Fig. 11)**

This terete-leaved species was found as an epiphyte in semi-deciduous, open forest near Sen Monorom, at 595 m asl. It was previously recorded from Thailand, Laos, Vietnam and China (Hainan).

***Dendrobium stuposum* Lindl. (Kew cult. 2013-1747; Fig. 12)**

This is another widespread species of which the occurrence in Cambodia was to be expected. We found it in disturbed, primary, evergreen hill forest in the Cardamom Mountains at 390 m asl. It was previously recorded from Northeast India, Bhutan, Myanmar, Thailand, Laos, China, Peninsular Malaysia, Sumatra, Java, Borneo, Lesser Sunda Islands and Sulawesi.



Fig. 19 *Zeuxine nervosa* (Wall. ex Lindl.) Benth. ex Trimen. In situ, Cardamom Mountains.



Fig. 20 *Zeuxine nervosa* (Wall. ex Lindl.) Benth. ex Trimen. Flowers. Kew cult. 2013-1674.

***Eulophia flava* (Lindl.) Hook.f. (Kew cult. 2015-1153 & 2015-1156; Figs 13–14)**

This species must be one of the most conspicuous orchids in Cambodia. The tall inflorescences carry large (6 cm diameter), bright yellow flowers that can be seen from far away. That such a striking plant had not been recorded until now demonstrates again how poorly studied the orchid flora of Cambodia really is. It is a terrestrial species that flowers in April from a large underground corm before the leaves are formed. We encountered it in the Seima Wildlife Sanctuary in open, evergreen dipterocarp forest close to a river at 340 m asl, and also near Sen Monorom in semi-deciduous forest at 595 m asl. It is a widespread but apparently uncommon species, restricted to continental Asia, from Northeast India, through Nepal, Myanmar, China, Thailand and Laos to Vietnam.

***Grosourdya appendiculata* (Blume) Rchb.f. (Kew cult. 2013-1584, 2013-1585 & 2013-1650; Figs 15 & 16)**

This small epiphyte is probably common in the Cardamom Mountains. We found it a few times at elevations of 430–470 m asl on fallen twigs, and once saw a substantial colony on a slender, mossy tree trunk. It was previously recorded from Myanmar, China, Thailand, Vietnam, Sumatra, Java, Borneo, Sulawesi and the Philippines.

***Smitinandia helferi* (Hook.f.) Garay (Kew cult. 2013-1588 & 2013-1590; Figs 17 & 18)**

Like the genera *Arachnis*, *Brachypeza* and *Grosourdya* mentioned above, this is a monopodial orchid, and another widespread species of which the occurrence in Cambodia was predictable. We found it as an epiphyte in secondary forest in the Cardamom Mountains, at 470 m asl. It was previously known from Myanmar, Thailand, Laos, Vietnam, Peninsular Malaysia and the Andaman islands.

***Zeuxine nervosa* (Wall. ex Lindl.) Benth. ex Trimen (Kew cult. 2013-1674; Figs 19 & 20)**

Without flowers, this species is quite similar to *Vrydagzynea albida*, which we recorded in the previous paper of this series (Schuiteman *et al.*, 2015). Both species have leaves with a broad, silvery grey, longitudinal band. However, *Zeuxine nervosa* grows in drier but well-shaded places, for example on top of flat rocks in evergreen forest. The specimen illustrated occurred at 430 m asl in the Cardamom Mountains. This very widely distributed orchid is also known from Sri Lanka, Northeast India, Nepal, Bhutan, Bangladesh, Andaman Islands, Myanmar, Thai-

land, Laos, Vietnam, China, Ryukyu Islands, Taiwan, the Philippines and New Guinea.

Conclusions

Almost all the species here recorded, except for *Bulbophyllum tridentatum* and *Dendrobium stuposum*, were known to occur in both Thailand and Vietnam. It is not unreasonable to predict that the majority of the lowland orchids that occur in both countries will eventually be found in Cambodia. Since the highest mountain in Cambodia reaches only about 1,800 m elevation, and with relatively little land lying above 1,000 m, it seems likely that the diversity of mountain orchids is much lower in Cambodia than in the neighbouring countries. Therefore we cannot simply assume that every orchid species that has been recorded from all three countries, Thailand, Laos and Vietnam, will probably occur in Cambodia. There is no substitute for continued exploration.

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Short Communication

New records of *Xanthophyllum ellipticum* and *X. obscurum* (Polygalaceae) in Indochina, with an identification key to species in the region

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Xanthophyllum Roxb. (Polygalaceae), comprising ca. 95 species, is a woody genus widely distributed in South-east Asia, extending to South India and Sri Lanka in the west and to North Queensland and the Solomon Islands in the east (Meijden, 1982; Pendry, 2001, 2014; Chen *et al.*, 2008). The largest number of species are found in tropical rain forest below 500 m asl (above sea level), usually in low densities, but some species occur in submontane rain forest up to 1,500 m asl (e.g., *X. monticolum* Meijden, *X. punctatum* Meijden), monsoon forest (*X. virens* Roxb.) and fresh water swamp forest (e.g., *X. ramiflorum*) (Meijden, 1982, 1988; Pendry, 2014). The species are characterized by at least two axillary buds per leaf axil (but seemingly single in some species), glands on the lower surface of lamina, five free petals and globose fruits (Meijden, 1982; Pendry, 2014).

Species of *Xanthophyllum* in Cambodia and Vietnam were reported by Gagnepain (1909, 1939), Meijden (1982), Dy Phon (2000), Ho (2003), and in the most recent account, Pendry (2014) enumerated five and 10 species, respectively (along with eight species for Laos), all of which belong to subgenus *Xanthophyllum*.

During botanical inventories in Bokor National Park, Kampot Province, southern Cambodia and Hon Ba Nature Reserve, Khanh Hoa Province, southern Vietnam from 2011–2015 (Fig. 1), we collected two unrecorded species of *Xanthophyllum* in the two countries in Indochina. These are *X. ellipticum* Korth. ex Miq. and *X. obscurum* A.W. Benn., belonging to the subgenus *Brunophyllum* Meijden and *Triadelphum* Meijden, respectively, both of which are known from West to East Malesiana with the northern limit in Peninsular Thailand (Meijden, 1982; Pendry, 2001). Here, we report the two new records, *X. ellipticum* for Cambodia and *X. obscurum* for Vietnam based on our newly collected materials. A key to *Xanthophyllum* species in Cambodia, Laos and Vietnam is also provided.

Voucher specimens are deposited in the Herbarium of the Forest Administration of Cambodia (hereafter PNP), the Herbarium of the Museum of Kyushu University (hereafter FU), the herbarium of Hon Ba Nature Reserve (hereafter Honb) and the Institute of Tropical Biology (hereafter VNM). In the accounts below, the herbarium codes follow the Index Herbariorum (Thiers, continuously updated) and we use an exclamation mark (!) to signify specimens that were examined by ourselves.

CITATION: Tagane, S., Toyama, H., Chhang P., Dang V.S. & Yahara, T. (2016) New records of *Xanthophyllum ellipticum* and *X. obscurum* (Polygalaceae) in Indochina, with an identification key to species in the region. *Cambodian Journal of Natural History*, 2016, 15–19.

Xanthophyllum ellipticum Korth. ex Miq., Ann. Mus. Bot. Lugduno-Batavi 1: 276 (1864); Ng, Tr. Fl. Malaya 1: 357 (1972); Meijden, Systematics and Evolution of *Xanthophyllum* (Polygalaceae): 135 (1982); Meijden, Fl. Males., Ser. 1, Spermat. 10: 530 (1988); Pendry, Fl. Thailand 7: 526 (2001). Type: INDONESIA, *Korthals s.n.* (lectotype L, L0016652, a digital image examined on the web; isoelectotypes G, L, U, S) (Fig. 2a–d).

Specimens from Cambodia: Kampot Province, Bokor National Park [at margins of dense evergreen forest on the plateau of Mt Bokor, 10°39'19.53" N, 104°03'36.61" E, 928 m asl, 9 May 2012, Toyama *et al.* 2769 (FU, PNP); *ibidem*, 8 August 2013, with fruits, Tagane *et al.* 5771 (BKF, KYO, P, PNP, RUPP)].

Distribution: Cambodia (new record), Indonesia, Malaysia, Singapore and Peninsular Thailand.

Habitat and ecology: *Xanthophyllum ellipticum* is scattered in tropical lower montane forest on the top plateau of Mount Bokor. Fruiting specimens were collected in August.

GenBank accession no.: Tagane *et al.* 2769: LC151411 (*rbcL*), LC151410 (*matK*).

Remarks: The fruit size of our materials, ca. 1.2 cm in diameter, is smaller than those of *X. ellipticum* previously known from West Malesiana (1.5–2.2 cm in diameter in Meijden, 1982), but the other characters are highly matched with typical *X. ellipticum*.

Xanthophyllum obscurum A.W. Benn., Fl. Brit. India [J. D. Hooker] 1(2): 211 (1874); Ng, Tr. Fl. Malaya 1: 361 (1972); Meijden, Systematics and Evolution of *Xanthophyllum* (Polygalaceae): 145 (1982); Meijden, Fl. Males., Ser. 1, Spermat. 10: 536 (1988). Type: SINGAPORE, *Maingay 144* (=3115) (holotype K!) (Fig. 2e–i).

Specimens from Vietnam: Khanh Hoa Province, Hon Ba Nature Reserve [on slope in evergreen forest, 12°06'39.77" N, 108°58'59.23" E, 617 m asl, 22 February 2014, Toyama *et al.* V1148 (FU, Honb, VNM); *ibidem*, 23 February 2014,

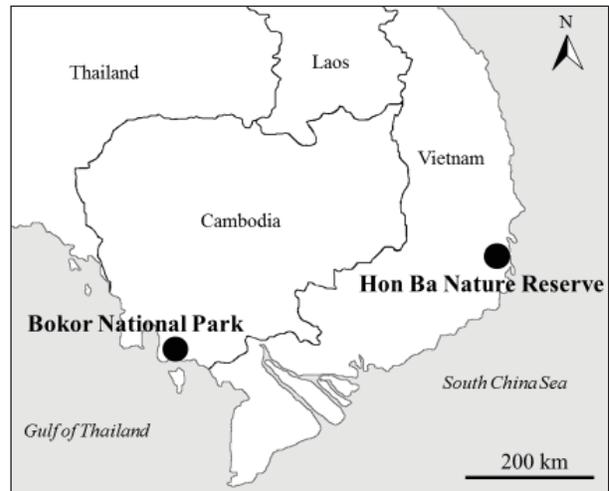


Fig. 1 Location of Bokor National Park in Cambodia and Hon Ba Nature Reserve in Vietnam.

Toyama *et al.* V1229 (FU, Honb, VNM); in evergreen forest near stream, 12°06'31.2"N, 108°59'14.1"E, 400 m asl, 12 July 2014, Tagane *et al.* V1501 (FU, Honb, VNM); 12°06'34.0" N, 108°59'12.6" E, 401 m asl, 14 July 2014, with fruits, Tagane *et al.* V1622 (BKF, FU, Honb, KYO, P, VNM)].

Distribution: Indonesia (Kalimantan, Sumatra), Malaysia (peninsula, Sabah, Sarawak), Singapore, Peninsular Thailand and Vietnam (new record).

Habitat and ecology: *Xanthophyllum obscurum* is occasional in lowland evergreen forest from ca. 400 to 620 m asl in Hon Ba Nature Reserve. Fruiting specimens were collected in July.

GenBank accession no.: Toyama *et al.* V1148: LC151412 (*rbcL*); Toyama *et al.* V1229: LC151413 (*rbcL*).

Remarks: *Xanthophyllum obscurum* is easily distinguished from the other species of the genus in Indochina by its tall height (taller than 20 m, up to 50 m in southern Thailand (Pendry, 2001), large fruits (8–10 cm in diameter) and thickly coriaceous, oblong leaves.

Key to the species of *Xanthophyllum* in Cambodia, Laos and Vietnam [modified from Meijden (1982) & Pendry (2014)]

1. Tertiary nerves scalariform, or finely reticulate when dry, areolae 1 × 1 mm² or smaller (Subgenus *Xanthophyllum*).
 2. Tertiary venation scalariform (Section *Xanthophyllum*).
 3. Leaves glabrous below
 - 3'. Leaves patently hairy below.
 4. Petals up to 11 mm long. Inflorescence with distinct nodal glands. Leaf base cordate
 - 4'. Petals up to 9 mm long. Inflorescence without nodal glands. Leaf base rounded or cuneate
 1. *X. flavescens*
 2. *X. eberhardtii*
 3. *X. annamense*
 2. Tertiary venation reticulate (Section *Eysanthes*).
 5. Leaves glaucous papillose below.



6. Ovules 8–9
 6'. Ovules 4.
 7. Ovary glabrous or sparsely hairy towards apex
 7'. Ovary densely hairy.
 8. Axillary buds in axil, sessile.
 9. Leaves (11–)18–25 cm. Petiole > 2 mm diameter. Secondary veins (8–)9–11
 9'. Leaves 3–18 cm. Petiole up to 2 mm diameter. Secondary veins 4–9.
 10. Petiole 3–7 mm. Buds 0.8–1.5 mm
 10'. Petiole 8–15 mm. Buds 2–4 mm.
 11. Petals 8–10 mm. Anthers 0.6–0.7 mm. Secondary veins (4–)6–9
 11'. Petals 6.5–8 mm. Anthers 0.4 mm. Secondary veins 5–6(–9)
 8'. Axillary buds 1–6 mm above axil, occasionally shortly stipitate.
 12. Buds hairy.
 13. Petals 9–14 mm. Inflorescence shorter than the leaves. Montane forest
 13'. Petals 6.5–9 mm. Inflorescence longer than the leaves. Lowland streamsides and marshes
 12'. Buds glabrous.
 14. Petals 5–8 mm. Outside of lateral petals glabrous at apex. Leaves often with irregular margin
 14'. Petals 9–14 mm. Outside of lateral petals hairy at apex. Leaves with regular margin
 5'. Leaves smooth below.
 15. Upper surface of midrib completely sunken or flat with central groove
 15'. Upper surface of midrib slightly prominent, with or without grooves.
 16. Uppermost buds 2–15 mm above axil
 16'. Uppermost buds < 1.5 mm above axil.
 17. Buds 2–5 mm
 17'. Buds < 1.5 mm.
 18. Ovary glabrous. Leaves 3–8 cm with a long acuminate tip
 18'. Ovary hairy. Leaves 5–15 cm, apex acute or acuminate.
 19. Petals pink, drying dark red. Nodes without appendages. Secondary veins 5–7, scarcely more prominent than the tertiary veins
 19'. Petals white, drying yellow-orange. Nodes with 0.2 mm diameter appendages. Secondary veins 7–9, more prominent than the tertiary veins
 1'. Tertiary nerves coarsely reticulate when dry, areolae usually not smaller than $2 \times 2 \text{ mm}^2$.
 20. Leaves elliptic, $4.7\text{--}7 \times 1.7\text{--}3.2 \text{ cm}$. Fruits ca. 1.2 cm in diameter, 1-seeded
 20'. Leaves oblong, $(6\text{--})7.6\text{--}12(20) \times (2.1\text{--})3.6\text{--}5.5 \text{ cm}$. Fruits > 8 cm in diameter, more than 8-seeded
4. *X. bibracteatum*
 5. *X. geminatum*
 6. *X. cochinchinense*
 7. *X. lanceatum*
 8. *X. gesinkii*
 9. *X. griffithii*
 10. *X. punctatum*
 7. *X. lanceatum*
 11. *X. virens*
 10. *X. punctatum*
 12. *X. sylvestre*
 11. *X. virens*
 9. *X. griffithii*
 13. *X. poilanei*
 14. *X. colubrinum*
 12. *X. sylvestre*
 15. *X. ellipticum*
 (Subgenus *Triadelphum*)
 16. *X. obscurum*
 (Subgenus *Brunophyllum*)

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Fig. 2 (previous page) *Xanthophyllym ellipticum* Korth. ex Miq. (A–D, 8 August 2013) and *Xanthophyllum obscurum* A. W. Benn. (E–I, 14 July 2014). A) fruiting branch; B) abaxial leaf surface; C) fruits; D) transverse section of fruit; E) Leafy branch; F) portion of abaxial surface of young leaf; G) trunk; H) fruiting branch; I) section of fruits (© Shuichiro Tagane).

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Short Communication

Range extension of *Cyclemys atripons* Iverson & McCord 1997 with the discovery of a population in Oddar Meanchey Province, northwestern CambodiaPeter BRAKELS^{1,*}, CHEA Samban² & Caleb JONES³¹ Lucíastraat 7, 5821CL Vierlingsbeek, The Netherlands.² Banteay Srey Butterfly Centre, Banteay Srey, Siem Reap, Cambodia.³ Hafod Olchon, Llanvaynnoe, Herefordshire, HR2 ONH, UK.

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During wildlife surveys conducted in July 2014 by the Angkor Centre for Conservation of Biodiversity in collaboration with the Forestry Administration's Department of Wildlife and Biodiversity, remains of what are thought to be six or seven western black-bridged leaf turtles *Cyclemys atripons* were found in a Royal Cambodian Army camp in the Dangrek Mountains of Oddar Meanchey Province, northwestern Cambodia. The turtles were collected from a nearby pond in evergreen forest at an altitude of 275 m asl (above sea level) within the community forest of Rolous Thom, Kriel Commune, Krong Samraong District (14°24' N, 103°32' E) (Fig. 1). The turtles were located using a dog and collected for consumption according to a soldier interviewed from the army camp. The remains were said to date from between a few days to a few months old and were discarded at the site after photographs were taken. Although no measurements were taken, it is thought that the remains consisted of two fully grown adults, three large sized sub-adults, one medium sized sub-adult and one small sub-adult or juvenile (Figs 2a & 2b), considering that carapace length of adults and sub-adults is >11 cm (Iverson & McCord, 1997).

Based on these photographs the shells were provisionally identified as *C. atripons* (U. Fritz, pers. comm. 2014), although it is difficult to distinguish between this and the eastern black-bridged leaf turtle *C. pulchristriata* Fritz, Gaulke & Lehr 1997 by means of morphological

characters (Fritz *et al.*, 2001, but see Auer *et al.*, 2012). Nevertheless, both species show distinct geographical distributions, with *C. pulchristriata* being confined to central and southern Vietnam, and within Cambodia, to the east of the Mekong River (Fritz *et al.*, 2008; van Dijk *et al.*, 2014). The specimens described herein were found within the known range of the Southeast Asian leaf turtle *C. oldhamii* Gray, 1863, a species that occurs over a much larger area, from northern Cambodia, to northern and central Vietnam, Laos, central and southern Myanmar (Burma), central and northern Thailand and perhaps neighbouring southern China (Fritz *et al.*, 2008; van Dijk *et al.*, 2014). A known population of *C. oldhamii* can be found approximately 90 km to the southeast of the recently discovered *C. atripons* population within Phnom Kulen National Park, Siem Reap Province (Durkin *et al.*, 2010, wherein *C. aff. atripons* is actually *C. oldhamii*; Durkin, 2012). *Cyclemys oldhamii* has also been reported from Prey Lang and Virachey National Park in central and northeastern Cambodia respectively (Stuart *et al.*, 2010; Hayes *et al.*, 2015).

There can be no confusion between the two species (Auer *et al.*, 2012). The *Cyclemys* species complex is divided into two morphologically distinct subgroups: the yellow-bellied turtles and the dark-bellied turtles (Fritz *et al.*, 2008). *Cyclemys oldhamii* belongs to the dark-bellied subgroup (see Figs 2–3 in Durkin *et al.*, 2010) and *C. atripons* to the yellow-bellied subgroup (Fritz *et*

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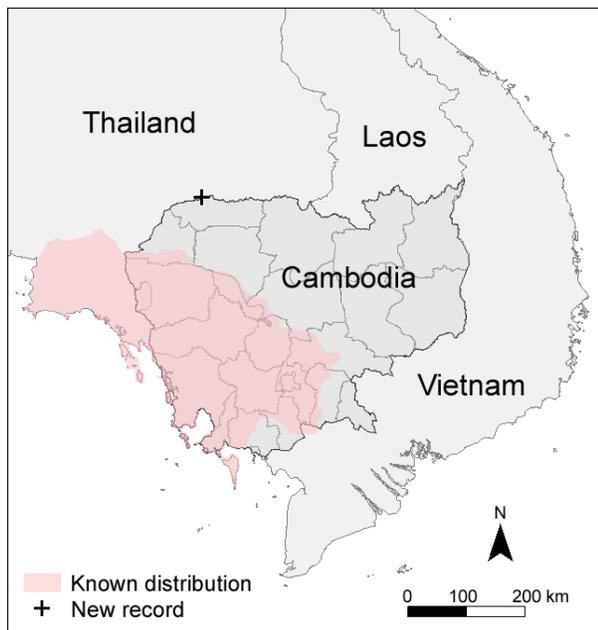


Fig. 1 Known distribution and new record of *Cyclemys atripons*. Distribution data from van Dijk *et al.* (2014).

al., 2008). It was thought that *C. atripons* only occurred in southeastern Thailand, the neighbouring region of southwestern Cambodia, and along the Gulf of Thailand to the border with Vietnam, making it a regional endemic (Daltry & Chheang, 2000; Stuart & Platt, 2004; Emmett & Olsson, 2005; Fritz *et al.*, 2008; van Dijk *et al.*, 2014) (Fig. 1). Although further investigations are needed to confirm the continued presence of *C. atripons* at this new location, the evidence provided here indicates the distribution of the species extends further north and covers a greater extent than previously estimated. Further survey effort is required in the northern provinces of Banteay Meanchey, Oddar Meanchey, Preah Vihear and the neighbouring region of Thailand to determine the limits of both *C. atripons* and *C. oldhamii* and possibly where their range overlaps. These provinces are overlooked with regards to biological surveys since this part of Cambodia was the last stronghold of the Khmer Rouge and are still plagued with unexploded ordinance which makes field work hazardous. Some of the community forests within the provinces were rapidly surveyed for the first time in 2010 (Elliot *et al.*, 2011) and more extensive surveys were later conducted throughout Oddar Meanchey Province (Jones *et al.*, 2014).

Evidence suggests the *C. atripons* population at Rolous Thom Community Forest may be seriously threatened by poaching and habitat loss. The community forest is split between low-lying plains originally domi-



Fig. 2 Remains of *Cyclemys atripons* found at army camp, Oddar Meanchey Province (© Peter Brakels).

nated by dry dipterocarp forest and upland areas to the north including the foothills of the Dangrek Mountain Range, covered in mixed and evergreen forest. Since the completion of a new road along the border in 2011, much of the low-lying area has been cleared and converted to agriculture. This is reportedly due to the activities of the military as well as in-migration of people from other provinces. To halt the ongoing loss of biodiversity and other valuable natural resources throughout this region of Cambodia, levels of protection for remaining forested areas need to be increased and properly enforced. Community protected forests and other unprotected forest areas in northwestern Cambodia are crucial for the survival of significant populations of Critically Endangered and Endangered species such as the giant ibis (*Thaumatibis gigantea*), green peafowl (*Pavo muticus*), banteng (*Bos*

javanicus), pileated gibbon (*Hylobates pileatus*) and Indo-chinese silvered langur (*Trachypithecus germaini*), among others (Jones et al., 2014).

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A report on the bees (Hymenoptera: Apoidea: Anthophila) of Cambodia

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មូលនិយមសង្ខេប

មុននឹងមានការសិក្សានេះ ការប្រមូលសំណាកសត្វឃុំត្រូវបានគេឃើញមាននៅកន្លែងស្រាវជ្រាវមួយចំនួនក្នុងប្រទេសកម្ពុជា ហើយឯកសារដ៏តិចតួចស្តីអំពីសត្វឃុំក៏មិនធ្លាប់ត្រូវបានពិនិត្យឡើងវិញដែរ។ របាយការណ៍ជាបឋមនេះបានប្រមូលផ្តុំទិន្នន័យដែលមានស្តីពី នានាភាពឃុំកម្ពុជា ដោយផ្អែកលើឯកសារកំណត់ត្រា សំណាកប្រមូលដោយក្រុមស្រាវជ្រាវសត្វឃុំតកម្ពុជា (Cambodian Entomology Initiatives) ជាមួយដៃគូសហការបរទេស និងទិន្នន័យរូបភាពប្រមូលបានដោយសារអ្នកវិទ្យាសាស្ត្រក្នុងស្រុក។ សរុបមានសត្វឃុំ៨២ប្រភេទ ស្ថិតក្នុង២៧ពួក និង៤អំបូរ ត្រូវបានធ្វើកំណត់ត្រាសម្រាប់ប្រទេសកម្ពុជា។ ពួកមួយចំនួន (ឧទាហរណ៍ *Hylaeus*, *Eupetersia* និង *Pseudoanthidium*) និងប្រភេទមួយភាគធំជាកំណត់ត្រាថ្មីសម្រាប់កម្ពុជា វាឆ្លុះបញ្ចាំងពីភាពមានកម្រិតនៃការប្រមូលសំណាក និងការសំយោគឯកសារក្នុងតំបន់។ ប្រភេទមួយចំនួនត្រូវបានគេគិតថាជាប្រភេទថ្មី រួមមានសំណាកនៃពួក *Nomia* (*Maculonomia*) និង *Anthidiellum* (*Ranthidiellum*) ដែលត្រូវបានរកឃើញក្នុងដំណើរការស្រាវជ្រាវក្នុងខែកុម្ភៈ ឆ្នាំ២០១៦ ក្នុងតំបន់ព្រៃការពារសីម៉ា។ ព័ត៌មានប្លែកៗស្តីពីជីវិតក្នុងធម្មជាតិក៏ត្រូវបានប្រទះនៅទីនោះ ដូចជាភាពអាចនឹងមានទំនាក់ទំនងរវាងជួរ *Lasioglossum* (*Homalictus*) និងបារ៉ាស៊ីត *Nomada* cleptoparasite។ រូបថតមួយចំនួនត្រូវបានបញ្ចូលដើម្បីបង្ហាញពីនានាភាពនៃសត្វឃុំដែលទើបតែស្គាល់។ ការបោះពុម្ពនេះធ្វើអត្ថាធិប្បាយសង្ខេបលើចំណែកថ្នាក់ និងរបាយប្រភេទក្នុងតំបន់ ព្រមទាំងកែតម្រូវកំហុសមួយចំនួនដែលមានក្នុងឯកសារបោះពុម្ពស្តីពីកំណត់ត្រាសត្វឃុំក្នុងប្រទេស។ នានាភាពនៃឃុំកម្ពុជាត្រូវបានពិភាក្សា និងប្រៀបធៀបជាមួយនឹងប្រទេសជិតខាងដូចជា ឡាវ ថៃ និងវៀតណាម។

Abstract

Prior to this study, few historical collections were made of bees in Cambodia and the sparse literature had never been reviewed. This preliminary report assembles available data on Cambodian bee diversity based on literature records, specimens collected recently by the Cambodian Entomology Initiatives team and foreign collaborators, and image databases assembled by resident citizen scientists. In total, 82 bee species and morphospecies in 27 genera and four families are recorded for the country. Some of the genera (e.g., *Hylaeus*, *Eupetersia* and *Pseudoanthidium*) and a large proportion of the species and morphospecies are new for the country, reflecting limited historical collecting and a lack

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of comprehensive regional revisions. Several species are believed to be new to science, including specimens of *Nomia* (*Maculonomia*) and *Anthidiellum* (*Ranthidiellum*) discovered on an expedition in February 2016 to Seima Wildlife Sanctuary. Novel life history information was also obtained there, including a probable host-parasite association between a tiny *Nomada* cleptoparasite and its presumed *Lasioglossum* (*Homalictus*) host. Photographs document some of the newly detected bee diversity. This paper briefly comments on the taxonomy and distribution of regional species and corrects some erroneous country records in the literature. Cambodian bee diversity is discussed and compared to the neighbouring countries of Laos, Thailand, and Vietnam.

Keywords

Biodiversity, biogeography, insect, pollinators, Southeast Asia.

Introduction

Bees (Apoidea: Anthophila) are important pollinators and play a crucial role in plant reproduction in natural and agricultural ecosystems. Their populations must be maintained to ensure food security and because bees are also of very great value as a source of honey and hive products (McNaughton & Sotha, 2009). In Cambodia in particular, bees provide a source of protein through consumption of their larvae. Although Cambodia is known to have high diversity in other taxa such as birds (Goes, 2013), knowledge of its bees other than the relatively well-studied highly eusocial hive bees (*Apini* and *Meliponini*) remains very limited and inaccessible. Documentation of the Southeast Asian bee fauna is generally poor, and many groups lack modern revisions. However, many species descriptions have been made from countries such as Thailand, Peninsular Malaysia, and Indonesia, and recent studies have improved knowledge of regional bee ecology and distribution (Kato *et al.*, 2008; Tadauchi and Tasen, 2009; see also references in Corlett *et al.*, 2004). Among Southeast Asian countries, Cambodia and Laos are the least well known because the relatively little melittological research that occurred in French Indochina seems to have been concentrated in Tonkin, now North Vietnam (e.g., Blüthgen, 1926). While the bees of Indochina received little attention in the past, some of the larger or otherwise more conspicuous bee species were described from elsewhere in Asia as long ago as the 18th century (Linnaeus, 1758; Drury, 1773; Fabricius, 1775, 1787, 1793) and the mid-19th century (e.g., Lepeletier de Saint Fargeau, 1841; Smith, 1853, 1857). Recent taxonomic studies on the Indochinese fauna have focused largely on stingless bees (Sakagami, 1975, 1978), whereas ecological studies have focused on plant-pollinator interactions rather than taxonomic diversity (e.g., Kato *et al.*, 2008, for the Vientiane Plain in Laos). The review of the conservation and management of pollinators for sustainable agriculture in Laos (Vandame, 2006 and references therein) is also relevant to Cambodia.

Documentation of the bee fauna of Thailand has been more extensive and includes a series of publications by T.D.A. Cockerell (e.g., 1929a,b,c) documenting the results of a collecting expedition during 1928–1929 when he, his wife W.P. Cockerell and A. Mackie collected type specimens of many new species some of which are recorded herein from Cambodia. More recently, a large-scale survey conducted from 2006–2009 by the Thailand Inventory Group for Entomological Research (TIGER, <http://sharkeylab.org/tiger/>) yielded large samples of bees from national parks across Thailand, many of which have been identified by specialists and sequenced for COI as a contribution to the global Bee Barcode of Life project led by L. Packer. Results of the TIGER project for apoid wasps are a major advance in knowledge of this group (Lohrmann *et al.*, 2012), with 22 new genera recorded for Thailand. Additional results now being compiled should also greatly advance knowledge of the regional bee fauna.

The few notable studies of bee diversity in Cambodia in the 20th century were mostly undertaken by Japanese researchers in the late 1950s. Professors T. Sato and T. Takayama, members of the 1957 Hyogo University of Agriculture Expedition to Cambodia, collected bees in Stung Treng Province and a few other places, as reported by Sakagami (1960). Soon after, Cambodia was included among destinations visited for collecting and biological studies by the Osaka City University Biological Expedition to Southeast Asia from November 1957 to March 1958 (Sakagami & Yoshikawa, 1961). Cambodian bees obtained by this expedition were evidently few overall, and Hirashima's (1962) report does not mention any, but Cambodian samples of stingless and other bees obtained in 1958 by K. Yoshikawa in Kampong Cham Province on 20 February and Oudong, Kampong Speu Province, on 28 February were included in Sakagami's (1978) review of *Tetragonula* stingless bees of continental Asia. A few Cambodian records for other bee taxa are also mentioned incidentally, without details, in extra-limital taxonomic publications (e.g., Matsumura & Sakagami, 1971).

Reflecting a lack of historical studies of bees in Cambodia, no currently valid species was described from Cambodia until Pauly (2009) described three Nomiinae species from Siem Reap Province (localities are included in Fig. 1, and nomiine and other bees are illustrated in Fig. 2) in a revision of Oriental Nomiinae: *Lipotriches* (*Macronomia*) *angkorensis* (Pauly) from Angkor, Preah (as “Preadh”) Khan Temple; and two species from Angkor (as “Angor”) Thom: *Lipotriches* (*Maynenomia*) *indochinensis* (Pauly) and *Nomia* (*Gnathonomia*) *cambodiana* (Pauly). The latter taxon is the only bee species currently considered to be endemic to Cambodia, as the other two nomiines with Cambodian type localities are more widely distributed (Appendix 1). The three holotypes from Cambodia are held in the Institut Royal des Sciences Naturelles de Belgique (IRSNB), where additional Cambodian material can be found (A. Pauly, pers. comm.). All three were collected between June to December 2003: *L. angkorensis* by F. Goes and the other two by D.R. Jump.

While this paper was in the proof stage we learned of an accepted manuscript on the diversity of stingless bees in Cambodia and Laos (Lee *et al.*, 2016, accepted version). This provided occurrence records and behavioural data for Cambodian species, but the accepted version available online was found to have a large number of errors. On examination of the figures provided, reports of new species for the country proved to be misidentifications, but we were fortunately able to confer with the authors to ensure these problems were addressed. Putative new country records for Cambodia, including erroneous reports of *Pariotrigona pendleburyi* (Schwarz) and *Tetragonula sirindhornae* (Michener and Boongird, 2004) were reported in a poster abstract (Duwal & Lee, 2014) and images of nest entrances reported by Lee *et al.* (2016) should also be interpreted with caution as some are inconsistent with verified nests of the taxa in question.

A milestone in the development of entomological capacity in Cambodia has been the establishment of the Cambodian Entomology Initiatives (CEI) based at the Royal University Phnom Penh (RUPP). Goals of this multi-faceted initiative include establishment of the first national entomology collection, field expeditions to document the Cambodian fauna, training of the first generation of Cambodian entomology students and public outreach. The initial taxonomic focus has been on crop pests in the Hemiptera, especially Homoptera such as leafhoppers (Cicadellidae), treehoppers (Membracidae) and allies. Since 2013, efforts have also been made to document beneficial insects including bee pollinators and wasp predators and parasitoids. The first CEI field trips to focus on Hymenoptera have already yielded

several new species for the country and have discovered potential new taxa for science which we report below.

Methods

This study consists of a summary of records compiled from the following sources: 1) the sparse literature on bees pertinent to Cambodia (summarized above), with emphasis on taxonomic and distributional studies of non-*Apis* species; 2) bee samples collected to date by the CEI team and studied by JSA during visits to RUPP; 3) bee images taken by SDG, GC and other photographers resident in Cambodia and identified by JSA; 4) preliminary results of a CEI–National University of Singapore (NUS) collecting expedition to Monduliri Province in February 2016; 5) specimens of Indochinese bees sent to JSA for study from two Austrian collections (Oberösterreichisches Landesmuseum in Linz and the private collection of Maximilian Schwarz); and 6) a limited number of additional records gleaned from publicly available databases.

The first Hymenoptera collecting expedition to Seima Wildlife Sanctuary (WS) in Monduliri Province (Fig. 1) was conducted in February 2016 by the CEI team from RUPP led by PS, a team of NUS bee researchers led by JSA and including CSX, Gabriel Low and Adeline Seah. These researchers and additional students also collected bees on the RUPP campus in Phnom Penh during a workshop held prior to the expedition.

Concurrent with these collecting efforts, there has been a rapid development of citizen science efforts in Cambodia. Leading the research on Cambodian arthropods, SDG built and administrates the Facebook group Natural Cambodia (<http://www.facebook.com/groups/naturalcambodia>), which invites Cambodian residents and visitors to photograph biodiversity (including arthropods) and share their findings. Since 2011, a large amount of data, including photos, dates and locations of sightings, have been gathered from the public and images of arthropods shared have been identified by various experts, leading to dozens of new species distribution records across the country. For example, GC has documented the occurrence and behaviour of bees in Koh Kong Province. SDG has also documented Cambodian arthropods through macrophotography in the Angkor Archaeological Park and its immediate surroundings since 2007. From 2012, SDG has followed the protocol developed by the Meet Your Neighbours project, an international effort using high-quality photography of arthropod species on a white background to advance research and raise awareness.

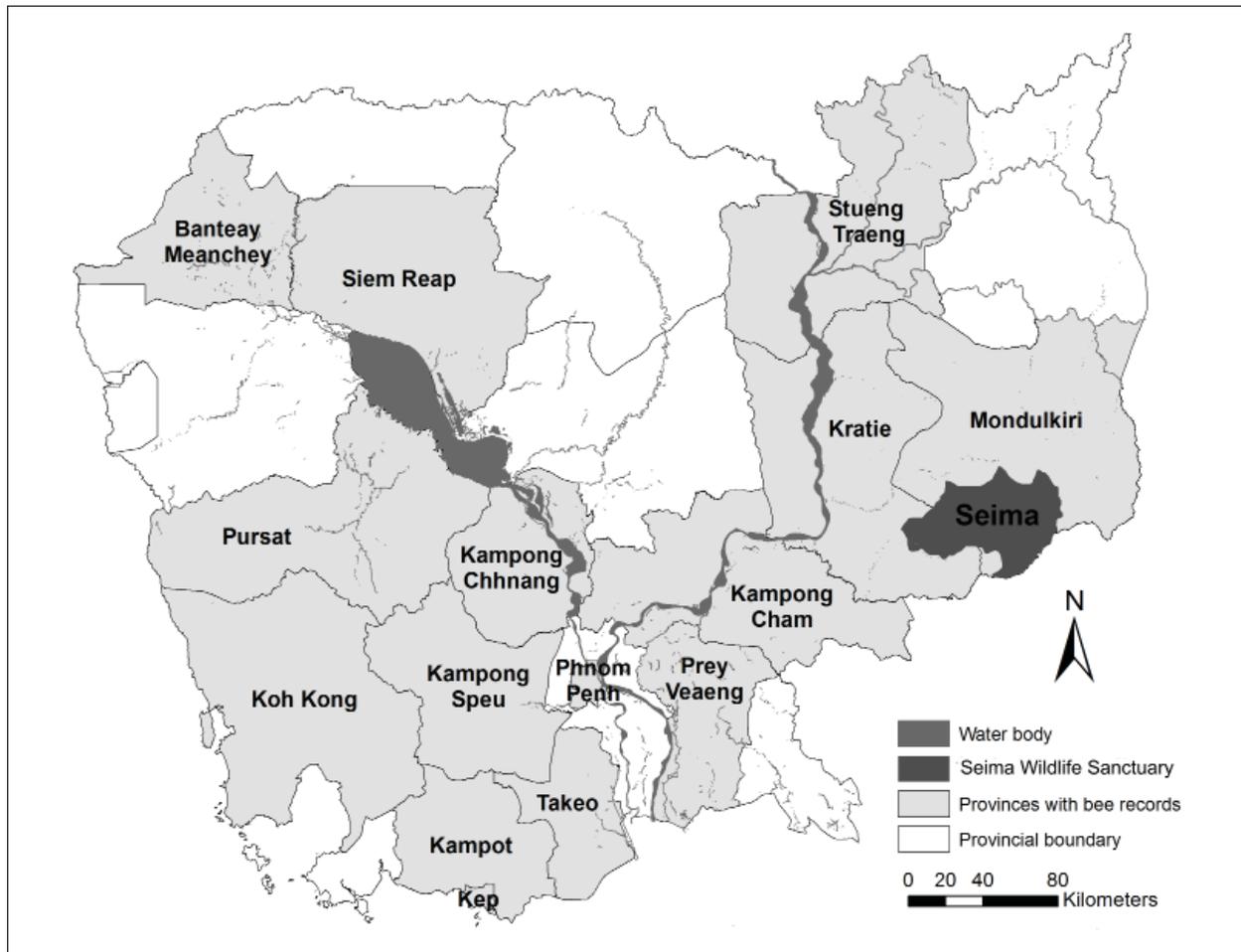


Fig. 1 Location of bee collection and survey areas in Cambodia.

Results

Records from Seima WS and RUPP campus

Notable findings of the 2016 expedition to Seima WS include the discovery of what are likely undescribed species of *Nomia* (*Maculonomia*) and *Anthidiellum* (*Ranthidiellum*). In addition, several genera were confirmed to occur in Cambodia for the first time including *Hylaeus* (Colletidae, a first country record for the family), the megachilid genera *Lithurgus*, *Anthidiellum*, *Pseudoanthidium*, *Heriades* and *Coelioxys*, and the apid genera *Braunsapis* and *Nomada*. At the subgeneric rank, notable findings included *Nomia* (*Maculonomia*) (three species), a *Lasioglossum* (*Homalictus*) species that appears to be the host of the small-bodied *Nomada*, and two species of *Ceratina* (*Xanthoceratina*). This expedition also documented the nest sites and nest entrances of many stingless bee species (tribe Meliponini) in evergreen forest and a total

of 48 bee species and morphospecies are now known from Mondul Kiri Province (Appendix 1).

Collections on the RUPP campus have confirmed the presence of *Pseudapis* (*Pseudapis*) *siamensis* (Cockerell, 1929b) in Phnom Penh, a new country record of a species first described from Thailand and now known to be widespread in the region. We have also established the presence of various other urban-adapted bee species including nests of stingless honey bees *Tetragonula fusco-balteata* (Cameron) and of *Megachile* (*Callomegachile*) aff. *umbripennis* Smith, inspected by *Coelioxys cleptoparasites* (Appendix 1).

Citizen science records

Photographs of bees taken for the Meet Your Neighbours project (Fig. 2) are of great scientific interest because they provide new provincial records for many well-known species and the first documentation of additional obscure

species including some potentially new to science, such as an unidentified species of *Lipotriches* (*Maynenomia*) (Fig. 2d). Subgenera and species new for Cambodia well-illustrated by these photographs include *Megachile* (*Lophanthedon*) *dimidiata* Smith (Fig. 2e) (this subgenus was recently described by Gonzalez & Engel, 2002) and *Amegilla* (*Glossamegilla*) *fimbriata* (Smith) (Fig. 2b), an attractive species recently redescribed and reported from Thailand by Attasopa & Warrit (2012). In addition to their scientific value, photographs of Cambodian bees are also of great utility for education and outreach.

Overview of the known bee fauna of Cambodia

Eusocial hive bees:

Apis honey bees are relatively well documented in Cambodia because their nests are of great economic importance as sources of honey, larvae consumed as food, and other hive products (McNaughton & Sotha, 2009); these are also the only bees that pose a serious danger to humans. Three species are very widely distributed in Cambodia and adjacent countries: the cavity-nesting Asian honey bee *Apis* (*Apis*) *cerana* F., the twig-nesting dwarf honey bee *A.* (*Micrapis*) *florea* F., and the giant honey bee *A.* (*Megapis*) *dorsata dorsata* F. which is migratory and seasonally builds very large nests under the high branches of dipterocarps and other tall trees. It also occupies manmade structures in open areas such as water towers, and nests are sometimes induced in rafters to facilitate harvesting of honey (Waring & Jump, 2004). A fourth species, the black dwarf honey bee *A.* (*Micrapis*) *andreniformis* Smith, is less well known because it may be more or less restricted to humid evergreen forest and has been overlooked historically due to its similarity to the more common *A. florea* (see review of the Asian species of *Apis* by Radloff *et al.*, 2011). Maa's (1953) revision of the Apini did not cite Cambodian records, but Otis (1996) included a few Cambodian records for *A. florea* and stated that *A. andreniformis* "almost certainly" occurs, a conclusion corroborated here.

Stingless honey bees (tribe Meliponini) are of great importance as pollinators (Heard, 1999) and as producers of honey and hive products that can be more valuable on a per-unit basis than those of *Apis*. Elsewhere in Southeast Asia, notably Malaysia, a rapidly growing meliponiculture (stingless bee keeping) industry has developed (Jalil & Shuib, 2014) with the goal of sustainably maintaining commercially viable populations of many species and, among researchers and hobbyists, maintaining demonstration hives of most others. A few small-bodied *Tetragonula* species (reviewed by Sakagami, 1978) such as *T. fuscobalteata* (Cameron) and *T. pagdeni* (Schwarz),

are widespread in open areas, with the former nesting in green spaces within Phnom Penh such the RUPP campus. However, a larger-bodied species of *Tetragonula*, *T. geissleri* (Cockerell), and other meliponine species — including the exceptionally large *Geniotrigona thoracica* (Smith), and other larger species such as *Homotrigona fimbriata* (Smith) *sensu lato* (see Sakagami, 1975; Rasmussen, 2008) and *Tetrigona apicalis* (Smith)— are associated with mature evergreen forests, in particular those with large dipterocarp trees that are used as nesting sites and sources of resin for nest construction. Such forest-dependent stingless bees may be of conservation concern when their habitat is heavily logged or fragmented, as shown by the failure of larger-bodied stingless bees to survive in urban and scrub habitat in Singapore (JSA and CSX, unpublished data). Certain minute stingless bees such as the three species of *Lisotrigona* species found at Seima WS, two recently described by Engel (2000) including the distinctive *L. carpenteri* (Fig. 3b), are rarely observed on flowers and are instead more often detected when they are attracted to the sweat of field workers. The nest entrances of the various stingless bee genera and species are typically affixed to the trunk of a large dipterocarp tree and are distinctive, with each taxon having a characteristic form (Sakagami *et al.*, 1983). For example, a long slender tube in *Tetragonilla collina* (Smith, 1857) as opposed to a shorter tube shaped like a trumpet bell in both Cambodian species of *Lepidotrigona*.

The taxonomy and distribution of Southeast Asian stingless bees is relatively well known (Schwarz, 1939; Sakagami, 1975, 1978; Rasmussen, 2008), but many difficulties remain, especially regarding recognition of medium-sized *Tetragonula* species such as *T. pagdeni* (Schwarz) and *T. laeviceps* (Smith). The former is expected to be widespread in Indochina, but is likely under-recorded due to identification problems, whereas the latter, while reported from Cambodia (e.g., by Rasmussen, 2008, under the name *T. valdezi*, which we consider a junior synonym, cf. Sakagami, 1978), is better known in Sundaland (the neotype locality is Singapore, as established by Rasmussen & Michener, 2010), and its status in Indochina requires further verification. A large-bodied Cambodian *Tetragonula* recorded with various spellings by Lee *et al.* (2016, accepted version) as *T. iridipennis* (Smith), an Indian species, is likely *T. geissleri* (Cockerell).

Rasmussen's (2008) catalogue of regional Meliponini cited several species for Cambodia on the basis of records correctly attributable to Thailand. For example, the localities "Kum Puang Creek", "Nan" and "Pahtoop Mountain", are not in Cambodia but in Nan Province of Thailand. Records of *Heterotrigona bakeri* (Cockerell) for "Tung Nui" and "Satul" in Cambodia by Rasmus-

sen (2008; and for Cambodia by Lee *et al.*, 2016, accepted version) were probably a misplacement of Ban Thung Nui in Satun Province of southern Thailand: a more plausible locality for a species described from Penang in North-west Peninsular Malaysia. Likewise, Rasmussen's (2008) record of *Tetrigona peninsularis* (Cockerell) from "Patalung" should be attributed to Phatthalung Province of southern Thailand. This species, like *H. bakeri*, is restricted to the Malay Peninsula (with verified records extending north only to the Phatthalung and Saraburi provinces). Rasmussen also miscited "Tung Nui" and "Satul" for Cambodian localities in his entry for *Tetragonula biroi* (Friese, 1898). He correctly noted that the records in question were misidentified, but the inclusion of records from mainland Southeast Asian records under the heading for a species actually restricted to New Guinea and the Philippines has led to confusion (e.g., citation of *T. biroi* for Cambodia by Lee *et al.*, 2016, accepted version). Another source of confusion is the recognition at species rank by Rasmussen (2008) of described forms of uncertain and sometimes doubtful validity. While this is convenient for the purposes of cataloguing all literature citations, it may lead some authors to conclude that the more conservative classification of Sakagami (1975, 1978) has received comprehensive taxonomic review and been supplanted, when this is not actually the case. We concur with Sakagami that variation in size, colour and other characters among species (or superspecies) such as *Homotrigona fimbriata* (Smith), *Lepidotrigona ventralis* (Smith), and *Tetragonula laeviceps* (Smith) (*sensu lato*) is complex and not sufficiently congruent with well-corroborated biogeographic patterns to permit ready subdivision of these and other variable taxa into reliably identifiable taxa. Pending revisionary studies and availability of molecular diagnostics across their ranges, we prefer to recognize such species in a broad sense following Sakagami (1975, 1978), while noting the observed variation. We therefore cite ranges separately for the two colour forms of *Homotrigona fimbriata* [the flavinic *aliceae* (Cockerell) in western Cambodia and the melanic *anamitica* (Friese) in eastern Cambodia] and cite *flavibasis* in synonymy as the name available for Cambodian *Lepidotrigona ventralis* (Smith) *sensu lato* if considered a distinct species (Appendix 1).

Solitary and primitively eusocial bees:

Colletidae are rather poorly represented in Southeast Asia, with *Colletes* (Colletinae) having only recently been reported from mainland Southeast Asia based on recent description of *C. packeri* Kuhlmann 2015 (Kuhlmann & Proshchalykin, 2015) from Thailand and Laos. This genus may be restricted to highlands in the region, but *Hylaeus* (*Hylaeinae*) is more widespread. However, discovery and description of regional *Hylaeus* species and

their placement to subgenus requires much additional work (see Dathe, 2011, who described a new Asian subgenus which likely occurs in Cambodia but has yet to be recorded). An undetermined *Hylaeus* (*Paraprosopis*) species was found on the expedition to Seima WS, and a female *Hylaeus* species with three subequal facial markings resembling *H. (Nesoprosopis) penangensis* (Cockerell, 1920) was recorded in the Koh Kong and Mondulhiri provinces. [Images of the type specimen of *H. (Nesoprosopis) penangensis* are available through the Smithsonian collections database]. A similar bee has also been found in Singapore (J.S. Ascher, unpublished data).

Halictidae are well represented in Cambodia and elsewhere in Southeast Asia, especially the subfamily Nomiinae. Pauly's (2009) revision of Oriental nomiines included descriptions of three new species from Cambodia (see above). Our work has confirmed the presence of additional widespread species and what is apparently a new taxon related to *Nomia (Maculonomia) sanguinea* (Pauly) (Fig. 4d) (see discussion of a potential new subspecies in Pauly, 2009) and additional potential new species of *Nomia (Maculonomia)* (Figs 4b, 4c) and *Lipotriches (Maynenomia)* (Fig. 2d). Including unnamed morphospecies, 10 Nomiinae species are now known from Cambodia (Fig. 4). Whereas few identification resources exist for Cambodian bees other than the sparse primary literature, described species of Nomiinae can in most cases be readily identified by referring to well-illustrated species pages at the Atlas Hymenoptera website (<http://www.atlashymenoptera.net>). However, further taxonomic review is required and some widely distributed species as delimited by Pauly (2009) are in our view composite taxa. For example, such as *Nomia (Maculonomia) apicalis* Smith *sensu lato*, the Cambodian representatives of which we assign to a separate species: *Nomia (Maculonomia) niti-data* Strand (new status).

Halictinae are as yet poorly known in Cambodia but certainly include multiple species of *Lasioglossum* (*Ctenonomia*), including the widely distributed *L. albescens* (Smith) (Matsumura & Sakagami, 1971) and *L. vagans* (Smith), and at least one *Lasioglossum (Homalictus)* species belonging to the *Indohalictus* group (Pauly, 1980). An unidentified species of *Patellapis (Pachyhalictus)* was also recorded in Seima WS (see review of this taxon as *Pachyhalictus* by Pauly, 2007; and the review of the Chinese species by Pesenko & Wu, 1997). An important discovery from one of the first CEI collecting trips focusing on bees was the first Cambodian records of *Eupetersia (Nesoepetersia) yanegai* Pauly, a parasitic halictine recently described from Thailand (Pauly, 2012) based in part on material collected during the TIGER project and now also known from mangroves in Singapore (J.S.

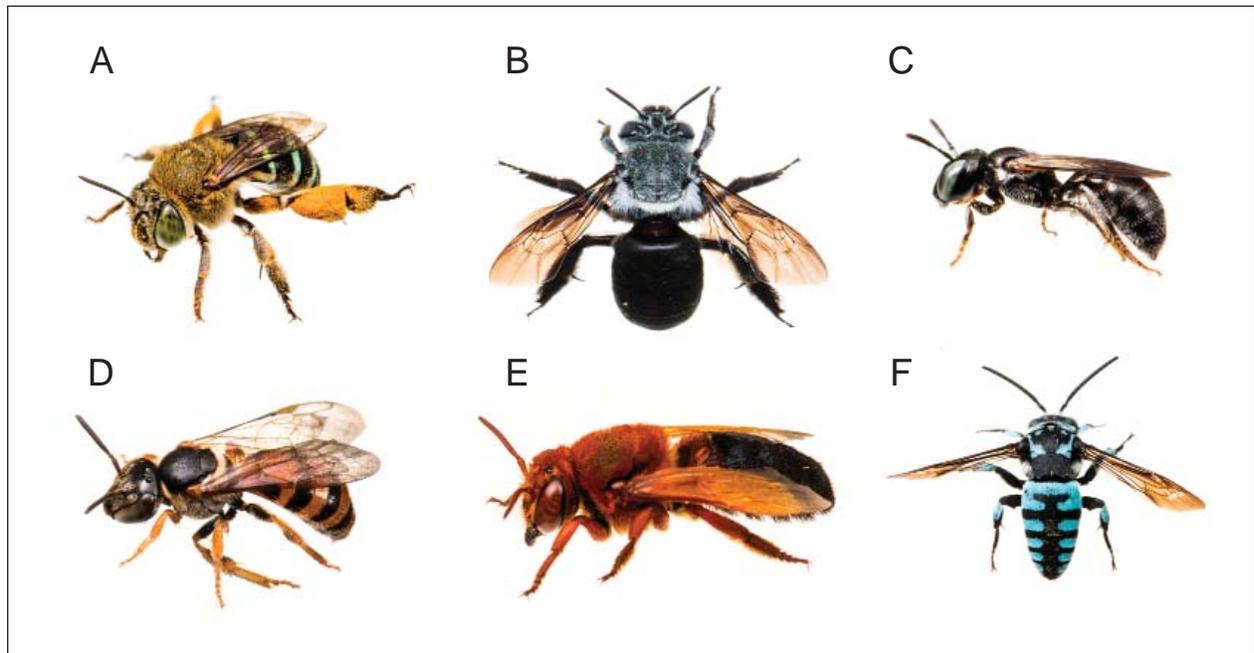


Fig. 2 Bees photographed at Angkor Archaeological Park: A) *Amegilla* (*Zonamegilla*) sp., ♀; B) *Amegilla* (*Glossamegilla*) *fimbriata* Smith, ♀; C) *Ceratina* (*Neoceratina*) *dentipes* Friese, ♀; D) *Lipotriches* (*Maynenomia*) sp., ♀; E) *Megachile* (*Lophanthedon*) *dimidiata* Smith, ♀; F) *Thyreus himalayensis* Radoszkowski, ♂ (© Stéphane De Greef).

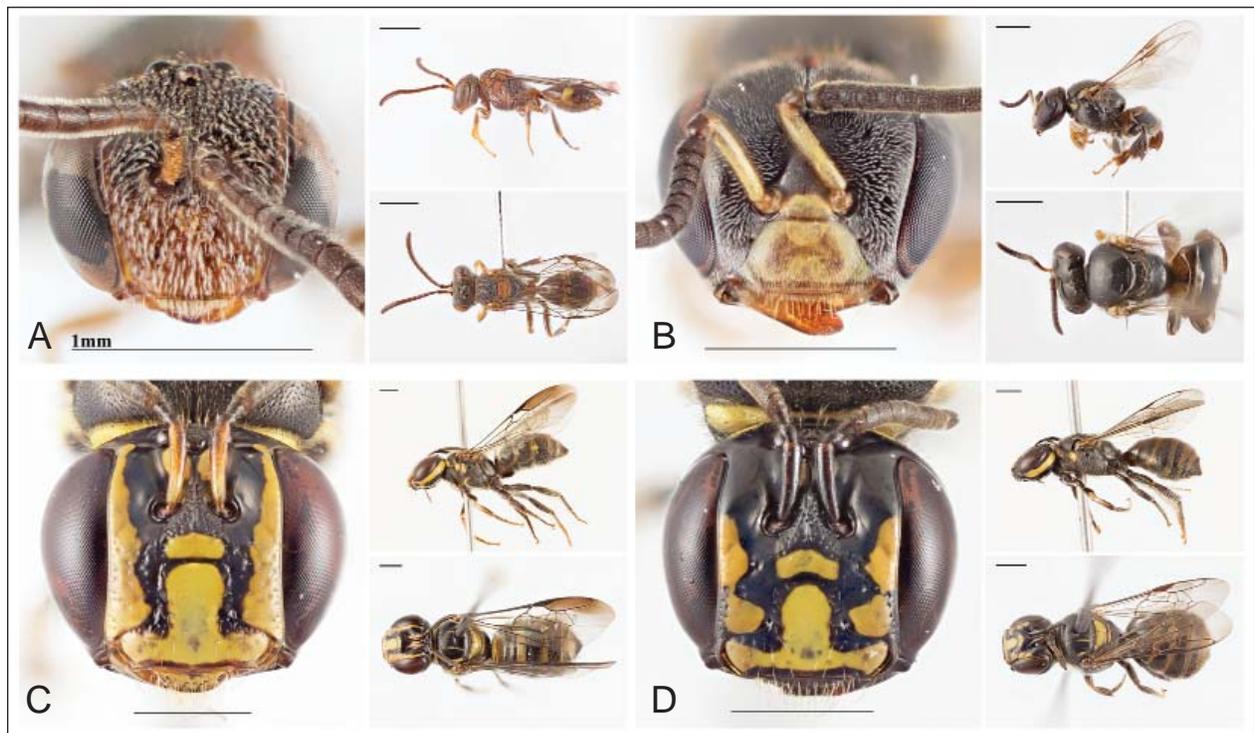


Fig. 3 General habitus plate of apid bees: A) *Nomada* sp., ♀; B) *Lisotrigona carpenteri*, ♀; C) *Ceratina* (*Xanthoceratina*) aff. *fuliginosa*, ♀; D) *Ceratina* (*Xanthoceratina*) aff. *humilior*, ♀ (© Chui Shao Xiong).

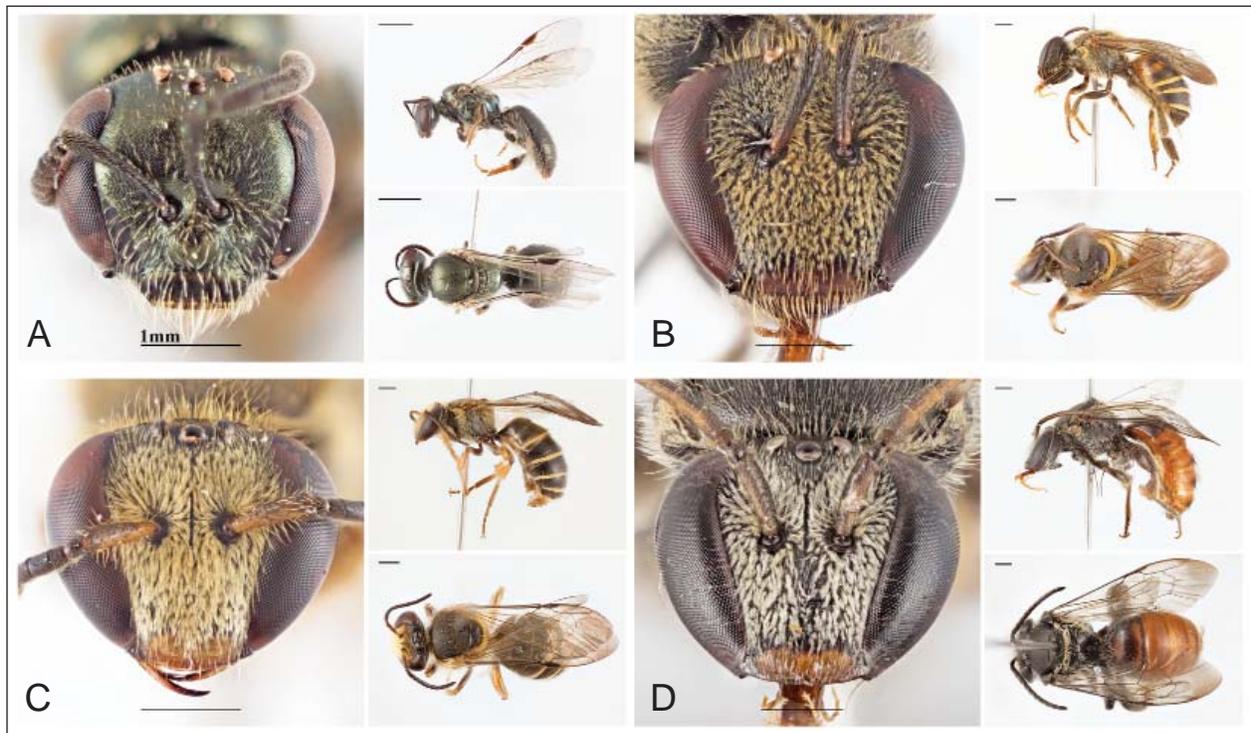


Fig. 4 General habitus plate of halictid bees: A) *Lasioglossum* (*Homalictus*) sp., ♀; *Nomia* (*Maculonomia*) n. sp., B) ♀ & C) ♂; D) *Nomia* (*Maculonomia*) *sanguinea*, ♂ (© Chui Shao Xiong).

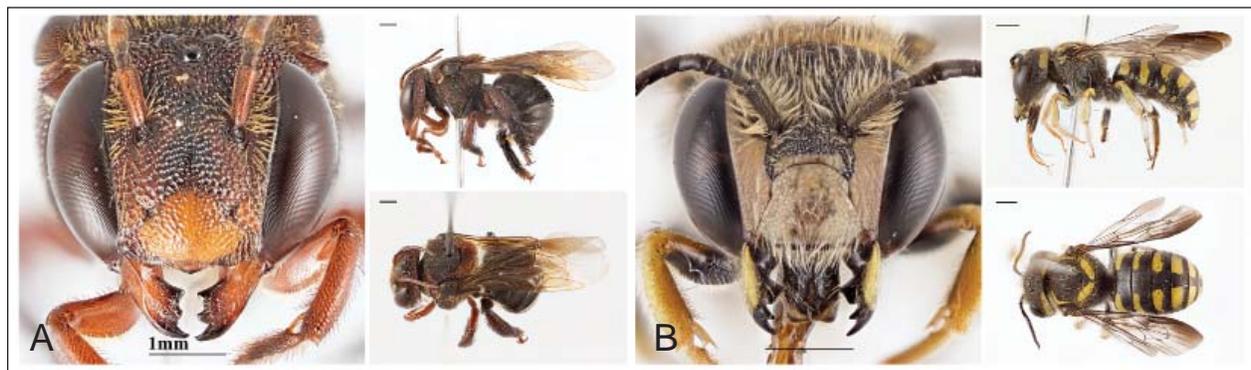


Fig. 5 General habitus plate of megachilid bees: A) *Anthidiellum* (*Ranthidiellum*) aff. *meliponiforme*, ♂; B) *Pseudoanthidium* (*Pseudoanthidium*) *orientale*, ♂ (© Chui Shao Xiong).

Ascher, unpublished data). The limited known distribution of *Eupetersia* (*Nesoeupetersia*) in tropical and subtropical Southeast Asia suggests a possible association with *Patellapis* (*Pachyhalictus*), but this remains to be demonstrated.

Megachilidae are diverse in Cambodia but like other families are under-recorded and many recorded taxa have not yet been identified to species (Fig. 5). Only four

identified *Megachile* species and six additional morphospecies have been confirmed, but many more surely exist in numerous subgenera, including both leaf-cutter and resin bees. These are parasitized by *Coelioxys* bees (also Megachilini) including a *Coelioxys* (*Allocoelioxys*) found at Seima WS and what is likely a different species observed on the RUPP campus (not included in Table 1 due to lack of a voucher specimen). In addition to Megachilini, the tribe Osmiini is represented by *Heriades* (*Michenerella*)

othonis Friese, 1914 (a new country record for the genus from Seima WS—species identification is tentative in the absence of a revision treating potentially similar or synonymous forms such as *Heriades laosella* Cockerell, 1929c, described despite its name, from Nan Province in Thailand). The Anthidiini tribe is represented by *Pseudoanthidium* (*Pseudoanthidium*) *orientale* (Bingham, 1897) (Fig. 5b) (new country record for the genus from the streambed below Bou Sra Waterfall; see revision by Pasteels, 1972, and photograph of a Thai specimen by Tadauchi & Tasen, 2009), and what may prove to be a new species of *Anthidiellum* (*Ranthidiellum*) (Fig. 5a) (new country record for the genus from Seima WS; see Engel, 2009). In addition to Megachilinae, the subfamily Lithurginae is represented in Seima WS by the wood-nesting *Lithurgus collieri* Cockerell, a species described from Thailand (Cockerell, 1929a).

Large carpenter bees in the genus *Xylocopa* (Xylocopinae: Xylocopini) are relatively diverse and numerous in Cambodia. These are large and conspicuous bees that attract attention through their burrows which can damage structural wood, but the regional fauna is relatively poorly known. Some *Xylocopa* subgenera are treated in a monograph by Hurd & Moure (1963; see also Maa, 1940a,b, 1946; Lieftinck, 1964) but definitive identification of all regional species of the *Koptortosoma* subgenus will require additional taxonomic revision and likely the use of molecular diagnostics given the difficulty of associating the sexes of certain species. Lieftinck (1964) recorded both *Xylocopa* (*K.*) *bryorum* (Fabricius) and *X.* (*K.*) *minor* Maidl from Cambodia. Blue-haired species belonging to the *Cyaneoderes* group of *Koptortosoma sensu lato* (synonymy of Michener, 2007) occur in Cambodia, of which we have identified only *X.* (*K.*) *caerulea* (Fabricius). However, the taxonomy of regional species has only recently been reviewed (Mawdsley, 2016) and additional species may be detected. Bamboo-nesting species of *Xylocopa* (*Biluna*) are commonly found even in Phnom Penh. Two (or more) species of *Xylocopa* (*Platynopoda*) are the largest bees found in Cambodia. The subgenus *Platynopoda* has been considered a junior synonym of *Mesotrichia* (Michener, 2007), but we agree with its reinstatement by Mawdsley (2015; endorsing the classification of Hurd and Moure, 1963). The smaller-bodied *Xylocopa* (*Zonohirsuta*) *dejeanii* Lepeletier (= *X. collaris* Lepeletier, 1841, pre-occupied) also occurs, females of which can be readily identified by the pale collar on the anterior of the thorax. This species is represented in French Indochina by the subspecies *yangweiiella* Maa, recorded from Laos and Vietnam (Maa, 1940), and our Cambodian records likely pertain to this form, but its taxonomic validity and status in Cambodia both require further verification.

Small carpenter bees belonging to the *Ceratina* genus (Xylocopinae: Ceratinini) are also well-represented in Southeast Asia (Shiokawa & Sakagami, 1969; Shiokawa, 2009, 2015; Warrit *et al.*, 2012) and Cambodia. The expedition to Seima WS recorded four species in the *Ceratinidia* subgenus, three of which were new for the country (*C. lieftincki* was cited for Siem Reap by Warrit, 2007). A review of the species in Thailand is useful for Cambodia as well (Warrit *et al.*, 2012; see also Warrit, 2007). The two regionally common species in the *Pithitis* subgenus (Hirashima, 1969; Shiokawa & Sakagami, 1969; Baker, 1997) also occur in Cambodia: *C. (P.) unimaculata* being represented by the green form *palmerii* Cameron, 1908, rather than the blue form *nanensis* Cockerell, described from Thailand (as *C. simanensis nanensis* Cockerell, 1929b). Two species of the forest-associated subgenus *Xanthoceratina* were recorded in Seima WS, a larger species aff. *fuliginosa* Cockerell (Fig. 3c), and a smaller one aff. *humilior* Cockerell (Fig. 3d). Finally, the smallest-bodied regional taxon *Ceratina* (subgenus *Neoceratina*), is represented by the widely distributed *C. (Neoceratina) dentipes* Friese (Fig. 2c) and a second, smaller species with a shinier, less punctate thorax and redder front legs.

The Xylocopinae subfamily is further represented by the *Braunsapis* genus of which three widely distributed species regionally (see revision by Reyes, 1991) are newly recorded for Cambodia from Seima WS. The genus occurs more widely in Cambodia as documented by photographs. The Nomadinae subfamily (Apidae) is represented only by a minute species of *Nomada* (*Nomadini*) (Fig. 3a) found in Seima WS in association with an earth bank visited by slightly larger females of *Lasioglossum* (*Homalictus*) (Fig. 4a) that we infer to be the hosts.

The bee genus *Amegilla* is widely distributed in Cambodia but species identification remains problematic in Indochina as historical research was concentrated in Sundaland and to a lesser extent Thailand (cf. Lieftinck, 1956). One visually distinctive species, *Amegilla* (*Glossamegilla*) *fimbriata* (Smith, 1879) (Attasopa & Warrit, 2012), has recently been photographed in Siem Reap Province (Fig. 2a) and Ratanakiri Province. A female of another species of *Amegilla* (*Glossamegilla*) with orange hair found in Ratanakiri Province is identified tentatively as *A. himalajensis* (Radoszkowski), based in part on the orange rather than black background colour of the clypeus. A female and a sleeping male of what appears to be the same species have been photographed by GC in Koh Kong Province. Smaller-bodied species in the *Zonamegilla* subgenus are abundant in Cambodia, and at least three species occur in Seima WS alone. This subgenus is taxonomically difficult (see Engel & Baker, 2006) and prevents reliable identification of all species at present, but

we have been able to identify some taxa to species or morphospecies by referring to an unpublished thesis by K. Attasopa (supervised by N. Warrit). These *Zonamegilla* are parasitized by species of *Thyreus*, of which the widespread *T. himalayensis* (Radoszkowski, 1893) (Fig. 2f) was recorded in the taxonomic revision by Lieftinck (1962).

Discussion

The present work summarizes the known bee diversity of Cambodia to the extent currently feasible based the scant historical literature and initial reports of ongoing explorations by scientists and citizen scientists. Both the November 1957–1958 expedition by the Osaka City University (Sakagami & Yoshikawa, 1960) and the authors expedition in 2016 were conducted during the dry season, an unfavourable time for bee collecting due to scarcity of flowers, so both expeditions likely overlooked many species that could be collected under more favourable conditions, i.e. when more diverse and abundant flowers are in bloom. With thorough collections, additional genera will undoubtedly be found in Cambodia. These will certainly include the following genera widespread in tropical Southeast Asia: *Ceylalictus* (Halictidae: Nomioidini), *Sphcodes* (Halictidae: Halictinae), and *Euaspis* (Megachilidae: Anthidiini; see Pasteels, 1980; Baker, 1995). *Ctenoplectra* (Apidae: Apinae: Ctenoplectrini) should be detected if collections can be made from oil-producing cucurbitaceous host plants. Several additional bee genera favouring temperate climates such as *Andrena* (mining bees) and *Bombus* (bumble bees) have been recorded from the mountains of neighbouring Southeast Asian countries and may also be found in Cambodia when its higher mountains are properly surveyed, although these may prove to be too low in elevation and too far south to support other genera with temperate affinities.

Many dozens of bee species unquestionably remain to be discovered in Cambodia and many of these will prove to be new to science (including enigmatic species reported and illustrated in this study). The 82 species and morphospecies recorded here from Cambodia, while a very incomplete account of the total fauna, still represent a major advance in documentation for the country's bees. Species recorded to date include many abundant and conspicuous pollinators and those of greatest economic importance and much additional taxonomic work will be required to describe potential new taxa to science already discovered and to verify preliminary species identifications. This will require study of type material which is

mostly housed in European collections and benefit from integrative taxonomy incorporating molecular diagnostic markers such as DNA barcodes.

Too little is known about the Southeast Asian bee fauna in general and that of Indochina and the other monsoonal countries in particular to definitively compare the Cambodian bee fauna with that of neighbouring countries. Despite the discoveries reported here, Cambodia still has the smallest known bee fauna of the countries considered, with the 82 species and morphospecies reported here being far fewer than the 222 described species now known to occur in Thailand, and also fewer than the 83 and 86 described species now known from Vietnam and Laos respectively. If more extensive morphospecies totals were available for countries in the region alongside Cambodia, these would increase the discrepancy in known taxonomic richness, as many unnamed morphospecies are documented by DNA barcodes and images within the Barcode of Life Database for bees (L. Packer, pers. comm.). In comparison to neighbouring countries, Cambodia shares the highest number of shared species and morphospecies with Thailand (57) and the second highest total (44) and highest percentage of shared species with Laos. Since a high proportion of species in the better known highly eusocial taxa such as *Apis* and the Meliponini are shared among countries, we also expect additional faunal overlap will be documented among solitary species as these become better known.

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Appendix 1 Checklist of the Bees of Cambodia

The following list compiles data from the literature on bees in Cambodia, bee sampling collected to date by CEI team, image databases of SDG and other photographers resident in Cambodia and preliminary results of CEI-NUS collections in Mondulakiri Province in 2016. Species records for Thailand, Laos and Vietnam are taken from Ascher & Pickering (2016) with reference to the literature and studies of collections including those mentioned above.

Note: KP – Kep; KC – Kampong Cham; KG – Kampong Chhnang; KH – Kratie; KK – Koh Kong; KS – Kampong Speu; KT – Kampot; MK – Mondulakiri; PH – Preah Vihear; PO – Pursat; PP – Phnom Penh; RO – Ratanakiri; SI – Siem Reap; ST – Stung Treng; TA – Takeo.

No.	Taxon (Apoidea)	Cambodia	Thailand	Laos	Vietnam
COLLETIDAE					
Colletinae					
1	<i>Hylaeus</i> sp. [cf. <i>H. (Nesoprosopis) penangensis</i> (Cockerell, 1920)]	KK, MK	-	-	-
2	<i>Hylaeus (Paraprosopis)</i> sp.	MK	-	-	-
HALICTIDAE					
Nomiinae: Nomiini					
3	<i>Lipotriches (Austronomia) laminatrochanter</i> (Pauly, 2009)	KS	*	-	*
4	<i>Lipotriches (Macronomia) angkorensis</i> (Pauly, 2009)	SI	*	*	*
5	<i>Lipotriches (Maynenomia) indochinensis</i> (Pauly, 2009)	SI	*	*	*
6	<i>Lipotriches (Maynenomia)</i> n. sp. (Fig. 2d)	KK, SI	-	-	-
7	<i>Nomia (Acunomia) iridescens</i> Smith, 1857	SI	*	-	*
8	<i>Nomia (Acunomia) strigata</i> (Fabricius, 1793)	SI	*	*	-
9	<i>Nomia (Maculonomia) nitidata</i> Strand, 1913, new status	MK	-	*	*
10	<i>Nomia (Maculonomia) sanguinea</i> (Pauly, 2009) [new subspecies?]	SI	*	*	-

Appendix 1 (cont'd)

No.	Taxon (Apoidea)	Cambodia	Thailand	Laos	Vietnam
11	<i>Nomia (Maculonomia) aff. penangensis</i> Cockerell, 1920	MK	*	*	-
12	<i>Nomia (Maculonomia) n. sp.</i> (Figs. 4b,c)	MK	-	-	-
13	<i>Nomia (Gnathonomia) aurata</i> Bingham, 1897	PP	*	*	-
14	<i>Nomia (Gnathonomia) cambodiana</i> (Pauly, 2009)	SI	*	*	*
15	<i>Nomia (Gnathonomia) thoracica</i> Smith, 1875	SI	*	*	*
16	<i>Nomia (Hoplonomia) elliotii</i> Smith, 1875	MK	*	-	-
17	<i>Pseudapis (Pseudapis) siamensis</i> (Cockerell, 1929)	KS, PP	*	-	-
Halictinae: Halictini					
18	<i>Eupetersia (Nesoeupetersia) yanegai</i> Pauly, 2012	KK, MK	*	-	-
19	<i>Lasioglossum (Ctenonomia) albescens</i> (Smith, 1853)	MK	*	*	*
20	<i>Lasioglossum (Ctenonomia) deliense</i> (Strand, 1910)	KS	-	-	-
21	<i>Lasioglossum (Ctenonomia) vagans</i> (Smith, 1857)	MK	*	-	-
22	<i>Lasioglossum (Homalictus) sp.</i> [<i>Indohalictus</i> group] (Fig. 4a)	MK	-	-	-
23	<i>Patellapis (Pachyhalictus) sp.</i>	MK	-	-	-
MEGACHILIDAE					
Lithurginae: Lithurgini					
24	<i>Lithurgus collieri</i> Cockerell, 1929	MK	*	-	-
Megachilinae:					
Anthidiini					
25	<i>Anthidiellum (Ranthidiellum) aff. meliponiforme</i> (Cockerell, 1919)	MK	-	-	-
26	<i>Pseudoanthidium (P.) orientale</i> (Bingham, 1897) (Fig. 5b)	MK	*	-	-
Megachilini					
27	<i>Heriades (Michenerella) othonis</i> Friese, 1914	MK	-	*	-
28	<i>Megachile (Callomegachile) aff. disjuncta</i> (Fabricius, 1781)	RO	-	-	-
29	<i>Megachile (Callomegachile) aff. faceta/facetula</i>	RO	-	-	-
30	<i>Megachile (Callomegachile) aff. umbripennis</i> Smith, 1853	PP	-	-	-
31	<i>Megachile (Chelostomoda) aureocincta</i> Cockerell, 1927	MK	*	*	-
32	<i>Megachile (Chelostomoda) sp.</i> [tergal hair bands white]	SI	-	-	-
33	<i>Megachile (Lophanthedon) dimidiata</i> Smith, 1853 (Fig. 2e)	SI	-	-	*
34	<i>Megachile (Amegachile) bicolor</i> (Fabricius, 1781)	KS	*	-	-
35	<i>Megachile (Paracella) tricincta</i> Bingham, 1897	KK	*	*	-
36	<i>Megachile (Paracella) sp.</i> [not <i>tricincta</i>]	MK	-	-	-
37	<i>Megachile sp.</i> [resembles <i>M. atrata</i> Smith, 1853, nests in sand]	SI	-	-	-
38	<i>Coelioxys (Allocoelioxys) sp.</i>	MK	-	-	-
APIDAE					
Xylocopinae: Xylocopini					
39	<i>Xylocopa (Koptortosoma) bryorum</i> (Fabricius, 1775)	PP	*	-	*

Appendix 1 (cont'd)

No.	Taxon (Apoidea)	Cambodia	Thailand	Laos	Vietnam
40	<i>Xylocopa (Koptortosoma) caerulea</i> (Fabricius, 1804)	KA, KK	*	*	-
41	<i>Xylocopa (Koptortosoma) minor</i> Moidl, 1912	widespread ¹	*	*	*
42	<i>Xylocopa (Zonohirsuta) dejeanii</i> Lepeletier, 1841 [for ssp. see text]	KK, SI	*	*	*
43	<i>Xylocopa (Platynopoda) latipes</i> (Drury, 1773)	KK, KP	*	*	*
44	<i>Xylocopa (Biluna) nasalis</i> Westwood, 1838	PP, SI	*	*	-
45	<i>Xylocopa (Platynopoda) tenuiscapa</i> Westwood, 1840	SI	*	*	-
Ceratinini					
46	<i>Ceratina (Ceratinidia) bryanti</i> Cockerell, 1919	MK	*	-	-
47	<i>Ceratina (Ceratinidia) collusor</i> Cockerell, 1919	MK	*	*	-
48	<i>Ceratina (Ceratinidia) lieftincki</i> van der Vecht, 1952	MK, SI	*	*	-
49	<i>Ceratina (Ceratinidia) nigrolateralis</i> Cockerell, 1916	MK	*	*	*
50	<i>Ceratina (Neoceratina) dentipes</i> Friese, 1914 (Fig. 2c)	MK, SI	*	-	-
51	<i>Ceratina (Neoceratina) sp. 1</i> [smaller than <i>dentipes</i>]	MK	-	-	-
52	<i>Ceratina (Pithitis) smaragdula</i> (Fabricius, 1787)	widespread ¹	*	*	*
53	<i>Ceratina (Pithitis) unimaculata</i> Smith, 1879	MK	*	*	*
54	<i>Ceratina (Xanthoceratina) aff. fuliginosa</i> Cockerell, 1916 (Fig. 3c)	MK	-	-	-
55	<i>Ceratina (Xanthoceratina) aff. humilior</i> Cockerell, 1916 (Fig. 3d)	MK	*	-	-
Allodapini					
56	<i>Braunsapis clarihirta</i> Reyes, 1991	MK	*	-	*
57	<i>Braunsapis hewitti</i> (Cameron, 1908)	MK	*	*	*
58	<i>Braunsapis philippinensis</i> (Ashmead, 1904)	MK	*	*	*
Nomadinae: Nomadini					
59	<i>Nomada</i> sp. [small, with <i>Lasioglossum (Homalictus)</i>] (Fig. 3a)	MK	-	-	-
Apinae: Anthophorini					
60	<i>Amegilla (Zonamegilla) anakawarna</i> Engel, 2007	MK	*	-	-
61	<i>Amegilla (Glossamegilla) fimbriata</i> (Smith, 1879) (Fig. 2b)	KK, SI	*	-	-
62	<i>Amegilla (Glossamegilla) himalayensis</i> (Radoszkowski, 1882)	KK, RO	-	*	*
63	<i>Amegilla (Zonamegilla) parhypate</i> Lieftinck, 1975	MK	*	-	-
64	<i>Amegilla (Zonamegilla) cf. sp. 2</i> of Attasopa and Warrit, unpub.]	MK	*	-	-
65	<i>Thyreus himalayensis</i> (Radoszkowski, 1893) (Fig. 2f)	PO, SI	*	*	*
Apini					
66	<i>Apis (Apis) cerana</i> Fabricius, 1793	widespread ²	*	*	*
67	<i>Apis (Megapis) dorsata dorsata</i> Fabricius, 1793	widespread ²	*	*	*
68	<i>Apis (Micrapis) andreniformis</i> Smith, 1857	KK, MK	*	*	*
69	<i>Apis (Micrapis) florea</i> Fabricius, 1787	widespread ²	*	*	*
Meliponini					
70	<i>Geniotrigona thoracica</i> (Smith, 1857)	KP	*	*	*

Appendix 1 (cont'd)

No.	Taxon (Apoidea)	Cambodia	Thailand	Laos	Vietnam
71a	<i>Homotrigona fimbriata</i> (Smith, 1857) [<i>aliceae</i> (Cockerell, 1929)]	widespread ³	*	-	-
71b	<i>Homotrigona fimbriata</i> (Smith, 1857) [<i>anamitica</i> (Friese, 1908)]	MK ³	-	*	*
72	<i>Lepidotrigona terminata</i> (Smith, 1878)	widespread ⁴	*	*	*
73	<i>Lepidotrigona ventralis</i> (Smith, 1857) [= <i>flavibasis</i> (Cockerell)]	MK	*	*	*
74	<i>Lisotrigona cacciae</i> (Nurse, 1907)	MK, SI	*	*	*
75	<i>Lisotrigona carpenteri</i> Engel, 2000 (Fig. 3b)	MK	-		*
76	<i>Lisotrigona furva</i> Engel, 2000	MK	*	*	-
77	<i>Tetragonilla collina</i> (Smith, 1857)	widespread ⁵	*	*	*
78	<i>Tetragonula fuscobalteata</i> (Cameron, 1908)	widespread ⁶	*	*	*
79	<i>Tetragonula geissleri</i> (Cockerell, 1918)	KK, MK	*	*	-
80	<i>Tetragonula</i> sp. [cf. <i>laeviceps</i> (Smith, 1857)]	PP?, SI?, ST?	*	*	*
81	<i>Tetragonula pagdeni</i> (Schwarz, 1939)	KC, KK, PP ⁷	*	*	*
82	<i>Tetrigona apicalis</i> (Smith, 1857)	MK, ST	*	*	*
Total Species [For Cambodia and shared with Cambodia (including morphospecies) and, in parentheses, total known described species (not including all known morphospecies)]		82	57 (222)	44 (86)	36 (83)

¹ Subsocial bee species recorded from four provinces, *X. minor*: KC, KP, PP & SI; *C. smaragdula*: KK, KP, MK & RO.

² Expected to occur in all provinces and recorded from the following: *A. cerana*: KC, KK, KS, MK, PO, PP, SI & ST; *A. dorsata dorsata*: KK, KS, KT, MK, PP, SI & ST; *A. florea*: KC, KG, KK, KS, MK, PP, SI & TA.

³ Among stingless bees, two colour forms of *Homotrigona fimbriata sensu lato* recognized as valid species are listed separately but counted as a single species in the species totals. The form *aliceae* was recorded by us from KC & SI, and by Lee *et al.* (2016, accepted version) from MK, PH & SR, whereas our specimens from MK represent the *anamitica* (Friese) form.

⁴ Recorded by us from four provinces: KH, MK, SI & ST.

⁵ Recorded by us from MK, OM, SI & ST, and by Lee *et al.* (2016, accepted version) from PO & SI.

⁶ Recorded by us from KK & PP, and by Lee *et al.* (2016, accepted version) from PO, PH & SI.

⁷ Recorded by us from KK & PP, and by Lee *et al.* (2016, accepted version) from KK.

Patterns of salt lick use by mammals and birds in northeastern Cambodia

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មូលនិយសរង្វេប

អំបិលធម្មជាតិ ឬខនិដលិត (mineral licks) ជាធនធានមានតម្លៃ ប៉ុន្តែមានដោយកម្រ និងដោយកន្លែងសម្រាប់សត្វព្រៃ។ សត្វមួយចំនួនធំទៅកន្លែងដីប្រាប (salt lick) ដើម្បីស៊ីដី ដែលវាទទួលបាននូវខនិដលិតបន្ថែមជួយសម្រួលបញ្ហាក្រពះ ពោះវៀន និងទប់ស្កាត់ឥទ្ធិពល ជាតិពុលដែលមានក្នុងអាហារ។ ដូច្នេះដីប្រាបត្រូវបានចាត់ទុកជាធនធានដ៏មានប្រយោជន៍ក្នុងរបបអាហារ ជាសារធាតុចិញ្ចឹម និងសម្រាប់សុខភាពសត្វដែលប្រើប្រាស់វា។ តំបន់អភិរក្សរ៉ែសៃ សៀមប៉ាងនៃប្រទេសកម្ពុជាតំបន់ដែលមានតម្លៃដីប្រាបខ្ពស់ រាប់បញ្ចូលទាំងតំបន់ដីប្រាបមួយចំនួនផងដែរ។ តាមរយៈការដាក់ម៉ាស៊ីនថតរូបស្វ័យប្រវត្តិ (camera trap) នៅប្រាំទីតាំងដីប្រាបនៃតំបន់អភិរក្ស យើងបានស្វែងយល់ពីដំណើរនៃការប្រើប្រាស់ដីប្រាបរបស់សត្វ ក្នុងគោលបំណងវាយតម្លៃពីសារៈសំខាន់នៃធនធានទាំងនេះក្នុងស្ថានប្រព័ន្ធ។ ក្នុងរយៈពេលជាង៥៣០ថ្ងៃនៃការដាក់ម៉ាស៊ីនថតរូបស្វ័យប្រវត្តិ មានថនិកសត្វប្រាំបួនប្រភេទ និងសត្វស្លាបពហុប្រភេទត្រូវបានប្រទះឃើញនៅទីតាំងដីប្រាប ប៉ុន្តែមានតែថនិកសត្វប្រាំមួយប្រភេទប៉ុណ្ណោះ (ស្វាពីរ សត្វកកេរមួយ និងសត្វចតុប្បាទបី) ដែលត្រូវបានឃើញច្បាស់ថាបានស៊ីដីប្រាប។ អត្រាធ្វើដំណើរ (visitation rate) ប្រេងកង់នៃការជួប (encounter frequency) និងរយៈពេលស្ថិតក្នុងទីតាំង គឺខុសគ្នារវាងប្រភេទទាំងនេះ ដូចគ្នាដែរចំពោះលំនាំនៃការផ្គុំជាក្រុម និងពេលវេលាទៅដីប្រាបប្រចាំថ្ងៃ។ ពួកស្វា និងខ្លឹងចំណាយពេលវែងនៅកន្លែងដីប្រាប បង្ហាញថាវាជាអេកូឡូស៊ី សំខាន់សម្រាប់ប្រភេទនេះ។ ខ្លឹង និងឈ្នួសក្រហមត្រូវបានប្រទះឃើញនៅពេលយប់នៅទីដីប្រាប ដែលនេះជាសកម្មភាពខុសប្រក្រតីរបស់ពួកវា។ ទោះបីជាសារៈប្រយោជន៍នៃការស៊ីដីមិនត្រូវបានបញ្ជាក់នៅក្នុងការសិក្សានេះ ប៉ុន្តែប្រេងកង់ និងលំនាំនៃការប្រើដីប្រាបដោយក្រុមសត្វរងគ្រោះ (endangered species) និងងាយរងគ្រោះ (vulnerable species) បង្ហាញពីសារៈប្រយោជន៍ចាំបាច់នៃការលិតដី និងឆ្លុះបញ្ចាំងពីតម្រូវការចាំបាច់ឲ្យមានការខិតខំប្រឹងប្រែងការអភិរក្ស និងការការពារតំបន់ទាំងនេះ។

Abstract

Natural salt or mineral licks are valuable, yet spatially limited resources for wild animal populations. Many animals visit salt licks to engage in geophagy, which may serve to supplement mineral intake, ease gastrointestinal issues or buffer the effects of dietary toxins. This makes salt licks beneficial resources for the diet, nutrition and health of the animals that use them. Veun Sai–Siem Pang National Park in Cambodia is an area of high biodiversity value, and includes a number of salt lick sites. By placing camera traps at five salt lick locations within the conservation area, we

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investigated the patterns of lick use by animals to assess the importance of these resources within the ecosystem. Over 530 camera-trap days, nine mammal and three bird species were found to visit the salt licks, but only six mammals (two primates, one rodent and three ungulates) clearly engaged in geophagy. Visitation rate, encounter frequency and duration of visits differed between these species, as did grouping patterns and daily timing of lick visits. Both primates and gaur spent prolonged periods of time at the salt licks, suggesting such sites are an important part of their ecology. Gaur and red muntjacs were found to be nocturnal salt lick visitors, which is atypical of their normal activity patterns. Although the functional benefits of geophagy were not confirmed by this study, the frequency and pattern of use by a variety of Endangered and Vulnerable species demonstrates the significance of the licks and highlights the need to focus conservation efforts on their protection.

Keywords

Camera trap, geophagy, mineral lick, primates, salt-lick.

Introduction

Geophagy, the deliberate ingestion of soil or clay, is a common practice for many animals. Among vertebrates, it has been documented in numerous mammals, including humans (Abrahams & Parsons, 1996), ungulates (Houston *et al.*, 2001; Ayotte *et al.*, 2008; Tobler *et al.*, 2009), primates (Krishnamani & Mahaney, 2000; Ferrari *et al.*, 2008; Rawson & Bach, 2011), bats (Bravo *et al.*, 2008; Voigt *et al.*, 2008), and rodents (Matsubayashi *et al.*, 2007a); as well as in birds (Diamond *et al.*, 1999; Gilardi *et al.*, 1999; Brightsmith & Muñoz-Najar, 2004). Several hypotheses exist to explain the functional benefit of geophagy for animals. One common proposition is that animals use geophagy to supplement minerals that are otherwise lacking in their diets (Ganzhorn, 1987; Moe, 1993; Powell *et al.*, 2009; Dudley *et al.*, 2012). Another suggestion is that geophagy can help alleviate gastrointestinal issues, such as neutralising gastric acidity (Oates, 1978), acting as an antidiarrhoeal agent (Mahaney *et al.*, 1995), or buffering the effects of dietary toxins (Johns & Duquette, 1991; Gilardi *et al.*, 1999). Geophagy might also be used to combat the negative effects of endoparasite infestations (Knezevich, 1998) or increase the pharmacological properties of certain plants (Klein *et al.*, 2008). Currently, no single theory fully explains the occurrence of geophagy; rather, it seems likely that animals consume soil for a number of reasons, which vary with diet, reproductive status, geography, environment and season (Davies & Baillie, 1988; Krishnamani & Mahaney, 2000; Voigt *et al.*, 2008).

Mammals and birds that engage in geophagy often seek out natural mineral or salt licks in their environment. Such licks are spatially-limited resources with soil, clay or ground water rich in minerals (Klaus & Schmid, 1998). They are mostly frequented by herbivorous and omnivorous species, presumably as a consequence of their predominately plant-based diets (Kreulen, 1985).

Unlike carnivores that gain sodium from their prey, the intrinsically low sodium in plant tissue means phytophagous species must seek this vital nutrient elsewhere (Dudley *et al.*, 2012). As such, sodium deprivation is often considered a key driver of natural lick visitation (Holdø *et al.*, 2002; Powell *et al.*, 2009; Bravo *et al.*, 2012), but other elements such as calcium and magnesium may also constitute motivating factors (Ayotte *et al.*, 2006; Matsubayashi *et al.*, 2007b), especially in tropical environments where soils (and therefore, plants) are depleted of major cations (Emmons & Stark, 1979; Vitousek & Sanford, 1986).

Maintaining mineral homeostasis is not the only dietary challenge herbivorous species might seek to overcome by visiting natural licks. The consumption of clay has been linked to the adsorption of deleterious chemicals such as tannins, alkaloids or other plant secondary compounds (Gilardi *et al.*, 1999; Dominy *et al.*, 2004), which are especially high in mature leaves and unripe fruit (de Souza *et al.*, 2002; Bennett & Caldecott, 2012). It also adsorbs organic molecules such as fatty acids, which can decrease stomach pH and cause acidosis (Oates, 1978; Kreulen, 1985). Thus, for folivorous and frugivorous species in particular, geophagy at mineral licks may allow animals to exploit potentially harmful plants in greater quantities than they otherwise could, or consume new plant types (Gilardi *et al.*, 1999; Houston *et al.*, 2001; Dominy *et al.*, 2004). The limited nature of salt lick sites can also be advantageous for carnivores, with the increased prey density providing productive hunting grounds (Matsubayashi *et al.*, 2007a).

While mineral licks can provide benefits to animals, their use is not without risk (Klaus & Schmid, 1998). As mentioned, predators (including humans) are known to target lick sites, making visits inherently dangerous (Moe, 1993; Matsuda & Izawa, 2008). The consumption of soil at mineral licks can also expose animals to addi-

tional parasites and disease if they eat soil contaminated by faeces or urine (Henshaw & Ayeni, 1971). Animals may also be forced to leave their typical niche to access the resource such as arboreal species spending unusually prolonged periods on the ground (Klaus & Schmid, 1998). Additionally, animals that pursue these resources outside their home ranges can incur energetic costs and lose corresponding feeding and foraging time (Klein & Thing, 1989; Powell *et al.*, 2009). The fact that many species seek out these resources despite the risks and costs suggests that they are of high ecological importance (Montenegro, 2004; Blake *et al.*, 2011).

Given the potential value of lick sites to animals and the potential anthropogenic risks associated with accessing them, it is imperative that such sites are appropriately protected (Matsubayashi *et al.*, 2007b; Matsubayashi *et al.*, 2011; Molina *et al.*, 2014). However, to develop appropriate plans, it is first necessary to understand the diversity of species that use these resources as well as how they are used and their relative importance (Klaus & Schmid, 1998). While such patterns have been widely documented in Africa and the Americas, there are fewer studies from Southeast Asia (Matsubayashi *et al.*, 2007a). In this study, we use camera traps to document species diversity at five salt lick sites within Veun Sai–Siem Pang National Park (VSSPNP, northeastern Cambodia) and describe their patterns of use, with the aim of clarifying the importance of these resources from a dietary and conservation perspective.

Methods

Study Site

Veun Sai–Siem Pang National Park (14°01' N, 106° 44' E) consists of approximately 55,000 ha of evergreen and semi-evergreen forest located within Ratanakiri Province, Cambodia (Fig. 1). It borders the larger 320,000ha Virachey National Park and is part of the Indo-Burma Hotspot, a region of global importance for conservation due to its biodiversity values and high threat levels (Myers *et al.*, 2000). Initial surveys have reported 60 species of mammals, 130 species of birds and 60 species of reptiles within the reserve (Conservation International, unpublished data). Cambodia has two distinct seasons: the wet season, which occurs from May through October and the dry season from November to April (Thoeun, 2015). It has a mean annual temperature of 28°C (ranging from an average maximum of 38°C in April to an average minimum of 17°C in January) while the mean annual precipitation ranges from 1,200–2,000mm and is governed by monsoons (Thoeun, 2015). To date this site

has been managed by the Forestry Administration with support from Conservation International.

Mineral Lick Sites

Five natural mineral licks within the VSSPNP were monitored for this study. These mineral licks represent a small subset of sites involved in a larger camera trap survey that is investigating species diversity in the region. The salt lick sites were selected based on reports from local community members that animals congregate at these locations to eat soil. Five camera traps were placed at these sites and their use as salt licks was confirmed from photographs. Location 1 was a clay bank infiltrated with the roots of trees, while locations 2, 3, 4 and 5 consisted of muddy depressions that were sometimes filled with water. All were surrounded by evergreen forest, except for location 5, which was situated within deciduous forest. All camera traps were located within largely undisturbed forest, but were in relatively close proximity to local ethnic minority villages who know and access these areas (see Fig. 1).

Camera Trap Monitoring

Reconyx PC85 RapidFire™ camera traps were used to document activity at the five mineral lick sites. One camera was placed at the edge of each lick. Cameras were triggered by integrated Passive InfraRed (PIR) motion detectors (with sensitivity on 'high') and were set to record three pictures per trigger, with a one second pause between pictures. There was no delay between trigger events. The exact time of each photograph was recorded by the cameras and logged in a database. Species were then identified from the photographs. Cameras were active from January to October 2010 and from January to April 2011. The units were checked approximately once a month for battery condition and damage as well as to download the photos. The total survey effort was 530 camera-trap days.

Data Analysis

Encounter frequencies and relative abundance indices were calculated for each species. Encounter frequencies were calculated by dividing the total number of camera-trap days (total survey effort) by the number of independent records for each species. They are thus expressed as one visit per x number of camera-trap days. Relative abundance indices were calculated by dividing the number of independent records (across all sites) by the total number of camera-trap days (total survey effort) then multiplying by 100, being expressed as the number of independent visits per 100 days. A camera-trap day

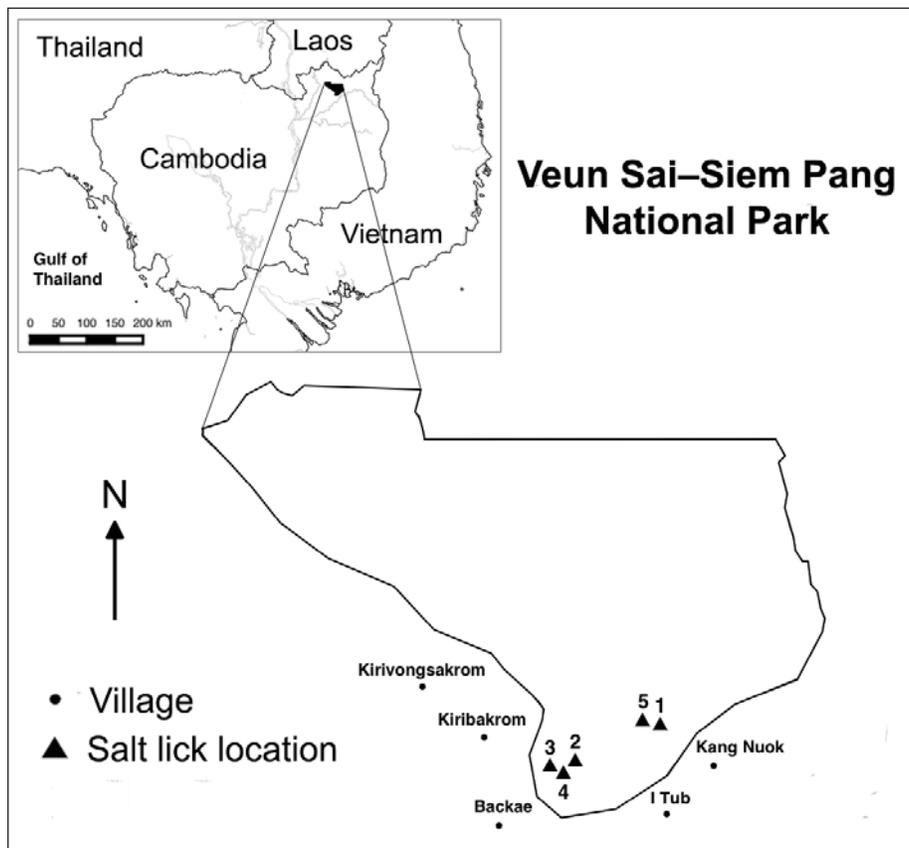


Fig. 1 Salt lick locations within the Veun Sai–Siem Pang National Park, Cambodia.

was defined as a 24-hour period when a camera was active. To avoid issues of non-independence of records, an encounter was considered independent if a period of 30 minutes had elapsed between photographs of the same taxon. While a 30 minute lapse is commonly used in salt lick camera trap studies (e.g., Rawson & Luu, 2011; Edwards *et al.*, 2012; Hon & Shibata, 2013), it was also necessary in this case because animals (especially primates) sometimes disappeared from the camera’s frame to access underground portions of the salt licks. Independent encounters from all mineral lick locations were pooled for the analyses.

To describe patterns of use, the following factors were considered for each species: maximum and mean group size, mean visit duration and mean time of day that species visited the licks. The mean visit duration (average time each species spent at licks) was calculated by summing the total time spent at a site during each independent encounter and dividing by the total number of visits. The mean and median times of day (circular means and medians) in which photos were taken was calculated for each species using Oriana version 4 for circu-

lar data. They are reported in the results as 24-hour time, with 95% confidence intervals (CI). A Mann-Whitney U test was used to determine if two primate species visited licks at different times of day. Here, the distributions of visit time were similar and the statistics were calculated using SPSS Statistics version 23. A *p*-value of < 0.05 was considered significant unless otherwise stated.

Rayleigh’s Uniformity Test (in Oriana) was used to test the null hypothesis that activity was uniformly distributed throughout the day for each species (cathemerality). Diurnal activity was defined as occurring between one hour after sunrise and one hour before sunset (approximately 07:00–17:00 hrs). Nocturnal activity occurred between one hour after sunset and one hour before sunrise (approximately 17:00–05:00 hrs). Crepuscular activity occurred between one hour before sunrise and one hour after sunrise (approximately 05:00–07:00 hrs), and one hour before sunset and one hour after sunset (approximately 17:00–19:00 hrs). Following Morales (2009), if cathemerality was rejected, species were classified as diurnal if >70% of photos were diurnal and classified as nocturnal if >70% of photos were noc-

turnal. Species were classified nocturnal-crepuscular if 45–70% of photos were nocturnal and >20% crepuscular, and were classified as diurnal-crepuscular if >45% were diurnal and >20% crepuscular.

Results

Species Assemblage

Over the 530 camera-trap days, 9,462 photos were taken of animals, representing 199 independent wildlife encounters. Nine species of mammals and three species of birds were recorded (Table 1). Together, these represent approximately 16.7% of all species recorded by all camera traps active within the VSSPNP borders (which form a larger camera trapping programme). While nine species of mammals were photographed at the salt lick

sites, only six (red-shanked douc, Annamese silvered langur, Malayan porcupine, red muntjac, sambar and gaur) were photographed eating soil (Fig. 2). Unfortunately, geophagy could not be confirmed for any of the birds. Humans (77 encounters) and domestic dogs (9 encounters) were also recorded at the mineral lick sites, but their purpose was not to engage in geophagy. People would use the clear areas as walkways to other destinations, while the dogs were accompanying the humans.

Encounter Frequencies

Encounter frequencies for species that were photographed at the licks but not recorded engaging in geophagy are shown in Table 1; however, these data are not included in the forthcoming analysis. Of the species that engaged in geophagy, encounter frequencies ranged from one visit per 7.5 days (red muntjac) to one visit per

Table 1 Wildlife species recorded at natural salt licks within the Veun Sai–Siem Pang National Park, Cambodia.

Common Name	Scientific Name	No. of Encounters	Relative Abundance ²	Group Size ³	Feeding Guild ⁴	IUCN Red List ⁵
MAMMALS						
PRIMATES						
Red-shanked douc ¹	<i>Pygathrix nemaeus</i>	50	9.4	3.1±3.2 (18)	H/F	EN
Annamese silvered langur ¹	<i>Trachypitecus margarita</i>	36	6.8	3.6±2.6 (10)	H/F	EN
RODENTIA						
Malayan porcupine ¹	<i>Hystrix brachyura</i>	7	1.3	1.4±0.8 (3)	H/F	LC
ARTIODACTYLA						
Red muntjac ¹	<i>Muntiacus muntjak</i>	71	13.4	1.1±0.3 (2)	H/F	LC
Sambar ¹	<i>Rusa unicolor</i>	9	1.7	solitary	H/F	VU
Gaur ¹	<i>Bos gaurus</i>	17	3.2	1.9±1.5 (6)	H/F	VU
Wild boar	<i>Sus scrofa</i>	2	0.4	14±16.97 (26)	O	LC
CARNIVORA						
Large Indian civet	<i>Viverra zibetha</i>	1	0.2	solitary	C/O	NT
Large spotted civet	<i>Viverra megaspila</i>	1	0.2	solitary	O	VU
BIRDS						
Red jungle fowl	<i>Gallus gallus</i>	2	0.4	1.5±0.7 (2)	O	LC
Crested serpent eagle	<i>Spilornis cheela</i>	2	0.4	solitary	C	LC
Spotted dove	<i>Spilopelia chinensis</i>	1	0.2	pair	G	LC

¹ Species recorded engaging in geophagy from photographs.

² Expressed as x number of visits per 100 days.

³ Expressed as mean±SD (max).

⁴ H/F=Herbivore-Frugivore; O=Omnivore; C=Carnivore; G=Granivore.

⁵ NT=Near threatened; LC=Least Concern; VU=Vulnerable; EN=Endangered.

75.7 days (Malayan porcupine). The two primate species, red-shanked douc and Annamese silvered langur, had the second and third highest encounter frequencies, averaging one visit per 10.6 days and one visit per 14.7 days, respectively. These were followed by gaur with one visit per 31.8 days and sambar with the second lowest frequency of one visit every 58.9 days. Table 1 also provides the relative abundance indices by species.

Species Group Sizes at Licks

A higher percentage (62.6%) of all salt lick photographs were of groups (two or more individuals) as opposed to solitary individuals. The mean maximum group sizes and the maximum group size per species are listed in Table 1. Due to their known gregarious nature, it was not surprising that primates had the largest maximum and mean group sizes. Single individuals accounted for only 38.0% of all independent encounters for the red-shanked douc, and 30.6% for all Annamese silvered langurs. It is unclear, however, if these animals truly were solitary individuals or if the larger group was just out of the camera frame. A known lone male red-shanked douc has been frequently encountered near one of the salt licks.

After primates, gaur had the next largest groups at salt licks. In contrast to primates, however, single individuals accounted for more independent encounters (64.7%) than did groups. The Malayan porcupine and red muntjac photographs consisted mostly of solitary individuals. Groups accounted for only 28.6% and 9.9% of all photographs for these species, respectively. Sambar were never observed in groups.

There were only a few instances where multiple species were photographed visiting the same salt lick site concurrently. These occurred when Annamese silvered langurs joined a group of red-shanked doucs at the same site; a red jungle fowl with red-shanked doucs; and a red jungle fowl with a group of gaur.

Daily Use Patterns

Species differed in how long they spent at the mineral lick per independent encounter. Annamese silvered langurs had the longest mean visit duration (55.0 ± 71.5 min), followed by red-shanked doucs (53.4 ± 49.5 min), then gaur (46.1 ± 102.1 min), red muntjac (7.7 ± 10.3 min), sambar (1.4 ± 2.0 min) and Malayan porcupine (0.8 ± 1.2 min). Visit duration was found to significantly correlate with maximum group size ($r_s = 0.695$, $df = 188$, $p < 0.001$).

Species also differed in the time of day they used the licks (Fig. 3). Photographs of red-shanked doucs and Annamese silvered langurs were usually taken during

the morning and afternoon respectively (red-shanked douc: mean = 09:46 hrs, 95% CI = 09:41–09:50 hrs, median = 09:28 hrs); silvered langur: mean = 13:39 hrs, 95% CI = 13:35–13:42 hrs, median = 13:30 hrs), while gaur and Malayan porcupine were photographed on average near midnight (gaur: mean = 00:19 hrs, 95% CI = 00:09–00:29 hrs, median = 23:53 hrs; Malayan porcupine: mean = 00:38 hrs, 95% CI = 00:09–01:06 hrs, median = 01:21 hrs). Both the muntjac and sambar were most frequently recorded at the salt lick in the very early morning (red muntjac: mean = 03:03 hrs, 95% CI = 02:45–03:20 hrs, median = 02:43 hrs; sambar: mean = 01:11 hrs, 95% CI = 00:48–01:33 hrs, median = 01:56 hrs).

A Mann-Whitney U test was undertaken to determine if the two primate species visited the mineral licks at different times of day. Median time of first appearance (per encounter) was significantly different between the species ($U = 227.5$, $p < 0.001$, $n[\text{douc}] = 50$, $n[\text{silvered langur}] = 36$).

Rayleigh's uniformity test demonstrated that species did not visit the site uniformly throughout the day (red-shanked douc: $Z = 2456.236$, $p < 0.001$; silvered langur: $Z = 2808.805$, $p < 0.001$; Malayan porcupine: $Z = 24.209$, $p < 0.001$; gaur: $Z = 685.382$, $p < 0.001$; red muntjac: $Z = 272.252$, $p < 0.001$; sambar: $Z = 76.214$, $p < 0.001$). From these data, the silvered langurs (99.9% diurnal) and red-shanked doucs (94.0% diurnal and 6.0% crepuscular) were classified as diurnal salt lick users. Nocturnal salt lick users included the Malayan porcupine (100% nocturnal) and all of the ungulates: sambar (96.9% nocturnal, 3.1% crepuscular), gaur (85.4% nocturnal, 0.9% diurnal, 13.7% crepuscular) and red muntjac (71.6% nocturnal, 13.4% diurnal, 15.1% crepuscular).

Discussion

To the best of our knowledge, this is only the second published report of species diversity at salt licks within Cambodia, with the first study comprising only a single camera trap and 57 camera-trap days (Edwards *et al.*, 2012). We recorded nine mammal species and three bird species at five salt licks within the VSSPNP. Of these, five of the mammals have been previously recorded at mineral licks in Asia: Malayan porcupine, red muntjac, sambar, gaur and wild boar (Moe, 1993; Matsubayashi *et al.*, 2007a,b; Edwards *et al.*, 2012). No instances of salt lick visitation by red-shanked doucs and Annamese silvered langurs have been reported outside the VSSPNP (Rawson & Bach, 2011). While other species of civets are known to visit mineral licks in Asia (Moe, 1993; Matsubayashi *et al.*, 2007a; Edwards, 2012), this is the first record of *Viverra zibetha* and *Viverra megaspila* visiting such resources. Sim-



Fig. 2 Photographs of species engaged in geophagy within the Veun Sai–Siem Pang National Park: A) red-shanked douc *Pygathrix nemaeus*; B) Annamese silvered langur *Trachypithecus margarita*; C) Malayan porcupine *Hystrix brachyura*; D) gaur *Bos gaurus*; E) red muntjac *Muntiacus muntjac*; F) sambar *Rusa unicolor*.

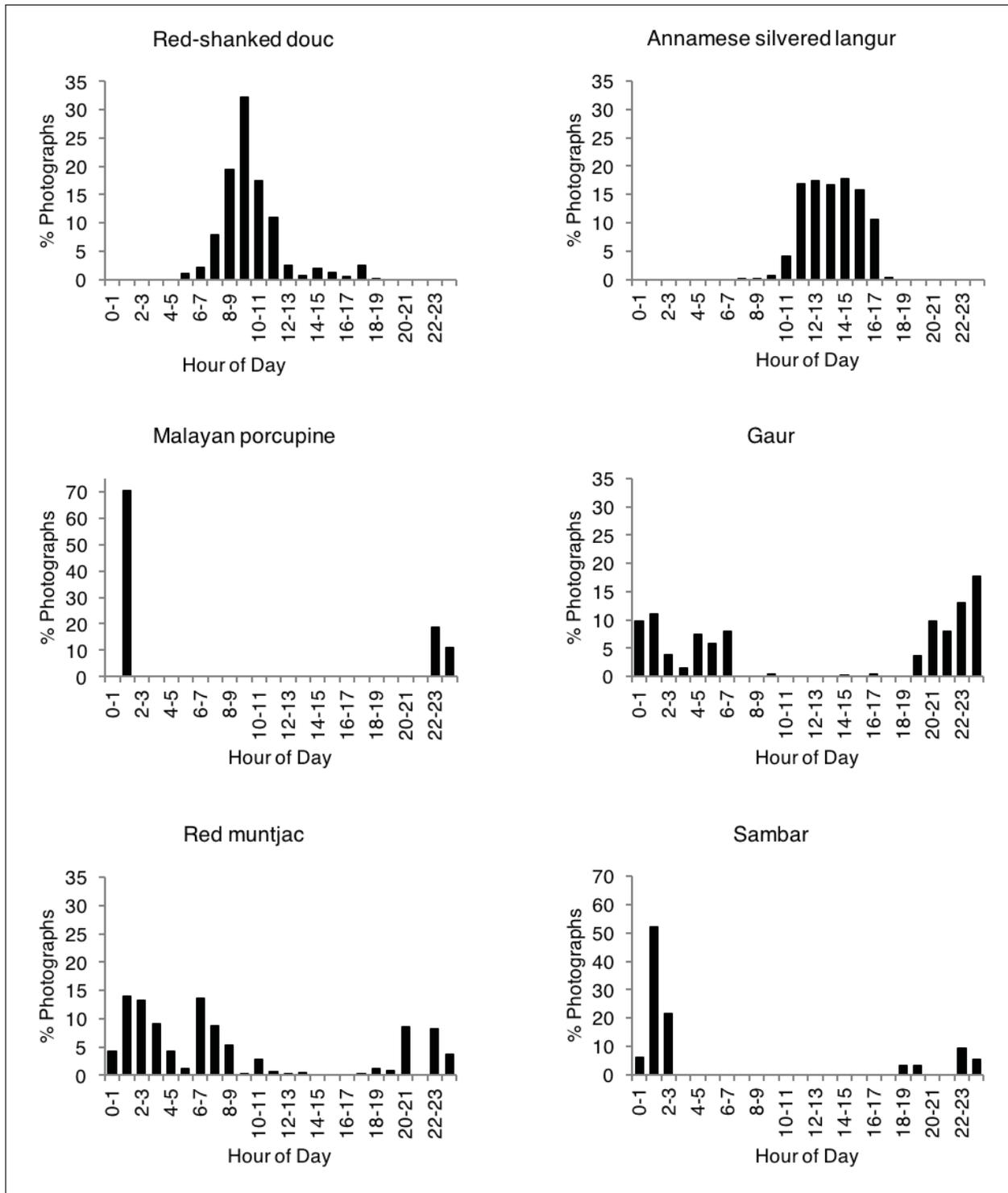


Fig. 3 Histograms representing the daily activity pattern of wildlife species that engaged in geophagy at natural salt licks.

ilarly, bird species within the Phasiniidae, Accipitridae and Columbidae families have been reported in previous salt lick studies (Diamond *et al.*, 1999; Symes *et al.*, 2005; Blake *et al.*, 2011; Edwards *et al.*, 2012), but *Gallus gallus*, *Spilornis chela* and *Spilopelia chinensis* have not.

Of the species recorded at the salt licks, only six appeared to engage in geophagy. Red-shanked doucs, Annamese silvered langurs, gaur and red muntjacs (all herbivores) visited the sites often and/or for prolonged periods, suggesting the licks may be especially important to the ecology of these species, but soil analyses are required to determine the exact benefit they are obtaining. Civets (carnivores) were photographed twice at the licks, but on both occasions they appeared interested only in drinking water that had pooled at the site. All the birds recorded at the sites had very short visits (with the exception of the crested serpent eagle, which spent a long time preening).

Mammals tended to visit the salt licks according to species-typical grouping behaviour (either as solitary individuals or groups), which suggests the licks did not serve a gathering function or act as a mating venue (Morales, 2009). However, across species, group size was found to correlate with visit duration, suggesting those species with larger groups may be better able to dominate this spatially limited resource or better protect themselves against predation, making it less risky to stay at the site for longer periods.

Other studies have reported increases in group size at salt licks for primates. In a study of white-bellied spider monkeys *Ateles belzebuth* in Western Amazonia, Link & Di Fiore (2013) found that these primates formed larger groups than normal when visiting salt lick sites because the licks were perceived as areas of high predation risk and larger groups provided some defence against this (Link *et al.*, 2011). While we did not find a similar pattern, there was one incident of a polyspecific association between the two primate species, which could be the result of perceived predation risk; however, we caution against drawing a strong conclusion based solely on one case. Generally, the primates visited the site at different times of day: red-shanked doucs frequented the site in the morning, and Annamese silvered langurs in the afternoon. This could represent an aspect of niche separation, designed to avoid direct competition for the resource (Rawson & Bach, 2011).

Gaur also visited the salt licks in groups of up to six individuals. Although the basic gaur social unit is a female-juvenile pair (Duckworth *et al.*, 2008), temporary assemblages or maternal herds have been reported in some regions (Steinmetz *et al.*, 2010; Ramesh *et al.*,

2012). Nonetheless, given the presence of known gaur predators at VSSPNP (such as leopards, dhole and historically, tigers), the larger groups could also represent a strategy to lower hunting risk. Evidence that the gaur are under pressure in this area additionally comes from their daily use patterns, which were more nocturnal than typical. In a study of mammals and birds, Blake *et al.* (2013) found that diurnal activity was reduced at salt lick sites with higher levels of hunting compared to hunting-free controls, with this particularly true for red brocket deer *Mazama americana*. Similarly, gaur in India become predominately nocturnal in response to severe habitat disturbance and human encroachment on their habitat (Duckworth *et al.*, 2008), as have banteng *Bos javanicus* in Cambodia (Chan & Gray, 2010). These pressures also may have affected the red muntjac within VSSPNP, as their activity patterns too are usually more diurnal/cathemeral than our data suggests (Kawanishi & Sunquist, 2004; Hon & Shibata, 2013).

Although the cause of salt lick visitation was not investigated in this study, the relatively high visitation frequency of six mammal species does suggest they are ecologically important resources. With six out of the 12 recorded animals listed as Near Threatened, Vulnerable, or Endangered by the IUCN (2015), it is important such resources are adequately protected to safeguard lick users against human hunting, habitat disturbance and snares. In VSSPNP, hunting hides have been detected at salt lick sites, presumably to take advantage of animals congregating in these areas, and as such enforcement efforts should aim to suppress such behaviour. To further understand the importance of salt licks on species ecology within Cambodia, additional research should be conducted, with studies that include soil analyses being a specific priority.

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The first population census of the Critically Endangered giant ibis in Western Siem Pang, northeastern Cambodia

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មូលនិយមសង្ខេប

ត្រយង់យក្ស *Thaumatibis gigantea* ជាបក្សីជិតផុតពូជដែលមានមាឌធំជាងគេក្នុងចំណោមត្រយង់ទាំង៣៦ប្រភេទនៃអំបូរ Threskiornithidae ហើយវាក៏ជាមិនិរន្តរ៍បក្សីជាតិនៃប្រទេសកម្ពុជាផងដែរ។ ពីមុនមក ត្រយង់យក្សធ្លាប់មានវត្តមាននៅទូទាំងភូមិភាគអាស៊ីអាគ្នេយ៍ ប៉ុន្តែបច្ចុប្បន្ននេះវត្តមានរបស់វាស្ទើរតែទាំងអស់មានតែនៅភាគខាងជើង និងខាងកើតនៃប្រទេសកម្ពុជាប៉ុណ្ណោះ។ តាមការប៉ាន់ស្មាន មានត្រយង់យក្សពេញវ័យប្រហែល១៩៤ក្បាលប៉ុណ្ណោះនៅក្នុងពិភពលោក។ ការប៉ាន់ស្មាននេះគឺពឹងផ្អែកលើទិន្នន័យដែលមានប្រភពមិនច្បាស់លាស់ និងការប៉ាន់ស្មានរបស់អ្នកជំនាញប៉ុណ្ណោះ ដូច្នេះវិធីរាប់មួយចំនួនដែលមានសុពលភាពគឺត្រូវការជាចាំបាច់ចំពោះប្រភេទដែលពិបាកសិក្សានេះ។ នេះជាលទ្ធផលនៃការវាយតម្លៃជាប្រព័ន្ធដំបូងគេលើចំនួនរបស់ត្រយង់យក្សក្នុងទីតាំងមួយកន្លែង។ វិធីសាស្ត្រដែលបានប្រើសម្រាប់ការសិក្សាគឺជាការរួមបញ្ចូលគ្នារវាងការកត់ត្រា តាមរយៈការអង្កេតដោយផ្ទាល់ និងតាមរយៈការស្តាប់សំឡេងនៅតាមត្រពាំង។ វិធីសាស្ត្រនេះចំណាយថវិកាតិច ដោយផ្អែកលើអេកូឡូស៊ីរបស់ប្រភេទសត្វនេះ។ ហើយវិធីសាស្ត្រនេះត្រូវបានសិក្សាសាកល្បងនៅដែនជម្រកសត្វព្រៃសៀមប៉ាងលិច ភាគឥសាននៃកម្ពុជាដែលពីមុនគេស្គាល់ថា តំបន់សត្វស្លាបសំខាន់ភាគខាងលិចសៀមប៉ាង នេះជាតំបន់មួយក្នុងចំណោមតំបន់ផ្សេងទៀតដែលមានចំនួនត្រយង់យក្សច្រើនជាងគេ។ យើងប៉ាន់ស្មានថាមានត្រយង់យក្សចំនួន៤៩.៥±១០ក្បាល នៅមានវត្តមាននៅក្នុងតំបន់នេះ។ យើងពិនិត្យយ៉ាងជាក់លាក់ទៅលើវិធីសាស្ត្រនេះ នឹងស្នើសុំឱ្យមានការផ្តល់យោបល់កែលម្អពីអ្នកជំនាញ។ ជាអនុសាសន៍ គឺស្នើឱ្យមានការរាប់ចំនួនឡើងវិញជាទៀងទាត់ ដោយប្រើវិធីសាស្ត្រស្តាប់ដំបូលគ្រប់តំបន់ការពារអាទិភាពនៃប្រភេទនេះ។ ជាលទ្ធផលគឺអាចឱ្យយើងដឹងពីបម្រែបម្រួលនៃចំនួន ក្នុងគោលបំណងវាយតម្លៃពីប្រសិទ្ធភាពនៃការអន្តរាគមន៍អភិរក្ស ព្រមទាំងការព្រមានទាន់ពេលវេលា ទប់ស្កាត់ការធ្លាក់ចុះនៃចំនួនប្រភេទសត្វដែលជិតផុតពូជនេះ។

Abstract

The Critically Endangered giant ibis *Thaumatibis gigantea* is the largest of 36 species in the Threskiornithidae and the national bird of Cambodia. The species historically occurred throughout Southeast Asia, but is now almost entirely restricted to northern and eastern Cambodia. The global population is estimated at 194 mature individuals. This estimate is based on incidental data and expert opinion, however, and a rigorous population census method has yet to be

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validated for this elusive species. We report the results of the first systematic population assessment of giant ibis at a single site. Our method combines visual and auditory detections at forest pools (trapeang) and provides a cost-effective survey approach based on species ecology. This was tested in Prey Siem Pang Khang Lech Wildlife Sanctuary in North-east Cambodia, previously known as Western Siem Pang Important Bird Area, one of the last strongholds of the giant ibis. We estimate that 49.5 ± 10 birds still occur in the site and critically review our method, suggesting refinements. We conclude by recommending repeated surveys using a standard method at all priority protected sites for the species. This will enable the interpretation of population trends to determine the efficacy of conservation interventions and provide an early warning, should further declines occur in this Critically Endangered species.

Keywords

Auditory detections, census, giant ibis, survey methods, visual detections, Western Siem Pang.

Introduction

Southeast Asia is experiencing the fastest rate of habitat conversion in the world (Sodhi *et al.*, 2010) and recent studies suggest that Cambodia is experiencing faster rates of tree loss than any other country in the region (Hansen *et al.*, 2013; Peterson *et al.*, 2015). Many animals in Cambodia consequently face a high risk of extinction (Keo *et al.*, 2009). For instance, the giant ibis *Thaumatibis gigantea* (Threskiornithidae; Fig. 1) was formerly widespread across mainland Southeast Asia, particularly Thailand, Laos, Vietnam and Cambodia. However, its range has contracted dramatically and the largest remaining populations occur in Cambodia (Fig. 2), with a few individuals believed to persist in Vietnam and Laos (BirdLife International, 2015a). The species is now extirpated from Thailand.

The giant ibis occurs in isolated populations across Cambodia but in relatively higher densities in northern and eastern areas of the country, including Chhiep Wildlife Sanctuary (formerly Preah Vihear Protected Forest) and Kulen Promtep Wildlife Sanctuary (where 24 pairs were monitored in 2014; Loveridge & Ty, 2015), and Prey Siem Pang Khang Lech Wildlife Sanctuary (with approximately 40 pairs; H. Wright, in litt., 2012). Other areas with significant populations include Srepok Wildlife Sanctuary (formerly Mondulkiri Protected Forest) and Lomphat Wildlife Sanctuary. Sum *et al.* (2011, 2013) estimated at least 10–15 pairs of giant ibises inhabit Lomphat Wildlife Sanctuary, and incidental camera-trap data (Gray *et al.*, 2014) suggest a population of 50 birds in Srepok Wildlife Sanctuary (T. Gray, pers. comm.). Other confirmed, although older sightings suggest that approximately five pairs may exist in Seima Wildlife Sanctuary (formerly Seima Protection Forest), Phnom Prich Wildlife Sanctuary, Veun Sai–Siem Pang National Park (formerly Veun Sai–Siem Pang Conservation Area), Yok Don National Park in Vietnam and scattered across the extreme south

of Laos (BirdLife International, 2015b). In addition, the species has also recently been confirmed at five other sites: a stretch of deciduous dipterocarp forest north of Sre Ambel in Koh Kong Province (Evans & Goes, 2011), Sang Sahakum Rukhavoan Community Forest in Oddar Meanchey Province, one site on the Sesan River near Stung Treng, a proposed bird nest protection area along the Mekong River in Kratie Province and Prey Lang Wildlife Sanctuary (Hayes *et al.*, 2015). It is estimated that each of these sites contain at least one pair of giant ibis. However, further survey effort is required to improve understanding of these populations and their distribution ranges to prioritise conservation efforts.

The primary habitat of the giant ibis is deciduous dipterocarp forest, where it is generally widespread at very low densities. Within this forest, the species relies on a matrix of habitats including forest pools ‘trapeang’ (Fig. 3), grasslands, and undisturbed roosting and nesting sites (Keo *et al.*, 2009). It breeds during the wet season (June–September) (Keo, 2008a) and nests in trees, with a preference for large *Dipterocarpus* species, generally more than 4 km from human habitation (Keo, 2008b). The species generally calls twice a day, in the morning from 04:30 to 07:00 hrs and in the evening from 18:00 to 18:30 hrs, and calls more frequently during the mating season before eggs are laid in June and July (Ty, 2013). It generally occurs in singles, pairs or small parties (BirdLife International, 2015b) and feeds in open water and on soft and hard muddy substrates surrounding the edges of trapeang (Wright *et al.*, 2012; J. Eames, pers. obs.). Its diet comprises a variety of invertebrates, crustaceans, eels, frogs and reptiles. The giant ibis is threatened by loss of suitable forest habitat throughout its range due to: 1) wholesale forest clearance by agricultural developments known as Economic Land Concessions (ELCs), 2) habitat conversion by small-scale agricultural encroachment by local communities, and 3) infrastructure and development initiatives, such as road construction through key



Fig. 1 (left) Giant ibis *Thaumatibis gigantea* (© Jonathan C. Eames).

Fig. 2 (below) Distribution of, and priority conservation zone for the giant ibis, including Yok Don National Park (Vietnam), Xe Pian National Biodiversity Conservation Area (Laos) and all priority protected areas for the species in Cambodia: A) Kulen Promtep Wildlife Sanctuary; B) Chhep Wildlife Sanctuary (formerly Preah Vihear Protected Forest); C) Siem Pang Wildlife Sanctuary and Prey Siem Pang Khang Lech Wildlife Sanctuary (formerly Siem Pang Protected Forest and Siem Pang Proposed Protected Forest II); D): Veun Sai–Siem Pang National Park (formerly Veun Sai–Siem Pang Conservation Area); E) Lomphat Wildlife Sanctuary; F) O’Yadao Protected Forest; G) Srepok Wildlife Sanctuary (formerly Mondulkiri Protected Forest); H) Phnom Prich Wildlife Sanctuary.

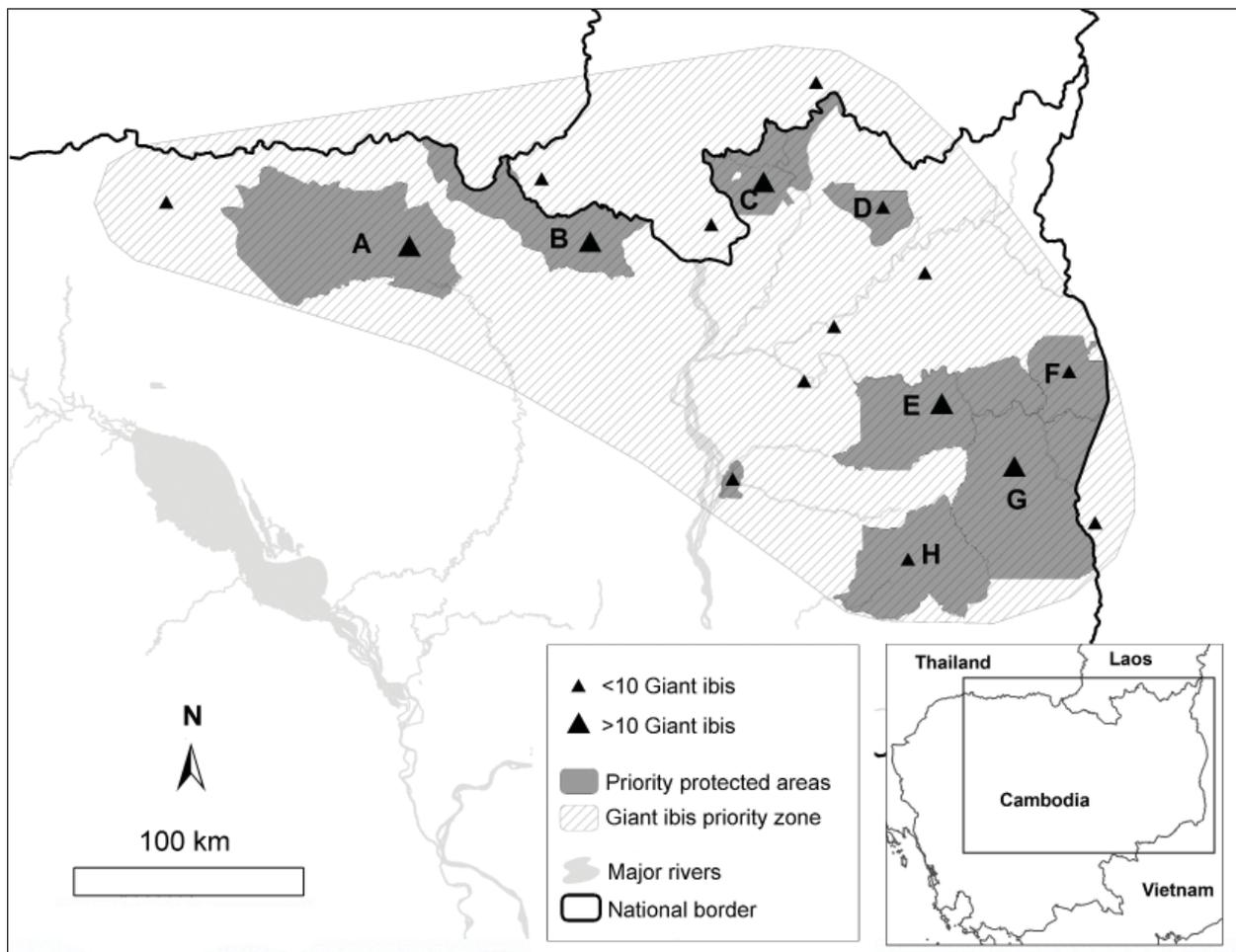




Fig. 3 Aerial photograph of a trapeang (forest pool) in deciduous dipterocarp forest, Cambodia (© Jonathan C. Eames).

habitats (BirdLife International, 2015a; Loveridge & Ty, 2015). These widespread threats are in addition to targeted threats facing the species, which include hunting and poisoning at sites where it occurs (BirdLife International, 2015a).

Recent efforts have been made to improve knowledge of giant ibis populations across Cambodia and the national population is currently estimated at 194 mature individuals (Loveridge & Ty, 2015). However, this estimate is based on incidental data and expert opinion and the development of a cost-effective survey method is urgently needed to identify remaining populations and prioritise future conservation efforts. This study reports the first systematic population assessment for this elusive species in Prey Siem Pang Khang Lech Wildlife Sanctuary, previously known as Western Siem Pang Important Bird Area (Seng *et al.*, 2003), one of the last strongholds for the giant ibis. The method combines visual and auditory detections at trapeang and provides a cost-effective survey approach based on the specific characteristics of the species. As the first census method proposed for the species, we encourage others to critically review this method and suggest refinements to improve its accuracy

at minimal cost. We present the method here as the first step towards developing a standard approach that can be applied at all priority protected sites within the species' range. This paper contributes to priority research actions in the 10-year national action plan for the giant ibis (Loveridge & Ty, 2015), specifically action 3.1 (improving baseline data for the species at priority sites) and action 3.2 (developing a unified census method that can be implemented at priority sites).

Methods

Study area

The study was conducted in 2014 in Prey Siem Pang Khang Lech Wildlife Sanctuary (PSPKLWS) which comprises 65,389 ha in Stung Treng Province, Northeast Cambodia (14°07' N, 106°14' E; Fig. 3). The site is contiguous with Siem Pang Wildlife Sanctuary (formerly Siem Pang Protected Forest) to the north and, before its designation as a wildlife sanctuary in May 2016, included an ELC largely comprised of deciduous dipterocarp forest

which was cancelled in early 2015. Both sites are contiguous with Virachey National Park to the east and Xe Pian National Biodiversity Conservation Area (Laos) to the west. The two wildlife sanctuaries collectively cover 132,321 ha, 50% of which comprises deciduous dipterocarp forest. Denser semi-evergreen forest represents 40% of the area and the remainder comprises degraded semi-evergreen forest (5%), deforested land including cultivation areas (3%) and water (2%) (BirdLife International, 2012). Forest cover is relatively open in many places, denser in others, and has a grassy understory. Climate is strongly monsoonal with average monthly rainfall as little as 0.9 mm during the dry season (November–April) and up to 333 mm in the wet season (May–October) (Thuon & Chambers, 2006; Wright, 2012). The Sekong River, a major tributary of the Mekong, flows through the area and supports extensive stretches of riverine forest (BirdLife International, 2012). The area supports five Critically Endangered bird species (white-shouldered ibis *Pseudibis davisoni*, giant ibis *Thaumatibis gigantea*, red-shouldered vulture *Sarcogyps calvus*, slender-billed vulture *Gyps tenuirostris* and white-rumped vulture *Gyps bengalensis*), as well as several Endangered mammals (Eld’s deer *Rucervus eldii*, gaur *Bos gaurus*, banteng *Bos javanicus* and Indochinese silver langur *Trachypithecus germaini*) (BirdLife International, 2012). PSPKLWS is surrounded by 14 villages in three communes. The total population comprises 10,124 people or 2,229 households, with 38% of households living under poverty line (Bou & Yam, 2014). Rice cultivation, cutting of wood for timber, non-timber forest product collection and fishing contributed most to local livelihoods in 2012 (Wright, 2012).

Sampling site selection

Our census method was based on observations at forest pools (trapeang) (Fig. 3), one of the most important foraging habitats for giant ibis and other waterbirds, especially during the dry season from November to May (Keo, 2008a). Due to resource limitations, we did not attempt to survey all trapeang known at PSPKLWS (over 200), but instead maximised the likelihood of detections by focussing on selected trapeang. Existing bird observations from 2009–2013 (BirdLife International, unpublished data) were reviewed to classify each trapeang at the site into four categories: 1) used by giant ibises from the late rainy season to the early dry season (October–December = 18 trapeang), 2) used during the mid dry season (January–March = 49), 3) used from the late dry season to the early rainy season (April–June = 29), and 4) used during the rainy season (July–September = 19). The 49 trapeang where the species was sighted during

the dry season months of January–March were selected for the census.

Survey effort and data collection

Monthly census counts were conducted in January–March 2014, from the 23rd to 28th day of each month. The 49 study trapeang were grouped into six zones, each zone comprising trapeang located <3 km apart (Fig. 4). One zone was surveyed per day by a team of 11 observers and overall, each trapeang was visited once a month by observers in pairs or singles.

Ty (2013) found that giant ibises frequently call at roosting sites in PSPKLWS from 05:00 to 06:00 hrs, then cease calling and travel to foraging sites around 06:00 hrs. He also found disturbance from human activity generally begins around 07:00 hrs. As a consequence, census counts were confined to 05:30–07:30 hrs to coincide with the start of call activity and least disturbed period of the day. To further avoid disturbance, surveyors approached trapeang slowly and chose vantage points that provided some concealment and a clear view of the entire trapeang before 05:30 hrs.

Two types of data were recorded during the census: visual detections and auditory detections of calling birds. Giant ibises produce a loud call which can be heard up to two kilometres away and used to locate them (Ty, 2013). For visual detections the following was recorded: number of birds observed; time seen; duration of stay at trapeang; entrance and exit direction, time, and flight height; and the identity of any birds flushed on approach to trapeang. Data recorded on auditory detections comprised call time, direction, bearing and estimated distance.

Data screening and analysis

Prior to analysis, data were screened to exclude three possible sources of double counts of individual birds, as follows:

1) *Double counts from auditory and visual detections of the same bird*— The direction of calling birds was recorded by observers and if birds were visually detected arriving from the same direction as an earlier auditory detection, the latter was excluded from analysis;

2) *Double counts from auditory detections*— Repeat auditory detections recorded by the same observer within a 45° degree radius were considered the same individual, unless these occurred simultaneously; and,

3) *Double counts from individual birds travelling between trapeang on the same day*— Each two-hour trapeang session

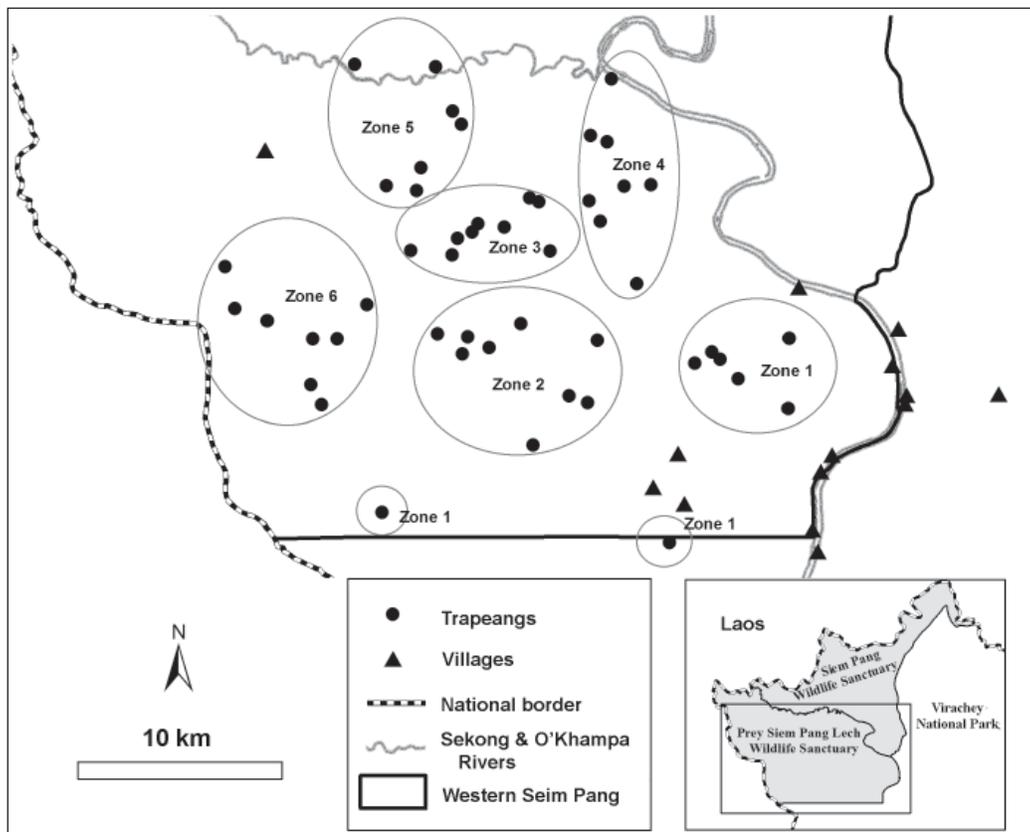


Fig. 4 Distribution of trapeang and survey zones in Prey Siem Pang Khang Lech Wildlife Sanctuary, Cambodia.

was split into four 30-minute intervals and numbers of birds recorded were calculated for each interval. The population count for the trapeang session was taken as the greatest count from a single interval, thereby reducing the likelihood of individual birds being recorded at different trapeang on the same day.

The possibility of double counts arising from the occurrence of individual birds in multiple survey zones was also considered in the census design. The giant ibis resides in deciduous dipterocarp forest and is thought to have a stable home range that incorporates key foraging resources such as trapeang (Keo, 2008a; Wright *et al.*, 2012). As trapeang have a clustered distribution in PSPLWS and survey effort was arranged into geographically discrete zones as far as practicable, individual birds were therefore considered unlikely to have foraged widely over the entire survey area.

On completion of screening, data were analysed to produce monthly population estimates for each of the six zones. A maximum monthly count for each zone was

calculated by summing the number of unique individuals recorded by both visual and auditory detections. A minimum monthly population count was then calculated for each zone based on visual detections alone. The actual monthly population estimate for each zone was taken as the mid-point between these two figures in providing a conservative estimate incorporating both types of detections.

Results

Numbers of giant ibises recorded at PSPKLWS each month varied significantly over the course of the 2014 census: 22 birds were recorded in January (=21 visual detections + 1 auditory detection), 59 in February (=40 visual detections + 19 auditory detections), and 33 in March (=16 visual detections + 17 auditory detections) (Table 1). These yielded monthly population estimates of 21.5 (min = 21, max = 22) birds in January, 49.5 (min = 40, max = 59) birds in February, and 24.5 (min = 16, max = 33) birds in March.

Discussion

Our census suggests 49.5 ±10 giant ibis (= 20–25 adult pairs) occur in PSPKLWS. As 40 pairs were previously estimated for the area (BirdLife International, 2012), this could mean a decline has occurred at the site, possibly due to ongoing forest degradation and loss. Repeated surveys using the same methods are required to verify this, however, and assessment of population trends is not attempted here. We consider our figure a conservative or minimum population estimate because: a) only 49 trapeang out of >200 were surveyed at the site, b) potential double counts were rigorously excluded, and c) our estimate does not include all auditory detections.

This study is the first attempt to develop a rigorous method for monitoring giant ibis populations at any site. Wright (2012) recorded 66 birds from 11,402 km of repeat survey journeys in the PSPKLWS area. As no evidence of migration has been observed for the species, this suggests that giant ibises are resident at the site (Wright *et al.*, 2012). Our population estimate is consequently based on the highest monthly population estimate, as we assume all birds recorded during the survey period are resident all year round.

Our findings suggest that February may be the best time to census giant ibises at trapeang sites. This is due to the strong seasonality of the region which reduces the availability of standing water and suitable foraging habitat during the dry season (November–April). During the wet season (May–October), heavy rainfall creates large amounts of standing water in countless depressions scattered throughout the landscape and as a result the giant ibis forages widely during this period, rarely visiting trapeang. By February, however, these have

largely evaporated and trapeang tend to contain the only remaining standing water at the site, leading to clustering in activity as the availability of other foraging habitats decreases. In March 2014, almost half of trapeang studied at PSPKLWS had dried out and the birds no longer visited, having moved to feed at pools alongside the margins of rivers that still contained water. Human disturbance also influences the likelihood of giant ibis detections (Keo, 2008b; BirdLife International, 2012; Wright, 2012). During our study, disturbance increased markedly in March when a logging company began operating in the area. This could have forced birds away from preferred foraging habitats into more remote forest areas, resulting in a lower population estimate for that month.

We suggest census approaches that combine visual and auditory detections are acceptable for generating rigorous population estimates, provided appropriate methods are employed to exclude potential double counts of individual birds. As the giant ibis exists at very low population densities and is challenging to detect (Keo, 2008a), censuses based on visual detections are likely to underestimate population size. Because giant ibis calls travel up to 2 km (Ty, 2013), they provide opportunities for additional detections and subsequent improvement of population estimates. Another way to avoid double counts would be to survey all sampling sites simultaneously, but this would require a large number of observers and much greater financial investment. For instance, at least 50–60 people would be needed to census all of the sites in our study simultaneously, whereas only 11 were needed using our approach. At sites where resources are limited therefore, we suggest that a single census employing our approach in February might be sufficient.

Table 1 Monthly numbers of giant ibises recorded from survey zones in Prey Siem Pang Khang Lech Wildlife Sanctuary.

Zone	No. of trapeang	January		February		March	
		Visual Detections	Auditory Detections	Visual Detections	Auditory Detections	Visual Detections	Auditory Detections
1	8	3	0	5	2	0	3
2	9	4	0	6	1	7	4
3	9	3	0	0	7	4	0
4	8	4	0	12	3	0	6
5	7	3	1	7	2	3	4
6	8	4	0	10	4	2	0
Subtotal		21	1	40	19	16	17
Total		22		59		33	

Alternative techniques for population estimation include random selection of sampling sites (Gregory *et al.*, 2004) and distance sampling (Bibby *et al.*, 1998). These can be used to generalise across large survey areas and allow lower sampling effort to generate site-based population estimates. As the giant ibis exists at very low population densities and is challenging to detect however, they would be unlikely to generate sufficient observations for meaningful analysis. To overcome low detection frequencies, a targeted approach that samples key habitats based on prior knowledge and pilot surveys may be needed (Loveridge *et al.*, in press). Recent advances in acoustic spatial-capture-recapture methods may also provide opportunities for estimating populations of species with distinctive calls, by sampling reduced, but representative survey areas (Kidney *et al.*, 2016).

We propose our method as a compromise between resource-intensive, single-occasion, large-scale surveys and randomized approaches that might yield insufficient data without numerous iterations. As our method requires prior knowledge of areas used by giant ibises, we encourage field teams to record all opportunistic sightings of the species as a first step towards its implementation. Resources permitting, future censuses in the Siem Pang region should include deciduous dipterocarp forests north of the O'kampa River and east of the Sekong River inside Siem Pang Wildlife Sanctuary to generate a comprehensive estimate for the area encompassed by this site and PSPKLWS. Further research to establish the habitat preferences and home range of giant ibises would also aid future census design in helping to avoid delineation of survey zones that favour the occurrence of a single bird in multiple zones. Ideally, survey zones should be separated by a distance not less than the home range diameter of the species to minimise the chance of individual birds being detected in more than one zone.

In conclusion, we advocate repeated surveys using standard methods at all priority protected sites within the limited range of the giant ibis (Fig. 2). This will enable interpretation of population trends to assess the efficacy of conservation interventions and provide an early warning, should further declines occur in this Critically Endangered species.

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Assessment of the economic contribution of non-timber forest products to rural livelihoods in Oddar Meanchey, Cambodia

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មូលនិយមសង្ខេប

ក្នុងប្រទេសកម្ពុជា ប្រាក់ចំណូលពីការលក់អនុផលព្រៃឈើ (NTFPs) ដើរតួយ៉ាងសំខាន់ក្នុងចំណូលសរុបប្រចាំគ្រួសារ។ យ៉ាងណាមិញ គ្រួសារតាមទីជនបទភាគច្រើនក្នុងខេត្តខត្តរមានជ័យរកប្រាក់តាមរយៈការលក់អនុផលព្រៃឈើទាំងនេះ ដែលផលនេះខុសគ្នាទៅតាមគ្រួសារផងដែរ។ គោលបំណងទីមួយនៃការសិក្សាគឺវាយតម្លៃពីការពឹងផ្អែកលើអនុផលព្រៃឈើ និងវាស់វែងពីកម្រិតចំណូលបានពីអនុផលព្រៃឈើក្នុងចំណូលសរុបសម្រាប់គ្រួសារ រវាងគ្រួសារដែលក្រដាង និងមានជាង។ គោលបំណងទីពីរគឺដើម្បីស៊ើបអង្កេតថា តើលក្ខខណ្ឌសេដ្ឋកិច្ចសង្គមជាក់លាក់ណាខ្លះមានឥទ្ធិពលលើការពឹងផ្អែកនេះ។ ព័ត៌មានស្តីពីលក្ខណៈគ្រួសារ ប្រភពចំណូល និងការលក់អនុផលព្រៃឈើត្រូវបានប្រមូលតាមរយៈការស្ទង់មតិយ៉ាងល្អិតល្អន់តាមគ្រួសារ ហើយត្រូវបានប្រើដើម្បីវាយតម្លៃពីភាពខុសគ្នានៃលក្ខខណ្ឌសេដ្ឋកិច្ចសង្គម រវាងគ្រួសារដែលពឹងផ្អែកលើអនុផលព្រៃឈើក្នុងកម្រិតខ្ពស់ មធ្យម និង ទាប។ លទ្ធផលបានបង្ហាញថា គ្រួសារដែលក្រពឹងផ្អែកលើអនុផលព្រៃឈើខ្លាំងជាងគ្រួសារដែលមាន ដោយប្រាក់ចំណូលពីអនុផលព្រៃឈើគឺ ២៩% (គ្រួសារក្រដាង) និង ២០% (គ្រួសារមានជាង) នៃប្រាក់ចំណូលសរុបក្នុងគ្រួសារ។ លទ្ធផលក៏បានបង្ហាញដែរថា គ្រួសារដែលពឹងផ្អែកលើអនុផលព្រៃឈើខ្លាំងជាងគឺជាគ្រួសារដែលមានសមាជិកច្រើនជាស្ត្រី មានដីកម្មសិទ្ធិតូចជាង និងមានប្រភពចំណូលតិចជាង។ ទីតាំង និងការអប់រំគ្មានឥទ្ធិពលលើការពឹងផ្អែកអនុផលព្រៃឈើនេះទេ។ លទ្ធផលនេះអាចជាប្រយោជន៍សម្រាប់គោលនយោបាយ ដើម្បីអភិវឌ្ឍឲ្យកាន់តែមានប្រសិទ្ធិភាព និងផ្ដោតជាសំខាន់ទៅលើគ្រួសារដែលរងគ្រោះជាងគេ។

Abstract

Income from the sale of non-timber forest products (NTFPs) plays an important role in total household income in Cambodia. While most rural households in Oddar Meanchey Province generate cash from these forest products, their contributions to income differ considerably across households. The first objective of this study was to assess NTFP dependence, measured as the share of NTFP income in total household income, between poorer and richer households. The second objective was to investigate whether certain socio-economic variables condition this dependence. Information regarding household characteristics, income sources and NTFP sales was gathered through a detailed household survey and used to evaluate differences in socio-economic variables between high, medium and low NTFP-dependent households. Results show that poorer households are more dependent on forest products than richer households, where NTFP incomes contribute 29% and 20% respectively towards total household income. Highly dependent households also appear to have more female household members, smaller land holdings and fewer income sources. Location and education do not condition NTFP dependence. These results may inform policy in the formulation of more effective interventions, with a specific focus on targeting the most vulnerable households.

Keywords Cambodia, non-timber forest products, Oddar Meanchey.

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Introduction

Forests play a central role in millions of people's lives. In 2004, more than 1.6 billion people depended to a varying extent on forests for their livelihoods, while 350 million people living within or adjacent to dense forests depended on them to a high degree for subsistence and income (World Bank, 2004). Since the late 1980s, non-timber forest products (NTFPs) have received significant attention from conservationists, donors and development agencies and have often been seen as a 'win-win' tool for forest conservation and sustainable development (Wollenberg & Ingles, 1998; Arnold & Ruiz-Perez, 2001). NTFPs are typically defined as all biological materials other than timber which are extracted from forests for human use (deBeer & McDermott, 1989), including fruit, nuts, honey, fibres, vegetables, medicinal plants, resins and grasses (Ticktin, 2004). In recent years however, studies have shown that NTFP harvesting is not necessarily more ecologically benign than timber logging (Peters *et al.*, 1989; Homma, 1992). Irrespectively, millions of households continue to harvest forest products (McElwee, 2008), particularly the poor who depend on them to a high degree (Neumann & Hirsch, 2000). Given the high rates of deforestation in developing countries (FAO, 2010), the importance of NTFPs for local livelihoods warrants further consideration.

NTFP exhibit several characteristics which make them attractive to the poor. Heubach *et al.* (2011) identify three major functions of NTFPs for rural households. Firstly, NTFPs act as vital cost-saving and open access forms of subsistence by providing energy, food, medicine and construction materials (Shackleton & Shackleton, 2004; Illukpitya & Yanagida, 2010). Secondly, forest products act as a safety net in times of crisis, such as income shortages or crop failures (Angelsen & Wunder, 2003). Finally, NTFPs are used as a means of cash income (Neumann & Hirsch, 2000). While NTFPs are an economic mainstay for some households, they only provide a supplementary income for others (Illukpitya & Yanagida, 2010). A meta-analysis of case studies globally indicates that, on average, forest products contribute 20–25% to overall household income (Vedeld *et al.*, 2004).

Substantial wealth differences usually exist in areas where poor people occur, and the contribution of NTFPs to individual household incomes differ accordingly. In Malawi, Kamanga *et al.* (2009) found that poorer households rely on NTFPs for 22% of their income, whereas the equivalent figure for richer households was only 9%. Other studies indicate that richer households can extract higher quantities of NTFPs and also receive greater cash returns from these (McElwee, 2008). The greater assets

and better connections of richer households may explain this (Sunderlin *et al.*, 2005). Vedeld *et al.* (2004) however found a negative correlation between the share of NTFP income and total household income. Increased absolute income reduces the relative contribution of forest products, thereby lowering household dependence upon these. It is thus clear that NTFP dependency varies across different levels of household welfare.

NTFP dependency has potential effects on the environment. Higher dependency has been found to correlate with environmental degradation (Shaanker *et al.* 2004), species composition (Vargheese & Ticktin, 2008) and ecosystem sustainability (Ticktin, 2004). Overexploitation often occurs when pressure to maximize short-term incomes exists in the absence of attendant rules and regulations. Strong local institutions such as cultural norms or harvest taboos (Colding & Folke, 2001) can also influence the degree of NTFP extraction and dependency, and understanding this variability is necessary to formulate effective conservation interventions.

The socio-economic characteristics of households can explain patterns of NTFP dependency within communities. Livelihood diversification reduces dependency on NTFPs as an income source (Ellis, 1998; Illukpitya & Yanagida, 2010) and Fisher (2004) found that NTFP dependency in Malawi decreased as income from off-farm activities increased. Emerton (2005) further maintains that richer households have more diverse income-earning opportunities due to better education and access to arable land. Additional factors influencing dependency include migration status (Lacuna-Richmann, 2002), distance to the market (Timko *et al.*, 2010) and household composition (Quang & Anh, 2006). In Vietnam for instance, households with higher numbers of females are more dependent on incomes derived from NTFPs (Quang & Anh, 2006).

As even small rural communities display such heterogeneity, further studies are needed to understand NTFP use and dependence (McElwee, 2008) and Angelsen & Wunder (2003) stressed the need for site-specific research into the role of forests at a household level in differing geographical and political contexts. Cambodia, and especially Oddar Meanchey Province, is of particular interest in this regard, as the challenges of large-scale land conversion, illegal logging and high population growth (Pfoffenberg, 2009) are placing considerable pressure on the environment. Cambodia's population is 85% rural (Kim *et al.*, 2008) and dependant on rice production, although fishing and collection of forest products also contribute substantially to rural livelihoods (Tola & McKenney, 2003). However, signs of resource deple-

tion due to unsustainable rates of extraction have already begun to show for over a decade (Sedara *et al.*, 2002).

Investigations into NTFP dependency are consequently important to determine the potential costs of deforestation and forest degradation on rural livelihoods. While the literature includes a multitude of case studies for different countries, few have been undertaken in Cambodia. Exceptions include Tola & McKenney (2003), who investigated the importance of resin extraction, Laval *et al.* (2011), who assessed the significance of medicinal plants, and Kim *et al.* (2008) who attempted to place a monetary value on NTFPs extraction in Ratana-kiri Province. As rigorous studies on the importance of NTFPs for rural livelihoods are still lacking nonetheless, this study addresses the current knowledge gap by exploring NTFP dependency among different wealth groups and its relationship with household characteristics in Oddar Meanchey Province. More specifically, it examines whether the magnitude of NTFP income, as a proportion of total household income, varies between poorer households and richer households, and whether NTFP dependency is linked to socio-economic status.

Methods

Study site

The study was conducted in July 2011 in Oddar Meanchey Province, north-western Cambodia (Fig. 1). As the area formed part of the Oddar Meanchey REDD+ project, which was in the design phase at the time, understanding household dependence on forest products was important. Two villages were selected for the study: Ou Sramour and Ou Anrea in Trapeang Tav commune of Anlong Veng district. Because these were similar in terms of in-migration levels and both were within 12 km of the local market and within 25 km of the mainly evergreen community forest, their general topography and ecology were comparable. Neither village had access to piped water or electricity.

Questionnaire design

As no prior study had been carried out in the area, informal interviews and participant observations were first undertaken to provide initial information on income sources and NTFPs harvested. This was used in the development of the household survey.

Socio-economic data collected included the size of the household size, number of female and male family members, education and migrant status. Respondents were asked to recall information on household incomes



Fig. 1 Location of study site in Oddar Meanchey Province, northwestern Cambodia.

and details of NTFP collection for the previous year (one-year recall). More specifically, respondents were requested to estimate the quantity, market price and cash income of all forest products collected. Following McElwee (2008), prompts were employed when respondents had difficulties recalling NTFPs collected (e.g., “Did you collect any mushrooms in the last year?”). Additionally, if forest products or parts of a product were observed in a respondent’s house and they failed to mention these, they were specifically inquired after.

Informant recall is a standard method in surveys of household living standards (World Bank, 2001). Data collection should ideally be spread over one year, with resource use and income information based on quarterly recall periods to account for seasonal differences and ensure accuracy (Cavendish, 2002). Due to practical constraints however, data collection was completed during a single month. In addition, because informant recall is imperfect, figures extracted should be considered as estimates. Respondents might also have difficulty remembering exact quantities of NTFPs harvested and sold, or may have overlooked minor products, biasing recall (Heubach *et al.*, 2011). Nevertheless, while some NTFPs of lesser importance may be under reported, those of greater significance are often emphasized.

Data collection

A structured household interview comprising closed and open questions was conducted using standard methods (Newing, 2011). This was translated into Khmer and first tested with seven households in the nearby village of

Trapean Tav. Modifications were then made to facilitate the flow of subsequent interviews.

Systematic methods were used to ensure a representative sample of households in the study villages (Newing, 2011). Twenty percent of households in each village were interviewed, such that surveys were conducted in every third house in Ou Sramour village and in every fifth house in Ou Anrea village, on both the left and right side of the main roads and side roads. This ensured all households had an equal chance of being interviewed regardless of their distance from the main road or other potentially segregating factor. Attempts were made to interview household heads and their spouse together to improve the accuracy of data. This was not always possible however and altogether, 55 households were interviewed out of 275 households in the two villages.

All wage related incomes and other income sources (e.g., monthly support from relatives) were recorded in riel (KHR) (US\$1 = KHR 4,000, July 2011). Income recorded from NTFPs was based on own-reported values (Cavendish, 2002) and information on crop production, livestock and vegetables was sought. The status of NTFP resources was assessed by asking respondents whether there had been any change in the abundance of one or more species within the past five years, and the reasons for any changes noted. A market survey was also conducted in Anlong Veng district to gather information on prices to validate respondent data. Due to seasonal fluctuations in prices, a mean price was calculated for each NTFP, similar to other studies (e.g., Heubach *et al.*, 2011).

Data analysis

Descriptive statistics on household characteristics, NTFP collection and sustainability were calculated using SPSS (vers. 19). Data from the two villages were pooled for analysis as there were no significant differences between these (Table 1, all values of $p > 0.05$). To test the hypothesis that poorer households are more dependent on NTFP income than richer households, the sample was divided into two groups, using the Cambodia's rural poverty line (\$0.43 per capita day; World Bank, 2006) as a benchmark. Twenty-nine of the households sampled lay below this poverty line (BPL households), whereas 26 lay above it (APL households). Due to the relatively small number of households sampled, data normality was not assumed (Eagle, 2011) and a Mann-Whitney U test was used to test for significant differences between income sources between the two groups. Relationships between the share of NTFP income and total household income were

assessed using Pearson's bivariate correlation (Caruso & Cliff, 1997).

To characterise households with differing NTFP dependency, data were divided into quartiles of roughly similar sample sizes based on the share of NTFP in total household income. Excluding households with no income from NTFPs ($n = 5$), highly dependent households ($n = 16$) were defined as those where NTFPs contributed $\geq 28\%$ of household income, medium dependent households ($n = 18$) where these represented 9–27% of income, and low dependent households ($n = 16$) where NTFPs contributed $\leq 8\%$ of income. A Kruskal–Wallis test was employed to test for significant differences in socio-economic variables between these groups.

Results

Household characteristics and income sources

Mean household size was 4.96, with 2.42 females and 2.33 children on average. The average size of land owned was 2.08 ha, yet only 31% (17/55) of households held a secure land title. The average length of local residence was 9.62 years, and households usually had three or more different sources of income.

NTFP harvesting proved to be a major activity in the area, with 95% of households extracting these from nearby forests or fallow land and collecting at least four wild species (such as fruit, rattan or mushrooms) on average. The most frequently collected NTFP was thatch grass (Table 2), which is processed into thatch roofing and sold to Thailand through a trader. Fish, bamboo shoots and medicinal plants were also frequently collected. Thatch grass generated the most relative income, whereas wild fruit, mushrooms and bamboo shoots were the least profitable.

Although only 4% of households collected NTFPs solely for subsistence purposes, 91% were involved in NTFP commercialization (Table 3): sale of NTFPs was by far the most common source of income (50 of 55 households). This was followed by agricultural labour (37), sale of rice (19), livestock (16) and charcoal (15). The greatest income was generated from off-farm occupations such as services, government jobs or other employment (e.g., craftsmanship). Services such as tailoring, shop vendors and motorbike taxi-drivers were the most profitable, although only 11% of households reported these as an income source.

Table 1 Summary characteristics of households (HHs) in two villages of Oddar Meanchey Province.

	Ou Sramour (<i>n</i> =23)	Ou Anrea (<i>n</i> =32)	Z	<i>p</i>
NTPF income (KHR)	714,039	785,156	-0.273	0.785
Total income (KHR)	3,821,170	4,090,125	-0.102	0.918
% NTPF in total income	25	24	-0.606	0.545

Table 2 Frequency and value of NTFPs for households (HHs) studied in Oddar Meanchey Province. '-' indicates a NTFP was not sold.

NTPF	No. of HHs collecting NTFP (%)	No. of HHs selling NTFP (%)	Mean income from sale KHR yr ⁻¹	Mean contribution to HH income (%)
Thatch grass	46 (84)	44 (80)	838,295	27
Frogs	22 (40)	6 (11)	220,000	16
Fish	32 (58)	7 (13)	203,429	6
Wild fruit	14 (25)	4 (7)	174,000	4
Mushrooms	14 (26)	10 (18)	104,800	3
Bamboo shoots	27 (49)	5 (9)	28,980	1
Bamboos/rattans	22 (40)	-	-	-
Wild vegetables	9 (16)	-	-	-
Medicinal products	26 (47)	-	-	-
Bushmeat	1 (2)	-	-	-
Other (e.g., snails, turtles)	2 (4)	-	-	-

Economic importance of NTFPs for household incomes

Combining the two study villages, mean yearly household income was KHR 3,977,653 (=US\$ 994). Across the two villages, NTFP sales represented the largest share of total household incomes at 24%. The second largest share was represented by labour-based incomes (13%), while rice production and other income sources constituted 12% apiece. Minor income sources included vegetable sales and financial support from relatives, at 3% and 1% respectively. Other income came from government employment (10%), charcoal (10%), livestock (5%) and timber (5%) sales, and services (5%).

NTPF dependency between different wealth groups

Households below the poverty line (BPL households, *n* = 29) generated 29% of their income from NTFPs and 24% from labour, whereas households above the poverty line (APL households, *n* = 26) generated 20% and 9% from these respectively (Fig. 2). More secure income sources

such as service occupations and government employment represented only 3% and 4% of incomes in BPL households, whereas APL households obtained 9% and 14% respectively. Significant differences were found in the contribution of labour and government jobs to household incomes between the two groups (Table 4). The contribution of NTFPs also differed between BPL and APL households at 29% and 20% respectively, although this difference was not statistically significant. Exclusion of households that lacked income from NTFPs (*n* = 5) from analysis widened this difference and made it almost significant, with NTFPs contributing 33% and 21% to the total incomes of BPL (*n* = 25) and APL households (*n* = 25), respectively (Mann-Whitney: *Z* = -1.805, *p* = 0.071). Despite the lack of significant differences, however, a positive relationship was found between NTFP income and total income (Pearson's bivariate coefficient: *r* = 0.335, *p* = 0.008). A negative relationship was also found between the contribution of NTFP income (%) and total income (Pearson's bivariate coefficient: *r* = -0.291, *p* = 0.031).

Table 3 Breakdown of household (HH) incomes across two study villages, Oddar Meanchey Province.

Income source	Mean income (KHR yr ⁻¹)	No. of HH (%)
Service jobs (motor-taxi driver, shop vendor, tailor)	2,842,667	6 (11)
Government jobs (military, police, teacher)	2,706,000	9 (16)
Other employment (craftsman, village chief)	2,463,846	13 (24)
Charcoal sales	1,556,000	15 (27)
Rice sales	1,496,316	19 (35)
Timber sales	1,333,333	6 (11)
Vegetable sales	962,222	9 (16)
NTFP sales	830,958	50 (91)
Livestock sales	661,563	16 (29)
Agricultural labour	592,053	37 (67)
Support from relatives	324,286	7 (13)

Socio-economic factors influencing NTFP dependency

Excluding households with no NTFP income ($n = 5$), the number of income sources possessed by households with high, medium and low dependency on NTFPs were significantly different (Table 5). Although not statistically significant, households with higher NTFP dependency also tended to have longer periods of rice shortage each year, more female members and larger household sizes. No significance differences were found in any other socio-economic indicators between households.

Sustainability of NTFP harvesting

Most respondents (62%) stated that they had noticed a decline in species, including mushrooms, bamboo shoots and thatch grass. The remaining 27% and 11% had not noticed a change and were not sure, respectively. Declines were noticed in the following NTFPs: thatch grass (12 respondents), bamboo/rattans (8), frogs (8), mushrooms (5), fish (4), wild fruits (2) and medicinal plants (1). The reasons most frequently stated for the declines were economic land concessions (33%) and unsustainable harvesting (24%).

Discussion

The present study suggests that NTFP sales contribute substantially to household incomes in Oddar Meanchey, with a mean contribution of 24%. While NTFPs represent as much as 60% of household incomes in India (Narendran *et al.*, 2001), their share falls to 6% in southwestern Cameroon (Amrose-Oji, 2003). In the latter country, their

contribution differs according to the livelihood strategy adopted by households (Timko *et al.*, 2010). For instance, hunter and gatherer communities in Cameroon can generate 90% of their income from forest products, whereas sedentary people in the same region retrieve 20% of their incomes from NTFPs. In areas such as the present study site where rice farming is the main economic activity, NTFPs can act as a major supplementary source of income. As forest-based incomes account for a fifth of household incomes worldwide on average (CIFOR, 2011), the contribution of NTFPs to rural livelihoods in Oddar Meanchey Province can be considered typical.

Household dependence on NTFPs

This study tested the hypothesis that poorer households are more dependent on NTFPs than richer households. Although differences between these were not statistically significant, households below the poverty line nonetheless derived somewhat more income from NTFPs (29%) than those above it (20%). This mirrors the findings of other studies (Cavendish, 2002; McElwee, 2008) and may be because the former earn income from less profitable activities, which results in lower total income, thereby amplifying the importance of NTFP income. The significant differences between labour-based incomes and government incomes suggests that households below the poverty line obtain more of their income from poorly-paid activities such as the former, while those above the poverty line are involved in more lucrative occupations, such as military or teaching employment. This is supported by the negative association between the contribution of NTFP income (%) and total income. Households

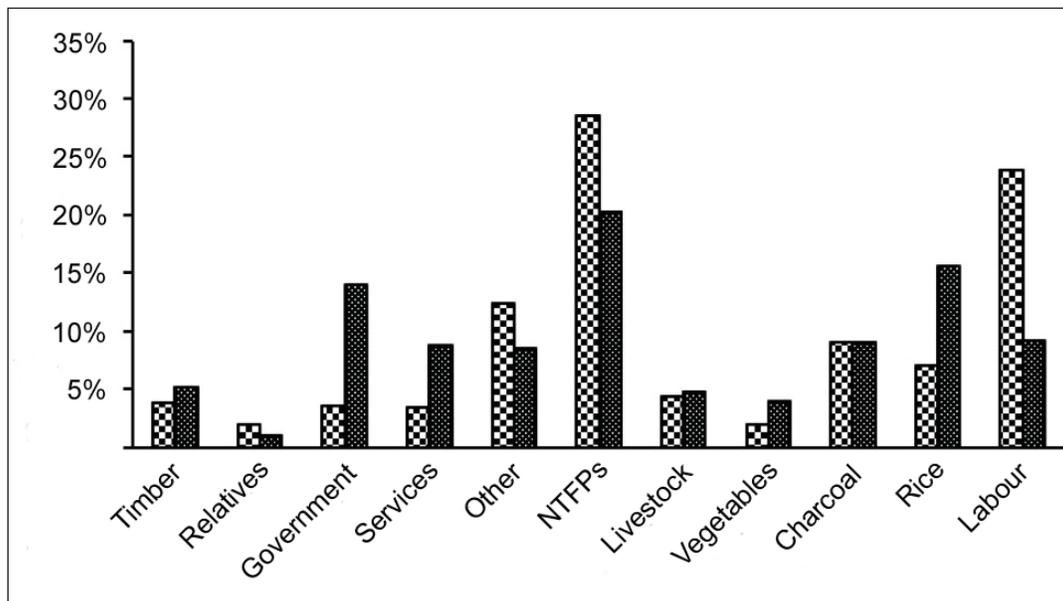


Fig. 2 Distribution of income for households below (hatched bars) and above (dark bars) the poverty line.

Table 4 Comparison of incomes for households (HHs) below and above the poverty line. BPL = below poverty line, APL = above poverty line.

Income source	% of total income		Z	p
	BPL HHs (n=29)	APL HHs (n=26)		
Agricultural labour	24	9	-2.834	0.005
Rice sales	7	16	-1.828	0.068
Charcoal sales	9	9	-0.870	0.384
Vegetable sales	2	4	-1.845	0.065
Livestock sales	4	5	-0.588	0.556
NTFP sales	29	20	-0.0936	0.349
Services	3	9	-1.775	0.076
Government employment	4	14	-1.976	0.048
Support from relatives	2	1	-1.048	0.295
Timber sales	4	5	-0.187	0.852
Other occupations	12	9	-0.690	0.490

with higher incomes engage in profitable activities, yet still appear to sell NTFPs as a means of livelihood diversification. The relative importance of NTFPs declines nonetheless, with the result that NTFP dependency decreases as total household income increases. This confirms the findings of Vedeld *et al.* (2004), although its causality remains uncertain (e.g., whether higher income results in

lower NTFP dependency or if higher NTFP dependency results in lower household income).

Influence of socio-economic status

This study assessed whether a variety of household characteristics are associated with different levels of NTFP dependency. Significant differences were found in the

Table 5 Socio-economic characteristics of households (HHs) with high, medium and low dependence on NTFPs.

Indicators	High dependency (n=16)	Medium dependency (n=18)	Low dependency (n=16)	χ^2	<i>p</i>
Number of females	2.75	2.50	2.31	1.485	0.476
Number of children	2.38	2.44	2.38	0.812	0.666
HH size	5.25	4.89	4.94	0.661	0.719
Land holdings (ha)	1.97	2.17	2.38	0.544	0.762
Sex of household head (1=female, 2=male)	81	78	63	1.637	0.441
School attendance, household head (1=yes, 0=no)	75	78	71	0.205	0.903
Number of years locally resident	9.25	11.18	8.93	0.327	0.195
Number of months of rice shortage per year	3.00	3.06	1.81	4.862	0.088
Number of income sources	2.75	3.61	3.81	8.190	0.017
Number of HH earners	2.31	2.78	2.56	1.188	0.390
HH income (KHR per year)	2,963,000	4,245,055	4,521,520	3.416	0.181

number of income sources possessed by households with high, medium and low NTFP dependency, highly reliant households having the least number of income sources. This supports the notion that livelihood diversification influences the degree of reliance (Paumgarten & Shackleton, 2009; Illukpitiya & Yanagida, 2010). Forest-based activities are among the least lucrative income sources, which is why households depending heavily on NTFPs in Oddar Meanchey have much lower total incomes.

Although no other significant differences were found between households with high, medium and low NTFP dependency, several trends were apparent. Firstly, households with high NTFP dependency had the greatest number of female members, similar to other studies (Quang & Anh, 2006; Timko *et al.*, 2010). Women usually have fewer income generation alternatives, possibly due to lower education or cultural norms (Momsen, 2004), and in Cambodia, their main responsibilities are usually in the domestic domain (Phat P. pers. comm.). This limits the potential for generation of alternative incomes and field observations also revealed that women are the main producers of thatch roofs at the study sites.

Secondly, households less dependent on NTFPs appear to have larger land holdings. This likely translates into greater crop production and food security and would explain the smaller shortages of rice these reported each year. As rice is the main component of every meal in Cambodia, its supply is of the utmost importance and households facing greater shortages must generate additional income for its purchase. NTFP sales are an important means of generating such income and this may

explain the higher reliance upon NTFPs among these households, similar to Vietnam (Quang & Anh, 2006).

Although communities located far from markets are often more dependent on forest products (Kamanga *et al.*, 2009), the lack of significant differences between households with differing NTFP dependency in the present study is likely due to the fact that they were all relatively close to the main road and because a visiting trader collected local produce, obviating the need for travel to sell products in the town market. The absence of a clear link between NTFP dependency and education is somewhat more surprising, since other studies (Babulo *et al.*, 2008; Kamanga *et al.*, 2009) have found these to be negatively related (higher education being expected to translate into better employment). However, as this study only determined if household heads had ever attended school (education usually being limited to primary school years), such a trend might emerge if a finer scale of analysis was employed, such as the number of years of school attendance (e.g., McElwee, 2008).

Sustainability of NTFP harvesting

The present study highlights the importance of NTFPs to rural livelihoods in Cambodia, particularly for poorer households. Though sustainable resource use is consequently central to income stability and livelihood security, environmental degradation appears to be the reality, with 67% of respondents claiming declines in the abundance of NTFPs in the previous five years. Although forest clearance due to economic land concessions was the most common reason stated for these declines, over-

harvesting also featured prominently. The latter may be exacerbated by low ecological knowledge, social heterogeneity and weak local institutions (Shaanker *et al.*, 2004; Mutenje *et al.*, 2011). The former was suggested by the reported felling of trees for fruit and occurrence of electro-fishing. The latter were suggested by the reported lack of rules or restrictions for NTFP harvesting and that 95% of respondents were migrants from 10 different provinces. Migrants elsewhere have been found to take greater advantages of forest resources (Ambrose-Oji, 2003) and low sustainable harvesting skills can result in greater environmental degradation (Lacuna-Richman, 2002). Nonetheless, forest loss and degradation due to economic land concessions (and illegal logging; Pfoffenberg, 2009) evidently constitute most serious threats to rural livelihoods involving NTFPs in Oddar Meanchey Province.

Conclusions

This study indicates poorer households are more dependent on NTFPs than richer households in Oddar Meanchey Province and suggests that several household factors may influence this dependence. Declines in NTFP resources in the province will impact poorer households the most. As a consequence, greater attention should be given to the importance of forests to rural livelihoods in the region. Cultivation of NTFPs could help support livelihood needs, whereas development of alternative income sources would help reduce forest dependence. Efforts to reduce forest loss and degradation could also be made through carbon credit schemes under the Reducing Emissions from Deforestation and Forest Degradation (REDD+) initiative.

Additional studies are recommended to evaluate the role played by NTFPs in household subsistence (as opposed to cash incomes) and determine their importance as a cost-saving strategy. These would likely amplify the value of NTFPs and emphasize the costs of environmental degradation. Further research into the household characteristics that influence NTFP reliance would also assist identification of highly dependent households, for whom tailored interventions could then be developed. Finally, additional assessments to determine the ecosystem service values and cultural significance of NTFPs (Vedeld *et al.*, 2007; Rist *et al.*, 2011) would serve to further highlight their importance for rural livelihoods and societal costs of continued deforestation (Delang, 2006).

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About the Author

CHRISTINA M. ENDER obtained her Master degree in Biodiversity, Conservation and Management in 2011 at the University of Oxford School of Geography and the Environment. She is interested in the sustainable use and protection of natural forests, which led her to complete her thesis on NTFPs. Christina worked for Wildlife Works, a carbon development company in Kenya for four years, before joining Conservation International's Africa and Madagascar Field Division as the Program Manager for Payment for Ecosystem Services, in Nairobi, Kenya.

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. 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.

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New species and taxonomic reviews

Bae, Y.-S., Shin, Y.-M., Na, S.-M. & Park, K.-T. (2016) The genus *Anarsia* in Cambodia and the Northern Vietnam (Lepidoptera, Gelechiidae), with descriptions of ten new species and a catalogue of the genus in the Central-East Asia. *Zootaxa*, **4061**, 227–252.

This paper reviews the moth genus *Anarsia* in Cambodia and North Vietnam, describing 10 species new to science and documenting nine new country records from these regions. Author: baeys@inu.ac.kr

Bayarsaikhan, U., Dubatolov, V.V. & Bae, Y.-S. (2015) The genus *Danielithosia* Dubatolov & Kishida, 2012 (Lepidoptera, Erebidae, Arctiinae) in Cambodia, with description of one new species. *Zootaxa*, **3964**, 494–497.

The moth genus *Danielithosia* includes 11 species worldwide, one of which was previously recorded in Cambodia. This paper describes a species new to science, *Danielithosia wooshini* sp. nov., based on specimens collected from Bokor National Park and Phnom Samkos Wildlife Sanctuary. Author: baeys@inu.ac.kr

Bayarsaikhan, U., Na, S.-M. & Bae, Y.-S. (2016) Review of the subfamily Aganainae (Lepidoptera, Erebidae) from Cambodia. *Journal of Asia-Pacific Biodiversity*, **9**, 219–229.

This review recognises 15 moth species belonging to five genera in the Aganainae subfamily from Cambodia. Keys and diagnoses are provided for the five genera and all species. Author: baeys@inu.ac.kr

Gale, S.W., Shuiteman, A., Watthana, S., Sando, T., Souvannakhoummane, K., Averyanov, L. & Suddee, S. (2016) Studies in Asian *Nervilia* (Nervilieae, Epidendroideae, Orchidaceae) VI: *N. mekongensis*, a new species from Thailand, Cambodia, Laos and Vietnam. *Phytotaxa*, **247**, 267–273.

A new species in the terrestrial orchid genus *Nervilia* is described and illustrated from material collected at several localities in Southeast Asia, including Cambodia. Author: stephangale@kfbg.org

Haitlinger, R. & Sundic, M. (2015) Two new species of *Calyptostoma* Cambridge, 1875 (Acari: Prostigmata: Calyptostomatidae) from Cambodia and Sulawesi, Indonesia. *Systematic and Applied Acarology*, **20**, 919–926.

This paper includes the description of one small arachnid species new to science from Cambodia: *Calyptostoma giuliae* sp. nov. This is the first record of the genus in the country. Author: ryszard.haitlinger@up.wroc.pl

Kanao, T. & Maruyama, M. (2015) Eight new species, a new record, and redescription of the genus *Discoxenus* Wasmann, 1904: the first record of termitophilous rove beetles in Cambodia (Coleoptera: Staphylinidae: Aleocharinae). *Zootaxa*, **4044**, 201–23.

This paper presents the first records of termitophilous rove beetles in Cambodia, including descriptions of eight species new to science. Author: kanatai1225@gmail.com

Kosterin, O.E. (2015) Dry season Odonata of the Cardamomean coast (Cambodia and Thailand) revisited in 2015. *Journal of the International Dragonfly Fund*, **89**, 1–36.

This paper includes checklists of Odonata at Ream National Park, Koh Rong Island and O'Som Village (Pursat Province). One new record for Bokor National Park is also presented. Author: kosterin@bionet.nsc.ru

Kosterin, O.E. (2015) *Onychargia priyadak* sp. nov. (Odonata, Platycnemididae) from eastern Cambodia. *International Journal of Odonatology*, **18**, 157–168.

A new species of damselfly is described from eastern Cambodia. The new species co-occurs with the widespread *Onychargia atrocyana* Selys, 1865 in the same region. Author: kosterin@bionet.nsc.ru

Kosterin, O.E. & Yokoi, N. (2016) *Asiagomphus reinhardti* sp. nov. (Odonata, Gomphidae) from eastern Cambodia and southern Laos. *Zootaxa*, **4103**, 35–42.

A new species of dragonfly is described based on specimens collected in the Annamese Mountains of eastern Cambodia and the Bolaven Plateau of southern Laos. Author: kosterin@bionet.nsc.ru

Lee J. & Chang C.Y. (2015) *Metacyclops woni* n. sp., a new cyclopoid species (Copepoda: Cyclopoida: Cyclopidae) from Cambodia. *Animal Systematics, Evolution and Diversity*, **31**, 247–256.

A new species of aquatic crustacean to science is described from specimens found in an ephemeral forest pool at Phnom Domnak Dambouk in southwest Cambodia. This is the first record of the genus from Cambodia and the fourth record from Southeast Asia. Author: cychang@daegu.ac.kr

Loyer, M., Depaquit, J. & Gay, F. (2016) A new cavernicolous sand fly from Cambodia: *Idiophlebotomus nicolegerae* n. sp. (Diptera: Psychodidae). *Acta Tropica*, **155**, 43–50.

This paper describes a new species of sand fly to science and documents three new country records for Cambodia, bringing the total number of sand fly species recorded in the country to 10. Author: reyol.cobalt@gmail.com.

Naiki, A., Tagane, S., Chhang P., Toyama, H., Zhu H., Dang V.S. & Yahara, T. (2015) Flora of Bokor National Park, Cambodia II: four new species and nine new records of *Lasianthus* (Rubiaceae) from Cambodia. *Acta Phytotaxonomica Geobotanica*, **66**, 153–179.

This paper documents the occurrence of 24 species of *Lasianthus* in Bokor National Park and provides descriptions of four species new to science, nine new country records and a key for all species of *Lasianthus* known to occur at the park. Author: naiki@lab.u-ryukyuu.ac.jp

Schuiteman, A. (2016) *Porpax verrucosa* (Orchidaceae), a new species from Cambodia. *Kew Bulletin*, **71**, 1–5.

A new species of orchid is described from the Cardamom Mountains. The new species is similar to *Porpax elwesii*, but differs in having much broader and longer, obovate petals that are covered with numerous, glassy and enlarged cells. Author: a.schuiteman@kew.org

Soh, W.-K. & Parnell, J. (2015) A revision of *Syzygium* Gaertn. (Myrtaceae) in Indochina (Cambodia, Laos and Vietnam). *Adansonia*, **37**, 179–275.

This systematic revision recognises 56 species of *Syzygium* in Indochina and provides an identification key, distribution maps, descriptions and notes on ecology, conservation status, phenology and vernacular names for each species. Author: sohwtcd@tcd.ie

Tagane, S., Dang V.S., Rueangrua, S., Suddee, S., Chhang P., Toyama, H. & Yahara, T. (2015) *Elaeagnus elongatus* Tagane & V.S. Dang (Elaeagnaceae), a new species from Cambodia and Thailand. *Thai Forest Bulletin (Botany)*, **43**, 30–35.

This paper describes a new species of *Elaeagnus* to science from specimens collected in Bokor National Park and localities in Thailand. Author: stagane29@gmail.com

Species ecology and status

Barca, B., Nuttal, M. & Hobson, K. (2015) A diurnal observation of small-toothed palm civets *Arctogalidia trivirgata* mating in Seima Protection Forest, Mondulkiri Province, Cambodia. *Small Carnivore Conservation*, **52–53**, 39–44.

This paper describes a chance observation of mating between two small-toothed palm civets in evergreen forest in eastern Cambodia. Author: mnuttall@wcs.org

Ibbett, H. (2015) *Understanding the impact of local people on Bengal florican populations in Central Cambodia*. MSc thesis, Imperial College London, UK.

This study investigates the impact of human livelihood activities on populations of the Critically Endangered Bengal florican in the Tonle Sap floodplain. Online: http://www.iccs.org.uk/wp-content/uploads/2015/11/Ibbett_Harriet_Consci_2015.pdf

Coasts, wetlands and aquatic resources

Urban, L.E. & Gorelick, S.M. (2016) Closing the irrigation deficit in Cambodia: implications for transboundary impacts on groundwater and Mekong River flow. *Journal of Hydrology*, **535**, 85–92.

Rice production in Cambodia is largely limited to the wet season, with 96% of lands cultivated remaining fallow in the dry season. This paper quantifies the extent of the dry season “deficit” area in the Cambodian Mekong River catchment. Demand for irrigation has been increasingly met by groundwater extraction, but if this continues to expand at current rates, the water table will drop below the lift limit of suction pump wells throughout much of the area within 15 years. Author: lerban@stanford.edu

Kang, Y. (2016) Arsenic-polluted groundwater in Cambodia: advances in research. *International Journal of Water and Wastewater Treatment*, **2**, 1–6. doi <http://dx.doi.org/10.16966/2381-5299.116>

The impacts of arsenic pollution on soil, rice and human health are insufficiently known. This article explores transitions in drinking water supply, arsenic pollution of groundwater and health risks, the impact of arsenic on paddy soil and rice, and technologies for removal of arsenic from tube well water in Cambodia. Author: kang@kochi-u.ac.jp

Lang O. (2015) Current status of sustainable aquaculture in Cambodia. In *Proceedings of the International Workshop on Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia 2014* (eds M.R.R. Romana-Eguia, F.D. Parado-Estepa, N.D. Salayo & M.J.H. Leбата-Ramos), pp. 27–40. Southeast Asian Fisheries Development Center, Tigbauan, Iloilo, Philippines.

Extension of fish aquaculture technologies is vital to improve the livelihoods of poor farmers in Cambodia. This paper examines the development of the aquaculture sector in the country. Author: langouch@yahoo.com

Pink, R.M. (2016) Cambodia: a rural water crisis. In *Water Rights in Southeast Asia and India* (ed. R.M. Pink), pp. 35–61. Palgrave Macmillan, USA.

Water supply and sanitation access in Cambodia is inadequate and unstable for millions of citizens. Because water security is closely related to sanitation and health, these deficiencies pose significant challenges for the government. Author: rpink2010@gmail.com

Forests and forest resources

Chheng K., Sasaki, N., Mizoue, N., Khorna S., Kao D. & Lowe, A. (2016) Assessment of carbon stocks of semi-evergreen forests in Cambodia. *Global Ecology and Conservation*, 5, 34–47.

Understanding carbon stocks relative to tree species is important in forest management to ensure that carbon emission reductions and biodiversity conservation outcomes result from the REDD+ scheme. This study analyses data from three provinces in Cambodia and estimates that carbon emissions resulting from the loss of semi-evergreen forests in Cambodia between 2002–2010 were 8.3 TgCO₂ year⁻¹. Author: nopsasaki@gmail.com

Ehara, M., Hyakumura, K., Nomurad, H., Matsuura, T., Sokh H. & Leng C. (2016) Identifying characteristics of households affected by deforestation in their fuelwood and non-timber forest product collections: case study in Kampong Thom Province, Cambodia. *Land Use Policy*, 52, 92–102.

This study explores characteristics of households affected by deforestation in their fuelwood and non-timber forest product (NTFP) collections in Kampong Thom Province, where tropical lowland forests are decreasing in size. Author: makotoehara1@gmail.com

Ishibashi, H. Inoue, M., & Motomu, T. (2015) Historical change in the traditional use of forests and its association with belief in tiger spirits in the Cardamom Mountains, Cambodia: the impact of war and wildlife trade on the relationship between humans and tigers. *Tropics*, 24, 119–138.

This article examines the impacts of war and wildlife trade on traditional forest use in the Cardamom Mountains by analyzing relationships among traditional beliefs, changes in tiger populations due to wildlife trade, and war-related changes in social order. Despite the apparent disappearance of tiger from the region, belief in the association between tigers and spirits and their roles in forest use has persisted. Author: h_m_ishibashi@yahoo.co.jp

Environmental practice

Nguyen T.T., Do T.L., Bühler, D., Hartje, R. & Grote, U. (2015) Rural livelihoods and environmental resource dependence in Cambodia. *Ecological Economics*, 120, 282–295.

Understanding rural livelihood strategies and environmental resource dependence can help to reduce and prevent livelihood stresses induced by environmental resource degradation. This study identifies livelihood strategies adopted by 580 farming households in Stung Treng Province and explores their determinants with a focus on environmental resource dependence. Author: thanh.nguyen@iuw.uni-hannover.de

Climate change

Keo S. (2015) *Impact of climate change on agricultural production in northwest Cambodia*. Conference on International Research on Food Security, Natural Resource Management and Rural Development, Tropentag 2015, Berlin, Germany.

Agriculture plays a major role in Cambodian food security and is affected by natural disasters caused by climate change. This paper investigates agricultural practices and climate change adaptation methods in six villages in the Banteay Meanchey and Siem Reap Provinces. Online: <http://www.tropentag.de/2015/abstracts/full/614.pdf>

Tum N. (2015) *Towards building drought resilience of rice production in Cambodia: from a system dynamics perspective*. PhD thesis, Michigan State University, USA.

Rainfed rice cultivation in Cambodia faces high risks and uncertainties associated with future climate change, particularly the projected increases in drought frequency. This study explores sources of drought resilience at household and commune levels and suggests ways to improve these. Online: <http://gradworks.umi.com/16/00/1600184.html>

Ung M., Luginaah, I., Chuenpagdee, R. & Campbell, G. (2016) Perceived self-efficacy and adaptation to climate change in coastal Cambodia. *Climate*, 4, 1–16.

Adaptation to climate change has become a focal point for research and policy developments. This study examines the relationship between perceived self-efficacy and anticipatory and reactive adaptations to climate change among 1823 households in coastal Cambodia. Online: <http://www.mdpi.com/2225-1154/4/1/1>

The Recent Literature section was compiled by Neil M. Furey, with contributions from Oleg Kosterin. All Internet addresses were correct at the time of publication.

Instructions for Authors

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The *Cambodian Journal of Natural History* (ISSN 2226–969X) is an open access, peer-review journal published biannually by the Centre for Biodiversity Conservation at the Royal University of Phnom Penh. The Centre for Biodiversity Conservation is a non-profit making unit, dedicated to training Cambodian biologists and the study and conservation of Cambodia's biodiversity.

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

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- Cambodian scientists on studies of natural history in any part of the world.

The Journal especially welcomes material that enhances understanding of conservation needs and has the potential to improve conservation management in Cambodia. The primary language of the Journal is English. For full papers, however, authors are encouraged to provide a Khmer translation of their abstract.

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Fisher, M. (2012) Editorial – To shed light on dark corners. *Cambodian Journal of Natural History*, **2012**, 1–2.

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

Manuscripts should be in English and use 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’ or ‘rtf’ format, preferably as a single file attached to one covering email.

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

The following are examples of house style:

Papers:

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

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

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

Books and chapters:

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

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

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

Reports:

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

Theses:

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

Websites:

IUCN (2010) *2010 IUCN Red List of Threatened Species*. [Http://www.redlist.org](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 each author (<150 words each), apart from what is obvious from the subject of the manuscript and the authors' affiliations.

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Cambodian Journal of Natural History

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The Editors are grateful to our reviewers for their kind assistance with the production of this issue.

Cambodian Journal of Natural History

Volume 2016, Number 1

Contents

- 1 Editorial: Will the recent changes in protected area management and the creation of five new protected areas improve biodiversity conservation in Cambodia? *Nicholas J. Souter, Virginia Simpson, Alistair Mould, Jonathan C. Eames, Thomas N.E. Gray, Ross Sinclair, Tracy Farrell, Joel A. Jurgens & Andrew Billingsley.*
- 6 News: 36th Youth Debate presented by Save Cambodia's Wildlife, Tep Boonny; Investigating the risk of human disease from parasites of small mammals and bats, *Gavin Smith & Ian Mendenhall.*
- 7 Short Communication: New records of Orchidaceae from Cambodia II, *André Schuiteman, Christopher Ryan, Nut Menghor, Nay Sikhoeun & Att Sreynak.*
- 15 Short Communication: New records of *Xanthophyllum ellipticum* and *X. obscurum* (Polygalaceae) in Indochina, with an identification key to species in the region, *Shuichiro Tagane, Hironori Toyama, Chhang Phourin, Dang Van Son & Tetsukazu Yahara.*
- 20 Short Communication: Range extension of *Cyclomys atripons* Iverson & McCord 1997 with the discovery of a population in Oddar Meanchey Province, northwestern Cambodia, *Peter Brakels, Chea Samban & Caleb Jones.*
- 23 A report on the bees (Hymenoptera: Apoidea: Anthophila) of Cambodia, *John S. Ascher, Heang Phallin, Kheam Sokha, Ly Kang, Lorn Sokchan, Chui Shao Xiong, Stéphane De Greef, Gerard Chartier & Phauk Sophany.*
- 40 Patterns of salt lick use by mammals and birds in northeastern Cambodia, *Amy King, Alison M. Behie, Hon Naven & Benjamin M. Rawson.*
- 51 The first population census of the Critically Endangered giant ibis in Western Siem Pang, northeastern Cambodia, *Ty Srun, Yav Net, Jonathan C. Eames, Sum Phearun, Hong Lina, Thi Sothearen, Bou Vorsak & Robin Loveridge.*
- 60 Assessment of the economic contribution of non-timber forest products to rural livelihoods in Oddar Meanchey, Cambodia, *Christina M. Ender.*
- 71 Recent literature from Cambodia, *Neil M. Furey.*
- 74 Instructions for Authors.

