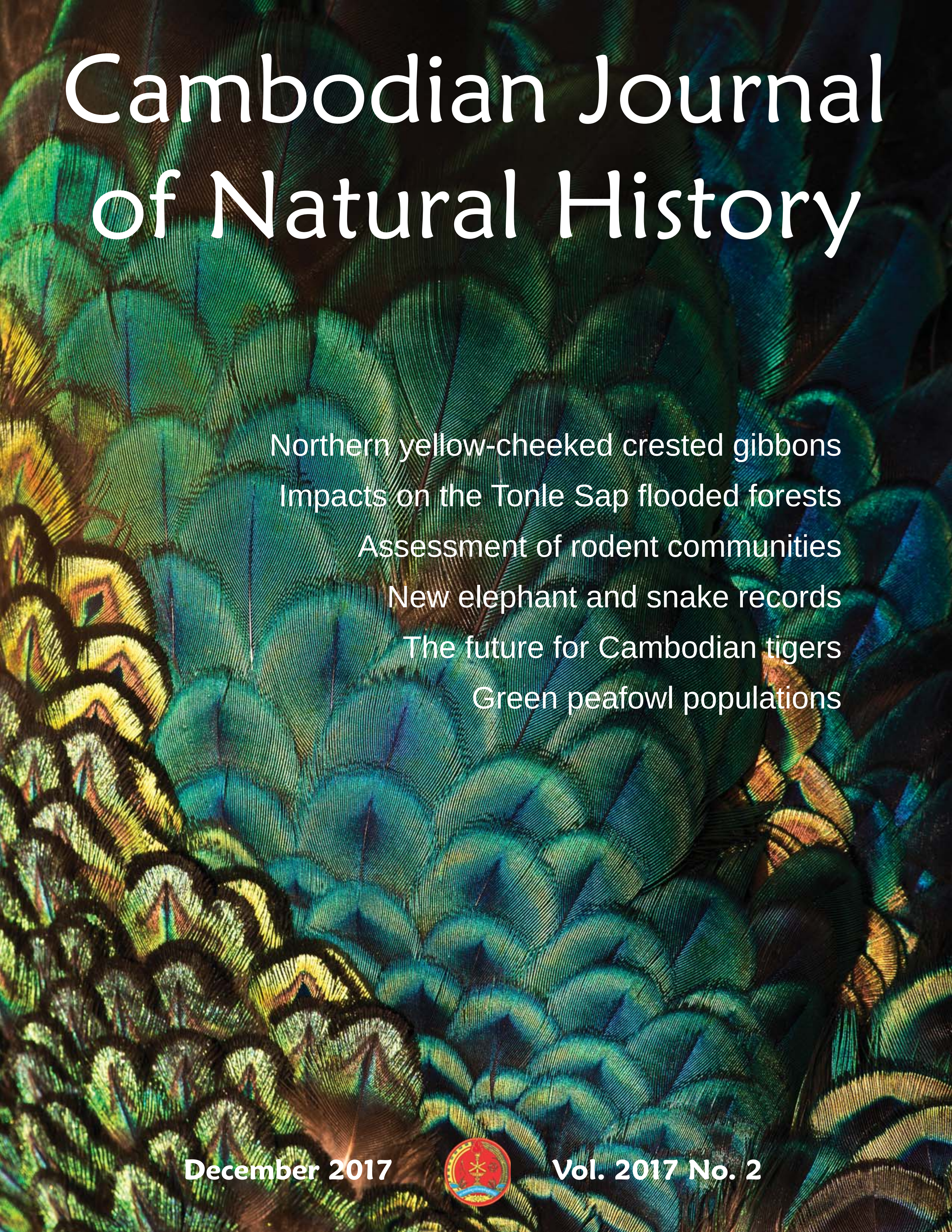

Cambodian Journal of Natural History

Northern yellow-cheeked crested gibbons

Impacts on the Tonle Sap flooded forests

Assessment of rodent communities

New elephant and snake records

The future for Cambodian tigers

Green peafowl populations

December 2017 Vol. 2017 No. 2

Cambodian Journal of Natural History

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

Cover image: Tail feathers of a captive green peafowl *Pavo muticus* in the Phnom Tamao Wildlife Rescue Center, 2016 (© Jeremy Holden). The status of the species in Cambodia is explored by Loveridge *et al.* in this issue (pages 157–167).

Editorial—Not yet an obituary for Cambodia's tigers

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November 2017 marks the 10th anniversary of the last confirmed tiger *Panthera tigris* record from Cambodia: a single female tiger photographed from deciduous dipterocarp forest in what is now Srepok Wildlife Sanctuary. Between 1999 and 2007, 12 tiger photographs were obtained from camera traps in eastern Cambodia (Fig. 1), but the 2007 photograph represents the country's final confirmed record. Subsequent intensive searches, using camera traps and other survey methods, have failed to record tigers. Sadly it therefore appears that tigers, Asia's most iconic species, became the first mammal extirpation from Cambodia in the 21st century. While extensive forest remains throughout the country, the decline and national extinction of tigers was driven by extensive hunting and links to regional wildlife markets during periods of civil unrest throughout the 1980s and 1990s. This was followed by targeted hunting for remaining individuals and depressed prey densities which further reduced survivorship and reproduction.

The Royal Government of Cambodia committed at the 2010 St Petersburg global tiger summit to recover the country's tiger population and signed up to the global goal of doubling tiger numbers under the Global Tiger Recovery Program. Acknowledging the species' functional extinction from Cambodia, tiger reintroduction was identified as a critical action in the Cambodia Tiger Action Plan (CTAP) endorsed by the Ministry of Agriculture Forestry and Fisheries in 2016. This was a significant and commendable step: Cambodia became the first country to acknowledge 21st century national extirpation of tigers and to develop clear steps for recovery. The Eastern Plains Landscape of Mondulkiri and the Cardamom Landscape of Koh Kong (Fig. 2) were identified in the CTAP as candidate landscapes for tiger reintroduction. At the Second National Forum on Protection and Conservation of Natural Resources in August 2017, the concept of tiger reintroduction into Mondulkiri was endorsed by Prime Minister Samdach Akka Moha Senabdeiy Techo Hun Sen who instructed the Ministry of Environment to work with other relevant government agencies, conservation partners, and the Global Tiger Forum to begin detailed planning.

However for tiger reintroduction to be successful there needs to be a paradigm shift in the way Cambodia's protected areas are managed and funded. While the country's protected area network covers >75,000 km^2 (approximately 41% of the national territory), the effectiveness of protected area management, government funding for protection, and on-the-ground ranger numbers remain low. Improved management needs to go beyond simply increasing the numbers of law enforcement rangers and requires strong systems for supervision of enforcement staff and ensuring zero tolerance of corruption. Strengthened legislation to protect wildlife, currently being drafted in the form of an Environmental and Natural Resources Code for Cambodia, is also required.

Improving law enforcement is critical to recover numbers of ungulate tiger prey sufficiently to support a reintroduced tiger population. Densities of medium-large ungulates in dry forests in South Asia often exceed 50 individuals per km^2 (Karanth & Nichols, 2000); current combined densities of medium-large ungulates in the ecologically similar Srepok Wildlife Sanctuary, proposed as the initial tiger release site within the CTAP, are ~5.0 individuals per km^2 (Gray *et al.*, 2017). In addition to enhanced enforcement, ungulate recovery will likely require in-situ conservation breeding and release

Editorial Note: The authors were invited to contribute this opinion piece to ongoing debate regarding the proposed reintroduction of tigers in Cambodia. Editorials are not peer-reviewed.

Fig. 1 Cambodia's final tigers. Clockwise from top-left: Seima Wildlife Sanctuary, 2000 (© DWB-FA/WCS); Virachey National Park, 2001 (© GDANCP-MOE/WWF); Srepok Wildlife Sanctuary, 2005 (© DWB-FA/WWF); Seima Wildlife Sanctuary, 2003 (© DWB-FA/WCS).

programmes for dry forest ungulate species including banteng *Bos javanicus* and Eld's deer *Panolia eldii*. Given the perilous state of the former two species, both globally and in Cambodia, such a conservation breeding programme would be inherently valuable and likely necessary irrespective of plans for tiger reintroduction. Another intriguing possibility would be to release domestic Asian water buffalo *Bubalus bubalis*. This could provide potential prey for tiger while simultaneously mimicking the ecosystem functions of previously abundant wild cattle. There must also be a concerted effort to address the widespread demand for wildlife meat throughout Southeast Asia. This will require long-term behaviour change communication, targeting the emotional and functional drivers of wild meat consumption. Any move to normalise wild meat consumption through wildlife farming needs to be strongly resisted given the potential for extremely negative impacts on biodiversity (Brooks *et al.*, 2010).

Furthermore, tiger conservation will only succeed if it is supported by the people who live near their habitats. That support can come in part from national pride, because tigers are a national and cultural icon, and it can come from the recognition that recovering tigers is good for development through activities such as ecotourism. However, returning large carnivores to areas from which they have been extirpated can be socially controversial. Human-carnivore conflict can arise over access to land and resources and also result in livestock depredation and human mortalities (Inskip & Zimmermann, 2009). Any tiger reintroduction into Cambodia will have to employ robust safeguards for preventing and responding to human-wildlife conflict. Surveys have indicated <40% of Cambodian people interviewed believe tigers are absent from the country's forests and have suggested relatively high levels of support for tiger recovery measures (Gray *et al.*, 2017). However further work is clearly required to sensitise local communities and wider Cambodian society for returning tigers to the country. Long standing cultural associations between tigers and non-Khmer ethnic groups in Cambodia may offer an opportunity to increase community support for tiger reintroduction (Ishibashi *et al.*, 2015). An additional requirement for tiger reintroduction to Cambodia is identifying a suitable source of tigers. Reintroduction success is generally higher when wild as opposed to captive individuals are used (Fisher and Lindenmayer, 2000). The Cat Specialist Group of the IUCN Species Survival Commission recently revised global tiger taxonomy and currently recognises just two tiger subspecies: the Sunda tiger *P. t. sondaica* and the continental tiger *P. t. tigris* (Kitchener *et al.*, 2017). We therefore believe that wild-to-wild translocation of tigers from stable *P. t. tigris* populations in South Asia is likely to represent the optimal source for a Cambodian reintroduction.

The Eastern Plains and Cardamom Landscapes support fantastic biological diversity including critical populations of many of Asia's most threatened species and, respectively, among the most significant expanses of deciduous dipterocarp forest and lowland evergreen rainforest remaining in Southeast Asia. Despite the challenges, we believe that tiger reintroduction has the potential to galvanise conservation within these landscapes. Tiger reintroduction can leverage the political and financial support necessary to transform conservation and protected area management in Cambodia and secure our shared biodiversity for perpetuity.

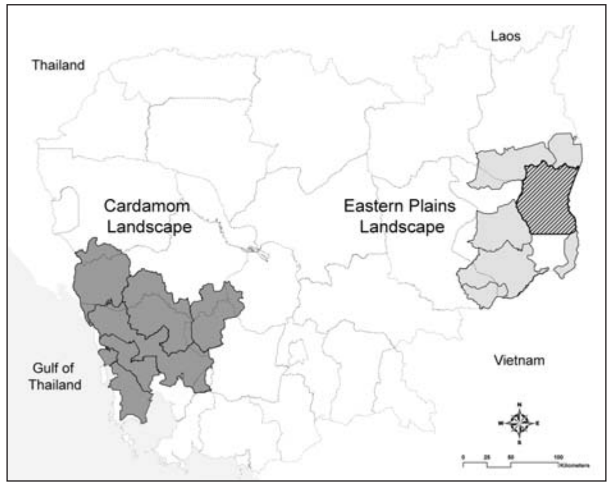

Fig. 2 Protected area complexes of the Eastern Plains and Cardamom Landscapes, Cambodia. Hatching represents Srepok Wildlife Sanctuary.

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News

Workshop shines spotlight on rare and endangered wildlife in the Mekong Basin

The Mekong Basin is a hotspot of biodiversity, but wildlife species in the region face serious threats, including habitat destruction and fragmentation, hunting and harvest, and the illegal wildlife trade. As the most vulnerable species become increasingly rare, they also become more challenging to study and conserve. To address such issues, a USAID-supported project Wonders of the Mekong recently convened a workshop titled "Saving species on the edge of extinction: building capacity to find and protect the Mekong's most imperiled wildlife". The workshop was hosted by the Ministry of Agriculture, Forestry and Fisheries and the Inland Fisheries Research and Development Institute, and was facilitated by the University of Nevada-Reno and the consulting company FISHBIO in Phnom Penh on 14–15 November 2017.

The workshop brought together over 60 participants from Cambodia, Laos, Thailand, and Vietnam to discuss rare species research, conservation management and outreach, and wildlife trafficking. Many early-career researchers presented their work on species such as the giant ibis, Asian giant softshell turtle, pangolin, and Mekong giant catfish. Four panel discussions allowed for dialogue on a range of issues, and attendees also participated in a hands-on communication training to develop messages, give video interviews, and speak with the media. The outcomes of the workshop included increased capacity to advance conservation research, outreach benefits from sharing positive conservation stories, and introduction of new approaches for improved conservation planning and counter-trafficking efforts.

The Wonders of the Mekong project seeks to improve understanding, management capacity, and appreciation of a functional and healthy Mekong River for fish, wildlife, and people, as well as increase the valuation and conservation of the Mekong River's ecosystem services, habitats, cultural heritage, and biodiversity. These goals will be accomplished through applied, interdisciplinary research, trainings and workshops, and communications products. Project updates can be found at https://www.facebook.com/MekongWonders.

Dr Zeb HOGAN (University of Nevada-Reno, USA), Erin LOURY (FISHBIO, USA) & Shaara AINSLEY (FISHBIO, USA). Email: zebhogan@hotmail.com, erinloury@fishbio.com, shaaraainsley@fishbio.com

The Cambodian dolphin project

The Irrawaddy dolphin *Orcaella brevirostris* is distributed in coastal waters, rivers, estuaries and lakes throughout Southeast Asia. The species is one of 11 marine mammal species found in Cambodia's seas, and like other cetaceans, faces a range of threats including mortality due to bycatch, habitat degradation and direct catch for aquaria. These threats are worsened by the proximity of the species to land. The Irrawaddy dolphin currently has a globally declining population and is considered Endangered by the *IUCN Red List of Threatened Species*, which makes it imperative to act quickly if the species is to survive in coming decades. While all cetacean species in Cambodia were protected by a Royal Decree in 2006, baseline data are much needed to strengthen implementation of existing laws through the creation of tailored conservation management strategies.

To this end, the Cambodian Dolphin Project was launched in September 2017. The initiative was established by Marine Conservation Cambodia, an NGO based in the Kep Archipelago in southern Cambodia, with help from the DMAD Marine Mammals Research Association, a Turkish NGO. The project is working in close collaboration with the Dolphin Division of the Cambodia's Fisheries Administration and will operate for 18 months. Its initial aims are to investigate the abundance, distribution and residency patterns of the Irrawaddy dolphin to facilitate identification and delineation of critical habitats for the species within the Kep Archipelago. Data on all marine mammal species encountered during the study will also be recorded.

Data generated by the project will ultimately be used to inform fisheries policy, providing a first step towards effective conservation of cetaceans and their ecosystems in Cambodia. As the project expands in future, it will utilize passive acoustic monitoring techniques, aerial surveys, and create a shared online photo-identification catalogue.

Sarah TUBBS (Marine Conservation Cambodia, DMAD Marine Mammals Research Association, Turkey) & Lucie BENNETT (Marine Conservation Cambodia). Email: sarahtubbs123@gmail.com, lucierose.bennett@gmail.com

News

Cambodia's first conservation genetics lab to tackle illegal ivory trade

It is estimated that >30,000 African elephants are killed every year for their ivory and that populations of the species declined by 30% between 2007 and 2014. Asian elephants are also facing severe threats, with fewer than 52,000 animals remaining. Though Cambodia has prohibited the sale of ivory since 1994, this does not include ivory originating from outside the country and Cambodia has been identified as a country 'important to watch' for illegal ivory trade by CITES. In 2015 and 2016, Fauna & Flora International (FFI) conducted market surveys to determine levels of ivory trade and consumer demand in three major cities: Phnom Penh, Siem Reap, and Sihanoukville. These revealed that the domestic market for ivory may be growing and that many retailers of ivory products target Chinese tourists. As Thailand and China become more proactive in stopping the ivory trade, there is concern that Chinese demand for ivory could shift to countries such as Cambodia.

To address these issues, FFI has initiated a new project to tackle illegal ivory trade in Cambodia. Supported by the UK Government's Department for Environment, Food and Rural Affairs, the project will allow FFI to build on its understanding of Cambodia's ivory markets through continued market surveys in the three major cities and research on trade networks. This information will be crucial to support effective law enforcement and policy interventions to stop illegal ivory trade in future. The project will also allow FFI and the Royal Zoological Society of Scotland to build on their work with the Royal University of Phnom Penh to support Cambodia's first conservation genetics laboratory. Using elephant dung previously collected by FFI and the Cambodian Elephant Conservation Group, staff will be trained in the development and use of genetic markers that allow confiscated ivory to be tested to see whether it is of African or Asian origin, providing useful information about poaching and trade networks. The project will also support implementation of the *Cambodia Elephant Conservation Action Plan* and *National Ivory Action Plan*. All of these actions will help to disrupt trade networks and ultimately reduce Cambodia's role in the transit and marketing of ivory.

Alice BÜCKER & Dr Jackson FRECHETTE (Fauna & Flora International, Cambodia). Email: alice.bucker@fauna-flora.org, jackson.frechette@fauna-flora.org

Our tribes—our heritage, indigenous minority groups in northeastern Cambodia

Cultural traditions add greatly to the richness and variety of a country. They also boost innovation, promoting economic growth and socially vibrant communities. Over 276,000 members of 24 indigenous groups are estimated to live in Cambodia (equalling 2% of the national population), mainly in Ratanakiri and Mondulkiri. Indigenous groups in northeastern Cambodia were not influenced by Indian culture like the ethnic Khmer majority and often adhere to ancient customs and animist beliefs which distinguish them from modern Khmer and each other. These are collectively known as *Khmer Loeu* (highland Khmer), a term introduced in the 1950s by the late King Norodom Sihanouk to encourage unity and harmony between indigenous minority groups and ethnic Khmer in Cambodia.

In August 2017, Save Cambodia's Wildlife, a local environmental NGO, released a 10-minute film and a lavishly produced book about four major indigenous tribes in northeastern Cambodia whose customs and practices are slowly disappearing: namely the Brao, Kavet, Kreung and Khmer-Lao. Supported by Welthungerhilfe and the German Federal Ministry for Economic Cooperation and Development, the book includes an introduction to indigenous groups in Cambodia and individual chapters devoted to the history, religious beliefs, traditions and lifestyles of each of the four groups in turn. Each chapter is leavened with testimonials that draw upon the perspectives of individuals each group, including shamans, farmers, housewives, village chiefs, fishermen and school teachers. These collectively illustrate the importance of forest and other natural resources for each indigenous group as well as the variety of threats these now face.

Save Cambodia's Wildlife empowers rural communities to preserve their culture and traditions. It supports these to understand their rights, traditions, and environment to enable them to protect their livelihoods and to reduce pressure on natural resources. Further information on its work and publications can be found at https://www.cambodiaswildlife.org.

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Short Communication

First records of three snake species from Cambodia

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Paper submitted 30 August 2017, revised manuscript accepted 9 November 2017.

Cambodia harbours a high diversity of aquatic, fossorial, terrestrial and arboreal snakes with about 96 species recorded so far (e.g., Saint Girons, 1972; Stuart & Emmett, 2006; Stuart *et al*., 2006, 2010; Grismer *et al*., 2008; Brooks *et al*., 2009; and references therein). Most snake species with wide distributions in Thailand, Laos and Vietnam are also usually found in Cambodia. Recent field work has revealed new snake species for the country, such as *Oligodon annamensis*, *Dendrelaphis ngansonensis*, and *Gongylosoma cryptum* (Neang & Hun, 2013; Neang *et al*., 2015). However, due to large gaps in survey coverage, many species in Cambodia are known only from a single or very few records, and some widely distributed species that likely also occur in Cambodia have yet to be documented (see below). Understanding which snake species occur where in Cambodia is imperative for their conservation, as many taxa are persecuted out of fear or heavily harvested for food, skins or medicinal purposes (Stuart *et al*., 2000; Brooks *et al*., 2009). In addition, some species of snakes are dangerously venomous to humans and therefore have medical significance.

This paper reports first records of three snake species in Cambodia, all verified with specimen vouchers and photographs in life. These include *Boiga guangxiensis* Wen, 1998, which was documented during fieldwork conducted on 22–28 September 2016 in Keo Seima Wildlife Sanctuary in Mondulkiri Province, and *Sinomicrurus macclellandi* (Reinhardt, 1844) and *Indotyphlops albiceps* (Boulenger, 1898), which were recorded during fieldwork on 13–16 February 2016 and 26 September–7 October 2017 in Bokor National Park in Kampot Province (Fig. 1). These new discoveries indicate that the knowledge on the herpetofauna of Cambodia remains incomplete and that additional field research is warranted.

Field surveys were carried out during the day and at night by searching for snakes on the ground, on vegetation, and under surface cover such as logs, leaf litter and

CITATION: Neang T., Chan S., Chhin S., Samorn V., Poyarkov, N.A., Stephens, J., Daltry, J.C. & Stuart, B.L. (2017) First records of three snake species from *Cambodia. Cambodian Journal of Natural History*, **2017**, 142–146.

rocks. Specimens were photographed in life, humanely euthanized using cardiac injections of MS-222, fixed in 10% formalin, and later transferred to 70% ethanol. Specimens were deposited in the zoological collection of the Centre for Biodiversity Conservation (CBC) at the Royal University of Phnom Penh, Cambodia.

Boiga guangxiensis Wen, 1998

Material examined: CBC 02791 (Fig. 2), O'Raing District, Mondulkiri Province, Keo Seima Wildlife Sanctuary, 12°19'13.5"N, 107°04'01.9"E, 490 m above sea level (asl), collected on 25 September 2016 by Neang Thy.

Remarks: A single female with a long, slender, compressed body, snout to vent length (SVL) 1159.8 mm; tail length (TaL) 368.9 mm, rather short, one third of SVL, ration of Tal/SVL 0.32 or SVL/TaL 3.1; head distinct from neck; eight supralabials, 3rd–5th touching orbit; 13 (left)/12 (right) infralabials; one loreal; one preocular; two postoculars; 4/3 anterior temporals; 4/5 posterior temporals; dorsal scale row formula (scales at neck, midbody and anterior to vent) 21–21–15; vertebral scales enlarged; 272 ventral scales; anal plate entire; 149 paired subcaudal scales. In life, our specimen has olive brown and dark brown transverse bars, with light brown blotches anteriorly, only becoming olive brown posteriorly. These conform to the diagnostic characters of *B. guangxiensis* given by Wen (1998), Ryabov & Orlov (2010), Ziegler *et al.*, (2010) & Nguyen *et al.*, (2011). Wen's (1998) statement that the supraocular does not touch the frontal may be in error. Our specimen has minor differences to specimens from China and Vietnam in having a higher number of ventral scales (1+272) [vs. 263–270 in Wen (1998), 257–270 in Ziegler *et al.*, (2010), and 261–266 in Nguyen *et al.*, (2011)]; a higher number of subcaudal scales (149) [vs. 119–147 in Ziegler *et al.*, (2010), and 142–144 in Nguyen *et al.*, (2011)]; a higher number of infralabials (12/13) [vs. 10–12 in Ziegler *et al.*, (2010)]; and a higher number of anterior temporals (4/3) [vs. 2–3/2–3 in Ziegler *et al.*, (2010), and 3/3 in Nguyen *et al.*, (2010)].

Ecology: Our specimen was found at night while slowly moving among tree branches about 0.6 m above the ground near a large tree in semi-evergreen forest.

Distribution: *Boiga guangxiensis* is known from China, Laos, and Vietnam (Wen, 1998; Ryabov & Orlov, 2010; Nguyen *et al.*, 2009, 2011; Uetz & Hallermann, 2017). Recently, *B. guangxiensis* was reported from Bu Gia Map National Park in Binh Phuoc Province, southern Vietnam (Vassilieva *et al.*, 2016) and from Cat Tien National Park in Dong Nai Province, southern Vietnam (Geissler *et al.*, 2011). Keo Seima Wildlife Sanctuary in Mondulkiri Province, (Cambodia), the location of our record, is situated in the western foothills of the Annamite (= Truong Son) Mountains across the Cambodian-Vietnamese border from Bu Gia Map National Park (Fig. 1). A congener of *B. guangxiensis*, *B. jaspidea* (Duméril, Bibron & Duméril, 1854), has been frequently documented in the national park (Vassilieva *et al*., 2016) but not yet in Cambodia, and so future records of the latter are also anticipated in the vicinity of Keo Seima.

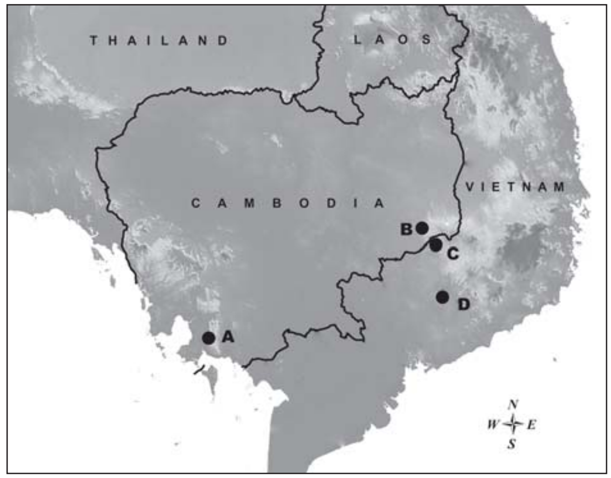

Fig. 1 Localities of new records of three snake species from Cambodia: A) *Sinomicrurus maclellandi* and *Indotyphlops albiceps* in Bokor National Park, Kampot Province; and B) *Boiga guangxiensis* in Keo Seima Wildlife Sanctuary, Mondulkiri Province. Also shown are known localities for *B. guangxiensis* in adjacent Vietnam: C) Bu Gia Map National Park, Binh Phuoc Province; and D) Cat Tien National Park, Dong Nai Province.

Sinomicrurus macclellandi (Reinhardt, 1844)

Material examined: CBC 02885 (Fig. 3), Teuk Chou District, Kampot Province, Bokor National Park, 10°39'01.5"N 104°03'41.6"E, 928 m asl, collected on 4 October 2017 by Neang Thy and Bryan L. Stuart. A photograph (Fig. 4) in the same locality near the "Black Palace" (10°37'10.97"N, 104°04'40.94"E, ca. 964 m asl) was taken on 11 February 2016 by Jack Stephens.

Remarks: CBC 02885 is a small male specimen with a cylindrical body; SVL 448.3 mm; TaL 46.9 mm; head short, rounded, slightly larger than neck, head length 11.9 mm; scale row formula 13–3–13; one preocular; two postoculars; seven supralabials; six infralabials; 1+1 temporals; 201 ventrals; 30 subcaudals, paired; anal plate divided; and tail ending in sharp spine. In life, the specimen was red above with 29 black transverse bars on dorsum, four on tail, not encircling belly; head black above with broad,

Fig. 2 *Boiga guangxiensis* (CBC 02791) in Keo Seima Wildlife Sanctuary, Mondulkiri Province, eastern Cambodia (© Neang Thy).

Fig. 3 *Sinomicrurus macclellandi* (CBC 02885) in Bokor National Park, Kampot Province, southern Cambodia (© Neang Thy).

Fig. 4 *Sinomicrurus macclellandi* (not vouchered) in Bokor National Park, Kampot Province, southern Cambodia (© Jack Stephens).

Fig. 5 *Indotyphlops albiceps* (CBC 02861) in Bokor National Park, Kampot Province, southern Cambodia (© Neang Thy).

yellowish-cream transverse band behind eye; indistinct scattered yellowish cream spotting anterior to eye, on internasals, and prefrontals; and ventral surface cream with black blotches. Photographs taken in February 2016 reveal a snake with a slim, cylindrical, red body, with regular transverse thin black bands, and a black head with a large cream band. Although the snake is partially obscured in the photographs, these characteristics are sufficient to confidently assign the individual to this species (Taylor, 1965).

Ecology: Our specimen was found under a rotting log in evergreen forest at 1240 hrs. The animal photographed in February 2016 was found on a forest trail within 15–20 m of another individual of the same species.

Distribution: *Sinomicrurus macclellandi* occurs from India and Nepal through Myanmar, Thailand, Laos, Vietnam, Hainan Island of China, Taiwan and the southernmost parts of the Ryukyu Islands in Japan (Taylor, 1965; Deuve, 1970; Nguyen *et al.*, 2009; Uetz & Hallerman, 2017). Due to its wide geographic distribution, the species was expected to occur in Cambodia, although Saint Girons (1972) anticipated that it would occur only in the mountains of the northeastern part of the country.

Indotyphlops albiceps (Boulenger, 1898)

Materials examined: CBC 02861 (Fig. 5), Teuk Chou District, Kampot Province, Bokor National Park, 10°40'51.4"N, 104°03'30.1"E, 841 m asl, collected on 14 February 2017 by Neang Thy and Samorn Vireak.

Remarks: Our single female specimen has SVL 211.3 mm; tail short, TaL 2.7 mm, ratio TaL/SVL 1.3%; head indistinct from neck; snout rounded, inferior suture complete, in contact with 2nd supralabial, superior suture incomplete, about one fourth the distance between nostrial and rostral-frontorostral suture; one preocular, in contact with 2nd and 3rd supralabial; one postocular; eye obscured by ocular shield; four supralabials, the 4th the largest; two infralabials; supralabial imbrication pattern T-III (third supralabial overlapping ocular shield) following Wallach (1993); body scalation formula 22–20–20, following Wallach (1993); diameter of mid-body 4.3 mm, about 50 times the total length; 375 mid-dorsal scales; seven subcaudals; and caudal spine present. Dark brown on dorsal surface and flanks; paler dark brown on venter; entire head, gular region, vent and tail white; and spine base and spine dark brown. These characters generally match those of *I. albiceps* (Pyron & Wallach, 2014; Taylor, 1965). However, our specimen from Bokor has 22 scale rows at neck rather than 18–20 scale rows reported from Thailand (Boulenger, 1898; Taylor, 1965). We assume that this minor difference reflects geographic variation within the species, but future taxonomic evaluation (including molecular analyses) of Cambodian specimens is warranted.

Ecology: Our specimen was found under a rotten log near an ant colony during the day in hilly semi-evergreen forest. A few dead ant larvae were seen together with the snake in a plastic bag used to retain the specimen overnight before preservation, suggesting these may have come from its stomach.

Distribution: *Indotyphlops albiceps* has been reported from Hong Kong, Myanmar, Thailand, Laos and west Malaysia (Taylor, 1965; Uetz & Hallerman, 2017). The type locality is "Chantaboon" (= Chanthaburi) in southeastern Thailand, and so our record of the species in southern Cambodia was expected.

Acknowledgements

We are indebted to H.E. Say Samal and H.E. Chea Sam Ang for permission to conduct field work in Cambodia. We also thank the MSc students from the Centre for Biodiversity Conservation in Phnom Penh who helped find the *Indotyphlops* specimen, Kung Putheara and Nuth Menghor for facilitating our field work, and Tuy Sereivathana and Ith Saveng for facilitating our museum work. Our work was supported by grants kindly provided by the Margaret A. Cargill Foundation, National Geographic Society (grant no. WW-R016-17), and Russian Science Foundation (RSF grant no. 14-50-00029).

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Short Communication

Assessment of rodent communities in two provinces of Cambodia

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Paper submitted 28 September 2017, revised manuscript accepted 30 November 2017.

Rodents play an important role in regulating ecosystems, in particular through seed dispersion and predation, and constitute a prey for mesopredators. However, rodents are considered pests in rural areas because they can cause significant damage to crops, especially during episodes of sudden population growth (Singleton, 2003). Rodents are also carriers or reservoirs for numerous zoonotic diseases that represent a serious threat to human health (Meerburg *et al.*, 2009; Luis *et al.*, 2013; Olival *et al.*, 2017). Multi-site assessments of rodent communities are consequently needed to understand the implications of various spatio-temporal factors on these ecosystem services, the epidemiology of rodent-borne diseases, and other interactions with humans.

Between June 2015 and April 2016, field surveys were conducted to assess rodent community composition at five sites in Cambodia: the Orona, Pouy Doem Svay and Ochra villages in Keo Siema District, Mondulkiri Province, and the Sro Lov Sroung and Rom Chek villages in San Dan District, Kampong Thom Province (Fig. 1). Each site was visited twice, once during the wet season (June–September 2015) and once in the dry season (January–April 2016). During each visit, 150 traps were deployed in a variety of habitats (including evergreen or semi-evergreen forest, and cultivated lands) whose locations were recorded using handheld GPS units (Garmin 60Cx, Garmin 60Csx, USA). Rodents were trapped using locally made and non-lethal Havahart traps for eight consecutive nights in each season at each site (=12,000 trap nights in total). All of the study procedures were approved by the Wildlife Conservation Society's Institutional Animal Care and Use Committee, under protocol #15:04.

Captured individuals were marked with a one millimetre ear notch. These skin samples were stored in 95% alcohol and placed in liquid nitrogen. Each animal was given a unique identification code and photographed before release. Morphological criteria (Wilson & Reeder, 2005; Francis, 2008; Chaval, 2011) and molecular analyses were employed for species identification. DNA was extracted from the skin samples using the Qiagen DNeasy® Blood & Tissue Kit according to the manufacturer's instructions. The primer set of BatL5310 (5′-CCTACTCRGCCATTTTACCTATG-3′) and R6036R (5′-ACTTCTGGGTGTCCAAAGAATCA-3′) were used

CITATION: Fillieux, C., Chea S., Ramassamy J.-L., Hul V., Olson, S., Fine, A., Dussart, P., Phimpraphi, W., Horwood, P.F. & Pruvot, M. (2017) Assessment of rodent communities in two provinces of Cambodia. *Cambodian Journal of Natural History*, **2017**, 147–152.

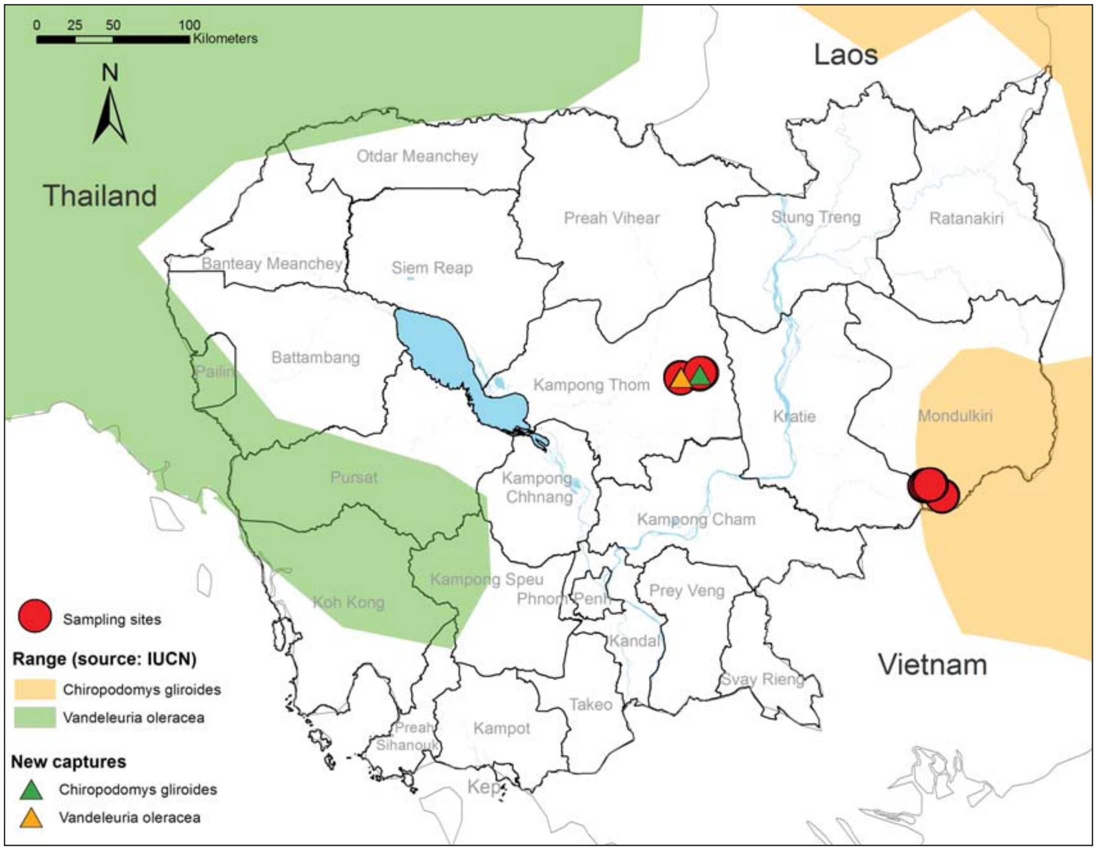

Fig. 1 Study locations in Kampong Thom Province and Mondulkiri Province, 2015–2016.

to amplify a 750 base pair fragment of the Cytochrome c oxydase subunit I (COI) gene, as described by Blasdell *et al.* (2015). Amplicons were sequenced using the Sanger method at a commercial facility (Macrogen, Seoul, South Korea). Species identifications were obtained by comparing DNA sequences to existing records. This process was facilitated by previous DNA barcoding efforts for rodent species in the region (e.g., CERoPath: www.ceropath.org).

Where results of molecular identification were not consistent with morphological characteristics (five individuals) or when DNA sequences were not available due to missing skin samples (25 individuals), species determinations relied on morphological identification validated using archived photographs. Due to missing data, 13 individuals could only be identified to genus (11 *Mus* spp. individuals and two *Rattus* spp. individuals). These were excluded from the results. Another 52 individuals which escaped from traps or during handling were also excluded from the study.

A total of 519 individuals were captured and identified to species level over the course of sampling at the five sites in the two seasons. These belonged to 13 different species (12 from the Rodentia order and one from the Scandentia order). Of the 519 individuals captured, 395 were captured during the wet season and 124 during the dry season.

Mus cervicolor, *Rattus tanezumi* and *Maxomys surifer* were the most dominant species in all sites and seasons (see discussion of the *R. tanezumi*/ R3 clade below), representing 94% and 85% of all individuals captured during the wet and dry season, respectively (Fig. 2). The remaining 10 species were represented by 44 individuals. Species abundance data for each site and season are provided in Table 1.

Community composition differed significantly between seasons (PERMANOVA: F=7.13, p=0.015), as indicated by a permutational multivariate analysis of variance on a Bray-Curtis dissimilarity matrix. Chao's method (Chiu *et al.*, 2014) was used to estimate the number of unseen species and total species richness for each site in each season (Fig. 3) and indicated this did not differ significantly between provinces (p=0.4) or seasons

Table 1 Species captured by site and season in Kampong Thom Province and Mondulkiri Province, 2015–2016.

Species	Season	Mondulkiri			Kampong Thom		Total per season	Total both seasons
		Orona	Pouy Doem Svay	Ochra	Sro Lov Sroung	Rom Chek		
Mus cervicolor (Hodgson, 1845)	Wet	50	45	35	61	64	**255**	**317**
	Dry	5	14	1	36	6	**62**	
Rattus tanezumi [a] (Temminck, 1844)	Wet	14	14	3	23	12	**66**	**84**
	Dry	1	3	3	3	8	**18**	
Maxomys surifer (Miller, 1900)	Wet	8	1	12	6	22	**49**	**74**
	Dry	4	5	3	3	10	**25**	
Tupaia belangeri [b] (Wagner, 1841)	Wet	-	-	-	-	7	**7**	**16**
	Dry	1	-	-	3	5	**9**	
Niviventer fulvescens (Gray, 1867)	Wet	-	1	-	-	4	**5**	**7**
	Dry	1	-	-	1	-	**2**	
Mus caroli (Bonhote, 1902)	Wet	-	-	-	-	5	**5**	**5**
	Dry	-	-	-	-	-	-	
Berylmys berdmorei (Blyth, 1851)	Wet	-	1	-	1	-	**2**	**5**
	Dry	-	2	-	-	1	**3**	
Rattus exulans (Peale, 1848)	Wet	-	3	-	1	-	**4**	**4**
	Dry	-	-	-	-	-	-	
Vandeleuria oleracea (Bennett, 1832)	Wet	-	-	-	-	-	-	**3**
	Dry	-	-	-	3	-	**3**	
Chiropodomys gliroides (Blyth, 1856)	Wet	-	-	-	-	-	-	**1**
	Dry	-	-	-	-	1	**1**	
Leopoldamys sabanus (Thomas, 1887)	Wet	-	-	-	-	-	-	**1**
	Dry	1	-	-	-	-	**1**	
Rattus losea (Swinhoe, 1870)	Wet	-	-	-	1	-	**1**	**1**
	Dry	-	-	-	-	-	-	
Rattus andamanenis (Blyth, 1860)	Wet	1	-	-	-	-	**1**	**1**
	Dry	-	-	-	-	-	-	
Total captures	Wet	73	65	50	93	114	**395**	**519**
	Dry	13	24	7	49	31	**124**	
Total rodent species [b]	Wet	4	5	3	6	5	**9**	**12**
	Dry	5	4	3	5	5	**8**	
Chao's estimate of rodent species richness [b]	Wet	4	6	3	9	5	**12**	**14** [c]
	Dry	8	4	3	5	6	**10**	

[a] *Sensu* Aplin *et al.* (2011): *Rattus* clade R3. [b] *Tupaia belangeri* is excluded here as it belongs to the Scandentia order (and therefore is not a rodent).
[c] Estimated by the bootstrap method.

(p=0.5). Although the distribution of traps in habitat types followed the same pattern at each site and between seasons, total capture figures for each site were heterogeneous (Table 1). A Poisson regression employing "site" as a random effect indicated that abundance was significantly greater during the wet season (p<0.0001) and at sites in Kampong Thom Province (p<0.0001), suggesting seasonal and large scale geographical variations. Because we could not sample all sites simultaneously, however, the timing of sampling may have confounded our

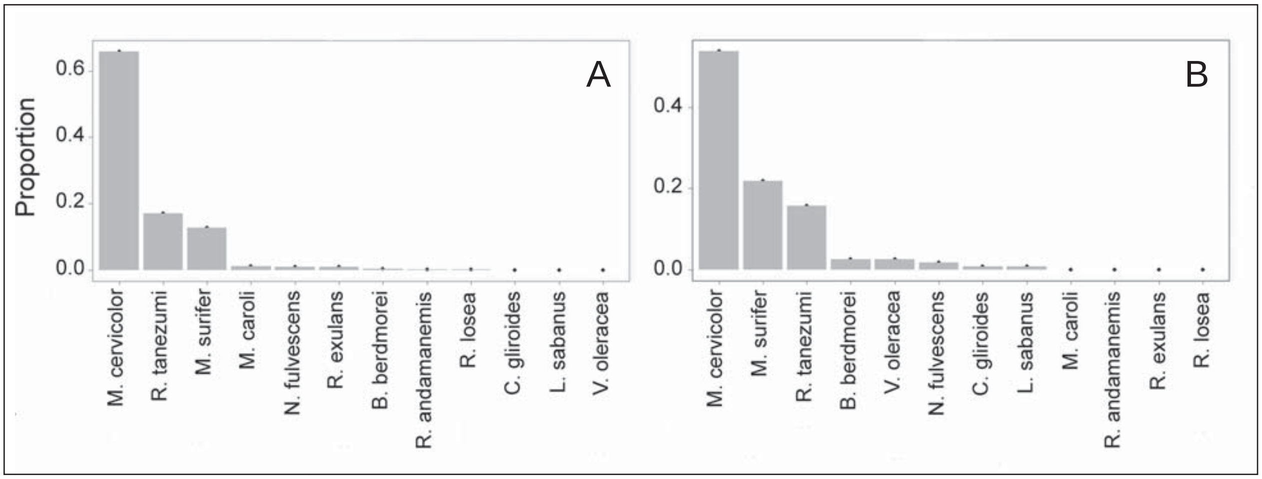

Fig. 2 Relative abundance of rodent species in five sites during A) 2015 wet season (*n*=395) and B) 2016 dry season (*n*=124).

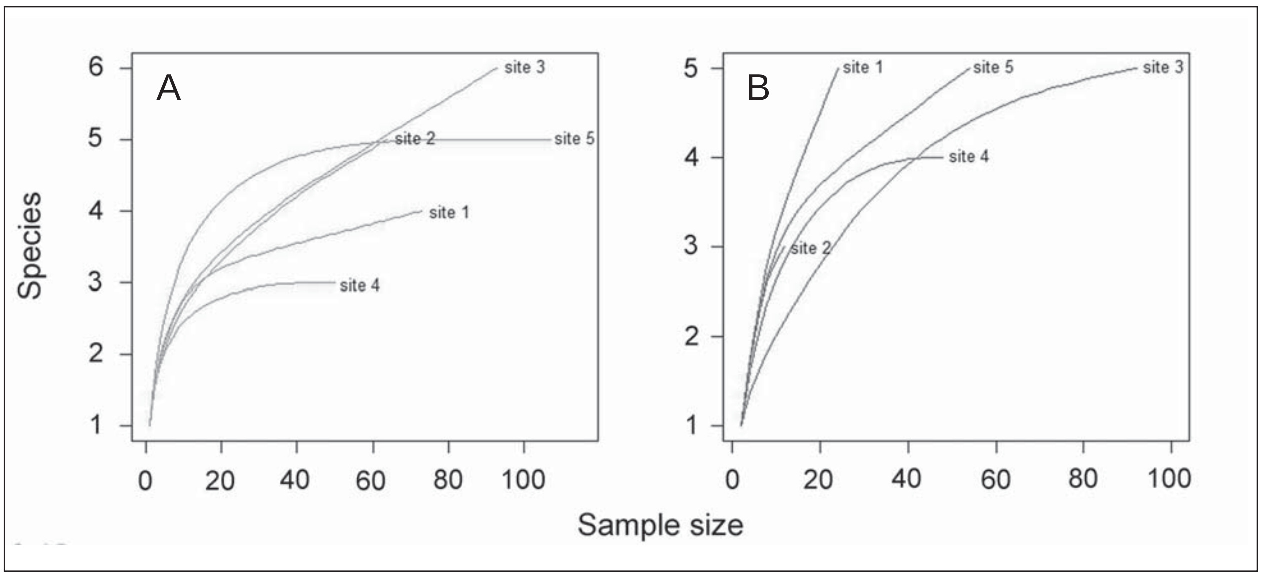

Fig. 3 Rarefaction curves for species richness at five study sites during the A) 2015 wet season and B) 2016 dry season. Site numbers: 1) Orona; 2) Pouy Doem Svay; 3) Sro Lov Sroung; 4) Ochra; 5) Rom Chek.

geographical analysis. Aside from the three dominant species which were recorded at all sites in both seasons, the remaining species were only captured at a few sites.

Ivanova *et al.* (2012) did not observe seasonal variation in rodent abundance in their surveys in Cambodia, but direct comparison of results is difficult due to the greater variety of landscapes and inclusion of village-based rodent captures (with traps provided to villagers) in their study. Climatic variations, and in particular the El Niño Southern Oscillation (ENSO), are known to influence rodent abundance and may have influenced our findings as well as those of previous studies (Ivanova *et al.*, 2012). The overall species richness of our study (12 Rodentia, 1 Scandantia) is similar to the results of Ivanova *et al.*, (2012), who also found *M. surifer* and *Rattus* spp. were the most dominant species. Unlike other studies in Southeast Asia (Herbreteau *et al.*, 2012; Ivanova *et al.*, 2012; Cosson *et al.*, 2014) however, we did not capture any *Bandicota* spp.

The Asian black rat has a complex evolutionary history which is illustrated by phylogenetic analyses of mitochondrial and nuclear DNA that are incongruent (Aplin *et al.*, 2011; Pagès *et al.*, 2013; Blasdell *et al.*, 2015). To assess lineages of *R. tanezumi*, *R. sakeratensis* and the

Table 2 Summary characteristics of *Chiropodomys gliroides* and *Vandeleuria oleracea* recorded in Kampong Thom Province during the dry season of 2016.

Site	Location (WGS 84)	Date	Species	Sex	Age	HB [1] (mm)	Tail (mm)
Rom Chek	12.870446 N, 105.487015 E	6 March 2016	*C. gliroides*	Female	Adult	75.5	103
Sro Lov Sroung	12.853912 N, 105.373021 E	13 February 2016	*V. oleracea*	Female	Neonate	47.5	74.6
Sro Lov Sroung	12.853879 N, 105.372590 E	17 February 2016	*V. oleracea*	Female	Juvenile	55.9	87.8
Sro Lov Sroung	12.851962 N, 105.376047 E	18 February 2016	*V. oleracea*	Female	Neonate	49.5	84.4

[1] HB=Head and body length.

putative *Rattus* taxon known as "R3", previous studies used diverse genetic markers: two mtDNA genes, one nuclear gene and eight microsatellite loci reflecting different rates of evolution and parental inheritance. Pagès *et al.* (2013) found that *Rattus* sp. R3 was more closely related to *R. tanezumi* on the basis of its nuclear genome (and morphological data) but more closely related to *R. sakeratensis* according to its mitochondrial genome. This was explained by geographical structuring or possible hybridisation with introgression from a species yet to be identified (Pagès *et al.*, 2013; Blasdell *et al.*, 2015). Most of the *R. tanezumi* specimens sampled during our study clustered with the *Rattus* sp. R3 clade (sensu Aplin *et al.*, 2011). Growing collections of genetic material for *Rattus* from Cambodia and other parts of Southeast Asia provide opportunities to clarify the taxonomy of the *Rattus* genus.

Two species (*Chiropodomys gliroides* and *Vandeleuria oleracea*) that we captured in Kampong Thom Province are rarely recorded in Cambodia in recent studies (Ivanova *et al.*, 2012; Cosson *et al.*, 2014). The locations of our records lie outside of the geographic ranges provided by IUCN (Lunde *et al.*, 2016; Aplin & Molur, 2017; Fig. 1) and thus represent range extensions. Each individual of these species was identified morphologically (Table 2) because DNA barcode reference sequences are not available for *V. oleracea* and the barcoding approach identified our *C. gliroides* as *M. cervicolor*. Our data will be integrated to the CERoPath database to improve existing DNA barcoding efforts for rodents in Southeast Asia.

In conclusion, our study highlights that rodent populations at our study sites were more abundant during the wet season and dominated by three species (*M. cervicolor*, *R. tanezumi* and *M. surifer*). This structure and dynamic could have significant consequences for the transmission of important pathogens hosted by rodents, such as *Leptospira*, *Orientia*, *Rickettsia*, hantaviruses and other emerging pathogens (Luis *et al.*, 2013; Morand *et al.*, 2015). Future work will focus on the dynamics of such pathogens in rodent communities and the effects of land-use change at smaller spatial scales.

Acknowledgements

This study forms part of the One Health LACANET project supported by the European Union (EuropeAid, INNOVATE Programme contract DCI/2013/315-151). The authors are grateful to the field team: Buor Vuthy, Chao Marany, Choerun Unthyda, Hun Udam, In Samat, Kang Sunsisonila, Kuy Lina, Nuon Sithun, Phon Sonara, Ros Sela, San Butum, San Sovannary, Sar Ratha, Sek Seng, Sin Chandara, Suos Sreyem, Ton Sophornn, Torng Sreyleap, Ty Yaren and Y Samnang, and villagers that also helped. We thank Ms Sapho Briand for her skilful project management assistance and Dr Serge Morand for his expert advice. We are also grateful to the Forestry Administration of the Ministry of Agriculture, Forests and Fisheries and to the Ministry of Environment of the Royal Government of Cambodia for authorizing and facilitating our research.

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Short Communication

Recent records of Asian elephant *Elephas maximus* in Virachey National Park, northeastern Cambodia

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Paper submitted 26 July 2017, revised manuscript accepted 17 October 2017.

The status of Asian elephants *Elephas maximus* in Virachey National Park (VNP) has long been poorly understood (M. Maltby & Thon S., pers. comm. 2017). In this article, we present the most recent records of Asian elephants from VNP in the Stung Treng and Ratanakiri provinces, northeastern Cambodia. To the best of our knowledge, the last wildlife surveys in VNP were undertaken by Conservation International in 2007 and by the Cambodia Protected Area Management Project in 2008 (Vuykeo N., pers. comm. 2017).

Over a three-year period from January 2014 to January 2017, we deployed 19 camera traps in the Veal Thom/Haling Halang area of VNP for a total of 5,659 camera trap nights. Seven camera traps were also deployed in the Yak Yeuk grassland area near the Laos border for 2,242 camera trap nights, providing a combined total of 7,901 camera trap nights (Fig. 1). Most of our field cameras were Bushnell 12MP Trophy Cam HD Essential Low Glow Trail camera traps (Bushnell Corporation, USA; *n*=14), with four additional Reconyx HC600 Hyperfire camera traps (Holmen, USA) and one Covert camera trap (Lewisburg, USA). These were set approximately 20–100 cm from the ground, depending upon slope, vegetation and anchoring trees. All camera traps were active for 24 hours each day and recorded time, date, and temperature when triggered. Because our main goal was to conduct a baseline survey of small to large terrestrial mammals in VNP, camera trap locations were selected based on the presence of wildlife trails, runs, tracks, scratchings and wallows. Elephants were not specifically targeted, though cameras were placed opportunistically near trails, feeding areas and dung.

On 18 January 2015, elephant tracks and fresh dung were found in the Yak Yeuk grassland area of VNP near the Laos border in Veun Sai District (Fig. 2). The presence of elephants was also confirmed by local Kavet guides living in Kuan Nuok village of Veun Sai District which borders VNP to the south. The dung and tracks were observed leading to and surrounding large stands of bamboo (14.3224 N, 106.8019 E), which were highly disturbed due to apparent elephant feeding. One camera trap was placed along a trail leading towards the Laos border and another camera trap was deployed facing a large mud wallow, measuring approximately 10 x 15 m. Despite this, elephants were not recorded on our camera traps.

On 19 November 2016, camera station #6 was triggered 28 times by elephants which resulted in photographs of at least nine individuals, including a small infant walking close to its mother and judging by its size, a juvenile (Figs 3 & 4). The location (14.3450 N, 106.9823 E) was near the headwaters of the O Gan Yu River close to the Laos border at the base of Phnom Haling-Halang. Piles of elephant dung were found within three to four kilometres on trails to the east and west of this location, as well as at another location approximately six kilometres to the south. Almost one hour later the same day, camera station #11 (14.3415 N, 106.98570 E) was triggered

CITATION: Pawlowski, K. & McCann, G. (2017) Recent records of Asian elephant *Elephas maximus* in Virachey National Park, northeastern Cambodia. *Cambodian Journal of Natural History*, **2017**, 153–156.

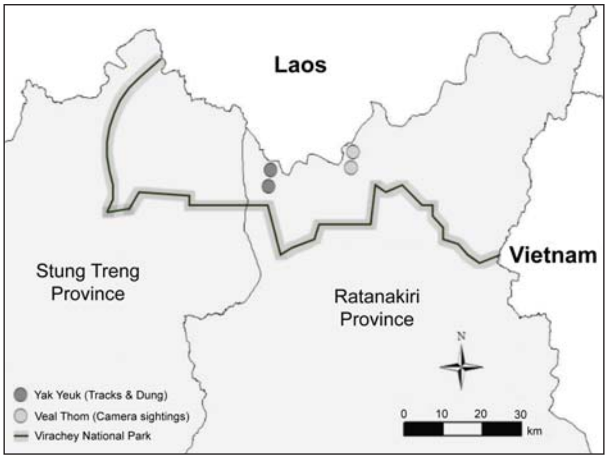

Fig. 1 Locations where Asian elephants were recorded by camera traps in Virachey National Park in 2016 and where tracks and dung were found in 2015.

Fig. 2 Fresh elephant track found in the Yak Yeuk grassland area of Virachey National Park near the border with Laos on 18 January, 2015.

Fig. 3 Adult elephant with young at the headwaters of the O Gan Yu River, near the base of Phnom Haling Halang in Virachey National Park on 19 November, 2016.

Fig. 4 Juvenile elephant at the headwaters of the O Gan Yu River, near the base of Phnom Haling Halang in Virachey National Park on 19 November, 2016.

Fig. 5 Adult elephant approximately four kilometres east of Phnom Haling Halang, Virachey National Park on 19 November, 2016.

by two adult elephants, resulting in three photographs. The elephants were standing fairly close to the camera and only their legs and torso were visible, indicating that they were either adults or sub-adults (Fig. 5). The distance between camera station #6 and #11 was approximately four kilometres and can be walked in around 1.5–2 hours. It is therefore possible that these animals were from the same herd, although this cannot be concluded with certainty.

At 01:02 hrs on 18 December 2016, camera station #6 was triggered by elephants 25 times. The images showed eight individuals including a small infant walking close to its mother. This would appear to be the same herd that triggered the camera trap station on 19 November.

We suspect that the lack of camera trap records for elephants in the Yak Yeuk grassland area may be due to seasonal movements or possible avoidance of humans, as there was increased logging in this area. Similarly, our records of elephants near the base of Phnom Haling-Halang may be due to its remote location and relatively undisturbed habitat.

National Context and Significance

It has been approximately 10 years since Asian elephants were camera-trapped in VNP, and our records demonstrate that elephants still exist at the site and provide evidence of recent breeding. The last known camera trap images of elephant from VNP were recorded in 2006 (M. Maltby, Thon S. & Vuykeo N., pers. comm. 2017) from the Siem Pang area, approximately 30 km west of our camera trap stations in Stung Treng Province. Prior to this, Asian elephants were recorded in VNP by camera traps between June 1999 and August 2001 (Gray *et al.*, 2012).

Although the overall population of elephants in Cambodia is unknown, the largest populations likely occur in the Cardamom Rainforest Landscape in southwestern Cambodia and Mondulkiri Province in eastern Cambodia (Gray *et al.*, 2017). Using capture-mark-recapture analysis of faecal DNA, Gray *et al.* (2014) estimated the Mondulkiri population to be approximately 300 individuals and 136 (SE ± 35) individuals in Phnom Prich Wildlife Sanctuary. Maltby & Bourchier (2011) estimated approximately 30 wild elephants in the Ratanakiri and Preah Vihear provinces with those in Ratanakiri being located in VNP.

The future of VNP is highly uncertain due to plans for a new road along the Laos border that would cut through the most inaccessible and pristine area of the park (McCann, 2017; Turton & Dara, 2017) where our records stem from. Virachey National Park and other protected areas in Ratanakiri Province are strongly impacted by large-scale illegal logging for the timber trade with Vietnam (Environmental Investigation Agency, 2017). This presents a serious threat to elephants in the landscape. Urgent measures should be taken by the government and NGOs in Cambodia to safeguard this wild elephant herd, which may be the last in Ratanakiri Province. For example, the proposed border road should be cancelled or redesigned to circumvent the area where elephants and many other species occur. Regular ranger patrols in this area would also help to ensure the long-term survival of elephants in VNP and the park could probably support higher numbers of elephants if poaching and snaring were reduced and effective protection measures put in place. To the best of our knowledge, there have been no reports of crop-raiding or any other form of human-elephant conflict in recent years.

Because our elephant records stem from areas close to the border with Laos, it is likely that these represent a trans-boundary herd. The area directly north of VNP forms part of Nam Ghong Provincial Protected Area in Laos, but likely receives little formal protection from Lao authorities. Given the current status of elephant in Cambodia, any populations outside of the Cardamom Rainforest Landscape and Mondulkiri Province should be regarded as nationally significant. Virachey National Park comprises a vast (3,325 km^2) and long undeveloped and un-demarcated mountainous border region with Laos, though construction of the proposed border road would change this. Additional studies should be carried out to determine if other elephant herds exist in the national park. Studies are also needed to determine the range of the herd we recorded because as this was located very close to the Laos border, national estimates on either side of the border could possibly double-count a trans-boundary population.

Acknowledgements

The authors would like to thank staff from the Ministry of Environment and Virachey National Park in Ratanakiri Province, including Chou Sophark, Prin Sambo, Thon Soukhon, Phon Khemrin, Vuykeo Nhuy, and Leam Sou. We would also like to thank Matthew Maltby, Andreas Neunert, Richard Wacha, Howie and Karen Nielsen, Jorge Leao, Dan Pawlowski, Conor Wall, David Carr, and Joy Wang.

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First systematic survey of green peafowl *Pavo muticus* in northeastern Cambodia reveals a population stronghold and preference for disappearing riverine habitat

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Paper submitted 21 June 2017, revised manuscript accepted 1 December 2017.

មូលន័យសង្ខេប

ចំនួនសត្វក្ងោកបៃតងបានថយចុះយ៉ាងឆាប់រហ័សនៅអាស៊ីអាគ្នេយ៍ ដោយសារកត្តានៃការបាត់បង់ទីជម្រក និងការបរបាញ់។ សត្វក្ងោកបៃតងត្រូវបានគត់ត្រាថាជាសត្វជិតផុតពូជ ហើយចំនួនច្រើនបំផុត ដែលនូវសេសសល់ទំនងជាមានតែនៅភាគឦសាន នៃប្រទេសកម្ពុជាតែប៉ុណ្ណោះ។ ដូច្នេះ ការអភិរក្សសត្វក្ងោកបៃតងក្នុងតំបន់នេះគួរតែជាអាទិភាពក្នុងការអភិរក្ស។ ទោះជាយ៉ាងណា នៅមានចំនុចខ្វះចន្លោះជាច្រើនទាក់ទងទៅនឹងពត៌មានលំអិតអំពីអេកូឡូស៊ីរបស់ប្រភេទសត្វនេះ ការមិនមានទិន្នន័យជាមូលដ្ឋាននៃចំនួនសត្វក្នុងទីតាំងសំខាន់ៗជាច្រើនដែលមានប្រភេទសត្វនេះរស់នៅ និងនៅមានជម្រើសវិធីសាស្ត្រតិចតួច សម្រាប់ប្រើប្រាស់ក្នុងការធ្វើការវាយតម្លៃទាំងនេះ។ យើងធ្វើការសិក្សាវាយតម្លៃជាលើកដំបូង ដើម្បីប៉ាន់ប្រមាណពីចំនួនរបស់វាក្នុងដែនជម្រកសត្វព្រៃសៀមប៉ាង ដោយប្រើប្រាស់វិធីសាស្ត្រនៃការចាប់យក និងចាប់យកឡើងវិញ spatially explicit capture-recapture (SECR) ដោយផ្អែកលើការស្តាប់របស់អ្នកសិក្សា។ នៅចន្លោះខែកុម្ភៈ និងខែមេសា ឆ្នាំ២០១៥ យើងកត់ត្រាបានសំលេងសត្វយំចំនួន ៣៧៥ ដង ក្នុងនោះមានសត្វចំនួន ៨៩ក្បាល ត្រូវបានកំណត់ថាជាសត្វឈ្មោល ដែលត្រូវបានរកឃើញអំឡុងពេលនៃការសិក្សានៅ ១៧៦ ចំនុចសិក្សាផ្សេងគ្នា ដែលអាចប៉ាន់ស្មានបានថារបាយនៃសត្វឈ្មោលមានចំនួន ១.៧ក្បាល/គីឡូម៉ែត្រក្រឡា (៩៥% CI=១.០៨–២.៦៦) នៅក្នុងទីជម្រកនៃព្រៃទ្រនាប់ដងទន្លេ ដែលចំនួននេះខ្ពស់ជាងជិតប្រាំដងនៃរបាយសត្វឈ្មោលមានចំនួន ០.៣៥ក្បាល/គីឡូម៉ែត្រក្រឡា (៩៥% CI=០.២១–០.៥៩) ក្នុងទីជម្រកដែលមិនស្ថិតតាមដងទន្លេ។ម្យ៉ាងទៀត ដង់ស៊ីតេរបស់វាក៏មានលក្ខណៈខ្ពស់ជាងចំពោះទីតាំង ដែលស្ថិតនៅឆ្ងាយពីលំនៅដ្ឋានរបស់មនុស្ស។ នេះបង្ហាញថា សត្វក្ងោកបៃតងអាចរងការគំរាមកំហែងពីការរំខានរបស់មនុស្ស ហើយសកម្មភាពអភិរក្សគួរតែផ្តល់អាទិភាពដល់ការការពារជម្រកតាមដងទន្លេនេះ។ ចំនួនដ៏ច្រើននៃសត្វក្ងោកបៃតងនៅក្នុងដែនជម្រកសត្វព្រៃសៀមប៉ាងត្រូវបានគេប៉ាន់ស្មានថាមានរហូតដល់ចំនួន ៥៧៩ក្បាល (៩៥% CI=៣៨៩–១២០៣) ហើយយើងគិតថាតំបន់នេះជាតំបន់ដែលទ្រទ្រង់ប្រភេទសត្វក្ងោកបៃតងនេះច្រើនជាងគេក្នុងប្រទេសកម្ពុជា។ វិធីសាស្ត្រនៃការស្តាប់សំលេងនេះ (SECR) ត្រូវបានវាយតម្លៃ ហើយយើងអាចផ្តល់ជាយោបល់ថាប្រសិនជាមានអ្នកជំនាញបច្ចេកទេសគ្រប់គ្រាន់ វាជាវិធីសាស្ត្រមួយមានប្រសិទ្ធិភាពខ្ពស់ និងចំណាយថវិកាតិចក្នុងការប៉ាន់ស្មានចំនួនរបស់វានៅតាមទីតាំងនីមួយៗ។

CITATION: Loveridge, R., Kidney, D., Ty S., Eang S., Eames, J.C. & Borchers, D. (2017) First systematic survey of green peafowl *Pavo muticus* in northeastern Cambodia reveals a population stronghold and preference for disappearing riverine habitat. *Cambodian Journal of Natural History*, **2017**, 157–167.

Abstract

The green peafowl has undergone a rapid decline across Southeast Asia as a consequence of habitat loss and hunting. The species is listed as Endangered and the largest remaining population likely occurs in northeastern Cambodia. Conservation of the species in this region should therefore be a priority, yet significant knowledge gaps remain. These include an inadequate understanding of peafowl ecology, the absence of population baselines for many sites across the species' range and insufficient methods to assess ecology and population size. We provide the first assessment and abundance estimate of green peafowl in Siem Pang Wildlife Sanctuary using a novel application of spatially explicit capture recapture (SECR) methods based on an array of listening stations. Between February and April 2015, 375 vocalisations attributed to 49 calling males were detected during 176 listening station survey periods, providing an estimate of 1.7 males/km^2 (95 % CI= 1.08–2.66) in riverine habitat, nearly five times higher than the estimate of 0.35 males/km^2 (95% CI=0.21–0.59) in non-riverine habitat. Peafowl density was also higher further from human settlements. This suggests that the green peafowl population in the wildlife sanctuary may be threatened by human disturbance and that future conservation actions should prioritize protection of riverine habitat. We estimate the abundance of green peafowl in Siem Pang Wildlife Sanctuary at 574 birds (95% CI=349–1,203) and suggest the site is a national stronghold for the species. We also evaluate the acoustic SECR methodology employed and suggest that with sufficient expertise it is a cost-effective means of generating site-based abundance estimates.

Keywords

Abundance, Cambodia, green peafowl, riverine habitat, SECR.

Introduction

The green peafowl *Pavo muticus,* with its striking, long and colourful train feathers, has strong cultural importance in Southeast Asia. The species is an ancient symbol of wealth and power in Myanmar, was used as the icon of the Burmese monarchs, was printed on Burmese banknotes until 1966 and is the emblem of the National League for Democracy. In Thailand, Laos and Cambodia, the green peafowl is frequently depicted in religious temples such as Angkor (Goes, 2009) and in Java, the species is a symbol of traditional dance (McGowan *et al.*, 1998). Its ecological values are less well known, but as the diet of the species includes seeds, it may have ecological importance as a seed disperser (Owens & McGowan, 2011).

Once described as "the commonest gamebird in Indochina" (Delacour & Jabouille, 1925), green peafowl have declined rapidly in range within the greater Mekong region, and the only sizeable remaining populations are found in forests in Cambodia (Evans & Clements, 2004), Myanmar (Hla *et al.*, 2015) and Vietnam (Brickle *et al.*, 1998; Brickle, 2002). However, Sukumal *et al.* (2015) resurveyed the same area of Vietnam as Brickle *et al.* (1998) and Brickle (2002) and showed that this population has drastically declined. Outside of this region, small populations of the species persist in western and northern Thailand, southern Laos (Vongkhamheng *et al.*, 2012), Yunnan in China (Han *et al.*, 2009) and on Java in Indonesia (van Balen *et al.*, 1995; BirdLife International, 2016).

Cambodia experienced the fastest acceleration in the rate of deforestation in the world between 2001 and 2014 (Petersen *et al.*, 2015). The decline of the once revered green peafowl is partly due to deforestation and poorly regulated exploitation of forests and wildlife in the region. Habitat fragmentation has isolated many small populations. As a ground-dwelling bird, the green peafowl is particularly vulnerable to habitat fragmentation and susceptible to local extinction (Goes, 2009). Limited evidence also suggests the species is hunted for meat and feathers, and collection of eggs and chicks for illegal sale into the pet trade (BirdLife International, 2016). The conspicuous appearance of the species and its regular use of the same roosting trees make it easily hunted. As a consequence of inferred population declines, the green peafowl is listed as Endangered on the IUCN Red List of Threatened Species (BirdLife International, 2016).

In their status review for green peafowl, Brickle *et al.* (2008) suggest that "northern and eastern Cambodia probably hold the largest single population of the species" and the national population has been estimated at 2,000 to 3,000 birds (Goes, 2009). However, this figure is poorly substantiated because the status of the species at sites across Cambodia has been largely inferred or extrapolated using data from incidental records, ornithologists' trips and relative indices (Goes, 2009). Only one systematic survey has been undertaken in a single protected area to date (Nuttall *et al.*, 2017). As a consequence, we aimed to contribute to filling this data gap by surveying the species in Siem Pang Wildlife Sanctuary (SPWS) in northeastern Cambodia.

Nuttall *et al.* (2017) surveyed green peafowl using line transects and distance sampling analysis of visual detections to estimate the abundance of the species in Keo Seima Wildlife Sanctuary. Encounter rates with green peafowl were low and so a large amount of surveys across multiple years were needed to robustly estimate abundance (Nuttall *et al.*, 2017). Because male green peafowl produce a characteristic and loud 'wail' call that can be heard up to one kilometre away (Indrawan, 1995), auditory detections provide an alternative means of studying the species (Brickle, 2002). For instance, Brickle (2002) used point distance sampling of auditory detections of the wail call to survey green peafowl in Vietnam. This yielded a higher number of green peafowl detections per survey event than Nuttall *et al.* (2017). Because species density and abundance are estimated more accurately with a larger number of detections (Buckland *et al.*, 2001), we opted to survey green peafowl using auditory detections.

Density estimation by point distance sampling of auditory detections relies on distances to detected individuals being observed (Buckland *et al.*, 2001) and has been shown to be sensitive to random error in distance estimation, even when distance is estimated without bias (Borchers *et al.*, 2015; Kidney *et al.*, 2016). However, advances in Spatially Explicit Capture Recapture (SECR) methods have enabled estimation of the effective sampling area of a capture-recapture experiment based on supplementary field data collection (Royle & Young, 2008) such as estimated angles and distances to detected animals (Borchers *et al.*, 2015). By assuming distributional forms for the distance and angle estimation error and estimating their parameters, SECR methods are able to produce unbiased estimates of density (Borchers *et al.*, 2015; Kidney *et al.*, 2016). Another advantage of SECR methods over conventional distance sampling is that they allow the stochastic availability of animals to be modelled in the form of calling probabilities and accounted for in density estimation (Borchers & Efford, 2008). As a result, acoustic SECR methods are increasingly employed for studying cryptic species and were adopted in the present study.

Previous surveys of green peafowl in Vietnam, China and Cambodia have found that the species is associated with permanent water sources (Brickle, 2002; Liu *et al.*, 2008; Nuttall *et al.*, 2017). Our study therefore focused on riverine habitat, which we recognize as including all habitats within a river channel and adjacent riparian or "gallery forest" that fall within its floodplain (Allen *et al.*, 2009; Maxwell, 2009). The aims of our study were to: 1) model the habitat preferences of green peafowl to inform future conservation management actions in SPWS; 2) provide a first abundance estimate for the species at the site to assess its conservation significance and provide a baseline for monitoring conservation efforts; 3) evaluate a novel approach for surveying green peafowl based on recent advances in acoustic SECR methods, thereby addressing the need for flexible survey methods for the species.

Methods

Site description

Our study was conducted between February and April 2015 in SPWS, a ca. 670 km^2 protected area within the Western Siem Pang Important Bird Area (centred on 14°17'N, 106°27'E) in Stung Treng Province, northeastern Cambodia (Fig. 1). Siem Pang Wildlife Sanctuary is dominated by semi-evergreen forest with smaller pockets of deciduous dipterocarp forest and riverine habitat (Fig. 1), all of which is at low elevations (<350 m asl). The Sekong River runs approximately north to south through the site, is navigable all year round, approximately 100–200 m wide and has a braided channel in the northern portion of the site, dotted with small bars and rocky outcrops. Three smaller rivers present at SPWS—the O'kampa, Stung Malu and Stung Ting Hing—are only partially

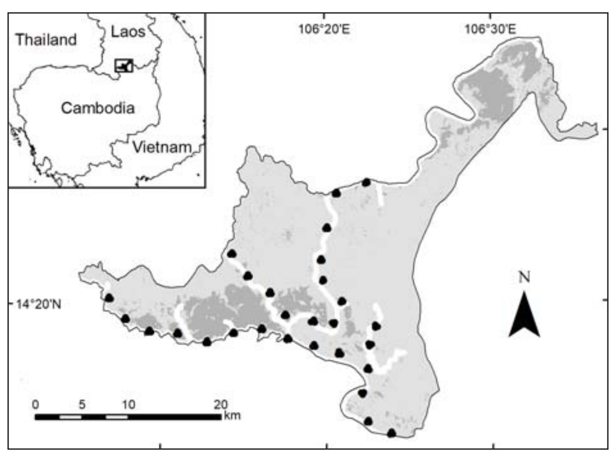

Fig. 1 Locations of listening stations (black circles) in triangle formations in relation to deciduous dipterocarp forest (dark grey), semi-evergreen forest (light grey) and riverine habitat (white) within Siem Pang Wildlife Sanctuary.

navigable during the wet season. Riverine habitats in the region experience intense seasonality, with river levels changing up to 10 m (Maxwell, 2009). As a consequence, seasonally flooded forests included in riverine habitat can extend some distance from a river's edge. In our study, a river channel and adjacent riparian forest within 100 m of the river edge were defined as riverine habitat. This distance was based on pilot transects from the river edge into the forest interior which quantified the presence/absence of structural criteria and species indicative of riparian and gallery forests including a closed canopy, signs of seasonal inundation, and presence of *Ficus* spp. and giant bamboo *Gigantachloa* spp. (Gardner *et al.*, 2000; Maxwell, 2009).

Siem Pang Wildlife Sanctuary became part of the Western Siem Pang Important Bird Area (IBA) in 2003, following the discovery of five Critically Endangered bird species there (Hout *et al.*, 2003). Since this time, surveys of deciduous dipterocarp forests in the southern sector of the IBA have confirmed the occurrence of >300 bird species (BirdLife International Cambodia Programme, 2012), including significant populations of the Critically Endangered slender-billed vulture *Gyps tenuirostris*, white-rumped vulture *G. bengalensis* and red-headed vulture *Sarcogyps calvus* (Clements *et al.*, 2013; Sum & Loveridge, 2016). Approximately 35% of the global population of the Critically Endangered white-shouldered ibis *Pseudibis davisoni* and 10% of the Critically Endangered giant ibis *Thaumatibis gigantea* also occur at the site (Wright *et al.*, 2012; Ty *et al.*, 2016). Confirmed sightings of Endangered mammal species including Indochinese silvered langur *Trachypithecus germaini*, yellow-cheeked crested gibbon *Nomascus gabriellae*, Eld's deer *Rucervus eldii*, dhole *Cuon alpinus* and banteng *Bos javanicus* have also been recorded (BirdLife International Cambodia Programme, 2012; Eames, 2014).

Survey design

We applied a modified form of the multi-occasion SECR model presented in Borchers *et al.* (2015) which includes an additional parameter giving the probability that an individual will be available for detection on a given sampling occasion (Kidney, 2014; Kidney *et al.*, 2016). In the case of vocalising species, this can be interpreted as the probability that an individual makes a call during a given observation period. The detectors in this case were the listening stations, which were arranged in 28 separate arrays. Each array consisted of three listening stations in a triangular formation with one observer per station (equalling three observers per array). Listening stations were arranged 300 m apart, with the two southerly stations positioned at equal latitude. The location of listening arrays within the survey area was systematic and followed principles outlined by Buckland *et al.* (2001) to achieve a spatially representative design of the target area (Fig. 1). This was achieved by converting the survey area to a raster grid of 1 km^2 numbered cells using ArcGIS vers. 9.3 (Environmental Systems Research Institute, USA). The centroid of the first array was then located in a randomly selected cell using a random number generator. The centroids of subsequent arrays were then located at 3-km intervals using the ArcGIS spatial measurement tool, following the permanent courses of the Sekong, Stung Malu, O'Kampa and Stung Ting Hing rivers. Where both sides of the river fell within the boundaries of the wildlife sanctuary, adjacent arrays were located on opposite sides of the river. Due to border disputes over river access along the northeastern boundary of the sanctuary, it was considered too unsafe to survey the upper reaches of the survey area.

Surveys were conducted between February and April 2015 to coincide with the breeding season and peak period for wail call vocalisations produced by male green peafowl (Indrawan, 1995; Brickle, 2002). Following Brickle (2002), all wail vocalisations were noted. To capture the most active calling periods of the day, the survey period for each array was defined as 16:30–18:30 hrs, with a repeat survey the following morning between 05:30–07:30 hrs (i.e. a two-occasion survey). The observer at each listening station noted the time, direction and estimated distance to calling individuals.

Data processing and density modelling

We undertook one week of trial data collection and review to develop a rigorous and replicable method for categorising whether green peafowl calls originated from one male or another. During this phase, observers recorded the distance and bearing of calling males each time they were heard. This allowed us to identify variation in: 1) estimated distance and directional bearing to a call; and, 2) movement of calling birds during the trial period. In almost all cases (14 of 16 calling individuals registered during the trial phase), the first detections of calling birds in the morning survey periods were from the same location as calls registered during the evening survey of the previous day. This suggested that birds vocalised from roost sites in the evening and again from the same roost site before moving on to display or foraging areas, and so in turn that individuals could be accurately re-identified between these two survey periods. When birds moved during a survey period, they often made repeat calls while travelling. This allowed us to track moving individuals and, through repeated surveys, estimate the total distance that individuals were likely to travel within a survey period. Based on these observations, detections were defined as originating from the same individual if they occurred within an estimated distance of 300 m from where the observer first heard the calling male or if they varied in bearing by less than 45°. An exception to this rule was made when more than one male was heard calling simultaneously. Brickle (2002) noted that green peafowl calls are socially facilitated and we noted occasional bursts of calling activity from multiple males simultaneously. This enabled identification of multiple males, located nearby. These spatial and angular protocols provide a conservative method for grouping multiple calls from the same male which avoids over-estimation of the number of different males, while allowing for minor movements in calling individuals and additional variation introduced by recorder error.

In preparation for SECR modelling, data were processed so that repeat recordings of individuals during the same survey period were averaged to generate a maximum of one detection per male per listening station per survey period (Fig. 2). A multi-occasion SECR model was considered appropriate for the survey data because recaptures between survey occasions could be identified with a high degree of confidence. In SECR modelling, the centre of activity for each animal over the course of multiple survey periods (days) was treated as a random effect. Estimates of model parameters (such as density) were derived by maximising the likelihood after marginalising over all possible values of the random effect (i.e. averaging across all possible activity centre locations). So while the bearing to detected animal locations within occasions were obtained by averaging bearings within occasions, animal activity centres across occasions were treated as random effects.

All models were fitted in R (R Core Team, Austria) using the gibbonsecr package (Kidney, 2015) which uses an integration grid called a 'habitat mask' (Efford *et al.*, 2009) to obtain maximum likelihood estimates (Appendix 1). Density estimation parameters used were an intercept-only sub-model for the detection function scale parameter, hazard rate detection function, gamma distribution for estimated distances and wrapped cauchy distribution for estimated bearings (Appendix 1). Density surface modelling was undertaken to explore the relationship between green peafowl density and habitat and anthropogenic disturbance covariates collected by field teams at listening stations (Loveridge *et al.*, 2016; Appendix 2). Because all of the habitat and threat covariates had potential biological significance for green peafowl, they were all modelled. Model simplification was carried out using the Akaike information criterion (AIC) (Akaike, 1974) and we report all models within two AIC (Anderson & Burnham, 2002).

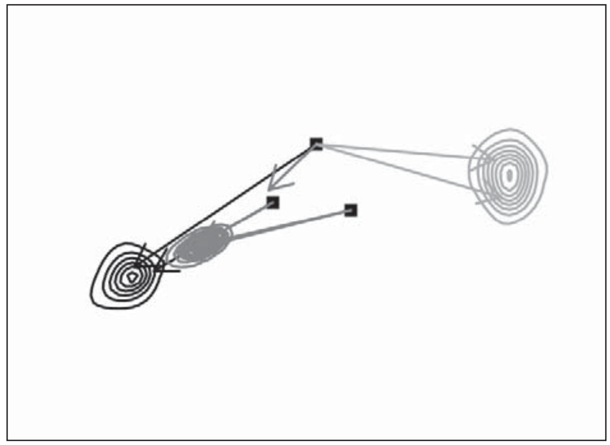

Fig. 2 Example spatial detections data recorded for listening array number 19. Black squares represent listening station locations. Arrows and green peafowl location probability contours (circles) are categorised by individual calling males. Arrow direction equals the bearing recorded by the observer and length of arrow represents the distance estimated by the observer.

Abundance estimation

Because green peafowl were detected using vocalisations made only by adult males (Indrawan, 1995), we estimated males/km^2 as the unit of density (Brickle, 2002). Estimated 95% confidence intervals for density were obtained using a parametric bootstrap by taking one million draws from the estimated sampling distributions of the model parameters for density and using the 2.5% and 97.5% percentiles from the derived sampling distributions of the density estimates. A conservative estimate of green peafowl abundance for SPWS was obtained by multiplying the density estimate of males by two (assuming a 1:1 sex ratio) and multiplying the density estimate for riverine habitat by the area of riverine surveyed (38.6 km^2). To the same end, all other habitats in the site were designated as non-riverine (631 km^2) and this area was multiplied by the lower density estimate for non-riverine habitat. Confidence intervals for abundance estimates were determined using the 95% confidence intervals of density estimates for riverine and non-riverine habitat.

Results

A total of 375 detections of the green peafowl's wail call were recorded over the course of 176 listening station survey periods. Of these, 131 were recorded during the evening survey period and 244 during the morning survey period. These detections were classified as originating from 49 different calling males, equalling 1.75

calling males per listening array. Of the 28 acoustic array locations, calling males were detected at 16. The placement of the arrays provided an effective survey area for riverine and non-riverine habitat of 38.62 km^2 and 227.73 km^2, respectively.

Density surface modelling of habitat and threat covariates determined that the model with the lowest AIC had a single binary covariate for riverine / non-riverine habitat (Fig. 3). One other model was within two AIC of this preferred model and was composed of the same riverine habitat covariate and a covariate for increasing distance to settlements (AIC=0.96). The latter explained less variation in green peafowl density than the former because a univariate model containing only the distance to settlements covariate had an AIC value of 14.68. Models containing other covariates for habitat and anthropogenic disturbance were not within two AIC of the most parsimonious model.

The density of green peafowl in riverine habitat was estimated as 1.7 males/km^2 (95% CI=1.08–2.66) from an effective sample area of 38.62 km^2. The density in non-riverine habitat was estimated as 0.35 males/km^2 (95% CI=0.21–0.59) from an effective sample area of 227.73 km^2. The abundance of green peafowl in SPWS was estimated at 574 birds (95% CI=349–1,203).

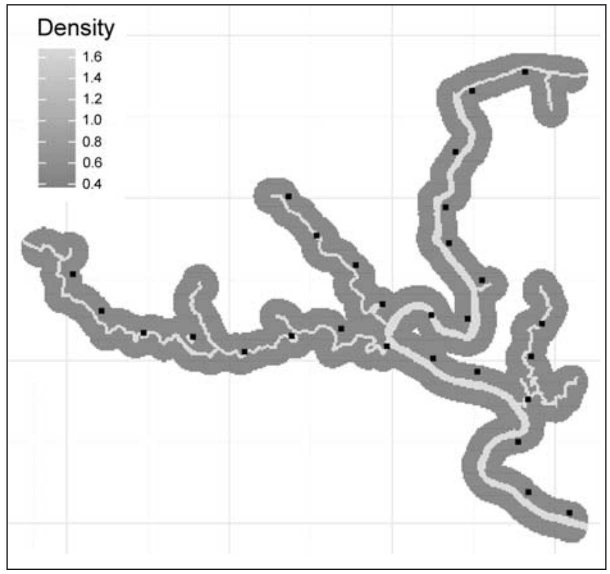

Fig. 3 Fitted density surface model for the lowest AIC model containing the binary riverine / non-riverine covariate. Black squares indicate centre points of the listening post arrays.

Discussion

Habitat preferences and conservation management

Our assessment of habitat preferences for green peafowl found that species density was nearly five times higher in riverine compared to non-riverine habitats. To a lesser extent, densities were also influenced by distance to settlements. In previous research on the habitat preferences of the species, Brickle (2002) subsumed all forest habitats under a 'deciduous forest' category. Our study builds on these findings by using remotely sensed and ground-truthed habitat data to generate finer-scale habitat classifications. Brickle (2002) found that detections were higher closer to water and our results concur with this finding. However, our study also shows that models including the binary riverine vs. non-riverine habitat variable predicted green peafowl density better than models that included the continuous variable of distance to rivers. This adds to the work of Brickle (2002) by identifying a specific association with riverine habitat, rather than simply proximity to rivers.

The fertile alluvial soils of riverine habitat provide a rich variety of food resources suitable for green peafowl, including *Ficus* spp. (Allen *et al*., 2009; Brun, 2013) which likely contribute to their preference for this habitat. The richness of riverine habitat contrasts greatly with the more open deciduous dipterocarp forests, which in Cambodia are often dominated by only four species of dipterocarpaceae and lack fruit-bearing trees species (Eames, 2014). However, riverine habitat is under significant threat due to its accessibility, presence of desirable resources including highly fertile soils for agriculture and proximity to fish stocks and hardwood species, all of which have resulted in greater species losses and elevated rates of degradation compared to other environments (Dudgeon, 2002; Allen *et al*., 2009). Green peafowl density was also higher further from settlements in our study, suggesting that its population at SPWS may be depressed by human disturbance. Given the species' close association with riverine habitat, iconic appearance and susceptibility to fragmentation and disturbance (Goes, 2009), green peafowl could provide a suitable flagship and/or indicator species for riverine habitat. Efforts to conserve the species should prioritize this habitat.

Conservation significance of SPWS for green peafowl

We estimate that 574 (95% CI=349–1,203) green peafowl occur in SPWS. This is comparable to the 541 birds estimated in Keo Seima Wildlife Sanctuary by Nuttall *et al.* (2017) who consequently identified the site as globally important for the species. In Vietnam, Sukumal *et al.* (2015) recorded a density of calling birds of 0.253 /km^2 in Yok Don National Park, and 3.025 /km^2 and 4.694 /km^2 in two separate zones of Cat Tien National Park. Our estimated density of 1.7 males/km^2 is low relative to comparable habitats in the latter. As density of the species is lower closer to settlements in SPWS, it is possible that it has been depressed by human disturbance at the site. Because large tracts of suitable riverine habitat still remain in SPWS, however, we suggest the site is a stronghold for the species in Cambodia, with a population comparable to other key sites for the species.

The global population of green peafowl is currently estimated at 15,000–30,000 birds (BirdLife International, 2016). This figure is approximate and likely represents an overestimate because it is based on few rigorous studies. Northern and eastern Cambodia have been identified as a priority zone for green peafowl conservation (Brickle *et al*., 2008; Owens & McGowan, 2011). Yet many protected areas exist within this region where the species is poorly known (Fig. 4). To improve the accuracy of global population estimates, surveys for green peafowl should be accorded high priority within these areas and could provide a platform for developing a national action plan to conserve the species in Cambodia.

Evaluation of acoustic SECR methodology

The trade-off between scientific rigour and financial resoruces is a major challenge in biodiversity monitoring (Sutherland *et al*., 2004). We used recent empirical advances in acoustic SECR to implement a cost-effective assessment for one species within a single field season. To achieve this, we selected a survey method that ensured a sufficient number of detections for robust statistical analysis. The total cost of our field survey was US$ 5,980. This comprised $3,095 for field expenses including boat hire, staff per diems and field equipment, $2,695 for staff salaries during the survey and $200 for travel expenses. These costs are lower than the cost of the multi-year study

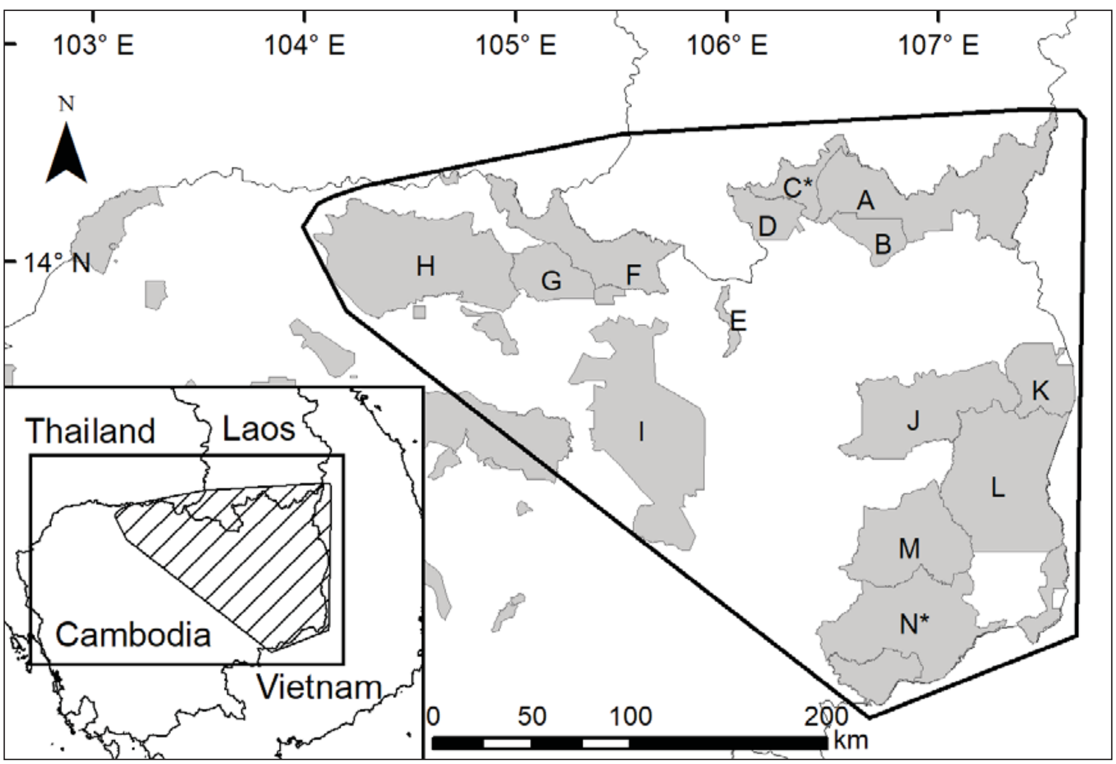

Fig. 4 The northeastern forest arc and proposed priority zone for green peafowl conservation (thick line on main map, cross hatched area on inset map) in Cambodia. Protected areas (grey shading) within the proposed priority zone include: A) Virachey National Park, B) Veun Sai-Siem Pang National Park, C) Siem Pang Wildlife Sanctuary, D) Prey Siem Pang Kang Lech Wildlife Sanctuary, E) Stung Treng Ramsar Site, F) Chepp Wildlife Sanctuary, G) Preah Rokar Wildlife Sanctuary, H) Kulen Promtep Wildlife Sanctuary, I) Prey Lang Wildlife Sanctuary, J) Lomphat Wildlife Sanctuary, K) Ou YaDav National Park, L) Srepok Wildlife Sanctuary, M) Phnom Prich Wildlife Sanctuary, N) Keo Seima Wildlife Sanctuary. * Indicates sites with a rigorous abundance estimate for green peafowl.

of Nuttall *et al.* (2017), which employed visual detections and distance sampling for multiple species.

The acoustic SECR method we employed has several analytical advantages over conventional distance sampling. These include accommodation of random error in distance estimation: a major issue in studies where the true distance to detected animals cannot be observed directly. The potentially least rigorous aspect of our approach was accurately distinguishing between calling individuals. To address this, we classified all detections within 300m or less than a 45° difference in bearing from an initial call as the same individual. These cut-off points were adopted to accommodate observer error in recording detected animals and allow for minor movements of detected animals during the survey period. However, as it remains unclear how strictly male green peafowl defend territories, several males not vocalising concurrently within a 300 m area could possibly be classified as a single male. It should be noted that our study is the first application of the acoustic SECR method to the green peafowl and required significant time to become acquainted with the analytical methods. However, we believe that the approach is suitable for esimating the abundance of this species in other poorly surveyed locations across its range and could also be applied to other vocal species, such as the Critically Endangered giant ibis.

Acknowledgements

We would like to thank the Forestry Administration and the Ministry of Environment of the Royal Government of Cambodia for their past and present support for Siem Pang Wildlife Sanctuary. We are indebted to the field monitoring team and support staff of the BirdLife International Cambodia Programme: Mem Mai, Bun Paeng, Vann Korsul, Mem Samphorn, Vann Vichet and Chea Sophea without whose technical skill, teamwork and sense of humour our research would not have been possible. We also thank Matthew Nuttall, Jackson Frechette, Ben Rawson and Jeremy Cusack for advice on survey design. Funding support was provided by the John D. and Catherine T. MacArthur Foundation and this research is an output of the project entitled: Western Siem Pang, towards a vision for biodiversity conservation in the dry forests of Cambodia: Phase 2. Finally, we also thank the editorial team of *Cambodian Journal of Natural History* for their valuable suggestions on improving the manuscript.

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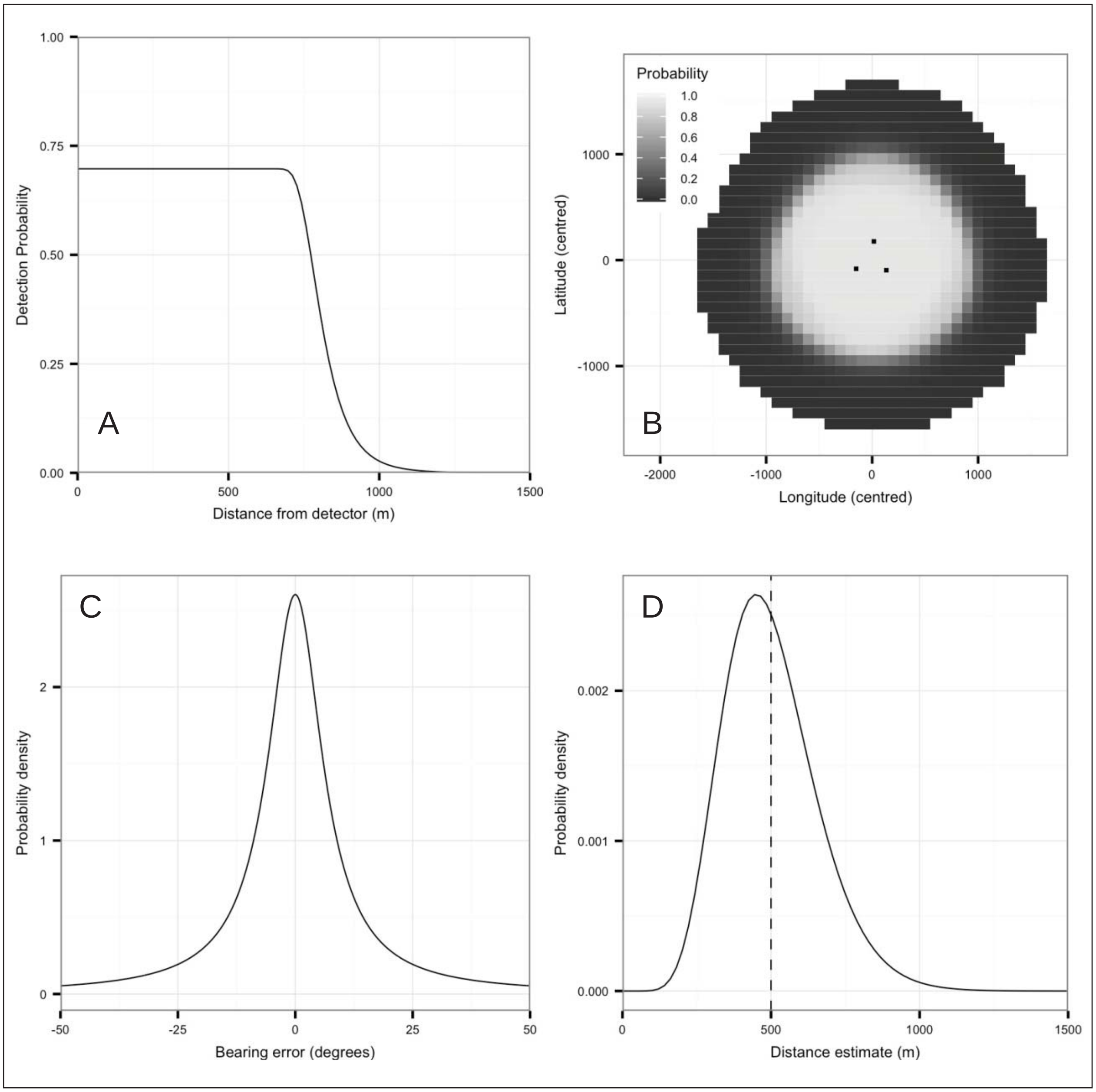
Appendix 1 Fitted observation sub-models from SECR analysis

Plot (A) shows the hazard rate detection function, which gives the detection probability for a calling individual at a single detector as a function of distance from the detector. Plot (B) shows the detection surface for array number 1 (black squares denote listening stations), which gives the overall probability of detection for an individual during the survey, given the spatial location of the activity centre (and taking account of the calling probability and detection function at each detector). Plot (D) shows the distribution of bearing errors, which were assumed to be unbiased, and plot (D) shows the distribution of distance estimates for an example case where the true distance is 500m (shown by the dotted line).



Appendix 2 Habitat covariates recorded at each listening station location

Covariate	Description
Tree density	A relascope (Gove *et al.*, 2001) was held at eye level 53 cm from the researcher whilst a 360° rotation was made about the central position of the listening station. The number of trees viewed as larger than the 1 cm opening in the relascope was counted and the number multiplied by two to give an estimate of tree basal area (m^2/ha).
Average tree height	A laser rangefinder (Nite Hawk Pin Predator 400) was used to estimate the height of four trees at each listening station. Tree selection was randomized by selecting tree stems closest to bearings of north, south, east and west from the centre of the plot. The average of these trees was then calculated.
Ground density	Ground density was considered as a cylinder of space with a circular area of 5 m radius, with the observer as the mid-point and vertical height from 0 to 0.5 m above ground. This was then scored as: 1 = 0–25% vegetation cover, 2 = 26–50% vegetation cover, 3 = 51–75% vegetation cover, 4 = 76–100% vegetation cover.
Understory density	Understory density was considered as a cylinder of space with a circular area of 5 m radius, with the observer as the mid-point and vertical height from 0.5 to 3 m above ground. This was then scored as: 1 = 0–25% vegetation cover, 2 = 26–50% vegetation cover, 3 = 51–75% vegetation cover, 4 = 76–100% vegetation cover.
Mid-story density	Mid-story density was considered as a cylinder of space with a circular area of 5 m radius, with the observer as the mid-point and vertical height from 3 m up 1 m below the canopy. This was then scored as: 1 = 0–25% vegetation cover, 2 = 26–50% vegetation cover, 3 = 51–75% vegetation cover, 4 = 76–100% vegetation cover.
Canopy density	Canopy density was considered as a cylinder of space with a circular area of 5 m radius, with the observer as the mid-point and vertical height as the top one meter of forest strata. This was then scored as: 1 = 0–25% vegetation cover, 2 = 26–50% vegetation cover, 3 = 51–75% vegetation cover, 4 = 76–100% vegetation cover.
Presence of cattle	0 = No evidence of cattle, 1 = evidence of cattle (dung / animals) observed in the plot.
Human disturbance	1 = No evidence of recent logging, 2 = Occasional single tree stumps and single trees felled, 3 = Frequent felled trees in the study plot, some evidence of trails cleared for vehicle access (hand tractors), 4 = Frequent felled trees grouped into piles, recent trail clearance for vehicle access (hand tractors/ trucks), land clearance for land grabbing, recent/ active logging camps.
Habitat type	Four habitat types recognised as follows: semi-evergreen forest, deciduous dipterocarp forest, bamboo stands, dry river beds. Each categorised as a seperate binary variable (present/absent).
Distance to settlements (km)	Straight line distance to the nearest permanent settlement.

Seasonal variation in the diet and activity budget of the northern yellow-cheeked crested gibbon *Nomascus annamensis*

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Paper submitted 4 November 2017, revised manuscript accepted 18 December 2017.

មូលន័យសង្ខេប

សត្វទោច (ពួក *Nomascus*) គឺជាក្រុមមួយ ក្នុងចំណោមក្រុមពានរផ្សេងទៀតដែលជិតផុតពូជ និង កង្វះការសិក្សានៅទូទាំងសាកលលោក។ សមាជិកមួយនៃក្រុមនេះគឺជាទោចថ្ពាល់លឿងនៅភូមិភាគឦសាន *Nomascus annamensis* រងការគម្រាមកំហែង និង ត្រូវបានលើកយកមកសិក្សាស្រាវជ្រាវខ្លះៗ។ ដោយការយល់ដឹងពីអាកប្បកិរិយានិងអេកូឡូស៊ីនៃប្រភេទ និង របៀបសម្របខ្លួនទៅនឹងការផ្លាស់ប្តូរបរិស្ថានរបស់វា ជាការចាំបាច់សម្រាប់ការងារអភិរក្សនៃប្រភេទនេះ គោលបំណងរបស់យើងគឺដើម្បីកំណត់ពីរបៀបដែល *N. annamensis* បន្សាំអាហារ និង អាកប្បកិរិយារបស់វាទៅនឹងការប្រែប្រួលនៃរដូវនៅភាគឦសាននៃប្រទេសកម្ពុជា។ យើងបានប្រើប្រាស់វិធីសាស្ត្រប្រមូលទិន្នន័យតាមបែបរហ័ស ដើម្បីកំណត់បរិមាណរបបអាហារ និង សកម្មភាពរស់នៅរបស់ទោចមួយក្រុមនៅឧទ្យានជាតិវីរៈសៃ-សៀមប៉ាង ចាប់ពីឆ្នាំ២០០៧ ដល់ ២០១៤។ លទ្ធផលបង្ហាញថា សកម្មភាពរបស់វាគឺប្រែប្រួលទៅតាមរដូវ ដែលការប្រែប្រួលនេះទំនងជាបណ្តាលមកពីសកម្មភាពស៊ីចំណីរបស់វា។ មានការកើនឡើងខ្លាំងនូវការស៊ីស្លឹកឈើ និង មានការថយចុះនូវការស៊ីផ្លែឈើក្នុងរដូវប្រាំង(វិច្ឆិកា-មេសា)។ ដោយការស៊ីស្លឹកឈើកើនឡើង សត្វទោចចំណាយពេលភាគច្រើនលើការស៊ីចំណី និងភាគតិចទៅលើសកម្មផ្សេងៗទៀត បើធៀបទៅនឹងរដូវវស្សា(ឧសភា-តុលា)។ ជារួម ទិន្នន័យរបស់យើងស្នើថា *N. annamensis* បង្ហាញពីទម្រង់អាកប្បកិរិយាស្រដៀងគ្នាទៅនឹងប្រភេទទោចផ្សេងៗទៀត ដែលត្រូវបានសិក្សាចងក្រង។

Abstract

Crested gibbons (genus *Nomascus*) are among the most highly endangered and understudied primates on the planet. One member of the group, the northern yellow-cheeked crested gibbon *Nomascus annamensis*, is similarly threatened and has been subject to few published studies. Because understanding the behaviour and ecology of a species and how it adjusts to changes in its environment are integral to its conservation, our aim was to determine how *N. annamensis* adapts its diet and behaviour to seasonal changes in northeastern Cambodia. To this end, we employed instantaneous scan sampling to quantify the diet and activity of a habituated group in Veun Sai-Siem Pang National Park from 2007 to 2014. Our results indicate that activity varied seasonally, and that this variation was likely due to changes in feeding activity. There was a pronounced increase in leaf consumption and a decrease in fruit consumption during the dry

CITATION: Frechette, J.L., Hon N., Behie, A.M. & Rawson, B.M. (2017) Seasonal variation in the diet and activity budget of the northern yellow-cheeked crested gibbon *Nomascus annamensis*. *Cambodian Journal of Natural History*, **2017**, 168–178.

(November–April) season. With the increase in folivory, gibbons spent more time eating overall and less time on other activities compared to the wet season (May–October). Overall, our data suggests that *N. annamensis* exhibits behavioural patterns similar to other gibbon species.

Keywords

Activity budget, gibbon, Hylobatidae, *Nomascus*, seasonal diets.

Introduction

The pronounced seasonality of some tropical forests has a strong influence on the availability of food resources (Janson & Chapman, 1999; Corlett, 2014). Primates often respond to these seasonal changes in food availability through dietary and behavioural changes (e.g., Poulsen *et al*., 2001). Seasonal variation in the diets of most primates often results in changes to activity patterns as a result of having to balance energy intake with the metabolic costs of maintaining body condition and reproduction (Milton, 1980). Because this depends on food quality, habitat structure and factors intrinsic to a species however, there is no universal behavioural response to dealing with periods of food shortage. For example, capped langurs *Presbytis pileatus* spend more time foraging when fruit is scarce (Stanford, 1991), whereas black howler monkeys *Alouatta pigra* spend more time inactive during periods of fruit scarcity (Pavelka & Knopff, 2004). Judging from available information on the northern *Nomascus* gibbons (*N. nasutus* and *N. concolor*), it is apparent that these also vary their activity patterns seasonally in response to changes in fruit availability. When fruit consumption is low, these animals conserve energy by spending more time inactive and less time feeding (Fan *et al*., 2008). Because large frugivorous primates are most vulnerable following habitat disturbance due to changes in patterns of fruit production and availability (Johns & Skorupa, 1987), understanding how these animals interact with their environment and deal with such changes is important.

Few gibbon species have been subjected to long-term studies thus far, the most notable exception being the white-handed gibbon *Hylobates lar* (Reichard & Barelli, 2008; Reichard, 2009). This is true for crested gibbons (*Nomascus*), a diverse genus which comprises seven species distributed from southern Vietnam and eastern Cambodia to southwestern Cambodia. Only three *Nomascus* species have received detailed ecological studies to date: the black crested gibbon *N. concolor* (Fan & Jiang, 2008; Fan *et al*., 2009a,b), the Cao-vit gibbon *N. nasutus* (Fan *et al*., 2012a,b) and the southern yellow-cheeked crested gibbon *N. gabriellae* (Kenyon, 2007; Kenyon *et al*., 2010; Bach *et al*., 2017). Little is known about the four remaining species beyond status reports and taxonomic descriptions (e.g., Traeholt *et al*., 2005; Duckworth, 2008; Rawson *et al*., 2011). We consequently present the first study of the behaviour and ecology of the northern yellow-cheeked crested gibbon *N. annamensis*, a recently described gibbon species occurring in northeastern Cambodia, southern Laos and east central Vietnam (Thinh *et al*., 2010b). Prior to its description (Thinh *et al*., 2010a), individuals within the distribution range of the species were assigned either to the more southerly *N. gabriellae* or the more northerly *N. siki*, although researchers had hypothesized that an additional and intermediately distributed taxon might exist based on vocalization analysis (Geissmann *et al*., 2000; Konrad & Geissmann, 2006). This was later confirmed by genetic and vocal characteristics (Thinh *et al*., 2010a,b).

Although the conservation status of *N. annamensis* has yet to be formally assessed, the species will likely qualify as Endangered on the IUCN Red List. Population surveys in Vietnam have revealed that as few as 200 groups have been recorded over the last decade with the largest known subpopulation comprising approximately 80 groups (Rawson *et al*., 2011). Populations of the species remain largely unknown in Laos, with none under effective protection, leaving those that exist extremely vulnerable to high levels of hunting pressure and habitat destruction (MAF, 2011). In Cambodia, the species occurs in the northeastern forests of Virachey National Park, Siem Pang Wildlife Sanctuary and Veun Sai-Siem Pang National Park, with the latter supporting an estimated 450 groups (Rawson, B. unpubl. data). While data on the overall population status of *N. annamensis* are relatively good, very little behavioural information exists for the species or for the more southerly *Nomascus* taxa in general, with the exception of two studies on *N. gabriellae* in southern Vietnam (Kenyon, 2007; Kenyon *et al*., 2010).

As a consequence, we present the activity budget and feeding ecology of a group of *N. annamensis* in northeastern Cambodia. The purpose of our study was to understand how the species adjusts its feeding and other behavioural activities over time and in response to seasonal change in an environment with relatively few threats. Because habitat destruction presents a major threat to *N. annamensis*, our overall goal was to improve knowledge of how the species adjusts its behaviour due to seasonal changes in food availability to better predict how it might respond to habitat and climate change in future.

Methods

Study site and study group

Data were collected between November 2007 and April 2013 in the Veun Sai–Siem Pang National Park (formerly a Conservation Area) (VSSP; 14°01'N, 106°44'E), a predominantly low elevation region (ca. 100 m) in northeastern Cambodia. The national park (56,000 ha) forms part of the Indo-Burmese forest biodiversity hotspot (Myers *et al*., 2000) and mostly comprises semi-evergreen and evergreen tropical forest. The wet season usually begins in April or May and continues until October. From 2008 to 2012, mean annual rainfall was 1,919 mm and averaged 400 mm per month during the wet season which usually peaked around August. The dry season runs from November to April with an average of 3 mm of rain per month and the driest month is December (Schneider *et al*., 2011).

Four hundred and fifty groups of *N. annamensis* are estimated to occur in VSSP, which is the largest documented population of the species (Rawson, B. unpubl. data). While hunting with guns is a major threat to the species in Vietnam and Laos (MAF, 2011; Rawson *et al*., 2011), guns have yet to become prevalent at VSSP where hunters mainly use dogs and crossbows. Because arboreal primates are less vulnerable to the latter (Iseborn, 2011), this could be one reason for the large population of *N. annamensis* in VSSP.

A single group of gibbons was followed for the purposes of our study. This group was first habituated for a two-month period and subsequently studied for two years (2005–2007) by a team led by Fauna & Flora International (Traeholt *et al*., 2007). Although the group was still wary and often lost after a few hours of contact in the early years of our study, it became comfortable with the presence of observers by 2011. So much so, that the adult male frequently descended almost to the ground on numerous occasions. The group consisted of an adult male and an adult female, and two immature individuals, the younger of which was likely born in 2007. A third infant was born in August 2011 but disappeared in March 2012. Gibbons generally live in small family groups, usually a socially monogamous pair and their offspring (Brockelman, 2009), although there are plenty of exceptions, including *N. concolor* for which polygynous groups are common (Fan & Jiang, 2010).

Behavioural data collection

We documented gibbon activity through instantaneous group-scan sampling, where the behaviour of visible individuals was documented at ten-minute intervals during contact time with the group. Gibbons were located in the morning by their song and followed until lost or when they settled in their sleeping tree for the night. Following the gibbons was quite difficult, particularly in the first few years of the study when they were less habituated and the group was frequently lost by midday. Because approximately 76% of our observational data was generated between 05:00–11:00 hrs, we acknowledge the potential existence of an information gap and consequently pooled data where appropriate to reduce possible bias.

Activities (and their sub-categories) were classified as: *social* (singing, playing, grooming, copulation and agonistic), *inactive* (scanning or resting), *feeding* (food type recorded), *travel* (brachiate, jumping, dropping, walking bipedally, walking quadrupedally and climbing), *other behaviour* or *out of view*. We tagged and recorded the locations of all plants used by the gibbons for sleeping, eating and singing, and these were subsequently identified by local researchers. Canopy use by each gibbon observed during the instantaneous scans was categorized as: low (<5 m), middle (5–15 m) or high (>15 m). The location of each scan was also recorded using GPS units and plotted in Google Earth to estimate the total range of the group over the course of the study period.

Data analysis

We used Spearman rank correlations of plant part consumption and activity categories to assess relationships between diet and activity patterns. SPSS vers. 20.0 was employed for these tests with a (two-tailed) statistical significance value of $p<0.05$. Precipitation data were acquired from the GPCC Global Precipitation Climatology Centre (Schneider *et al*., 2011). To examine relationships between precipitation, activity and diet, monthly data were aggregated by year to determine the effect of precipitation on the probability of a gibbon being documented as traveling, feeding and eating different plant parts. Analysis was undertaken using R vers. 3.0.2 (R Core Team, Austria) using generalized maximum likelihood with a logit link. As data were not normally distributed, Mann-Whitney U tests were employed for sex-based comparisons (male $n=50$, female $n=50$). Because the sex of juvenile *N. annamensis* cannot be confirmed visually, only data from adults were used for sex-based comparisons of diet and activity.

Results

Activity budgets

A total of 1,368 hours of contact time were spent with the study group from 2007 to 2013, resulting in 32,040 scans. Overall, inactivity accounted for most of the group's daily activity budget at 31.8%, followed closely by travel (30.3%) and feeding behaviour (26.3%). The remaining time was spent in social interactions (10.4%) and other behaviour (1.3%). For time spent on travel, 43.7% was spent brachiating, 24.6% was spent jumping and 17.1% was spent dropping. The remainder was devoted to walking, either bipedally (7.5%) or quadrupedally (4.8%), and climbing (2.0%). Time spent socializing was largely spent playing (54.4%) and vocalizing (40.3%), with the remainder dedicated to grooming, copulating and agonistic. The observed range of the group during the study period was estimated at 1.27 km^2.

Social behaviour among the gibbons peaked in early morning (before 07:00 hrs; Fig. 1), which comprised singing of the dawn duet song. Travel and feeding behaviour peaked between 07:00 and 10:00 hrs and slowly tapered off as the afternoon progressed, with the animals becoming inactive by 16:00 hrs (Fig. 1). There was no seasonal variation in this pattern. Because days when the gibbons did not sing were inconsistently recorded, we were unable to quantitatively assess field observations (Frechette, J. pers. obs.) that the group avoided singing during rain.

The frequency of feeding behaviour was greater during the dry season (November–April) compared to the wet season (May–October; Fig. 2) and precipitation had a significant negative effect on the probability of feeding (p=<0.001; Fig. 3a). Logistic regression analysis showed that precipitation also had significant positive effect on the probability of traveling (p=<0.001; Fig. 3b) and inactivity (p=<0.001; Fig. 3c). No significant differences in activity were observed between males and females.

Diet and feeding behaviour

Fruit comprised over half of the study group's diet, constituting 58.6% of the total related scans (Fig. 4). We identified 56 different species of fruit consumed by gibbons. *Ficus* spp. was the most common fruit consumed, constituting ca. 14% of the total fruit diet, although the most commonly eaten fruit sometimes varied annually (Table 1). Young leaves formed the next highest proportion of the diet at 25.5%, while flowers comprised 10.6%. The most common species of flower eaten was *Dipterocarpus costatus*, which composed 60% of the observed flower diet (Table 2). Approximately 90% of all flowers

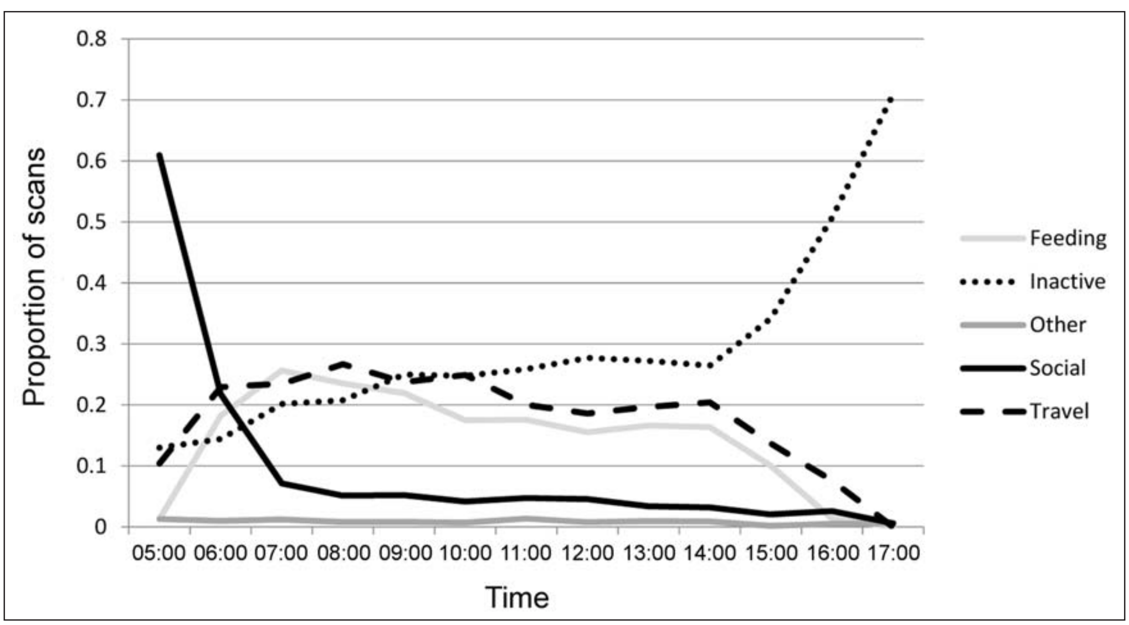


Fig. 1 Daily activity pattern of yellow-cheeked crested gibbons *N. annamensis in* Veun Sai–Siem Pang National Park, northeastern Cambodia, 2007–2013.

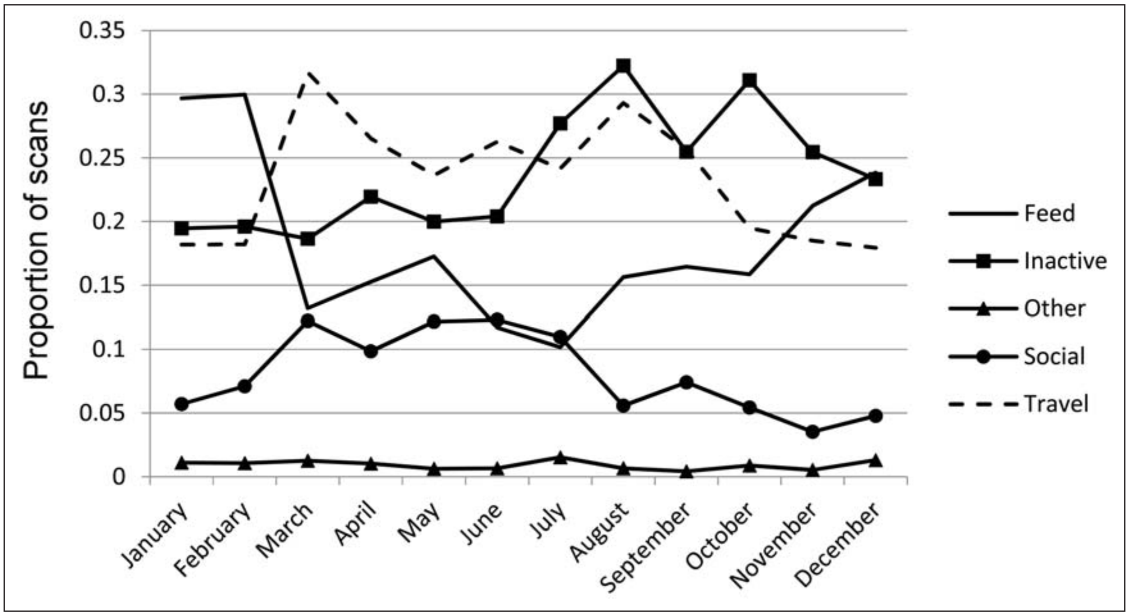
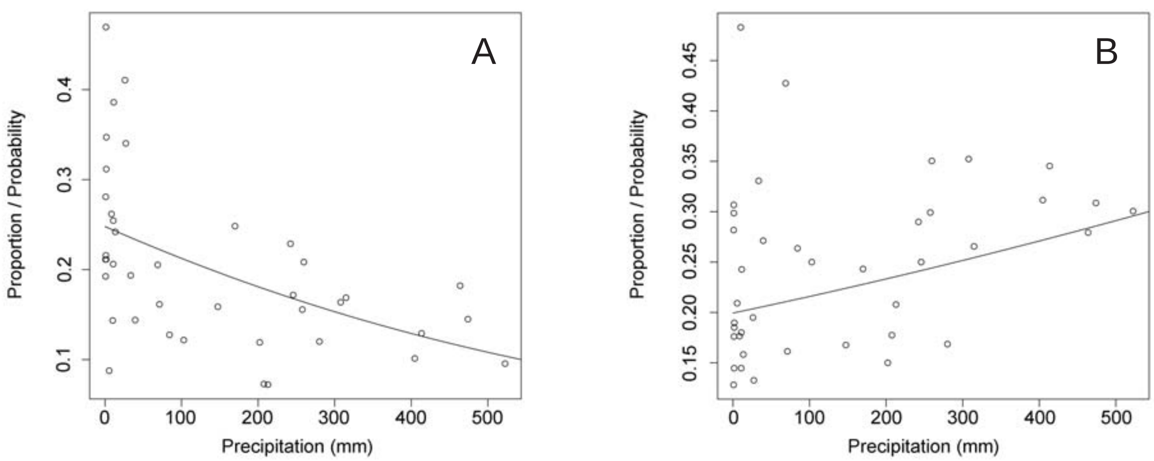


Fig. 2 Monthly variation in activity of yellow-cheeked crested gibbons *N. annamensis* in Veun Sai–Siem Pang National Park, northeastern Cambodia, 2007–2013.



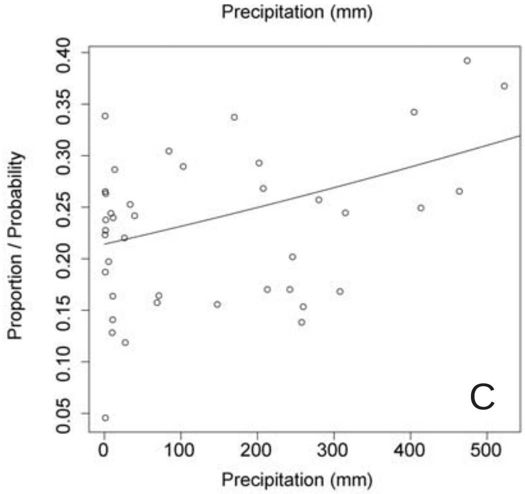


Fig. 3 Variation in the proportion of scans for A) feeding behaviour, B) travel, and C) inactivity of yellow-cheeked crested gibbons *N. annamensis* in relation to precipitation in Veun Sai–Siem Pang National Park, northeastern Cambodia, 2007–2013. Open circles represent monthly precipitation and solid lines are the fitted logistic models showing the probability of a sample representing feeding behaviour, travel or inactivity given the precipitation. All models show a significant effect (p<0.05).

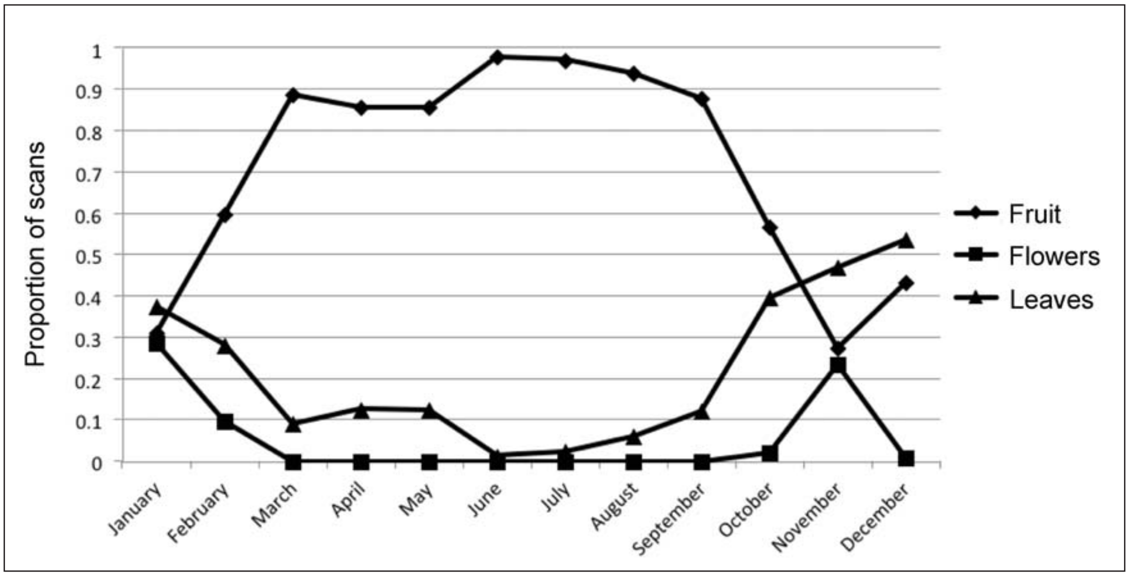


Fig. 4 Monthly variation in the proportions of scans that yellow-cheeked crested gibbons *N. annamensis* spent eating different plant parts in Veun Sai–Siem Pang National Park, northeastern Cambodia, 2007–2013.

eaten belonged to the Dipterocarpaceae (Table 2). The remaining portions of the diet comprised mature leaves (1.4%), leaves of unknown maturity (1.9%) and other items that could not be confidently identified (1.4%).

Fruit consumption peaked during the wet season (April–October), whereas leaf and flower consumption peaked during the dry season (Fig. 4). Logistic regression models indicated significant positive correlations between fruit consumption and precipitation (p=<0.001; Fig. 5a), whereas consumption of leaves (p=<0.001; Fig. 5b) and flowers (p=<0.001; Fig. 5c) were significantly negatively related to precipitation. The decrease in fruit consumption during the dry season was also significantly and negatively correlated with time spent feeding (r_{sp}=0.596; p=0.001), indicating that when fruit consumption decreases, animals spend more time feeding. There were no differences in food consumption between the sexes.

Canopy use

Our study group used the upper canopy (>15 m) most often (57.0%), followed by the middle canopy (5–15 m: 42.1%). Although the gibbons did use the lower canopy (<5 m) on occasion, <1% of behaviour occurred in this forest stratum. The amount of time spent in the lower canopy increased during the rainy season (Fig. 6), although insignificantly. The adult male also spent more time than the adult female in the lower canopy (2.69 vs. 0.66% respectively; z=2.015; p=0.04).

Discussion

Our study gibbons showed distinct seasonality in behavioural patterns in response to precipitation. The group was highly frugivorous but had a seasonal dependence on leaves and flowers. Dietary shifts coincided with changes in rainfall, which were likely indicative of fruit availability (see below). Overall, our data indicate that the activity and feeding patterns of *N. annamensis* are similar to those of other gibbon species. These include *Hoolock leuconedys* (Fan *et al*., 2013), *Hylobates lar* (Raemaekers, 1978; Palombit, 1997), *N. gabriellae* (Bach *et al*., 2017), *N. nasutus* (Fan *et al*., 2012a), *N. concolor* (Fan *et al*., 2008) and *Symphalangus syndactylus* (Chivers, 1974; Palombit, 1997).

Our study group mostly began singing between 05:00 and 07:00 hrs and rarely sang more than once a day. Because the adult male and female sang together in a duet, this resulted in social behaviour peaking in early morning and juveniles occasionally joined in singing bouts. This is consistent with studies of *N. gabriellae* which found that 60% of calling bouts occurred during a 30 minute window that began 10 minutes before sunrise, with 80.6% of calls occurring in the first hour after dawn (Rawson, 2004; Kenyon, 2007). Rawson (2004) also found that single bouts of song were the norm for *N. gabriellae*, suggesting that its vocal behaviour is similar to *N. annamensis*. In our study, this peak in social behaviour was followed by a long period of traveling and feeding which peaked before 10:00 hrs and subsequently decreased until 14:00 hrs at which point it slightly increased before declining dramatically. This pattern of activity is similar

Table 1 Frequency and relative proportion of scans for each fruit species consumed by yellow-cheeked crested gibbons *N. annamensis* in Veun Sai–Siem Pang National Park, northeastern Cambodia. Figures in the sum proportion column equal the proportion of the total number of scans. Seeds eaten: Y=Yes, N=No, U=Unknown. *= <0.01.

Species	No. of scans	Proportion of scans							Sum proportion	Seeds eaten
		2007	2008	2009	2010	2011	2012	2013		
Unknown	838	0.43	0.13	0.14	0.35	0.22	0.24	0.04	0.2201	
Ficus sp. (Moraceae)	542	0.07	0.04	0.20	0.12	0.25	0.08	0.11	0.1423	Y
Willughbeia edulis (Apocynaceae)	423	-	0.05	*	0.09	0.15	0.08	0.41	0.1111	Y
Mircrocos paniculata (Malvaceae)	270	-	0.02	0.04	0.15	0.05	0.09	-	0.0709	Y
Nephelium hypoleucum (Sapindaceae)	260	0.07	0.04	0.08	0.08	*	0.14	-	0.0683	Y
Syzygium sp. (Myrtaceae)	206	-	0.06	-	0.01	0.07	0.08	-	0.0541	Y
Garcinia schomburgkiana (Clusiaceae)	196	-	0.15	-	0.07	0.02	0.07	-	0.0515	Y
Parinari annamensis (Chrysobalanaceae)	86	-	0.02	-	0.03	-	0.05	-	0.0226	N
Bouea oppositifolia (Anacardaiceae)	85	-	0.06	-	0.01	0.05	-	-	0.0223	Y
Dialium cochinchinensis (Fabaceae)	84	0.43	-	0.09	-	*	0.04	-	0.0221	Y
Anisoptera costata (Dipterocarpaceae)	72	-	0.14	-	-	0.01	-	-	0.0189	N
Dipterocarpus costatus (Dipterocarpaceae)	64	-	-	0.01	-	-	0.05	0.01	0.0168	N
Irvingia malayana (Irvingiaceae)	61	-	*	-	-	0.04	0.01	-	0.0160	N
Madhuca elliptica (Sapotaceae)	60	-	-	0.04	-	0.04	-	-	0.0158	Y
Colophyllum sp. (Calophyllaceae)	59	-	-	-	0.05	-	0.01	0.08	0.0155	Y
Vor Tnang (Local name)	56	-	0.12	0.01	-	-	*	0.01	0.0147	Y
Vor Antong (Local name)	48	-	-	-	*	-	0.04	-	0.0126	Y
Vor Sleng (Local name)	48	-	-	-	*	-	-	0.25	0.0126	Y
Khoh (Local name)	35	-	*	0.09	*	-	0.01	-	0.0092	Y
Mak Derk Kory (Local name)	26	-	-	0.09	-	-	-	-	0.0068	U
Khor Mouy (Local name)	25	-	-	0.08	*	-	-	-	0.0066	U
Sandoricum koetjape (Meliaceae)	23	-	0.05	*	-	-	-	-	0.0060	Y
Vor Tong (Local name)	23	-	0.05	-	-	-	-	-	0.0060	Y
Vor Krovanh (Local name)	21	-	-	0.01	-	0.01	-	-	0.0055	Y
Vor Tang Ant (Local name)	20	-	-	0.06	0.01	-	-	-	0.0053	Y
Yang Ying (Local name)	19	-	-	-	-	0.02	-	-	0.0050	U
Bok Nang (Local name)	17	-	-	-	-	*	-	0.06	0.0045	U
Sayak (Local name)	14	-	0.03	-	-	-	-	-	0.0037	U
Calamus palustris (Arecaceae)	13	-	-	-	0.02	-	-	-	0.0034	Y
Dong Kov Ankoy (Local name)	12	-	-	-	-	0.01	-	-	0.0032	U
Vor Khay Khov (Local name)	12	-	-	-	-	0.01	-	-	0.0032	U
Mak Takorng (Local name)	9	-	-	0.03	-	-	-	-	0.0024	Y
Kakoung (Local name)	8	-	-	-	-	0.01	-	-	0.0021	U
Pok Nang (Local name)	8	-	-	-	-	0.01	-	-	0.0021	U
Vor Chro Kor (Local name)	8	-	-	-	0.01	*	-	-	0.0021	U
Makuak (Local name)	6	-	-	-	-	-	-	0.03	0.0016	U
Vor Khay Kov (Local name)	6	-	-	-	-	0.01	-	-	0.0016	U
Euphoria cambodiana (Sapindaceae)	5	-	-	-	-	*	*	-	0.0013	Y
Anomianthus dulcis (Annonaceae)	5	-	0.01	-	-	-	-	-	0.0013	Y

Table 1 Continued

Species	No. of scans	Proportion of scans							Sum proportion	Seeds eaten
		2007	2008	2009	2010	2011	2012	2013		
Vor Takoung (Local name)	5	-	-	-	-	-	*	-	0.0013	U
Kleang (Local name)	4	-	-	-	-	*	-	-	0.0011	U
Mak Kong (Local name)	4	-	-	-	-	*	-	-	0.0011	U
Mouy (Local name)	4	-	-	-	-	*	-	-	0.0011	U
Mak Peng (Local name)	3	-	0.01	-	-	-	-	-	0.0008	U
Mitrella mesnyi (Sapindaceae)	3	-	-	0.01	-	-	-	-	0.0008	Y
Trobok (Local name)	3	-	-	-	-	*	-	-	0.0008	U
Fagraea fragrans (Gentianaceae)	2	-	-	-	-	*	-	-	0.0005	Y
Bok Yum (Local name)	1	-	-	-	-	-	*	-	0.0003	U
Brung Yum (Local name)	1	-	-	-	-	-	*	-	0.0003	U
Garcinia sp. (Clusiaceae)	1	-	-	-	-	*	-	-	0.0003	Y
Porki Pheng (Local name)	1	-	-	*	-	-	-	-	0.0003	U
Sro Tap (Local name)	1	-	-	-	-	-	*	-	0.0003	U
Vor Khay Khov (Local name)	1	-	-	-	-	*	-	-	0.0003	U
Xylopia vielana (Annonaceae)	1	-	-	-	-	-	*	-	0.0003	Y

Table 2 Frequency and relative proportion of scans for each flower species consumed by yellow-cheeked crested gibbon *N. annamensis* in Veun Sai–Siem Pang National Park, northeastern Cambodia.

Species	No. of feeding observations	Proportion of observations
Dipterocarpus costatus (Dipterocarpaceae)	410	0.606
Anisoptera costata (Diperterocapraceae)	201	0.297
Unknown species	45	0.066
Koh (local name)	12	0.018
Garcinia schomburgkiana (Cluseasaceae)	4	0.006
Hopea sp. (Dipterocarpaceae)	3	0.004
Sterculia lychnophora (Malvaceae)	2	0.003
Total	677	

to that reported for *N. concolor* and *H. agilis*, although these species have a more pronounced bimodal pattern of feeding behaviour which peaks in mid-afternoon (Gittens, 1982; Fan *et al*., 2008).

Gibbons are considered highly frugivorous, but as we document here, frugivory is highly seasonal in *N. annamensis*. Figs (*Ficus* spp.) appear to be an important fruit item for the species, similar to other gibbon taxa (McConkey *et al*., 2003; Fan *et al*., 2009a). During the dry season, fruit consumption significantly decreased within our study group while leaf and flower consumption significantly increased. This likely reflects decreased fruit availability during the dry season, which is common for seasonal forests in Southeast Asia (Fan *et al*., 2013; Corlett, 2014). We also found a strong negative relationship between fruit consumption and feeding time, indicating that when fruit availability declines during the dry season, *N. annamensis* compensates by devoting more time to feeding.

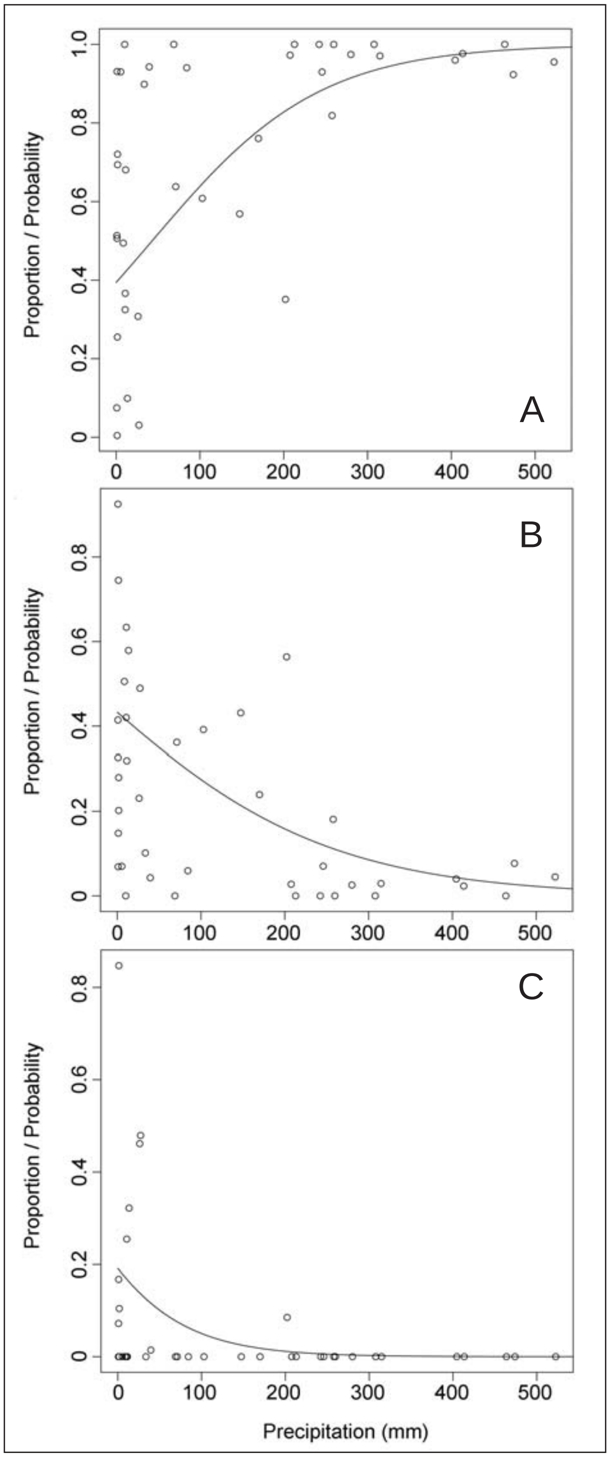


Fig. 5 Seasonal differences in diet as reflected in the proportion of scans for A) fruit, B) leaves, and C) flowers consumed by yellow-cheeked crested gibbons *N. annamensis* in Veun Sai–Siem Pang National Park, northeastern Cambodia. Open circles represent monthly precipitation and solid lines are the fitted logistic models showing the probability of a gibbon eating fruit, leaves or flowers in relation to precipitation. All models show a significant effect ($p<0.05$).

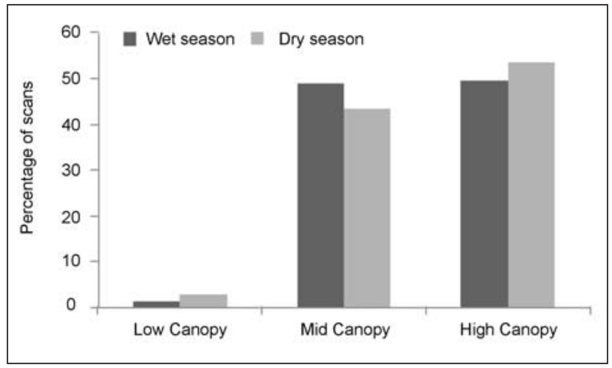


Fig. 6 Seasonal differences in canopy use by yellow-cheeked crested gibbons *N. annamensis* in Veun Sai–Siem Pang National Park, northeastern Cambodia.

Because leaves have a lower energy content than fruit (Hamilton & Galdikas, 1994), gibbons may need to spend more time eating the former to meet their energy demands when fruit is not available (Raemaekers, 1978; Fan *et al*., 2008). However, recent studies of the highly frugivorous spider monkey *Ateles chamek* show that this species selects food items to maintain protein rather than energy intake, indicating it may ingest fewer leaves to meet protein demands (Felton *et al*., 2009). Animals have a finite amount of time to perform all activities, thus the increase in feeding time we observed had to come at the expense of other behaviours, in this case feeding and traveling. This suggests that the increase in feeding time, coupled with a reduction in travel time, may actually reflect the need for gibbons to move around less while feeding on ubiquitously distributed leaves, compared to fruit which would require greater travel within and between patches. It also suggests they may need to spend more time inactive to cope with the high cellulose content of leaves (Stanford, 1991; Zhou *et al*., 2007).

Gibbons are known to eat insects (Elder, 2009) and although our study group frequently ate insects (Frechette, pers. obs.), we were unable to determine the influence of insectivory on behaviour as our study protocol did not adequately capture the frequency of insect consumption. We also observed the adult male consuming a baby bird from a nest, and our study group frequently foraged in tree cavities (Frechette, J. pers. obs.). Animal consumption is consequently under represented in our study.

Our study represents the largest dataset for *N. annamensis* and one of the largest generated for *Nomascus* gibbons to date. Overall, our results demonstrate the importance of dietary and behavioural plasticity for these large-bodied and highly frugivorous primates. In addition, the relationships we observed between behaviour and precipitation are particularly interesting in the context of forthcoming climate change. In improving understanding of the dietary needs of *N. annamensis* and how its activity patterns change seasonally, we anticipate our results will assist efforts to conserve the species. For instance, site-based management efforts for *N. annamensis* should accord high priority to protecting areas with a diverse complement of fruiting trees and particularly important food sources such as figs and dipterocarps.

Acknowledgements

We wish to thank the Forestry Administration for permission and support to work in Veun Sai-Siem Pang National Park. All research methods adhered to Cambodian legal requirements. We are indebted to the local research team, especially Lot Soulit, for its efforts and Phan Channa for his input. We would also like to make special reference to the memory of Lim Kannitha and thank two anonymous reviewers whose comments greatly improved this manuscript. This project was funded by the USFWS Great Ape Conservation Fund (Assistance Award No. 7-G214 GA-0376 and 0-G259 GA-0756), the Margot Marsh Biodiversity Foundation, the John D. and Catherine T. MacArthur Foundation (Grant No. 09-92460-000-GSS), the Bay and Paul Foundation, Primate Conservation Inc., and an anonymous donor. We greatly appreciate their support.

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The hollow drum: impacts of human use on the Tonle Sap flooded forest at Kampong Luong, Cambodia

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Paper submitted 7 November 2017, revised manuscript accepted 20 December 2017.

មូលន័យសង្ខេប

ព្រៃលិចទឹកនៅតំបន់បឹងទន្លេសាបនៃប្រទេសកម្ពុជា ផ្តល់ទីជម្រកដល់ជីវៈចម្រុះ ដែលមានលក្ខណៈពិសេសៗ ទាំងរស់នៅលើគោក និងក្នុងទឹក។ ប្រភេទព្រៃលិចទឹកទាំងនោះ ជួយរក្សាផលិតភាពដល់ផ្នែកជលផលទឹកសាបដ៏សំខាន់បំផុតមួយក្នុងពិភពលោក ហើយវាពិតជាមានសារៈសំខាន់យ៉ាងខ្លាំង សម្រាប់សន្តិសុខស្បៀងអាហារនៅក្នុងប្រទេសកម្ពុជា។ វាក៏ផ្តល់ផងដែរនូវប្រភពអុស អាហារ ឈើប្រើប្រាស់និងរុក្ខជាតិឱសថដល់ប្រជាជនក្នុងតំបន់។ តែយ៉ាងណាក្តី សកម្មភាពមនុស្សបាននឹងកំពុងបំផ្លិចបំផ្លាញ ឬ កែប្រែតំបន់ព្រៃលិចទឹកដ៏ធំទាំងនោះ តាមរយៈការទន្ទ្រានយកដីធ្លីធ្វើកសិកម្ម និង ការដកហូតឈើសម្រាប់ថាមពលចំហេះ និង សំណង់ជាដើម។ យើងបានធ្វើការពិនិត្យពីផលប៉ះពាល់របស់មនុស្សទៅលើគម្របព្រៃលិចទឹកនៅក្បែរកំពង់លួង ដែលវាជាតំបន់ភូមិអណ្តែតទឹកធំជាងគេនៅលើបឹងទន្លេសាប។ ដោយការប្រើប្រាស់ទូក ការសិក្សាពីប្រភេទរុក្ខជាតិព្រៃលិចទឹកត្រូវបានធ្វើឡើង នៅតាមខ្សែបន្ទាត់ត្រង់ស្ថិតនៅសងខាងភូមិអណ្តែតទឹកកំពង់លួង ក្នុងអំឡុងឆ្នាំ២០១៤។ ការសម្ភាសក៏ត្រូវបានធ្វើឡើងជាមួយប្រជាជននិងថ្នាក់ដឹកនាំភូមិ ដើម្បីសិក្សាពីរបៀបនៃការប្រើប្រាស់និងគ្រប់គ្រងព្រៃលិចទឹក។ ទោះជាតំបន់ព្រៃលិចទឹកនៅកន្លែងខ្លះ នៅរក្សាបាននូវលក្ខណៈដើមពីធម្មជាតិនៅឡើយ យើងក៏សង្កេតឃើញភស្តុតាងនៃការផ្លាស់ប្តូរយ៉ាងខ្លាំង ដោយឥទ្ធិពលនៃសកម្មភាពមនុស្ស។ ស្ទើរគ្រប់ចំណុចសិក្សាតាមខ្សែបន្ទាត់ត្រង់ គម្របព្រៃបានបាត់បង់សឹងតែគ្មានសល់ ហើយតាមរយៈការវិភាគរូបភាពទទួលបានពីផ្កាយរណបក៏បានបង្ហាញថា ទីកន្លែងនោះ និង កន្លែងមួយចំនួនផ្សេងទៀតត្រូវបានគេកាប់ឆ្ការតាំងពីឆ្នាំ២០០៤មកម្ល៉េះ។ ការខូច ខាតគម្របព្រៃលិចទឹកដោយសកម្មភាពមនុស្សនេះ គឺដោយសារគ្មានការហាមឃាត់លើការដកហូតធនធានព្រៃលិចទឹក និង កង្វះវិធានការគ្រប់គ្រង។ ប្រសិនបើលទ្ធផលនៃការសិក្សានេះ តំណាងឲ្យស្ថានភាពព្រៃលិចទឹកដទៃទៀតនៃតំបន់បឹងទន្លេសាបនោះ យើងអាចសន្និដ្ឋានបានថា តំបន់ព្រៃលិចទឹកនៅបឹងទន្លេសាបទាំងមូលត្រូវការការគ្រប់គ្រងយ៉ាងសកម្មជាចាំបាច់ ក្នុងគោលបំណងដើម្បីលើកស្ទួយប្រជាជនមូលដ្ឋាន ឲ្យបន្តទទួលបាននូវនិរន្តរភាពនៃការប្រើប្រាស់ធនធានធម្មជាតិ ព្រមទាំងចូលរួមអភិរក្សទីជម្រកធម្មជាតិដ៏សំខាន់នេះ។

Abstract

The floodplain vegetation of Cambodia's Tonle Sap Great Lake provides habitat for a diversity of unique terrestrial and aquatic organisms. This vegetation helps maintain the productivity of one of the world's most important inland

CITATION: Thi S., Lee Y.T., Gaw L.Y.F., Grundy-Warr, C. & Souter, N.J. (2017) The hollow drum: impacts of human use on the Tonle Sap flooded forest at Kampong Luong, Cambodia. *Cambodian Journal of Natural History*, **2017**, 179–188.

fisheries which is vital to Cambodian food security. It also provides local people with wood, food and medicinal plants. However, human activities have destroyed or converted large areas of the Tonle Sap's flooded forest through land encroachment for agriculture and exploitation of wood for fuel and construction. We examined human impacts on the vegetation cover of flooded forests adjacent to Kampong Luong, the largest floating settlement on the lake. Vegetation surveys were undertaken along one transect on each side of the settlement by boat during the 2014 wet season. Interviews were conducted with villagers and village leaders to determine how the floodplain vegetation has been used and managed. While some of the vegetation retained natural characteristics, significant changes were also evident due to human impacts. Nearly all plots surveyed along one transect had almost no vegetation cover and analysis of satellite imagery revealed that these and other areas had been cleared since 2004. Vegetation changes caused by human activity were facilitated by unrestricted access to a common resource and lack of active floodplain forest management. If our results are applicable to other floating settlements on the Tonle Sap Great Lake, the vegetation of the lake's floodplain needs to be actively managed to ensure that local people have sustainable access to natural resources and to conserve this important habitat.

Keywords

Flooded forest, floodplain, human impact, Kampong Luong, Tonle Sap, vegetation cover.

Introduction

Located in the centre of Cambodia, the Tonle Sap Great Lake is one of the Mekong River's major tributaries. The Tonle Sap Lake is the biggest freshwater body in Southeast Asia and supports a highly productive fishery and large human population (Campbell *et al*., 2009). The floodplains that surround the lake experience large seasonal fluctuations in water level and are home to a diverse assemblage of unique terrestrial and aquatic organisms. The vegetation of the floodplains is a mix of forest, shrub land, grassland and agricultural land (Araki *et al*., 2007; Arias *et al*., 2012, 2013). The composition of these vegetation communities is structured by interactions between seasonal flood pulses, soil properties and human impacts (Araki *et al*., 2007; Arias *et al*., 2012, 2013). The floodplain vegetaton provides habitat for a wide range of species including water birds, mammals, reptiles, invertebrates and fishes (Nikula, 2005). The vegetation is also adapted to partial or full submergence and provides a crucial nursery for a wide variety of migratory fish species, while also providing excellent habitats for fish to feed, spawn, hatch and rear their young (Lamberts, 2006).

The huge production of fish supported by the Tonle Sap's floodplains, particularly its flooded forests, is central to Cambodia's food and livelihood security. Freshwater fish and other aquatic animals provide 80% of the protein consumed by people in Cambodia (Hortle, 2007). Approximately 4.1 million people live in the six provinces (Siem Reap, Pursat, Kampong Thom, Battambang, Kampong Chhnang and Banteay Meanchey) bordering Tonle Sap Lake. These depend on the lake and its floodplain for farming and fishing, while over 1.2 million people derive livelihoods from fishery activities (Oeur *et al*., 2014). Consequently, the Tonle Sap's floodplain vegetation not only plays a critical role in sustaining aquatic ecology and supporting numerous fish species, but also directly benefits local livelihoods and economic life (Roudy, 2002). Fishing and agriculture are the major occupations for people who live around the lake, particularly for people who live in Tonle Sap's floating communities (Keskinen, 2006). Compared to people who live further from the lake, they are often poorer, less well educated, and often do not own agricultural land (Keskinen, 2006). Alongside fishing, other livelihood activities link these people with the flooded forest. These include collection of wood for building materials and firewood for cooking and fish processing, and collection of other flooded forest products including wild foods and medicinal plants (Nikula, 2005).

The extent of the Tonle Sap's floodplain vegetation has declined due to human disturbance (Nikula, 2005; Campbell *et al*., 2009). Human activities including an increase in the number and size of human settlements, extensive agricultural conversion and exploitation of wood for fuel and construction materials have destroyed or converted large areas of floodplain vegetation (Roudy, 2002; Campbell *et al*., 2009). Fires, either accidental or intentionally lit for clearing or hunting, have also played an important role in modifying habitats throughout the floodplain (Campbell *et al*., 2006). The area of flooded vegetation declined from 791,000 ha in 2002 to 688,170 ha in 2005 and ca. 55,566 ha of flooded forest was lost between 2005 and 2010 (Mak, 2015; and references therein). Because the flooded forests play an important role in sedimentation, nutrient cycling, primary and secondary production and providing habitat for fish (Arias *et al*., 2012), their degradation threatens the livelihood and food security of millions of people who depend on the natural resources of the Tonle Sap Lake (MoE, 2001). The future productivity of the lake is also threatened by hydropower developments upstream, because these are predicted to change the seasonal pattern of flooding (Arias *et al*., 2013).

While degradation of the Tonle Sap's flooded forest is widespread, many of the drivers of degration occur at a local scale, and are replicated throughout the lake area. To investigate local drivers, we examined the impact of humans on the floodplain vegetation adjacent to Kampong Luong, the largest floating settlement on the Tonle Sap Lake (Mak, 2012). To determine the importance of environmental factors and human use in structuring the flooded forests in this area, we surveyed the vegetation on either side of the Kampong Luong settlement and interviewed local people to evaluate how the forest is used and managed. Given emerging threats to the system, we provide guidance on how management can mitigate future change.

Methods

Study area

The field survey was undertaken at the floating settlement of Kampong Luong (Fig. 1). Located on the southern shore of the Tonle Sap Lake, Kampong Luong has a population of approximately 10,000 people, who comprise Khmer and a large number of Vietnamese who catch and trade fish. Similar to many other floating settlements on the lake, Kampong Luong changes location throughout the year in response to the changing shoreline. Kampong Luong is located on the border of two communes, the Anlong Tnaot Commune, where it officially resides, and the neighbouring Kbal Trach Commune.

Canopy and floating vegetation survey

We surveyed canopy and floating vegetation during the wet season on 20–21 September 2014. Two transects were surveyed in the flooded forests adjacent to Kampong Luong. Each transect began at the outer (lakeward) edge of the flooded forest on either side of the channel leading out of Kampong Luong and proceeded landwards until the vegetation became impenetrable. The transects were located so that they encompassed the

Fig. 1 The Kampong Luong floating settlement and adjacent flooded forests. The main figure shows a landsat image of the area on 14 October 2014, the extent of the settlement (blue dotted lines) during the survey period and location of vegetation plots (light green dots) on the western and eastern transects. The small and large inset maps show the location of the settlement in Cambodia and the dark and light grey areas represent the minimum and maximum extent of the Tonle Sap Lake, respectively.

flooded forests closest to the floating settlement (Fig. 1). Thirty-two 314 m^2 vegetation plots were surveyed, 20 along the 1.9 km western transect in Anlong Tnaot Commune, and 12 along the 1.1 km eastern transect in Kbal Trach Commune. Vegetation plots were spaced at 100 m intervals and accessed using a boat. At each plot location, a tennis ball attached to a line was thrown in the four cardinal directions from the bow of the boat to establish a circular plot measuring 10 m in radius. We visually estimated total plant cover and the percentage cover of each species within each plot. Water depth (m) was recorded within each plot. Plant species were identified following Dy Phon (2000) and Campbell *et al.* (2006), and local names were employed for plant species that could not be identified.

Statistical analyses

Multivariate data analyses were conducted using the Vegan 2.3 package (Oksanen *et al*., 2015) in the R statistical program (R Core Team, Austria). Relationships between vegetation plots were examined using nonmetric multidimensional scaling (NMDS) via the *metaMDS* procedure, and hierarchical clustering via the *hclust* procedure. NMDS represents the position of communities in multidimensional space as accurately as possible using a reduced number of dimensions that can be easily plotted and visualized. Objects closer together in NMDS plots are more similar, whereas objects further apart are more dissimilar. In hierarchical clustering, all samples begin as single objects and are aggregated into progressively larger clusters based on their similarities. For both the NMDS and hierarchical clustering, similarities between survey plots was determined using the square root of Bray-Curtis similarity values. A dendrogram was generated using Ward's grouping method for clustering.

We used two methods to determine if there was a relationship between water depth and vegetation structure. The *envfit* procedure was used in Vegan to examine the relationship between water depth and the position of vegetation plots in the ordination space (Oksanen *et al*., 2015). Differences between water depth and vegetation plots were examined using similarity percentages (SIMPER: Clarke & Warwick, 2001) via the *simper* command. In *simper* analysis, the water depths of vegetation plots were arranged into three categories: shallow water samples (2.0–3.99 m), medium depth samples (4.0–4.99 m) and deep water samples (5.0–7.0 m). These categories were chosen to ensure that numbers of samples in each were roughly even. Use of SIMPER facilitated identification of plant species contributing most to pairwise differences between categories. Three pairwise comparisons were examined to this end: deep vs. medium depth water, deep vs. shallow water, and medium depth vs. shallow water. Discriminating species were selected based on the average contribution of each plant species to overall dissimilarity, the ratio of average contribution to standard deviation, and the greatest differences between average plant cover.

Forest loss

We examined the extent of forest loss adjacent to Kampong Luong between 2000 and 2014 using the Global Forest Watch Dataset (Hansen *et al*., 2014) and Google Earth Engine (Gorelick *et al*., 2017). A 1,846 ha polygon was assessed around Kampong Luong which comprised 0.09 ha of flooded forest in the year 2000. Following Hansen *et al*. (2014), forest loss was defined as removal or mortality of vegetation greater than 5 m height at a resolution of 30x30 m between the years 2000–2014. Changes in forest cover were explored visually for each year.

The role of fire in forest degradation was examined using the Fire Information for Resource Management (FIRMS) dataset in the Google Earth Engine (2017). Daily FIRMS data were derived from MODIS satellites at a resolution of 1 km^2. FIRMS provides the brightness temperature of a fire pixel and a confidence rating that each event was a fire on a scale of 0–100. For each year from 2000 to 2014, areas within the Kampong Luong forests which displayed a high confidence (<50) of having had a fire were identified and displayed graphically.

Semi-structured interviews

We conducted semi-structured qualitative interviews with knowledgeable locals to gather data regarding traditional knowledge, and current use, management and threats to the flooded forest around Kampong Luong. Purposeful sampling methods were adopted (Suri, 2011) and interviewees were chosen to obtain as much information as possible in the short time span available. These comprised six local informants, namely: the head and sub-head of the Kampong Luong settlement, two traditional medicine practitioners, one policeman and one fisherman. All interviews were conducted verbally and recorded with the consent of the participants. Efforts were made to retain the original ideas of each respondent interviewed. Important points voiced by the respondents were recorded and assessed as direct quotes.

Results

Canopy and floating vegetation of the flooded forest

Fourteen plant species belonging to 11 families were recorded in the two survey transects during the study. Thirteen of these were identified to species level and 11 were native: *Barringtonia acutangula* (Lecythidaceae), *Utricularia aurea* (Lentibulariaceae), *Polygonum barbatum* (Polygonaceae), *Combretum trifoliatum* (Combretaceae), *Merremia hederacea* (Convolvulaceae), *Gmelina asiatica* (Lamiaceae), *Bridelia cambodiaria* (Phyllanthaceae), *Impomoea aquatica* (Convolvulaceae), *Oryza rufipogon* (Poaceae), *Diospyros cambodiana* (Ebenaceae), *Derris* sp. (Fabaceae) and a single unidentified taxon known locally as Ronhia. The remaining two species, *Eichhornia crassipes* (Pontederiaceae) and *Mimosa pigra* (Fabaceae), were non-native invasive species.

There appeared to be little relationship between canopy and floating vegetation cover and water depth along either of the two transects (Fig. 2). Our western transect had high vegetation cover at either end, but was largely bare in the middle. Our eastern transect showed an almost opposite pattern, with generally sparser vegetation at either end and higher cover in the middle.

Our NMDS ordination produced a two-dimensional solution with moderate stress (0.13) (Fig. 3). Vegetation plots from the eastern and western transects tended to separate along the second axis, with western transect plots located towards the top of the ordination, and eastern transect plots towards the bottom. This corresponded with a weak depth gradient, whereby shallow water plots (2.0–3.99 m) were loosely grouped at the top and medium water plots (4.0–4.99 m) at the bottom. Deep water plots (5.0–7.0 m) tended not to group together. Vegetation plots from position 9 to 14 on the western transect formed the closest group and occurred in medium depth and shallow water. The *envfit* procedure produced a statistically significant but weak depth gradient (r^2=0.08; p<0.02) and suggested that water depth only explained around 8% of the variation in our vegetation plots.

Our hierarchical classification produced six clusters (Fig. 4). The dendrogram initially split into two groups, these comprising one group (A–B) which was confined to vegetation plots from the western transect, and another larger group (C–F) containing plots from both transects. Group A contained samples from the outer (lakeward) edge of the western transect, whereas group B contained plots from the middle and landward sections of the transect. Group D comprised plots in medium water depths on the eastern transect. The remaining groups (C, E and F) could not be assigned according to transect location, position on the transect or water depth.

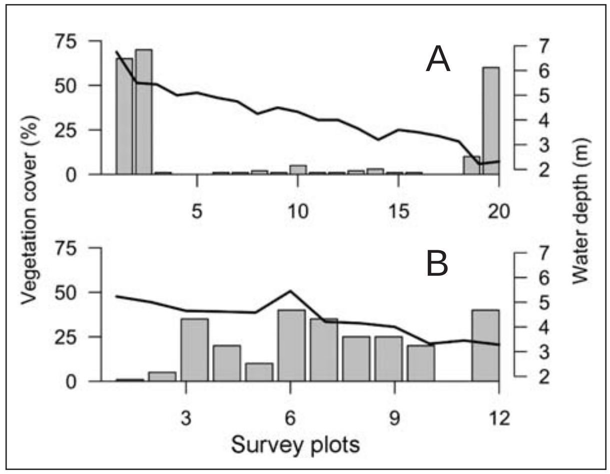

Fig. 2 Vegetation cover (bars) and water depth (black line) in survey plots along the A) western and B) eastern transects at Kampong Luong.

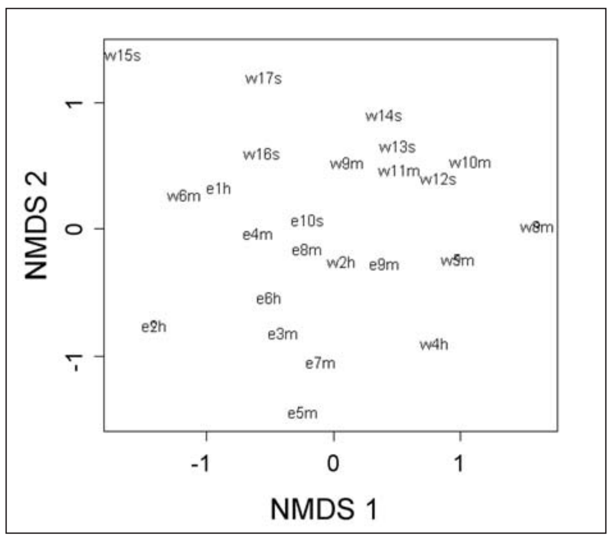

Fig. 3 Two-dimensional NMDS ordination of vegetation survey plots from the eastern and western transects at Kampong Luong. Plot labels denote transect (W=West, E= East), transect position (each transect began in deep water) and water depth (s=shallow, m=medium, h=deep).

SIMPER analysis identified seven plant species as being good discriminators of water depth (Table 1). *Barringtonia acutangula* contributed the most to overall dissimilarity and had the highest cover in deeper water plots. Cover of *E. crassipes* was lower in plots with medium water depth than plots in deeper or shallower

Table 1 Similarity percentages (SIMPER) output for plant cover across different water depths. HD=deep water (5.0–7.0 m), MD=medium depth (4.0–4.99 m), SD=shallow water (2.0–3.99 m).

Species	Contribution	Standard deviation	Ratio	Average plant cover		
				HD	MD	SD
Deep vs. medium depth water						
Barringtonia acutangula	0.314	0.322	0.974	17.142	0.923	-
Eichhornia crassipes	0.089	0.122	0.734	3.285	0.692	-
Combretum trifoliatum	0.080	0.156	0.511	0.142	2.0	-
Ronhia (Local name)	0.070	0.164	0.426	0.714	1.923	-
Merremia hederacea	0.067	0.148	0.453	0.142	2.615	-
Deep vs. shallow water						
Barringtonia acutangula	0.302	0.322	0.939	17.142	-	2.857
Eichhornia crassipes	0.114	0.138	0.826	3.285	-	3.0
Merremia hederacea	0.144	0.132	1.091	0.142	-	6.571
Gmelina asiatica	0.091	0.162	0.562	0.0	-	4.571
Medium depth vs. shallow water						
Barringtonia acutangula	0.081	0.125	0.648	-	0.923	2.857
Eichhornia crassipes	0.080	0.107	0.749	-	0.692	3.0
Combretum trifoliatum	0.087	0.161	0.538	-	2.0	0.285
Merremia hederacea	0.193	0.163	1.179	-	2.615	6.571
Gmelina asiatica	0.109	0.167	0.654	-	0.384	4.571
Oryza rufipogon	0.088	0.134	0.660	-	0.384	0.857

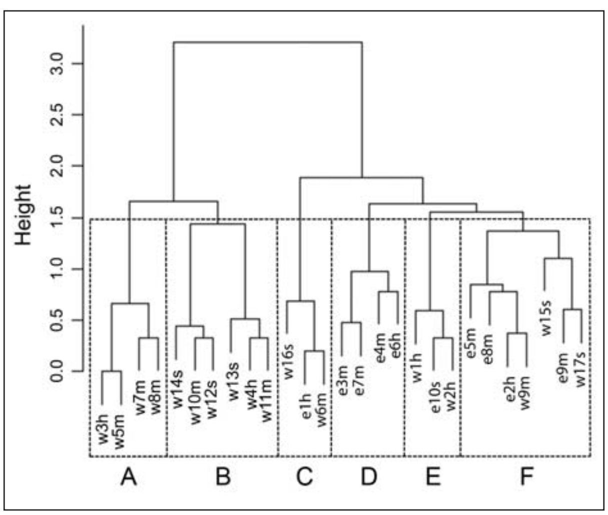

Fig. 4 Hierarchical dendrogram of vegetation plots from Kampong Luong. Plot labels denote transect (W=West, E=East), transect position (each transect began in deep water) and water depth (s=shallow, m=medium, h=deep).

water. Cover of *C. trifoliatum* and Ronhia was higher in plots with medium water depth than those in deeper or shallower water. Cover of *M. hederacea*, *G. asiatica* and *O. rufipogon* was greater in shallow water compared to medium depth and deep water. *Gmelina asiatica* was not found in deep water. These results suggest that similarity was greater within than between the two transects and that plots in deeper water on the western transect were more similar than those from lesser depths. There appeared to be little to differentiate plots from the eastern transect, although plots in medium depth waters did bear some similarities.

Forest loss

From 2000 to 2014, 1,187 m^2 (13%) of forest was lost around the Kampong Luong settlement, whereas forest cover increased by 49 m^2 (0.5%) in previously deforested areas. In the year 2000, the area surrounding the settlement was extensively forested (Fig. 5). Although only a small amount of forest was lost by 2003, large areas were deforested in 2004. This corresponded with a high probability of large fires in the adjacent area, which was believed to have been illegally cleared to provide wood for use in fishing activities (Heng S., pers. comm.). Steady forest loss occurred each year until 2014, mostly through enlargement of areas already cleared. Potential fires were detected in 2004, 2007, 2008, 2011 and 2013 (Fig. 5). Although many trees in the shallower portion of the eastern transect were defoliated and local reports indicated that this area had been burnt during the preceding dry season, this was not detected in satellite imagery. This indicates that small fires may have occurred more frequently than our analysis of satellite imagery would suggest.

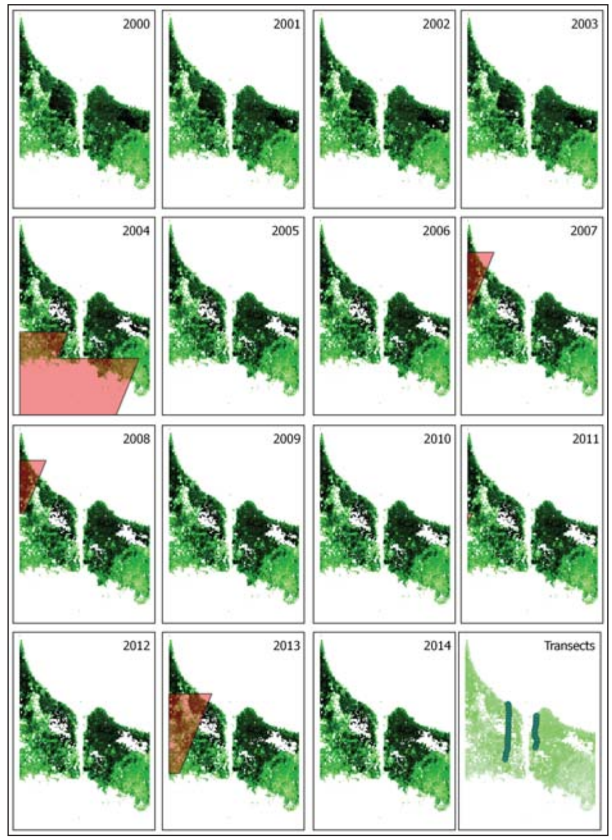

Fig. 5 Yearly forest loss and fire occurrence around Kampong Luong settlement. Green shading represents forest areas, with darker shading representing denser forest. White denotes no forest cover. Red polygons in 2004, 2007, 2008, 2011 and 2013 represent areas with a high likelihood of fire. The settlement occupies the white, non-forested strip dividing the two blocks of forest. The dark dots in the bottom-right panel show the locations of the study transects.

Flooded forest use, management and threats

According to local informants, flooded forests surrounding Kampong Luong settlement are extensively used by local residents and outsiders for fishing during the wet season and for collection of timber, medicinal plants, vegetables, fruit and bark.

Informants reported that local residents and outsiders from the mainland both fish around Kampong Luong. Use of illegal fishing gear was attributed to the latter. Forest vegetation was actively managed during the dry season to facilitate fishing in the wet season and involved burning the forest so that gill nets could be set and retrieved without getting caught in submerged vegetation and becoming damaged or lost. This activity was also attributed to outsiders and local informants reported that efforts to hinder and prosecute these activities by local law enforcement officials were ineffective. Local informants described the importance of a complex floodplain habitat for fish and recognised the importance of conserving the flooded forests to maintain a healthy ecosystem and high fish yields. They also expressed beliefs that reductions witnessed in fish diversity and harvests were related to forest degradation. Despite this, locals evidently extract wood from the flooded forests, and one informant revealed that most wood is extracted during the dry season (although this increases the likelihood of being observed by the police) because access to the forest during the wet season requires a boat. The local police official interviewed emphasised that the forest was protected and that timber extraction and burning were both prohibited. Locals caught breaking these rules were reportedly turned over to officials from the Ministry of Environment or the Fisheries Administration, although locals were allowed to cut small amounts of wood for construction of fish traps. Burning of cleared land prior to the wet season for rice cultivation was also permitted.

Our informants confirmed that locals were aware of the location of Kampong Luong on the boundary of two communes. Locals reportedly use a shrine located on the edge of the flooded forest as a marker beyond which they do not fish, as they claim it marks the boundary of the neighbouring Kbal Trach Commune. Kampong Luong is situated within Anlong Tnaot Commune for most of the year, but floating houses may occasionally cross into Kbal Trach Commune, particularly during the wet season. The location of a nearby and state-enforced fish sanctuary was poorly demarcated however. Some villagers reported that this sanctuary began “where the forest ends”, whereas others believed that it was located deeper within the forest. We could not determine how much fishing activity occurs within the fish sanctuary, but the boundaries of fish sanctuaries supported by NGO's appeared to be better known and protected.

Connections between Kampong Luong and the wider world were revealed in interviews. Kampong Luong is a popular source of fish for traders who sell these to the rest of Cambodia. One fisherman interviewed revealed that he earned 2,000 riel (ca. US$ 0.50) for 1 kg of small, gutted and decapitated fish. These were sold to Cambodian traders who in turn sold the fish in bulk for export to Thailand, where they were dried and then re-imported to Cambodia.

The two traditional medicine practitioners we interviewed stated that a range of floodplain plants were used in traditional medicine (Table 2), and that many locals were aware of the medicinal properties of many plants. Use of such plants for medicine was reported to have decreased due to the availability of modern pharmaceutical medicines. Notwithstanding this, the flooded forest reportedly continues to be important to local spiritual beliefs. Tales of evil spirits reportedly abound and locals obtain protective talismans from the medicine men before they venture into the forest to extract timber or non-timber forest products (Fig. 6).

Discussion

The canopy and floating vegetation adjacent to the Kampong Luong settlement shows signs of being structured by environmental factors and human interactions. Human interactions appear to be the dominant driver. A weak water depth gradient in vegetation composition was apparent in our study, with different species characterizing the outer (lakeward) edge of the forest, medium water depths and shallower waters closer to the shore line. Consistent with previous studies (Araki *et al*., 2007; Arias *et al*., 2013), the outer edge of the forest was characterised by a band of mature *B. acutangula*. Cover of the early successional liana *C. trifoliatum* was greatest in medium depth and shallow waters and this species was previously associated with disturbed forest (Araki *et al*., 2007). In many cases, dead shrubs presumably killed by burning during the previous dry season were covered with *C. trifoliatum*. Plants indicative of shallow waters such as *M. hederacea* are associated with cultivated or fallow fields, and the early successional liana *G. asiatica* is associated with shrub communities (Araki *et al*., 2007).

The extensive clearance of forest evident in satellite data from 2000 to 2014 reveals the extent of human impacts on the forest. In interview, the head of Kampong Luong summarised relationships between humans and forest cover surrounding the settlement as follows:

Table 2 Medicinal and food plants in the flooded forest surrounding the Kampong Luong settlement and their traditional uses and associated beliefs.

Species	Traditional uses
B. acutangula	Bark boiled in water can prevent a loose bladder. After harvesting the bark from the tree, one must 'soothe' the tree wound with soil.
B. cambodiaria	The stem and root are used to treat gynecological conditions and reduce temperature.
D. cambodiana	The fruit can prevent diarrhoea, but as it is bitter it is commonly eaten with prahoc.
E. crassipes	White roots can be ground and drunk with coconut juice to prevent diabetes and abnormal swelling of body parts.
G. asiatica	Roots boiled in water can reduce fever.
I. aquatica	Commonly known as morning glory, this species is extensively cultivated for sale as a vegetable.
M. hederacea	Used to treat gynecological conditions, and to reduce temperature.
Ronhia (Local name)	Cannot be used alone. Must be mixed with other plants for medicinal effects which depend on the latter.
C. trifoliatum	Fruit and bark boiled in water can prevent diarrhoea.

"*The villagers are smart. Outside, the forest looks untouched – so when the environment officers from Phnom Penh check by boat, it looks protected! But actually, inside it is all cut! The forest is hollow like a drum!*". This pattern was most evident to the west of Kampong Luong and was detected in our transect there (Fig. 2a). It was not detected in the eastern transect (Fig. 2b), although an area of cleared forest and open water further to the east also fit this pattern (Fig. 1, Fig. 5). As such, further surveys would undoubtedly reveal more regarding the composition and extent of vegetation surrounding Kampong Luong. As our study took place during the wet season, much of the floral diversity of the flooded forest was not sampled. Because many small shrubs, grasses and herbs would occur in the forest understorey and bare patches during the dry season, additional sampling would undoubtedly reveal this diversity and facilitate comparisons with other published surveys (e.g., Araki *et al*., 2007; Arias *et al*., 2012). As a consequence, our results are localised and cannot be extrapolated to the rest of the floodplain, where we anticipate environmental factors may play a greater role in structuring vegetation (Araki *et al*., 2007; Arias *et al*., 2012). Irrespectively, it would be interesting to test if the 'hollow drum' pattern revealed by our study occurs around other floating settlements on the Tonle Sap Great Lake.

Humans extensively use the natural resources of the flooded forests surrounding Kampong Luong. This resource use is open access and non-exclusive as residents of Kampong Luong and outsiders from the mainland freely access the forest. Local forest resources are also inevitably subject to rivalry because timber cut by one person means less for another. Fishermen from outside of Kampong Luong reportedly fished in the forest during the wet season and were alleged to frequently use illegal fishing gear and burn the forest in the dry season to avoid their gear getting tangled. Although the residents of Kampong Luong understand that the flooded forest provides important spawning grounds for fish, they apparently feel powerless to restrict access to those who either do not understand this or have no qualms about destroying the forest for short term gains.

Kampong Luong is located near the boundary of the Anlong Tnaot and Kbal Trach communes and seasonal movements can shift the settlement between these. Our interviews indicated that local residents are aware of the commune boundaries and this may partly explain why many of our survey plots on the western transect retained almost no vegetation cover. This area is located within the Anlong Tnaot Commune (where the settlement officially resides) and is consequently likely to be considered safer to access by locals. During the field work, greater fishing activity was observed to the west of Kampong Luong compared to the east. Perceptions of the flooded forest as open access are spatially limited by commune boundaries. For political delineations established only 13 years ago (Romeo & Spyckerelle, 2004), this indicates success and faith in the current regulatory regime. However, this must be compared against more recent forest degradation observed to the east, caused by the dry season burning of the flooded forest, allegedly by outsiders. The reported lack of response to this burning by local officials could also partly be due to this activity occurring in the adjacent commune and therefore outside of the bounds of their responsibility.

The transboundary nature and movement of the Kampong Luong settlement defies the clearly-structured commune system, making management of activities difficult through this system. This may be why government enforcement of laws related to flooded forest use has been seemingly lackadaisical; many interviewees reported that areas of forest under NGO jurisdictions are better protected. Kampong Luong bears testimony to the process of centralised power weakening at peripheries in Cambodia, commune boundaries in this case (Grundy-Warr, 1993; Battersby, 1999). Although jurisdictional uncertainties caused by the movement of Kampong Luong may not be typical of all settlements on the Tonle Sap Great Lake, it nonetheless represents one of the many challenges the Cambodian government faces in managing resource-based populations on the lake.

Fig. 6 A talisman prepared by the local medicine man at Kampong Luong settlement to protect villagers entering the forest against evil spirits.

Significant changes are predicted in the natural flow regime of the Tonle Sap Lake in the coming decade due to construction and operation of dams upstream. The operation of these dams for hydropower will flatten the flood pulse of the Mekong River: peak flood levels will be lower during the wet season (Arias *et al*., 2013), while lake levels will be higher during the dry season (Kummu & Sarkkula, 2008). This will affect the vegetation of the surrounding floodplains. The vegetation closest to the centre of the lake, the outer wall of the drum, will become permanently inundated and unlikely to survive, while landwards vegetation will be threatened by clearance for agriculture. Thus, the walls of the hollow drum may collapse. Local communities can do little to alter hydrological changes that would originate as far upstream as the headwaters of the Mekong in China. For the Tonle Sap's flooded forest to continue to provide natural resources to local people and those further afield, improvements in forest management are needed, not only to protect what is left, but to ensure that a productive forest can emerge from forthcoming changes.

Acknowledgements

The authors would like to thank Sambun Vannarong, student of general biology at the Royal University of Phnom Penh, and Chhin Sophea, a senior researcher from the Centre for Biodiversity Conservation at the same university for their assistance during the vegetation survey. Our field work was made possible by cooperation grants provided by National University of Singapore and Centre for Biodiversity Conservation. We acknowledge the use of data and imagery from LANCE FIRMS operated by the NASA/GSFC/Earth Science Data and Information System (ESDIS) with funding provided by NASA/HQ.

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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.

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

If you or your organisation have recently published a technical paper, report or conference abstract that you wish to be included in the next issue, please send an electronic copy, summary or web-link to: Editor.CJNH@gmail.com or Editor.CJNH@rupp.edu.kh

New species & taxonomic reviews

Bresseel, J. & Vermeersch, X.H.C. (2017) The first record of the genus *Olcinia* Stål, 1877 from Cambodia and Vietnam with the description of two new species (Orthoptera: Tettigoniidae: Pseudophyllinae: Cymatomerini). *Belgian Journal of Entomology*, **56**, 1–16.

Describes two species of katydids new to science, including one from Kirirom National National in Cambodia: *Olcinia constanti* sp. nov. A generic key is presented for all Asian genera of Cymatomerini as well as a specific key for the genus *Olcinia.* Author: joachimbresseel@gmail.com

Heppner, J.B. & Bae Y.-S. (2017) A new *Prophaecasia* species from Cambodia and the female characters of the genus (Lepidoptera: Tortricidae: Olethreutinae: Olethreutini). *Zootaxa*. DOI 10.11646/zootaxa.4291.3.12

Paper not seen.

Kosterin, O.E. (2016) *Coeliccia poungyi dasha* subsp. nov. (Odonata, Platycnemididae, Calicnemiinae) from eastern Cambodia. *Journal of the International Dragonfly Fund*, **97**, 1–16.

A new subspecies of damselfly to science is described from the Annamese Mountains in Mondulkiri Province. The new subspecies differs from the nominotypical one in colouration of the mesepisternum in males and end of the abdomen in both sexes, as well as in the length of the terminal lobe of the genital ligula. Author: kosterin@bionet.nsc.ru

Kosterin, O.E. & Kompier T. (2017) *Coeliccia rolandorum* sp. nov. from eastern Cambodia and southern Vietnam, the eastern relative of *C. kazukoae* Asahina, 1984 (Odonata: Platycnemididae). *Zootaxa*, **4341**, 509–527.

The authors describe a species of damselfly new to science from Mondulkiri Province. The new species is related to *C. kazukoae*, which is known from the Cardamom and Sankamphaeng Mountains, and replaces it in eastern Indochina. Author: kosterin@bionet.nsc.ru

Lacroix, A., Duong V., Hul V., San S., Davun H., Keo O., Chea S., Hassanin, A., Theppangna, W., Silithammavong, S., Khammavong, K., Singhalath, S., Afelt, A., Greatorex, Z., Fine, A.E., Goldstein, T., Olson, S., Joly, D.O., Keatts, L., Dussart, P., Frutos, R. & Buchy, P. 2017. Diversity of bat astroviruses in Lao PDR and Cambodia. *Infection, Genetics and Evolution*, **47**, 41–50.

Astroviruses infect humans and a wide range of animal species, and can cause gastroenteritis in their hosts. This study tested 1,876 bats for astroviruses at 45 sites from 14 and 13 provinces in Cambodia and Laos respectively. Results reveal a high diversity of astroviruses among Yangochiropteran and Yinpterochiropteran bats. These formed distinct phylogenetic clusters within the genus *Mamastrovirus*, which is most closely related to other known bat astroviruses, and include a new species of astrovirus to science in fruit bats. Author: buchyphilippe@hotmail.com

Merklinger, F.F., Chhang P. & Wong K.M. (2017) *Schizostachyum cambodianum*, a new species of bamboo (Poaceae: Bambusoideae) from Cambodia. *Zootaxa*. DOI 10.11646/phytotaxa.298.1.9

Describes a species of woody bamboo new to science from the Cardamom Mountains. The new species is distinguished by a very large suborbicular projection at the base of the culm sheath and by forming lax clumps due to its long-necked rhizomes and largely glabrous culm sheaths with only scattered pale hairs.

Naiki A., Tagane S., Chhang P., Dang V.S., Toyama H., Nagamasu H. & Yahara T. (2017) Two new taxa and one new record of *Tarenna* (Rubiaceae) for the flora of Cambodia and Vietnam. *Acta Phytotaxonomica et Geobotanica*, **68**, 93–100.

Describes a new plant variety (*Tarenna pilosa* var. *parvifolia*) to science from Bokor National Park and reports the first record of *T. costata* for Cambodia. A key to species of *Tarenna* in Cambodia, Laos and Vietnam is also provided. Author: naiki@lab.u-ryukyu.ac.jp

Oguri E., Tagane S., Chhang P., Toyama H., Murakami N. & Yahara T. (2017) Flora of Bokor National Park VI: a new species of *Wikstroemia* (Thymelaeaceae), *W. bokorensis*. *Phytotaxa*, **317**, 280–285.

The authors describe a species of *Wikstroemia* new to science from Bokor National Park. The species is morphologically most similar to *W. nutans* in southern China and Vietnam, but differs in having pubescent branches and leaves, smaller anthers, a single disk scale and glabrous ovary.

Park K.T. & Bae Y.S. (2017) Additional three new species of *Anarsia* Meyrick (Lepidoptera, Gelechiidae) from Cambodia and Vietnam. *Zootaxa*. DOI 10.11646/zootaxa.4254.2.8

Three new species to science are described within the butterfly genus *Anarsia*, including two from Cambodia: *A. pursatica* sp. nov. and *A. degeneralis* sp. nov. Images of adults and genitalia for the new species and a check list of species known from Cambodia and Vietnam are provided.

Pham T.T., Tagane S., Chhang P., Yahara T., Souladeth P. & Nguyen T.T. (2017) *Lagerstroemia ruffordii* (Lythraceae), a new species from Cambodia and Vietnam. *Acta Phytotaxonomica et Geobotanica*, **68**, 175–180.

Describes a tree species new to science within the *Lagerstroemia* genus from Vietnam and Cambodia. The new species is morphologically similar to *L. petiolaris*, but is distinguished mainly by its narrower leaves, larger flowers and distinctly 6-ridged calyx tube. Author: phamtrang.botanydep@gmail.com

Polhemus, D.A. (2017) An initial survey of aquatic and semi-aquatic Heteroptera (Insecta) from the Cardamom Mountains and adjacent uplands of southwestern Cambodia, with descriptions of four new species. *Tijdschrift voor Entomologie*, **160**, 89–138.

Aquatic Heteroptera were largely undocumented in Cambodia until recently. A literature review and recent surveys in the Cardamom Mountains and Kirirom and Bokor plateaus of southwestern Cambodia demonstrate that at least 68 species of water bugs occur in these areas. Four species new to science are described based on the recent surveys: *Amemboa cambodiana* sp. nov, *Microvelia penglyi* sp. nov, *M. setifera* sp. nov and *M. bokor* sp. nov. Author: bugman@bishopmuseum.org

Tagane S., Toyama H., Fuse K., Chhang P., Naiki A., Nagamasu H. & Yahara T. (2017) *A Picture Guide of Forest Trees in Cambodia IV, Bokor National Park*. Center for Asian Conservation Ecology, Kyushu University, Fukuoka, Japan.

Based on specimens collected between 2011 and 2013, the authors provide illustrated accounts for 747 plant species at Bokor National Park, including 24 species new to science and mostly endemic to the national park. Author: stagane29@gmail.com

Zhao S., Park K.-T., Bae Y.-S. & Li H. (2017) *Dichomeris* Hübner, 1818 (Lepidoptera, Gelechiidae, Dichomeridinae) from Cambodia, including associated Chinese species. *Zootaxa*. DOI 10.11646/zootaxa.4273.2.4

Including related Chinese species, the authors recognise 13 micromoth species within the genus *Dichomeris* in Cambodia, eight of which are described as new to science: *D. arcuata* sp. nov., *D. splendiptera* sp. nov., *D. samkosensis* sp. nov., *D. foliforma* sp. nov., *D. magnimacularis* sp. nov., *D. hainanensis* sp. nov., *D. cambodiensis* sp. nov. and *D. acutivalvata* sp. nov.

Biodiversity inventories

Averyanov, L.V., Pham V.T., Maisak, T.V., Le T.A., Nguyen V.C., Nguyen H.T., Nguyen P.T., Nguyen K.S., Nguyen V.K., Nguyen T.H. & Rodda, M. (2017) Preliminary checklist of *Hoya* (Asclepiadaceae) in the flora of Cambodia, Laos and Vietnam. *Turczaninowia*, **20**, 103–147.

Provides data on 33 species of *Hoya* obtained in fieldwork mainly during 2012–2017 in Cambodia, Laos and Vietnam, including first records of two species for Cambodia. Knowledge of the flora of Cambodia is increased to include at least eight species of *Hoya*, whereas the flora of eastern Indochina includes at least 45 species. Author: av_leonid@mail.ru

Averyanov, L.V., Ponert, J., Nguyen P.T., Nong V.D., Nguyen S.K & Van C.N. (2017) A survey of *Dendrobium* Sw. sect. *Formosae* (Benth. & Hook.f.) Hook.f. in Cambodia, Laos and Vietnam. *Adansonia*, **38**, 199–217.

The authors provide an identification key for 19 species of *Dendrobium* orchids in Indochina, together with updated information on species nomenclature, morphology, phenology, ecology, distribution and tentative conservation status. Author: av_leonid@mail.ru

Kosterin, O.E. (2017) A short survey of Odonata in Stung Treng Province in northern Cambodia in midsummer 2016. *Journal of the International Dragonfly Fund*, **105**, 1–40.

Presents the results of surveys in Stung Treng Province in July–August 2016. Fifty-five species were recorded, including first records of two species in Cambodia: *Gynacantha saltatrix* and *Macrogomphus matsukii*. Author: kosterin@bionet.nsc.ru

Kosterin, O.E. & Chartier, G. (2017) Update of 2014 and 2016 to Odonata found at the marshy coast of SW Cambodia including three species added for the country. *Journal of the International Dragonfly Fund*, **101**, 1–26.

Reviews the Odonata of selected areas in Koh Kong Province. Fifty-five species are considered, including first records of three species for Cambodia: *Gynacantha bayadera*, *Lyriothemis mortoni* and *Pornothemis serrata.* Author: kosterin@bionet.nsc.ru

Lacroix, A., Duong V., Hul V., San S., Davun H., Keo O., Chea S., Hassanin, A., Theppangna, W., Silithammavong, S., Khammavong, K., Singhalath, S., Greatorex, Z., Fine, A.E., Goldstein, T., Olson, S., Joly, D.O., Keatts, L., Dussart, P., Afelt, A., Frutos, R. & Buchy, P. 2017. Genetic diversity of coronaviruses in bats in Lao PDR and Cambodia. *Infection, Genetics and Evolution*, **48**, 10–18.

It has been speculated that bats are hosts for zoonotic viruses such as Severe Acute Respiratory Syndrome (SARS) and are consequently responsible for outbreaks of the virus. Between 2010 and 2013, the authors sampled 1,965 bats for coronaviruses (CoV) at human-wildlife interfaces in Laos and Cambodia. A total of 93 samples (4.7%) from 17 genera of bats tested positive. Sequence analysis revealed the presence of potentially 37 and 56 coronavirus belonging to alpha-coronavirus and beta-CoV, respectively. The latter group is known to include coronaviruses pathogenic to humans, such as SARS-CoV and MERS-CoV. Author: buchyphilippe@hotmail.com

McCann, G. (2017) Asian golden cat *Catopuma temminckii* at Virachey National Park, Ratanakiri Province, Cambodia. *Southeast Asia Vertebrate Records*, **2017**, 31–33.

Provides camera trap records for Asian golden cat between June 2014 and January 2017 in Virachey National Park, northeastern Cambodia. Author: greg.mccann1@gmail.com

McCann, G. & Pawlowski, K. (2017) Small carnivores' records from Virachey National Park, north-east Cambodia. *Small Carnivore Conservation*, **55**, 26–41.

Presents the results of a two-year camera trapping project in Virachey National Park, northeastern Cambodia. Ten species of small carnivore were recorded, including spotted linsang *Prionodon pardicolor,* binturong *Arctictis binturong* and hog badger *Arctonyx collaris*. The authors conclude that Virachey National Park appears to have many small carnivores, despite years of conservation neglect. Author: greg.mccann1@gmail.com

Rodpai, R., Intapan, P.M., Thanchomnang, T., Sanpool, O., Sadaow, L., Laymanivong, S., Aung, W.P., Phosuk, I., Laummaunwai, P. & Maleewong, W. (2016) *Angiostrongylus cantonensis* and *A. malaysiensis* broadly overlap in Thailand, Lao PDR, Cambodia and Myanmar: a molecular survey of larvae in land snails. *PLoS ONE*, **11**, e0161128.

Angiostrongylus cantonensis is a zoonotic nematode parasite which causes human eosinophilic meningitis (or meningoencephalitis) worldwide. A closely related species, *A. malaysiensis*, may also be a human pathogen. Using larvae obtained from land snails, this study provides the first molecular identification of the two species from Laos, Cambodia, and Myanmar, and maps overlap in their regional distributions. Author: wanch_ma@kku.ac.th

Ustjuzhanin, P.Y. & Kovtunovich, V.N. (2017) First data on Pterophoridae of Cambodia (Lepidoptera: Pterophoridae). *SHILAP Revista de Lepidopterologia*, **45**, 507–511.

Paper not seen.

Species ecology & status

Gray, T.N.E., Crouthers, R., Ramesh, K., Vattakaven, J., Borah J., Pasha, M.K.S., Lim T., Phan C., Singh, R., Long, B., Chapman, S., Keo O. & Baltzer, M. (2017) A framework for assessing readiness for tiger *Panthera tigris* reintroduction: a case study from eastern Cambodia. *Biodiversity and Conservation*, **26**, 2383–2399.

Reintroduction is a viable conservation strategy for large carnivores but requires robust feasibility assessments to ensure that ecological, management and social factors are considered before implementation. The authors provide a framework for undertaking feasibility assessments for tiger and other large carnivore reintroductions and apply this to existing plans to reintroduce tigers into Srepok Wildlife Sanctuary in Cambodia. They suggest that current conditions within the sanctuary are not suitable for tiger reintroduction because although densities of ungulate prey may be sufficient, levels of protected area management and law enforcement fall below global standards for tiger recovery. Author: tomnegray@hotmail.com

Hoem T., Cappelle, J., Bumrungsri, S., Lim T. & Furey, N.M. (2017) The diet of the cave nectar bat (*Eonycteris spelaea* Dobson) suggests it pollinates economically and ecologically significant plants in southern Cambodia. *Zoological Studies*, **56**, 17.

The importance of the cave nectar bat as a pollinator of economically and ecologically significant plant species is increasingly recognised, although information on plants visited by the species was hitherto confined to Thailand and Peninsular Malaysia. The authors show that the diet of the bat in Cambodia includes at least 13 plant taxa. Only three significant colonies (>1,000 bats) of cave-roosting pteropodids are currently known in Cambodia, all of which are in Kampot. Public education and law enforcement efforts are recommended to conserve these colonies because Kampot is the premier region for Cambodian durian and this crop depends on nectarivorous bats for fruit set. Author: neil.m.furey@gmail.com

Mahood, S.P., Silva, J.P., Dolman, P.M. & Burnside, R.J. (2016) Proposed power transmission lines in Cambodia constitute a significant new threat to the largest population of the Critically Endangered Bengal florican *Houbaropsis bengalensis*. *Oryx*. DOI 10.1017/S0030605316000739

The last population of Bengal florican in Indochina breeds in the floodplain of Cambodia's Tonle Sap Lake and could be affected by plans to construct high-tension power transmission lines in this area. Using data from 17 birds monitored by satellite transmitters over four years, the authors estimated the annual survival rate of adult birds to be 89.9%. Migration routes between breeding and non-breeding areas of all birds for whom data were sufficient crossed the proposed route for the transmission line. The route of the line also impinged on the margins of two breeding concentrations. The authors conclude that the proposed transmission lines present an additional threat to the species in Indochina. Author: smahood@wcs.org

Moritsuka E., Chhang P., Tagane T., Toyama H., Sokh H., Yahara T. & Tachida H. (2017) Genetic variation and population structure of a threatened timber tree *Dalbergia cochinchinensis* in Cambodia. *Tree Genetics & Genomics*, **13**, 115.

Despite legal protection, the conservation status of the commerically important tree *Dalbergia cochinchinensis* is of concern in Southeast Asia due to population declines. This study examines genetic variation and structure in four populations of the species in Cambodia. Author: htachscb@kyushu-u.org

Vamberger, M., Durkin, L., Kim C., Handschuh, M., Seng R. & Frit, U. (2017) The leaf turtle population of Phnom Kulen National Park (northwestern Cambodia) has genetic and morphological signatures of hybridization. *Journal of Zoological Systematics and Evolutionary Research*, **55**, 167–174.

Cambodia harbours three distinct species of Southeast Asian leaf turtles (*Cyclemys* spp.) which are heavily traded and common in wildlife seizures. Because confiscated leaf turtles are often released to natural habitats, knowledge of the distribution of each species is important to avoid introduction of non-native turtles and competition and hybridization risks. The authors conducted morphological and genetic analyses of leaf turtle populations at Phnom Kulen National Park and suggest these represent either a natural hybrid swarm of *C. atripons* and *C. oldhamii* or a distinct undescribed species with introgressed mitochondria of *C. atripons*. Author: melita.vamberger@senckenberg.de

Coasts, wetlands and aquatic resources

Chheng P., Un S., Tress, J., Simpson, V. & Sieu C. (2016) *Fish Productivity by Aquatic Habitat and Estimated Fish Production in Cambodia*. Inland Fisheries Research and Development Institute and WorldFish, Phnom Penh, Cambodia.

Presents a review of existing information on the fish productivity of major aquatic habitats in Cambodia. The authors report average yearly values for fish production in rain-fed rice fields, flooded rice fields, reservoirs, flooded forest, shrub land, open water and flooded grassland and swamp. When related to the surface area of each habitat in Cambodia, rice fields are found to potentially contribute >60% of total fish production. The sum of production figures per habitat equals a total fish production of 560,000 tonnes per year. Https://www.worldfishcenter.org/content/fish-productivity-aquatic-habitat-and-estimated-fish-production-cambodia

Gray, T.N.E., Phommachak, A., Vannachomchan, K. & Guegan, F. (2017) Using local ecological knowledge to monitor threatened Mekong megafauna in Lao PDR. *Plos One*, **12**, e0183247.

Pressures on freshwater biodiversity in Southeast Asia are accelerating, yet the status and conservation needs of many of the region's threatened fish species are unclear. This study interviewed fishermen from six villages on the Mekong River in the Siphandone area of Laos to generate monitoring baselines for eight species. Larger species and those with higher Red List threat status were caught less recently than smaller species of less conservation concern. The authors suggest that their approach may be effective for monitoring freshwater fish of conservation concern and highlight the importance of understanding the cultural background and context of sites where data are collected. Author: gray@wildlifealliance.org

Kang Y. (2016) Arsenic-polluted groundwater in Cambodia: advances in research. *International Journal of Water and Wastewater Treatment*. DOI 10.16966/2381-5299.116

Although arsenic pollution of groundwater in Cambodia has been investigated since the mid-2000s, the impacts on soil and rice as well as human health have not been sufficiently clarified. This article reviews transitions in drinking water supply, arsenic pollution of groundwater and health risks to residents, the impact of arsenic on paddy soil and rice, and technologies for removal of arsenic from tube well water in Cambodia. It suggests that arsenic-affected areas deserve more attention and that regulations are needed to insure that arsenic-contaminated rice does not appear in markets. Author: kang@kochi-u.ac.jp

Krishna-Bahadur, K.C., Bond, N., Fraser, E.D.G., Elliott, V., Farrell, T., McCann, K., Rooney, N. & Bieg, C. (2017) Exploring tropical fisheries through fishers' perceptions: fishing down the food web in the Tonlé Sap, Cambodia. *Fisheries Management and Ecology*, **24**, 452–459.

Despite their importance as a source of protein for human populations, management of tropical fisheries such the Tonle Sap Lake are hampered by lack of data. This study explored the implications of increased fishing pressure by evaluating the perceptions of fishers who rely on the ecosystems of the lake for their survival. Although the total size of the fish catch has remained consistent in recent years, the size of individual fish and diversity of species caught has declined. These perceptions are examined in relation to food web theories that explore how fishing pressure can lead to ecosystem change. Author: krishnak@uoguelph.ca

Nop S., DasGupta, R. & Shaw, R. (2017) Opportunities and challenges for participatory management of mangrove resource (PMMR) in Cambodia. In *Participatory Mangrove Management in a Changing Climate. Disaster Risk Reduction (Methods, Approaches and Practices)* (eds R. DasGupta & R. Shaw), pp. 187–202. Springer, Tokyo.

Mangroves play a crucial role in protecting coastal areas and maintaining marine ecosystems but have declined in recent decades. The authors analysed opportunities and challenges for participatory management of mangrove resources in Cambodia. They identify major barriers to this and conclude that effective management of mangroves will require development of specific legislation for their protection, improved coordination and collaboration between relevant actors, community empowerment and further awareness raising on the importance of mangrove forests. Author: sothun.nop@gmail.com

Pool, T., Holtgrieve, G., Elliott, V., McCann, K., McMeans, B., Rooney, N., Smits, A., Phanara T., Cooperman, M., Clark, S. Phen C. & Chhuoy S. (2017) Seasonal increases in fish trophic niche plasticity within a flood-pulse river ecosystem (Tonle Sap Lake, Cambodia). *Ecosphere*, **8**, e01881.

Fish assemblages were studied for five years (2010–2014) in the Tonle Sap Lake using stable isotope and Bayesian statistical approaches to explore isotopic niche variation associated with seasonal flooding within and among species. Fish of the same species tended to have a broader isotopic niche during the wet season, while isotropic niches among species tended to overlap and range more broadly during the same season. The authors conclude that the flood-pulse dynamic typical of tropical aquatic ecosystems may be essential to support the community structure and diversity of freshwater fish that underpin the food web of the Tonle Sap Lake. Author: tpool@uw.edu

Savage, J.M. (2017) *The design and implementation of marine management strategies in Cambodia*. PhD thesis, University of Southampton, UK.

This study identified changes in the health of coral reefs in the Koh Sdach Archipelago of Cambodia between 2002 and 2013. The author examined the socio-economic impacts of management programmes protecting the Cambodian coastal zone and explored community perceptions in relation to governance, change and threats. The findings of the study highlight governance issues at multiple institutional levels and stress the need for greater government support and communication within and between management organisations. They also suggest that involving volunteers and community members in field surveys would help address the current paucity of data for coral reef systems in Cambodia. Https://eprints.soton.ac.uk/413765/

Tran T. (2016) Transboundary Mekong River Delta (Cambodia and Vietnam). In *The Wetland Book II: Distribution, Description, and Conservation* (eds C.M. Finlayson, G.R. Milton, R. Crawford Prentice & N.C. Davidson), pp. 1–12. Springer, The Netherlands.

Covering 5.5 million ha, the Mekong River Delta is one of the largest river deltas in the world. Wetlands within the delta support rich biodiversity and enormous ecosystem services and products. Rapid economic development in recent decades have resulted in extensive loss of wetlands within the region and as of 2016, only 14 protected wetlands existed, representing ca. 1.5% of the delta land area. Climate change and upstream hydropower development pose the most important threats to wetlands of the delta, although their cumulative impacts are still poorly understood. Author: ttriet@gmail.com

Forests and forest resources

Beauchamp, E. (2016) *Seeing the people for the trees: impacts of conservation on human well-being in northern Cambodia*. PhD thesis, Imperial College London, UK.

Conservation initiatives increasingly include poverty alleviation goals or aim to improve human well-being alongside their conservation objectives. This study used three approaches to investigate the effects of conservation interventions on human well-being at different geographical scales in northern Cambodia. Its findings highlight the complexity of attributing conservation impacts and capturing the direct and indirect consequences of conservation and development policies, and suggest more nuanced evaluations of their impacts on humans could guide future interventions. Https://spiral.imperial.ac.uk/handle/10044/1/54853

Chervier, C. & Costedoat, S. (2017) Heterogeneous impact of a collective payment for environmental services scheme on reducing deforestation in Cambodia. *World Development*, **98**, 148–159.

Although Payments for Environmental Services (PES) schemes are increasingly used as incentives to improve forest conservation outcomes in tropical countries, little is known about the performance and conditions under which they can be effective. The authors assessed the impact of a PES scheme on reducing deforestation in the Cardamom Mountains and found that it contributed to saving about 0.17% of the enrolled PES area on average per year during 2005–12. The study highlights that factors such as slope, proximity to roads, and number of households involved are associated with heterogeneous PES impacts. Author: colas.chervier@irstea.fr

Chervier, C., Le Velly, G., Ezzine-de-Blas, D. (2017) When the implementation of payments for biodiversity conservation leads to motivation crowding-out: a case study from the Cardamoms forests, Cambodia. *Ecological Economics*. DOI 10.1016/j.ecolecon.2017.03.018

Payments for Environmental Services (PES) schemes in forest-dependent economies can involve significant restrictions on forest resource use. These imply changes in the way people relate to forests, including perceptions of why the forest is valuable. This study evaluated the impact of a PES scheme designed to conserve biodiversity on perceptions of forest values and assessed correlations between perceived values and conservation behaviours. Results suggest that the scheme had a significant impact on perceived forest values, which changed from subsistence-related to money-related values. The authors suggest that these changes will have consequences for the long-term effectiveness of the scheme, because significantly more individuals emphasizing money-related values reported they would break conservation rules after payments ended. Author: colas.chervier@irstea.fr

Dyrmose, A.M.H., Turreira-García, N., Theilade, I. & Meilby, H. (2017) Economic importance of oleoresin (*Dipterocarpus alatus*) to forest-adjacent households in Cambodia. *Natural History Bulletin of the Siam Society*, **62**, 67–84.

The genus *Dipterocarpus* provides marketable liquid oleoresin which is an important source of income for forest communities in Southeast Asia. This study quantified yields from one of the most intensively tapped resin species (*D. alatus*) and estimated household incomes from resin extraction in the Prey Lang forest complex. Forest-adjacent households were highly dependent on resin extraction for cash income and gross incomes from liquid resin averaged $US 3,236 per household/year. Resin yields were positively correlated with the size and health of trees and proximity to watercourses. Yields were also influenced by season and condition of the tapping-hole. Author: am.dyrmose@gmail.com

Harrison, R.D., Sreekar, R., Brodie, J.F., Brook, S., Luskin, M., O'Kelly, H., Rao, M., Scheffers, B. & Velho, N. (2016) Impacts of hunting on tropical forests in Southeast Asia. *Conservation Biology*. DOI 10.1111/cobi.12785

Though deforestation and forest degradation are often considered the most significant threats to biodiversity across Southeast Asia, substantial areas of natural habitat have few wild animals, except for a few hunting-tolerant species. This study reviews hunting impacts on forest vertebrate populations in the region and concludes that hunting is by far the greatest immediate threat to the survival of most of the region's endangered vertebrates. Unless a step change occurs in efforts to reduce wildlife exploitation to sustainable levels, the region will likely lose most of its iconic species and many others within the next few years. Author: r.harrison@cgiar.org

Hoeurn C. & Sopheak K. (2017) *Natural resource dependency and indigenous people's behavior toward biodiversity in Virachey National Park, Cambodia*. Economy and Environment Program for Southeast Asia, WorldFish, Los Baños, Philippines.

Virachey National Park is home to the Brou, Kavet and other indigenous communities. The authors conducted an economic valuation of the direct use values of selected natural resources within the national park and examined factors affecting indigenous peoples' behaviour toward biodiversity, particularly wildlife. Ninety-two percent of households surveyed were found to benefit directly from natural resources through fishing, wildlife hunting, being ecotourism guides and NTFP collection. Approximately 48% of households surveyed hunted wildlife. Larger household sizes were positively associated with the likelihood of hunting, but those that had a family member working for an NGO or the government were less likely to do so. Author: chebhoeurn@gmail.com

Kenzo T., Sano M., Yoneda R. & Chann S. (2017) Comparison of wood density and water content between dry evergreen and dry deciduous forest trees in central Cambodia. *Japan Agricultural Research Quarterly*, **51**, 363–374.

The authors compared the density and water content of wood samples from dry evergreen forest and dry deciduous forest in Cambodia. Overall, there were little differences in density and water content between the forest types, although their species composition and ecological traits differed significantly. Author: mona@affrc.go.jp

Kibria, A.S.M.G., Behie, A., Costanza, R. Groves, S. & Farrell, T. (2017) The value of ecosystem services obtained from the protected forest of Cambodia: the case of Veun Sai-Siem Pang National Park. *Ecosystem Services*, **26**, 27–36.

This paper provides a first valuation of Veun Sai-Siem Pang National Park in Cambodia, a forest area largely unfamiliar to the international community yet very significant in biodiversity values. The contribution of the park was estimated at US$ 129.84 million annually, including air purification, water storage, soil-erosion reduction, soil-fertility improvement, carbon sequestration, provisioning services and recreation values. Additional values were also identified, including cultural significance, knowledge generation and network development services. Despite these, the park faces threats such as illegal logging, wildlife poaching, population pressure and corruption. Author: kibria.asmg@gmail.com

Kiyono Y., Ito E., Monda Y., Toriyama J., Saito H., Furuya N., Sum T., Tith B., Keth N., Keth S., Chandararity L., Phallaphearaoth O., Chann S. & Sokh H. (2017) A feasibility study for determining the mean annual aboveground biomass gain of tropical seasonal forests in Cambodia. *TROPICS*. DOI 10.3759/tropics.MS15-27

To assess the feasibility of determining the mean annual above-ground biomass gain of tropical seasonal forests in Cambodia, the authors estimated the gain (i.e., increase due to growth of living trees) and loss (i.e., decrease due to tree death) of above-ground tree stand biomass using 49 permanent sample plots nationwide from 2005 to 2015. Author: kiono@ffpri.affrc.go.jp

Environmental policy & practice

Claassen, A.H., Sok K., Arnold, T.W. & Cuthbert, F.J. (2017) Effectiveness of direct payments to increase reproductive success of sandbar-nesting river birds in Cambodia. *Bird Conservation International*. DOI 10.1017/S0959270916000368

Direct payments to communities or individuals are increasingly used as a tool for species conservation, although few studies have evaluated their effectiveness. The authors tested if direct payments for nest protection improved the reproductive success of six sandbar-nesting bird species on the Mekong River from 2010 to 2014. Nests were guarded by community members and exclosures were also used to protect nests of river tern *Sterna aurantia*. Overall, nest protection involving direct payments was highly effective, but required diligent use of nest exclosures, frequent monitoring and strong community relationships. Author: claas004@umn.edu

Gray, T.N.E., Marx, N., Khem V., Lague, D., Nijman, V. & Gauntlett, S. (2017) Holistic management of live animals confiscated from illegal wildlife trade. *Journal of Applied Ecology*. DOI 10.1111/1365-2664.12916

Failure to adopt holistic and multifaceted approaches for dealing with live animals confiscated from the illegal wildlife trade could create conservation, ethical, animal rights and resource issues. The authors suggest solutions to this issue and identify outstanding research needs based on 15 years of experience of wildlife rapid rescue teams in Cambodia. Author: gray@wildlifealliance.org

Gray, T., Milliken, T., Khem V. & Gauntlett, S. (2017) Cambodia's increasing role in the African ivory and rhinoceros horn trade. *TRAFFIC Bulletin*, **29**, 45–46.

Details seizures of African ivory and rhinoceros horn en route to, within and coming from Cambodia in 2011–2017. The authors suggest that Cambodia may be emerging as a transit hub for the illegal transcontinental trafficking of high-value wildlife products and that a robust response by law enforcement agencies and global conservation community is required. Author: gray@wildlifealliance.org

Mak S. (2017) Water governance in Cambodia: from centralized water governance to farmer water user community. *Resources*, **6**, 44.

Cambodia has abundant water resources in the wet season and a scarcity of water in the dry season. Because these phenomena undermine development in the country, effective water governance is critical. This study explored practices, challenges and opportunities for water governance in Cambodia using a large-scale water management system and community-based water management systems in three provinces. It concludes that water governance in Cambodia is too weak and fragmented to address water security issues affecting the country and that reorganisation of the framework for water governance is required to address long term issues. Author: maksithirith@cdri.org.kh

Nathan, I. & Pasgaard, M. (2017) Is REDD+ effective, efficient, and equitable? Learning from a REDD+ project in northern Cambodia. *Geoforum*, **83**, 26–38.

Drawing on results from a REDD+ project in Cambodia, this paper contributes to the debate about whether

REDD+ projects can accommodate economic (efficiency), environmental (effectiveness) and social (equity) concerns. The authors illustrate some mechanisms that are likely to constrain the ability of REDD+ projects to ensure net-gains for local communities, and the risk that effectiveness and equity could suffer if these projects rely solely on the private market. They conclude that a tension exists between the objectives of creating financial value from carbon stored in trees through the private market, and environmental and social equity concerns. Author: in@ifro.ku.dk

Nguyen T. & Frechette, J. (2017) The market for elephant ivory in Cambodia. *TRAFFIC Bulletin*, **29**, 65–72.

Presents the results of market surveys in 2015–2016 which aimed to determine levels of ivory trade and consumer demand in three major cities: Phnom Penh, Siem Reap, and Sihanoukville. These revealed that the domestic market for ivory may be growing and that many retailers of ivory products target Chinese tourists. Author: trang.nguyen@wildact-vn.org

Nhem S., Lee Y.J. & Phin S. (2017) Sustainable management of forest in view of media attention to REDD + policy, opportunity and impact in Cambodia. *Forest Policy and Economics*, **85**, 10–21.

The media plays a vital role in raising public awareness and concerns. The authors analysed media attention to the policy, opportunity and impact of REDD+ in enhancing sustainable forest management and mitigating climate change. They found that major factors limiting media discourses on REDD+ were that institutions did not share information on related events with the media and that journalists lacked knowledge of REDD+ and found the technical issues difficult. Author: leeyj@kongju.ac.kr

Peou H., Natarajan, I., Tianhua, H. & Philippe, D. (2016) From conservation to sustainable development—a case study of Angkor World Heritage Site, Cambodia. *Journal of Environmental Science and Engineering A*, **5**, 141–155.

The World Heritage Committee of UNESCO has called for strategic commitment from state parties to strengthen links between heritage conservation and sustainable development. This will require integration of world heritage site conservation with sustainable use and management of natural resources beyond their boundaries. This article argues that the Angkor World Heritage Site has the potential to demonstrate an ecosystem approach to sustainable development which is advocated under the UN Convention on Biological Diversity.

Pienkowski, T., Dickens, B.L., Sun H. & Carrasco, L.R. (2017) Empirical evidence of the public health benefits of tropical forest conservation in Cambodia: a generalised linear mixed-effects model analysis. *Lancet Planet Health*, **1**, e180–87.

Empirical evidence of the effect of ecosystem degradation and protection on public health outcomes is scarce, restricting the ability of policy makers to assess the health effects of land-use changes. The authors analysed demographic data for 1,766 communities across forest gradients in Cambodia between 2005 and 2014. Loss of dense forest was associated with an increased incidence of diarrhoea, fever and acute respiratory infections in children. Protected area coverage was associated with decreased incidences of diarrhoea and acute respiratory infection. The authors suggest that protected areas could help to alleviate health burdens and present possibilities for simultaneously achieving public health and conservation goals. Author: pienkowski.thomas@gmail.com

Spiegel, S. (2016) Land and 'space' for regulating artisanal mining in Cambodia: visualizing an environmental governance conundrum in contested territory. *Land Use Policy*, **54**, 559–573.

This article draws on a case study of disputed gold mining territory in Kratie Province to examine how commitment to the Minamata Convention presents a conundrum for the Cambodian government given its prioritization of larger-scale concessions in land use policy. In most mineral-rich regions of Kratie and other provinces, mineral exploration and/or mining rights — and other kinds of resource concessions— have already been granted to established companies and powerful actors, leaving ambiguous physical and political space for licensing artisanal mining. Author: sam.spiegel@ed.ac.uk

Souter, N.J., Hughes, A.C., Savini, T., Rao, M., Goodale, E., Van Nice, A., Huang N., Liu J.-X., Hunt, M.P., O'Connor, D.A., Heung-Lam A.L., Gnuen, G., Sun Y. & Silva, I. (2017) Building conservation capacity in Southeast Asia: outcomes of the ATBC 2015 Asia-Pacific chapter meeting conservation education symposium. *Applied Environmental Education & Communication*. DOI 10.1080/1533015X.2017.1322012

Presents the outcomes of discussions during the 2015 ATBC meeting in Phnom Penh on three types of capacity-building programmes: career development, project-specific activities and outreach, and delivering conservation information to diverse audiences. The authors suggest that successful delivery of conservation education in Southeast Asia requires understanding conservation's place in society, developing a feeling of community among students, providing students with financial support, practical teaching, and crafting appropriate messages. Author: nicholas.souter@alumni.adelaide.edu.au

Va D., Taplin, R., Bajracharya, B., Regan, M. & Lebel, L. (2016) Entry points for climate-informed planning for the water resources and agriculture sectors in Cambodia. *Environment, Development and Sustainability*. DOI 10.1007/s10668-016-9788-5

Incorporating climate change concerns into national development planning can help adaptation to occur alongside sustainable development of a country. This article identifies entry points for incorporating climate change issues into the water resources and agriculture sectors in Cambodia. It suggests that the national planning process restricts the involvement of actors such as researchers, civil society and private sector, but is also flexible in providing opportunities for including climate change and other related concerns. Author: dva@bond.edu.au

Touch V., Martin, R.J., Scott, F., Cowie, A. & De L.L. (2016) Climate change impacts on rainfed cropping production systems in the tropics and the case of smallholder farms in North-west Cambodia. *Environment, Development and Sustainability*. DOI 10.1007/s10668-016-9818-3

The consequences of climate change on smallholder farms are locally specific and difficult to quantify because of variations in farming systems, complexity of agricultural and non-agricultural livelihood activities and climate-related vulnerability. This study identifies practical, social and economic constraints to the adoption of climate adaptation options in upland cropping systems in northwest Cambodia. Author: van.touch84@gmail.com

The Recent Literature section was compiled by Neil M. Furey, with contributions from Andrea Claassen, Thomas Gray, Oleg Kosterin and Tagane Shuichiro.

Instructions for Authors

Purpose and Scope

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.

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The following types of manucripts are accepted:

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- Short communications (300–2,000 words, excluding references)
- News (<300 words)
- Letters to the editor (<650 words)

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

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

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

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

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- Summaries of important news from an authoritative published source; for example, a new research technique, or a recent development in conservation.

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

Recent Literature

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

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Authors are welcome to contact the editors at any time if questions arise before or after submitting a manuscript.

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Authors should consult previous issues of the journal for general style, and early-career authors are encouraged to consider guidance provided by:

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.

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Reports:

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Theses:

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

Cambodian Journal of Natural History

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

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The Editors are grateful to our reviewers and to Regine Weckauf, Thi Sothearen, Hun Seiha, Srey Saovina and Kheam Sokha for their kind assistance with the production of this issue.

Cambodian Journal of Natural History

Volume 2017, Number 2

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