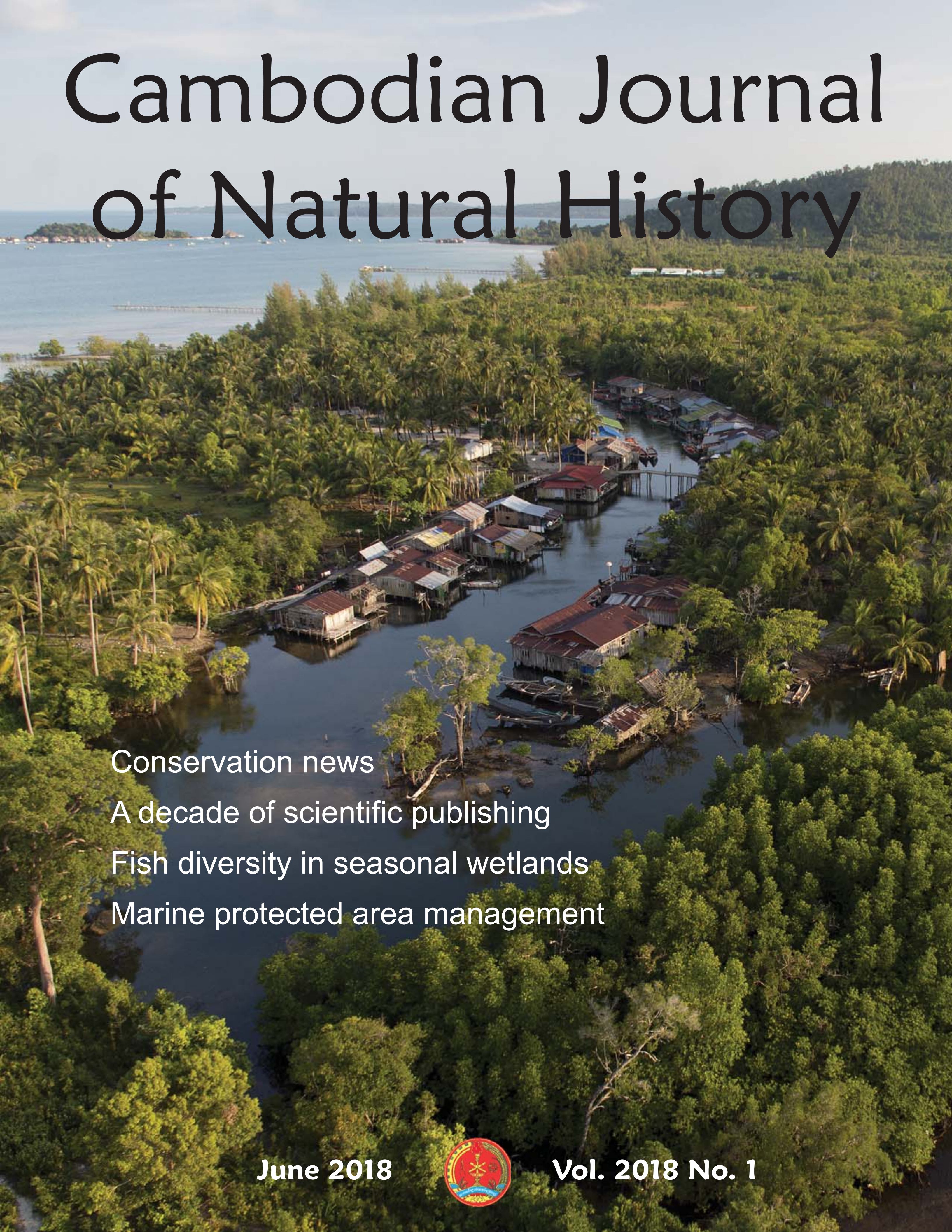
Cambodian Journal of Natural History



Conservation news

A decade of scientific publishing

Fish diversity in seasonal wetlands

Marine protected area management

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Cambodian Journal of Natural History

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Cover image: Prey Svay village in the Kong Rong Archipelago Marine Fisheries Management Area (© Jeremy Holden/FFI). The effectiveness of law enforcement efforts in deterring illegal fishing within the protected area is explored by Roig-Boixeda *et al.* in this issue (pages 9–23).

Editorial—A decade of the *Cambodian Journal of Natural History*, the Kingdom's first peer-reviewed science journal

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Launched in 2008, the *Cambodian Journal of Natural History* witnessed its first decade of continuous publication last year. The original idea for creating a national science journal sprang from the realisation that while a great deal of research had been conducted in Cambodia over the previous decade, very little of this work was available to other scientists or decision makers in the country (Daltry, 2008). Since its launch, 18 issues of the journal have been produced, with two issues published in most years (typically June and December). In this editorial, we look back at the journal's output over the years and consider whether it still serves a useful purpose in Cambodia.

Not counting the 223 conference abstracts published in a special issue in 2015, 230 articles comprising 1,230 pages of material appeared in the journal between 2008 and 2017 (Table 1). Almost half (49%) of these articles comprised short communications and full papers which were peer reviewed by at least two recognised experts in the relevant fields, whereas the remainder comprised non-peer reviewed articles including MSc thesis abstracts (28%), news articles (10%), editorial pieces (7%), recent literature reviews (5%) and letters (1%). In recent years, 27–30 articles appeared in the journal each year.

Unlike many peer-reviewed journals that seek to maximize their impact factor (the average number of citations received by an article in a given year) above all else, the primary mission of the journal has always been to encourage and enable environmental scientists in Cambodia to share their findings and address the critical need for reliable information on the conservation status and management requirements of Cambodian biodiversity. This is reflected in our editorial approach which seeks to coach early-career scientists to develop their writing skills and bring their findings to a wide audience. Evidence also suggests that peer-reviewed periodicals play a pivotal role in promoting decision-maker's recognition of the importance of conservation and biodiversity for sustainable economic growth (Walther *et al*. 2016). Importantly, unlike many peer-reviewed journals, the journal does not charge reader or author fees, relying solely upon the generosity of sponsors for its publication and distribution to ensure as many people as possible have access.

As an intended consequence of supporting Cambodian scientists, these were the lead (first) authors of 44% of the 230 articles published between 2008 and 2017. Almost half of the 230 papers were single-author articles (48%), whereas 39% had multiple authors and 13% had two authors. This suggests that the journal has been successful in its mission to some extent, but also that more could be done. Approximately one third of all authors in the same period were female. While this proportion seems to reflect the global gender disparity in high-quality research, it is considerably higher than the average of 19.8% reported for Asia (Bendels *et al.*, 2018). This is remarkable for Cambodia, where women tend to be under-represented in biodiversity conservation jobs and have fewer opportunities for higher education. A similar number of authors gave their main place of work as an international NGO (30%) or a higher education institution, research institute or museum overseas (29%). Higher education institutions and government agencies in Cambodia represented the lead institution for a further 20% and 10% of authors respectively, whereas

Table 1 Articles published in the *Cambodian Journal of Natural History*, 2008–2017.

Year/ No. of issues	Editorials	Letters	News	Short communications	Full papers	MSc abstracts	Recent literature	Total
2008/1	1	0	1	1	2	0	0	5
2009/1	1	0	0	1	4	6	0	12
2010/2	2	2	1	9	6	6	2	28
2011/2	2	0	2	5	11	12	2	34
2012/2	2	0	0	6	10	5	2	25
2013/2	2	0	4	2	7	11	2	28
2014/1	1	0	0	5	4	0	0	10
2015/2[1]	2	0	4	5	4	15	1	31
2016/2	2	0	6	7	7	3	2	27
2017/2	2	0	4	6	11	6	1	30
Total	17	2	22	47	66	64	12	230

[1] Excludes 223 conference abstracts published in the first issue of 2015.

the remainder were independent (6%) or hailed from Cambodian NGOs (3%).

The credibility of the journal as an open-access platform for environmental science and evidence-based decision-making is reflected in its recent inclusion on the ASEAN Citation Index (https://www.asean-cites.org/) and unsolicited testimonials submitted by government agencies. To date, the journal remains the only Cambodian periodical currently recognised by a peer-reviewed journal index and so could serve as a model for other Cambodian journals to follow. The journal's significance is also reflected in a recent study that demonstrated conservation practitioners and researchers in developing countries obtain most of their information from open-access journals and do not choose journals based on impact factor (Gossa *et al.*, 2014).

So what influence has the journal had on our understanding of Cambodian biodiversity? While difficult to gauge quantitatively, 179 (78%) of articles to date have concerned a specific ecosystem or environment. Not surprisingly, most of these focused on forest (55%) and freshwater (25%) ecosystems, followed by marine (11%), grassland (5%) and agricultural (4%) environments. Of the 168 articles (73%) that concerned a specific taxonomic group, most focussed on plants (20%), followed closely by large mammals (18%), birds (15%), invertebrates (15%), reptiles (12%), small mammals (11%), fish (5%) and amphibians (3%). The range of topics covered has also been broad, including new distribution records, taxonomic assessments, ecological studies and conservation status reviews. Consequently, it might be said that the journal has played an important role in documenting the composition, ecology and conservation status of Cambodia's ecosystems and wildlife.

Yet the journal's contributions clearly go beyond this. For example, a recent article provided much-needed clarification of nation-wide changes in the governance structure of protected areas (Souter *et al.*, 2016), whereas the present issue includes a paper that provides a rare insight into compliance issues with natural resource laws in a marine environment (Roig-Boixeda *et al.*, 2018). One-fifth of articles in the journal over the last decade have focussed on topics such as natural resource management and use, protected area management and environmental education and while the conservation sector may have a poor record for translating research findings into action (Gossa *et al.*, 2014), the fact remains that the lessons gained from such studies can greatly inform and measure its effectiveness.

Recognizing the need for further improvements to the journal, we took actions this year to diversify the scientific disciplines represented on the journal's international editorial board. The board was largely revised as a result (current members are listed on the inside cover page of the present issue) and we thank all former board members for their support. Allied to this, a new website hosted by the Royal University of Phnom Penh was created for the journal (http://rupp.edu.kh/cjnh), which includes facilities for downloading individual articles alongside specific issues. While all issues of the journal have long been freely available online, we are also seeking to include the journal on additional bibliographic databases to improve its archiving and future accessibility to readers.

Looking forwards, the enormous changes taking place throughout Cambodia and complex challenges facing decision makers and stakeholders at all levels mean that access to reliable information on the status, use and management of biodiversity is needed more than ever. We remain conscious that much important research in Cambodia can still be found only in donor reports or expensive journals which are generally unavailable to local scientists and decision makers, or worse still, remains unpublished in personal or institutional databases and files. To mark the journal's first decade of publication, we are now seeking funding to assist early-career conservationists in Cambodia to make such datasets available through a series of mentoring workshops on scientific-publishing and would be delighted to hear from any organizations or individuals interested in participating.

References

Bendels, M.H.K., Muller, R., Brueggmann, D. & Groneberg, D.A. (2018) Gender disparities in high-quality research revealed by Nature Index journals. *PLOS ONE*, **13**, e0189136.

Daltry, J. (2008) Editorial – Cambodia's biodiversity revealed. *Cambodian Journal of Natural History*, **2008**, 3–5.

Gossa, C., Fisher, M., Milner-Gulland, E.J. (2014) The research-implementation gap: how practitioners and researchers from developing countries perceive the role of peer-reviewed literature in conservation science. *Oryx*, **49**, 80–87.

Roig-Boixeda, P., Chea P., Brozovic, R., You R., Neung S., San T., Teoh, M. & West, K. (2018) Using patrol records and local perceptions to inform management and enforcement in a marine protected area in Cambodia. *Cambodian Journal of Natural History*, **2018**, 9–22.

Souter, N.J., Simpson, V. Mould, A., Eames, J.C., Gray, T.N.E., Sinclair, R. Farrell, T., Jurgens J.A. & Billingsley, A. (2016) Editorial—Will the recent changes in protected area management and the creation of five new protected areas improve biodiversity conservation in Cambodia? *Cambodian Journal of Natural History*, **2016**, 1–5.

Walther, B.A., Boëte, C., Binot, A., By, Y., Cappelle, J., Carrique-Mas, J.J., Chou, M., Furey, N., Kim S., Lajaunie, C., Lek S., Méral, P., Neang M., Tan B-H., Walton, C. & Morand, S. (2016) Biodiversity and health: lessons and recommendations from an interdisciplinary conference to advise Southeast Asian research, society and policy. *Infection, Genetics and Evolution*, **40**, 29–46.

News

Southern Cardamom REDD+ project launched

The Cardamom Rainforest Landscape is critical for biodiversity conservation and ecosystem services, supporting more than 50 IUCN threatened vertebrate species while being Cambodia's most important watershed and largest climate regulator and carbon sink. The Southern Cardamom REDD+ (Reducing Emissions from Deforestation and Forest Degradation) Project is a joint initiative of the Ministry of Environment of the Royal Government of Cambodia, Wildlife Alliance and Wildlife Works Carbon and will provide sustainable long-term financing to support the protection of almost 500,000 hectares in the Southern Cardamom National Park and Tatai Wildlife Sanctuary, Koh Kong Province. We estimate that the project will generate avoided emissions of more than 115 Million tonnes of CO_2e over its 30 year lifespan. Project activities will include effective and results-based law enforcement patrolling combined with community development activities, particularly community-based ecotourism and sustainable agricultural development which will address the drivers of deforestation in the landscape. A fund will also be provided to support scholarships for children from project communities to address one of the critical drivers of poverty in the landscape: low education rates and limited opportunities for post-primary school education. Developed under the Voluntary Carbon and Climate, Community and Biodiversity standards for the voluntary carbon market as one of the Ministry of Environment's three REDD+ pilot projects, the project is designed to be fully aligned with the Cambodian National REDD+ Strategy and thus eligible for future compliance carbon payments. Full documentation regarding the project can be found at http://www.vcsprojectdatabase.org/#/ccb-all-project-details/PL1748 and https://www.wildlifealliance.org/redd/

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A new marine conservation research scholarship for Cambodian university students

In the 2014 issue of the *Cambodian Journal of Natural History*, Kathe R. Jensen and Ing Try drew attention to circumstances hindering effective science-based management of Cambodia's marine environments. Issues such as a lack of meaningful funding for basic ecological research and low involvement of Cambodian nationals in such programmes have arguably led to a lack of interest in the field and shortages in related capacity. At the same time, the traditional way of life of many coastal communities is increasingly threatened by rapid development and uncontrolled resource extraction which have the potential to devastate marine ecosystems if not properly mitigated. As a consequence, strong understanding of the ecological and socio-cultural circumstances of a given region is necessary to make well-informed management decisions, and where information is lacking, the ability to conduct research is crucial.

The PADI Foundation Scholarship for Cambodian Marine Conservation Research has been founded to develop pertinent research capacity in Cambodia. Thanks to financial support from the PADI Foundation in California, Cambodian university students will have the opportunity to conduct fully-funded thesis research with Marine Conservation Cambodia (MCC). The scholarships will cover all costs for a several-month stay in the coastal region of Kep, where experienced MCC staff will provide training in scuba diving and survey methods for marine life, thereby strengthening interest and expertise in marine ecology. Students will acquire multiple scuba certifications and complete a research project on any aspect of marine conservation science agreed upon by the student, MCC and academic supervisors. Students should aim to become culturally-competent leaders in local marine conservation and to establish a self-sustaining, regional interest in Cambodia's marine environments. Further information can be obtained from the contact person below.

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News

Understanding urban wildlife meat consumer profiles through human-centred design

Illegal commercial hunting is the greatest immediate threat to wildlife in Cambodia. With an increase in disposable incomes, escalating recreational consumption of wildlife meat has become a significant driver of hunting. Most wildlife meat is hunted using wire snares which indiscriminately kill a wide range of species. Despite the significant threat to Cambodia's endangered species, there have been few actions to reduce the demand for wildlife products. As a consequence, Fauna & Flora International has undertaken research to understand the behaviours of urban wildlife meat consumers with support from the US Fish and Wildlife Service. This will be used to create a behaviour change campaign that aims to reduce demand for wildlife meat and by extension the practice of wildlife snaring.

In partnership with iDE Cambodia, the research used a human-centred design methodology and ethnographic and anthropological tools to acquire an understanding of consumers and their environments and routines. Two consumer groups (across six profiles) were revealed: occasional consumers and regular consumers. Within the occasional group, consumption exclusively takes place in rural provinces. Among regular consumers, consumption takes place in rural areas and Phnom Penh. Major triggers prompting individuals to eat wildlife meat across all six profiles included 'curiosity', 'breaking the routine' and 'social pressure'. Drivers contributing to increases in wildlife meat consumption were also identified. For occasional consumers, these included 'lack of knowledge' and 'cognitive dissonance', whereas all drivers for regular consumers were related to the social act of consumption.

Forthcoming phases of the initiative will employ these findings to design and deliver a behaviour change campaign to reduce wildlife meat consumption in Cambodia. For a copy of the research or should you wish to collaborate on the project, please contact Dr Jackson Frechette (jackson.frechette@fauna-flora.org).

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Organic honey as a social business product in northeastern Cambodia

Save Cambodia's Wildlife (SCW) has identified a need to transform mindsets and work practices in the development sector. It also believes that social entrepreneurship can promote community ownership and sustainability of environmental initiatives. This forms an important part of the SCW organizational strategy (2017–2021) and social business strategy, which alongside promotion of natural products includes a focus on sustainable ecotourism, creation of a youth development curriculum and an environmental membership programme.

With funding secured, field and market research to identify suitable products for social entrepreneur schemes began in 2017. Bamboo, malvat nut and rice wine were initially considered, although pure honey was later selected due to high demand for its use in medicine in northeastern Cambodia. A partnership with a local beehive supplier was subsequently secured and 30 farmers in Kratie Province were trained in beekeeping and honey production. Following the development of a value chain and retail partnerships, the honey was launched as an environmentally and socially sustainable product in early 2018 in the Kratie and Ratanakiri provinces and Phnom Penh.

The organic honey is produced using ecologically friendly practices and its sale ensures fair prices for local communities. As response to the product has been very positive to date, SCW plans to train another 30 farmers from Kratie Province in honey production this year. Save Cambodia's Wildlife takes an intermediate role to build the capacity of people in rural areas and help them to create efficient marketing platforms and sustainable value chains. This supports sustainable livelihoods and contributes to environmental protection. Further information on SCW's work and social products can be found at https://www.cambodiaswildlife.org/honey

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Short Communication

Lecanorchis vietnamica (Orchidaceae), a newly recorded mycoheterotrophic genus and species from Cambodia

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Lecanorchis Blume comprises about 30 species of mycoheterotrophic orchids characterized by numerous long, thick, horizontal roots produced from a short rhizome, the presence of a calyculus (i.e., a cup-like structure located between the base of the perianth and apex of the ovary) and an elongate column with a pair of small wings on each side of the anther (Hashimoto, 1990; Pridgeon *et al*., 2003).

Species within the *Lecanorchis* genus are distributed across a wide area in South, Southeast and East Asia and the Pacific region, including China, India, Indonesia, Japan, Korea, Laos, Malaysia, New Guinea, Pacific islands, the Philippines, Taiwan, Thailand and Vietnam (Seidenfaden, 1978; Hashimoto, 1989, 1990; Pearce & Cribb, 1999; Szlachetk & Mytnik, 2000; Pridgeon *et al*., 2003; Averyanov, 2005, 2011, 2013; Suddee & Pedersen, 2011; Ong, 2017). In Cambodia, no species of *Lecanorchis* has been recorded so far. Although the distribution map of Pridgeon *et al*. (2003) indicated the occurrence of the genus in the country, Suddee & Pedersen (2011) noted that they were unable to find any records of *Lecanorchis* from Cambodia with a voucher specimen.

During a field survey in Bokor National Park, Kampot Province, southern Cambodia in 2012, we discovered one species of *Lecanorchis: L. vietnamica* Aver. (Fig. 1). We therefore document the occurrence of *L. vietnamica* as a newly recorded genus and species for the flora of Cambodia. The following description is derived from our Cambodian material.

Lecanorchis vietnamica Aver., Rheedea, 15, 92 (2005).

Type: Vietnam, Thua Thien-Hue Province, A Luoi District, A Roang Municipality, Tra Lenh Forestry Department station, around point 16°04′38″N, 107°29′10″E, elevation 700–800 m, on tops of ridge, 20 April 2005, *L. Averyanov, P.K. Loc, N.T. Vinh et al. HAL 724* (holotype HN [Vietnam Academy of Science and Technology], image!; isotype LE [Komarov Botanical Institute of the Russian Academy of Science], image!).

Synonym: *Lecanorchis flavicans* Fukuy. var. *acutiloba* T. Hashim., *Annals of the Tsukuba Botanical Garden,* **8**, 8 (1989).

Type: Japan, Kagoshima Prefecture, Yakushima Island, Mt. Motchomu, 24 July 1979, *Y. Hanei s.n.* (holotype TNS [National Museum of Nature and Science]!).

CITATION: Suetsugu K., Tagane S., Toyama H., Chhang P. & Yahara T. (2017) *Lecanorchis vietnamica* (Orchidaceae), a newly recorded mycoheterotrophic genus and species from Cambodia. *Cambodian Journal of Natural History*, **2018**, 6–8.

Terrestrial, mycoheterotrophic herb, 20–30 cm tall. Roots not seen. Stem usually branched or occasionally simple, blackish brown, glabrous, 0.5–1 mm in diameter, with several membranous scale-like sheaths along stem. Inflorescences loosely (1–)2–4 flowered, rachis up to 3 cm long; floral bracts triangular, 0.6 mm long, apex obtuse or broadly acute, glabrous; pedicellate ovary ascending, ca. 12 mm long, dull olive-brown, glabrous. Calyculus somewhat rugose, ca. 0.5 mm long. Flowers hardly opening; sepals similar, olive-brown to yellowish-brown, oblong-spathulate, 10.5–12 mm long, ca. 3 mm wide, apex obtuse, with three indistinct veins; petals olive-brown to yellowish-brown, obliquely oblong-spathulate, 10.5–12 mm long, ca. 3.5 mm wide, apex obtuse, with three indistinct veins; lip slightly longer than other tepals, 11–13 mm long, ca. 8 mm wide when fattened, adnate at the base to lateral sides of column and forming an inflated sac-like nectary, ca. 2.5 mm long; lip blade broadening to 3-lobed apex; lateral lobes erect, triangular, ca. 2 mm long, apex acute, margins slightly irregularly denticulate; midlobe semiorbicular, slightly recurved, 3 mm long, 4 mm wide, densely covered with long, flexuose, white to light yellow hairs. Column clavate, 5–6 mm long, about halfway connate with the lip, with obtuse-trapezoid lateral wings. Anther cap hemispheric, ca. 1 mm across. Fruit capsules, cylindrical, 18–23 mm long, black.

Specimen examined: Cambodia, Kampot Province, Bokor National Park, moist evergreen forest near Popokvil Waterfall, 10°39′35.42″N, 104°03′03.09″E, elevation 903 m, 13 May 2012, *Toyama H., Tagane S., Mishima T., Tagawa K., Zhang M., Chhang P., Iwanaga F., Nagamasu H. & Yahara T. 3156* (deposited in the herbarium of Forest Administration in Cambodia).

Distribution: Cambodia (Kampot Province, new record), Japan (Tokushima Prefecture, Kagoshima Prefecture [Yakushima and Amami-oshima Islands], Okinawa Prefecture [Okinawa Island]), Laos (Saravan Province), Taiwan (New Taipei City and Yilan City) and Vietnam (Thua Thien-Hue Province).

Habitat and ecology: Only three individuals were found in a 3×3 m area near *Castanopsis acuminatissima* (Blume) A.DC. in the understory of evergreen forest along the stream below Popokvil Waterfall. The forest nearby was surveyed using a 100×5 m plot (Zhang *et al.* 2016: Fig. 1, plot 7). In the plot, dominant trees were *Beilschmiedia penangiana* Gamble (Lauraceae), *Macaranga andamanica* Kurz (Euphorbiaceae), *Baccaurea ramiflora* Lour. (Phyllanthaceae), *Nephelium hypoleucum* Kurz (Sapindaceae), and *Timonius corneri* K.M.Wong (Rubiaceae) for which we recorded more than five trees taller than 4 m and *Dacrycarpus imbricatus* (Blume) de Laub. (Podocarpaceae) for which we recorded two large trees taller than 20 m. The flowering specimen was collected in May.

Fig. 1 Flowering plant of *Lecanorchis vietnamica* at Bokor National Park, Cambodia.

Conservation status in Cambodia: Lecanorchis vietnamica is only known from a single population in Bokor National Park, where the aforementioned specimen was collected. Given that mycoheterotrophic plants are highly dependent on the activities of both the fungi and the trees that sustain them (Suetsugu *et al.*, 2017b), they are particularly sensitive to environmental disturbance. Because deforestation for resort development is rapidly expanding very near the locality of this species, urgent attention is needed to conserve the Cambodian population.

Notes: Lecanorchis vietnamica is most similar to *L. triloba* J.J.Sm. in having relatively small flowers whose tepals are less than 15 mm and whose lip midlobe is covered with a dense mass of white hairs. However it can be distinguished by its (1–)2–4-flowered inflorescences (vs. frequently more than 10-flowered) and lip without a pair of calli on the disc (vs. lip with a pair of calli on the disc; Hsu *et al.*, 2016; Suetsugu *et al.*, 2017a). Our Cambodian specimen possesses these characters. Considering that botanical surveys have recently discovered many new species and distribution records for the *Lecanorchis* genus (Suddee & Pedersen 2011; Suetsugu & Fukunaga 2016, 2018; Suetsugu *et al.*, 2018), *L. vietnamica* could also prove to be more widespread in future. Our report of the species in Cambodia constitutes the most southerly locality currently known for the species.

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References

Averyanov, L.V. (2005) New orchids from Vietnam. *Rheedea*, **15**, 83–101.

Averyanov, L.V. (2011) The orchids of Vietnam illustrated survey, part 3. *Turczaninowia*, **14**, 15–100.

Averyanov, L.V. (2013) New and rare orchids (Orchidaceae) in the flora of Cambodia and Laos. *Turczaninowia*, **16**, 26–46.

Hashimoto T. (1989) Taxonomic miscellanies of orchidaceous plants (4). *Annals of the Tsukuba Botanical Garden*, **8**, 1–9.

Hashimoto T. (1990) A taxonomic review of the Japanese *Lecanorchis* (Orchidaceae). *Annals of the Tsukuba Botanical Garden*, **9**, 1–40.

Hsu T.C., Hsieh C.L. & Chou Y.C. (2016) *Lecanorchis flavicans* var. *acutiloba* (Orchidaceae), a newly recorded orchid in Taiwan. *Taiwan Journal of Biodiversity*, **18**, 115–121.

Ong, P.T. (2017) Flora of Peninsular Malaysia—Vanilloideae. *Malesian Orchid Journal*, **21**, 69–116.

Pearce, N. & Cribb, P. (1999) Notes relating to the flora of Bhutan: XXXVII. New species and records of Orchidaceae from Bhutan and India (Sikkim). *Edinburgh Journal of Botany*, **56**, 273–284.

Pridgeon, A.M., Cribb, P.J., Chase, M.W. & Rasmussen, F.N. (2003) *Genera Orchidacearum 3. Orchidoideae (part 2), Vanilloideae*. Oxford University Press, Oxford, UK.

Seidenfaden, G. (1978) Orchid Genera in Thailand VI. *Neottioideae Lindl. Dansk Botanisk Arkiv*, **32**, 1–195.

Suddee, S. & Pedersen, H.Æ. (2011) A new species of *Lecanorchis* (Orchidaceae) from Thailand. *Taiwania*, **56**, 37–41.

Suetsugu K. & Fukunaga H. (2016) *Lecanorchis tabugawaensis* (Orchidaceae, Vanilloideae), a new mycoheterotrophic plant from Yakushima Island, Japan. *PhytoKeys*, **73**, 125–135.

Suetsugu K. & Fukunaga H. (2018) A new variety of the mycoheterotrophic plant *Lecanorchis triloba* (Orchidaceae) from Okinawa Island, Ryukyu Islands, Japan. *Acta Phytotaxonomica et Geobotanica*, **69**, 63–67.

Suetsugu K., Hsu T.C. & Fukunaga H. (2017a) The identity of *Lecanorchis flavicans* and *L. flavicans* var. *acutiloba* (Vanilleae, Vanilloideae, Orchidaceae). *Phytotaxa*, **306**, 217–222.

Suetsugu K., Yamato M., Miura C., Yamaguchi K., Takahashi K., Ida Y., Shigenobu S. & Kaminaka H. (2017b) Comparison of green and albino individuals of the partially mycoheterotrophic orchid *Epipactis helleborine* on molecular identities of mycorrhizal fungi, nutritional modes and gene expression in mycorrhizal roots. *Molecular Ecology*, **26**, 1652–1669.

Suetsugu K., Yiing L.C. Naiki A., Tagane S., Takeuchi Y., Toyama H. & Yahara T. (2018) *Lecanorchis sarawakensis* (Orchidaceae, Vanilloideae), a new mycoheterotrophic species from Sarawak, Borneo. *Phytotaxa*, **338**, 135–139.

Szlachetko, D.L. & Mytnik, J. (2000) *Lecanorchis seidenfadeni* (Orchidaceae, Vanilloideae), a new orchid species from Malaya. *Annales Botanici Fennici*, **37**, 227–230.

Zhang M., Tagane S., Toyama H., Kajisa T., Chhang P. & Yahara T. (2016) Constant tree species richness along an elevational gradient of Mt. Bokor, a table-shaped mountain in southwestern Cambodia. *Ecological Research*, **31**, 495–504.

Using patrol records and local perceptions to inform management and enforcement in a marine protected area in Cambodia

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មូលន័យសង្ខេប

ការយល់ពីភាពមិនអនុលោមទៅតាមច្បាប់ដែលបានចែងស្តីពីការអភិរក្សគឺ មានសារៈសំខាន់ណាស់ សម្រាប់ការគ្រប់គ្រងតំបន់ការពារធម្មជាតិដែនសមុទ្រឲ្យមានប្រសិទ្ធភាព។ ទោះជាយ៉ាងណា ការតាមដានសកម្មភាពខុសច្បាប់គឺជាបញ្ហាប្រឈមដ៏សំខាន់មួយ ហើយអ្នកអនុវត្តការតាមដានទាំងនោះ ទាមទារឲ្យមានវិធីសាស្ត្រមួយដែលអាចកាត់បន្ថយភាពលម្អៀង និង ការចំណាយថវិកាច្រើន។ យើងបានធ្វើការអង្កេតពីទំហំ របាយ និង ដើមហេតុនៃសកម្មភាពនេសាទខុសច្បាប់ ព្រមទាំងកម្រិត និង របាយនៃកិច្ចប្រឹងប្រែងក្នុងការងារល្បាតនៅ "តំបន់គ្រប់គ្រងធនធានជលផលសមុទ្រ ប្រជុំកម្រងកោះរ៉ុង" ក្នុងអំឡុងពេលមួយឆ្នាំក្រោយការចេញប្រកាសនៅក្នុងប្រទេសកម្ពុជា។ បន្ទាប់មកយើងបានបញ្ចូលគ្នានូវព័ត៌មាន ដែលបានកំណត់ត្រាអំពីការល្បាតចំនួន១៦១លើក ធ្វើឡើងនៅចន្លោះខែមិថុនា ឆ្នាំ២០១៦ និង ខែមីនា ឆ្នាំ២០១៧ រួមជាមួយនឹងលទ្ធផលទទួលបានពីការស្រាវជ្រាវសេដ្ឋកិច្ចសង្គម ដែលត្រូវបានធ្វើឡើងក្នុងអំឡុងខែមីនា ឆ្នាំ២០១៧។ ចំនួន១៦៣គ្រួសារត្រូវបានជ្រើសរើសសម្រាប់ការស្រាវជ្រាវផ្នែកសេដ្ឋកិច្ចសង្គម ដែលក្នុងនោះមាន៣៣គ្រួសារគឺជាអ្នកនេសាទ។ ចម្លើយដែលបានពីគ្រួសារទាំងនោះត្រូវបានយកមកប្រៀបធៀបនឹងទិន្នន័យសម្ភាសន៍បែបពាក់កណ្តាលមានរចនាសម្ព័ន្ធ (semi-structured interviews) ដែលផ្តល់តាមការសម្ភាសន៍ជាមួយជនបង្គោលសំខាន់ៗចំនួន២១នាក់រួមមាន៖ អ្នកនេសាទនៅមូលដ្ឋាន ប្រតិបត្តិករទេសចរណ៍ និង អង្គការក្នុងតំបន់ជាដើម។ លទ្ធផលរកឃើញបានបង្ហាញថា អ្នកនេសាទខុសច្បាប់ភាគច្រើនគឺជាប្រជាជនមកពីតំបន់ផ្សេង ដែលភាគច្រើនពួកគេចូលមកនេសាទនៅពេលយប់(នៅពេលមិនសូវមានសកម្មភាពល្បាត) សកម្មភាពនេសាទខុសច្បាប់ទាំងនោះមានរបាយមិនស្មើគ្នាទេ និង នៅពាសពេញផ្ទៃសមុទ្រ។ ការអនុលោមទៅតាមច្បាប់នៃតំបន់ការពារធម្មជាតិកើតមានឡើងដោយសារ ការយល់ដឹង និង ភាពស្របច្បាប់នៃការនេសាទ រីឯកត្តាចម្បងៗដែលបង្កឲ្យមានសកម្មភាពនេសាទខុសច្បាប់រួមមាន ការលើកទឹកចិត្តផ្នែកសេដ្ឋកិច្ចឬជីវភាពគ្រួសារ និង កង្វះខាតការយល់ដឹង។ តាមលទ្ធផល យើងសូមផ្តល់អនុសាសន៍ឲ្យមានការបង្កើនការផ្សព្វផ្សាយចំណេះដឹង និង ជួយទ្រទ្រង់ផ្នែកអនុវត្តច្បាប់នៅតំបន់ការពារធម្មជាតិ ព្រមទាំងបង្កើនសកម្មភាពល្បាតឲ្យកាន់តែមានប្រសិទ្ធភាព ដើម្បីបំបាក់អាកប្បកិរិយាមិនគោរពច្បាប់។ យើងក៏សូមផ្តល់យោបល់ ឲ្យមានការល្បាតធ្វើឡើងនៅតំបន់គោលដៅសំខាន់ៗដែលគ្មានការគោរពច្បាប់ កាត់បន្ថយការព្យាករណ៍របស់ពួកគេ (សកម្មភាពល្បាត)ដោយបង្កើនសកម្មភាពល្បាតនៅពេលយប់។ ការសិក្សាស្រាវជ្រាវរបស់យើងក៏បានលើកឡើងពីបញ្ហាប្រឈមមួយចំនួននៅក្នុងការពិនិត្យតាមដានបញ្ហាមិនគោរពច្បាប់នៅក្នុងតំបន់ការពារធម្មជាតិដែនសមុទ្រ ព្រមទាំងបង្ហាញពីវិធីដែលអាចប្រើប្រាស់គំនិតយោបល់របស់សហគមន៍មូលដ្ឋាន ទៅបំពេញបន្ថែមទិន្នន័យដែលបានពីការល្បាត និង ធ្វើអត្តសញ្ញាណពីភាពទន់ខ្សោយនៅក្នុងប្រព័ន្ធគ្រប់គ្រង។

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Abstract

Understanding non-compliance with conservation rules is crucial for effective management of marine protected areas. However, monitoring illegal activities is challenging and practitioners require practical methods that minimise biases and costs. We investigated the scale, distribution and motivations for illegal fishing and the level and distribution of patrol effort in the Koh Rong Archipelago Marine Fisheries Management Area one year after its proclamation in Cambodia. To this end, we combined information from records of 161 patrols undertaken between June 2016 and March 2017 and the results of a socio-economic survey conducted in March 2017. One hundred and sixty-three households participated in the socio-economic survey, including 33 fishers. Their responses were compared with data provided by semi-structured interviews with 21 key informants including local fishermen, tourism operators and local organisations. Our results suggest that illegal fishing is mostly conducted by outsiders, occurs mainly at night (when patrols are rare), and is unequally distributed across the seascape. Compliance with the rules of the protected area appeared to be driven by awareness and perceived legitimacy of the rules, whereas the main motivations for illegal fishing included economical or livelihood incentives and a lack of awareness. Drawing from our results, we recommend increasing awareness of and support for the laws of the protected area and improving the efficiency and effectiveness of patrols to discourage rule-breaking behaviour. We also suggest that patrols should target important areas of non-compliance, decrease their predictability and that the proportion of night patrols should be increased. Our study highlights some of the challenges in monitoring non-compliance in marine protected areas and demonstrates how local perceptions can be used to complement data from patrols and identify weaknesses in management systems.

Keywords Illegal fishing, law enforcement, local knowledge, marine protected areas, non-compliance, patrols.

Introduction

The Convention on Biological Diversity's targets for 2020 (CBD, 2010) and more recent Sustainable Development Goals for 2030 (UN, 2015) have led to an increase in the coverage of marine protected areas worldwide (Chape *et al.*, 2005; Roberts *et al.*, 2005; Wood *et al.*, 2008). However, legal designation of marine protected areas cannot be effective without adequate management and high and widespread compliance with their rules and regulations (Campbell *et al.*, 2012; Pieraccini *et al.*, 2017). Non-compliant behaviours such as illegal fishing must be addressed to prevent negative impacts on food security, economic losses, social conflicts, over-exploitation and environmental degradation (MRAG, 2005; BOBLME, 2015).

Constant adaptation and a good knowledge of local context are required to effectively manage non-compliance and combat illegal fishing. It is therefore crucial that protected area managers have an in-depth and current understanding of the specific factors that describe, influence and prevent compliance with the rules of their site (Arias, 2015). However, limited funds (James *et al.*, 2001) and the sensitive and covert nature of non-compliance (Gavin *et al.*, 2010; Arias, 2015) hinder effective monitoring and research of illegal activities in protected areas.

In most protected areas, ranger patrols routinely record information on illegal activities which can be used to determine the scale and characteristics of illegal activities, as well as their spatial and temporal distributions (Gavin *et al.*, 2010). Despite its availability, such data has historically been rarely used to inform management due to the lack of standardisation in collection practices, imprecise spatial references, laborious data-entry and a lack of skills for analysis (van Cayzeele, 2017).

Recently developed systems such as MIST (Management Information System) and SMART (Spatial Monitoring and Reporting Tool) facilitate and standardize data collection, analysis and reporting of patrol records to encourage their use within adaptive management frameworks (www.ecostats.com, http://smartconservationtools.org). However, patrol records are still vulnerable to significant biases that may limit their utility, partly because they are collected opportunistically and because the main objective of patrols is to deter rule-breaking (Keane *et al.*, 2011).

In June 2016, Cambodia designated its first formally established multiple-use marine protected area (i.e. Marine Fisheries Management Area, MFMA) in the Koh Rong Archipelago (KRA) (Mizrahi *et al.*, 2016). Its designation came after more than five years of baseline social and biophysical research alongside intensive consultations and collaborative work with government agencies, NGOs, local authorities, tourism operators and community fisheries (CFis). Across Cambodia, CFis are legally recognised community-based organisations representing local marine resource users (RGC, 2005) and these played a central role in the design and management of the KRA MFMA (Mulligan & Longhurst, 2014; Mizrahi *et al.*, 2016). Due to the absence of regular government patrols, community patrol teams were formed by elected members of CFis within the KRA. Unless accompanied by staff of the Fisheries Administration (FiA), Royal Navy or police, CFi patrol members do not have the authority to enforce the MFMA rules (i.e., give sanctions or arrest offenders) beyond giving verbal or written warnings to offenders. Patrol targets (e.g., total number of patrols to be conducted in the MFMA or parts of the MFMA) are established with support from the FiA and conservation NGOs in monthly and quarterly meetings, whereas the specific routes and timing of patrols is decided by the local CFis and when present on patrols, FiA officers. During patrols, teams record information on illegal activities using a logbook and a hand-held GPS and inform fishers and other users of the rules of the MFMA. All data collected by the patrol teams are later uploaded to a SMART database. These data are analysed by FiA with support from Fauna & Flora International and are reviewed during CFi and management meetings to inform subsequent patrol strategies.

Since the adoption of SMART monitoring, weaknesses associated with poor data collection practices and biases inherent to patrol data have been identified. As the management plan for the KRA MFMA specifies that regular social surveys must be conducted (Mizrahi *et al.*, 2016) to monitor changes in the socio-economic circumstances, perceptions and behaviours of local communities, it was decided to use these to complement non-compliance data obtained from patrol records.

Social surveys using direct questioning are regarded as a cost-effective method to assess illegal exploitation of natural resources and can provide information on many aspects that describe illegal behaviour (Arias, 2015). However, these can experience bias due to the social, legal, or moral controversy of non-compliance (Gavin *et al.*, 2010; St. John *et al.*, 2010; Solomon *et al.*, 2015). While indirect questioning techniques have been developed to reduce respondent sensitivity and minimise such biases, these often require large sample sizes and sophisticated analyses and can be misunderstood by participants (Nuno *et al.*, 2013; Nuno & St. John, 2014). As a consequence, an easier and less costly alternative to reduce sensitivity is to ask respondents about their perceptions of the behaviour of others instead of their own engagement in illegal activities (Bergseth *et al.*, 2015).

Our study combined patrol records and social research methods to investigate illegal fishing in the KRA MFMA and explores the biases and limitations of each approach as well as the benefits of combining multiple methods. Our objectives were to assess the prevalence of illegal fishing and to identify underlying motivations to ultimately inform future management strategies. We also aimed to determine weaknesses in the current enforcement system and to provide recommendations for its improvement by exploring the spatial and temporal distributions of illegal fishing and patrols in the MFMA.

Methods

Study site

The KRA MFMA lies 20 km off the coastal town of Sihanoukville in the Gulf of Thailand and encompasses 403.69 km^2 including fringing coral reefs, seagrass beds and mangroves (Fig. 1). Declared by the Royal Government of Cambodia's Ministry of Agriculture, Forestry and Fisheries, the KRA MFMA aims to "protect, conserve, and use marine fisheries resources sustainably, […] and contribute to poverty reduction" (Mizrahi *et al.*, 2016). The MFMA includes six different management zones

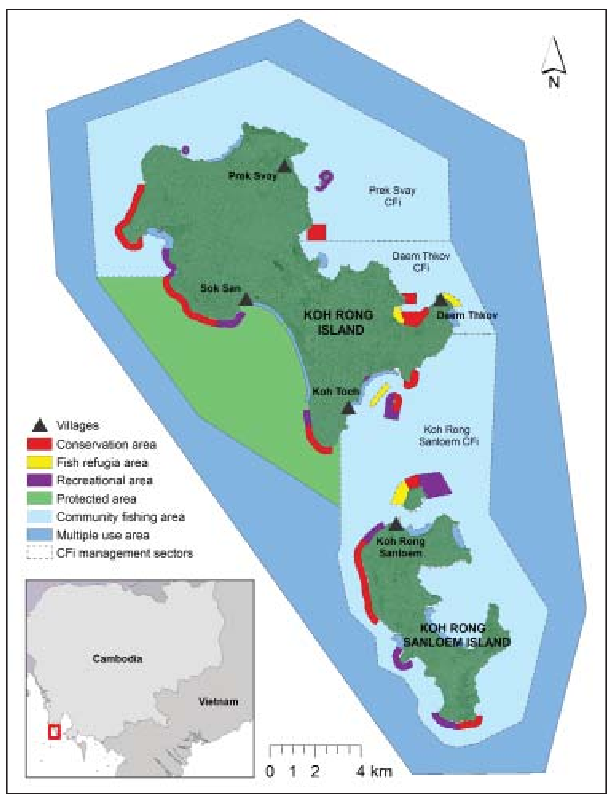

Fig. 1 Koh Rong Archipelago Marine Fisheries Management Area and its management zones.

(Fig. 1; Mizrahi *et al.* 2016). Some zones restrict access (e.g., conservation areas) or only allow non-extractive recreational activities (e.g., recreational areas), whereas others allow non-damaging small-scale fishing (e.g., protected area). Large-scale (i.e., industrial) fishing is forbidden within the entire MFMA, but non-damaging medium-scale fishing (i.e., use of middle-scale and individual fishing gears) is permitted in the outer multiple-use area surrounding the Community Fishing and Protected areas (Fig. 1) (FiA, 2007).

Approximately 546 permanent households occur in the archipelago in five main villages: Prek Svay, Daem Thkov, Koh Toch, Sok San and Koh Rong Sanloem (village chiefs, pers. comm. 2017). For most people, infrastructure for water supply and sanitation is generally poor although road networks and tourism facilities are rapidly increasing (Leng *et al.*, 2017; Mulligan & Longhurst, 2014). Livelihood strategies include fishing and tourism but vary significantly between the five villages (Leng *et al.*, 2017). The recent increase in tourism development, particularly in the villages of Koh Toch and Koh Rong Sanloem, is leading to diversification and changes in livelihoods (Leng *et al.*, 2017).

Although the KRA MFMA is a government-led initiative with a management structure at the provincial level (Preah Sihanouk Province), planning and implementation for the protected area has adopted a co-management approach, with extensive consultation and participation of local stakeholders (Mizrahi *et al.*, 2016). Communities are largely involved in the management and governance of the MFMA through CFis. Three CFis with four community patrol teams exist within the MFMA, one patrol team for the Prek Svay CFi, one for Daem Thkov CFi and two for the Koh Rong Sanloeam CFi (one around Koh Toch and one around Koh Rong Sanloem). The patrol team in Prek Svay occasionally visits waters in the vicinity of Sok San. Patrols typically last 2–3 hrs and occasionally up to 4 hrs. Although CFis members lead these patrols, they cannot enforce the law unless accompanied by officials from FiA (which occurs on approximately half of monthly patrols), the Royal Navy or the police force.

Social survey

A social household survey was conducted across the five main permanent settlements in the KRA in March 2017 as part of a study of local attitudes, awareness and perceptions regarding the MFMA. Structured face-to-face interviews were conducted by three Cambodian assistants, including university students and former staff of conservation NGOs. Overall, 163 households were randomly surveyed from the estimated 546 households present (village chiefs, pers. comm. 2017) (Table 1). Where possible, the survey targeted household heads (usually male, >70% of households). Participants (*n*=51 females and *n*=112 males) were permanent residents of the KRA and ranged between 18 and 73 years in age. These included 77 people working in small local businesses, 45 tourism operators, 33 fishers, two farmers, and six people with other occupations. All interviewees verbally consented to participate in the survey.

Our questionnaire was prepared in English and translated into Khmer language. It included questions on i) the demographics of the respondent and livelihood strategies of their household, ii) their perceptions on nature, timing, spatial distribution and drivers of non-compliance with MFMA rules, and iii) their perceptions on the spatial distribution of law enforcement. Questions were framed in the period since the creation of the MFMA and employed phrases such as "over the last year". All questions were open-ended to avoid influencing respondent answers (Schaeffer & Presser, 2003), though potential responses were pre-coded to facilitate recording and minimize costs of data processing (Lavrakas, 2008). Responses not matching pre-coded options were recorded in Khmer and translated during data entry by bilingual staff. Sensitive questions investigating illegal fishing did not refer to a respondents' engagement in illegal activities but to their perceptions regarding the behaviour of others (Bergseth *et al.*, 2015). This was considered appropriate to avoid bias and evasive answers associated with direct questioning (Warner, 1965; Fisher, 1993) and the technical and financial resources required by other indirect techniques (Nuno & St. John, 2014).

We used participatory-mapping to obtain spatially explicit information on the perceived distribution of illegal fishing and patrols. This entailed use of a gridded map with 511 coded grid cells measuring 1 km^2. Answers were recorded as specific references to grid cell numbers and less specific information such as local area names where the respondent was unable to indicate areas on the map. Ninety-nine participants provided spatial references on the distribution of illegal fishing in the MFMA, although the responses of four participants were excluded due to imprecise references (i.e., "south island" [*n*=1], "western south island" [*n*=2], "north of the north island" [*n*=1]). Our effective sample size thus comprised 95 participants (including 31 fishers and 18 boat and dive operators). Perceived patrol effort distribution was mapped in the same way based on an effective sample size of 65 participants (including 25 fishers and 12 tourism operators). This excluded the responses of 39 participants for being overtly vague (e.g., "everywhere" [*n*=12], "Koh Rong" [*n*=16], "Koh Rong Sanloem" [*n*=6]).

Table 1 Estimated number of households and study sample sizes for five villages in the Koh Rong Archipelago Marine Fisheries Management Area. Figures in parenthesis represent percentages.

	Prek Svay	Daem Thkov	Koh Toch	Sok San	Koh Rong Sanloem	Total
Number of households (village chiefs, pers. comm.)	145 (26.6)	78 (14.3)	103 (18.9)	109 (20)	111 (20.3)	546 (100)
Households interviewed	40 (24.5)	24 (14.7)	33 (20.3)	33 (20.3)	33 (20.3)	163 (100)
Key informant interviews	2	2	6	4	7	21

We complemented, contrasted and contextualised the results of the household survey through semi-structured interviews with 21 local key informants (Table 1). The objective of these interviews was to better understand results obtained from the structured household questionnaire. Foreign tourism operators (*n*=8) and members of local organisations (*n*=2) were recruited as key informants using "snowball sampling" (Patton, 1990). This began with a group of individuals known to the authors who were asked to introduce other individuals. In addition, local fishers (*n*=7) and tourism operators (*n*=4) interviewed for the household survey who were particularly talkative and knowledgeable on the issues raised were also interviewed as key informants. Key informants were considered to be less likely to blame outsiders and were thus useful to contrast information from local fishers and tourism operators. The questions posed to key informants were broad and open-ended and addressed the same topics as the household survey: i) background of respondent, ii) perceptions of illegal fishing, iii) perceptions of law enforcement, and iv) participatory mapping.

Patrol-based data

Patrol routes and illegal activities observed in the KRA MFMA have been systematically recorded using SMART since October 2015. Rangers register their patrol routes using a hand-held GPS and record infractions observed in logbooks. Information on infractions includes the type of offence, its location, actions taken by rangers and information on the offenders (e.g., number and origin of offenders). To ensure comparability with data obtained from the social surveys, only data from patrols undertaken between 16 June 2016 (i.e., the official proclamation of the MFMA) and 16 March 2017 (i.e., the start of the social survey) were included in the study. We also discarded observations which did not clearly refer to illegal fishing (e.g., illegal entry) where possible, because perception data were exclusively based on this infraction.

Data analysis

We used descriptive statistics to analyze data obtained from the household survey. Some responses were re-coded prior to data analysis (Appendix 1). Responses of fishers and other respondents were contrasted using Mann-Whitney U tests for ordinal variables and Chi-square tests for categorical variables, or Fisher's exact test where test assumptions were not met (i.e., when the expected count cell for any combination of variables was <5). Data collected from key informant interviews were analysed qualitatively by scanning, ordering, summarising and comparing participant responses.

We calculated the number of infractions (i.e., illegal fishing) detected per hour of patrol (IDPH) and compared these between day and night patrols. Patrols that lasted less than one hour or over five hours (*n*=15) were excluded due to issues in the recording of their duration. We considered night patrols as those that included at least one hour of patrol effort between 18:00 and 06:00 hrs (i.e., sunset and sunrise). We used Kolmogorov-Smirnoff to test data normality and Mann-Whitney U to test for differences between night and day patrols, as data were not normally distributed.

To analyze the perceived distributions of illegal fishing and patrols, we used the number of people reporting a specific location (i.e., grid cell) as a proxy for the relative intensity of illegal fishing and awareness of patrol occurrence therein, respectively. Actual patrol effort was mapped using the number of patrols recorded per grid cell in SMART. Levels of illegal fishing reported by patrols were calculated as the number of infractions (i.e., illegal fishing) detected per patrol (IDPP). The IDPP map was restricted to a smaller area (151 x 1 km^2 grid cells) than other maps because IDPP could not be calculated for unpatrolled cells (360 x 1 km^2 grid cells). Other maps included all grid cells within the MFMA (Fig. 1). The overall spatial association between perceptions and patrol-data was calculated using Spearman correlation coefficients based on count and IDPP values.

To facilitate visual comparisons of maps, we transformed all variables (i.e., frequency of citations, number of patrols, IDPP) into a common scale with four categories: high, moderate, low and non-existent. We assigned the 3% of grid cells with the highest values to the "high" category and the 10% of cells with the next highest values to the "moderate"category. The remaining grid cells were classified as "low" or "non-existent" (i.e., where values were zero).

We systematically identified hotspot areas in each map. These comprised grid cells within the "high" category and a buffer totalling 35 km². Buffering was considered necessary to prevent unrealistic disagreement between maps because i) patrols surveying a particular location might detect infractions beyond the coordinates recorded due to the extended view-shed at sea, and because ii) spatial references provided by respondents can be imprecise. We assessed the overlap of hotspots between maps using the phi-coefficient statistic, which measures the strength of the relationship between two dichotomous distributions (i.e., presence/absence of hotspots; Brown *et al.*, 2017).

Maps were created using the ArcGIS software v. 9.3.1 (ESRI, USA) and spatial associations were analysed using R software v. 3.4.1 (R Development Core Team, 2017). All other analyses employed IBM SPSS Statistics for Windows v. 23.0 (IBM Corp., USA).

Results

Prevalence of non-compliance in the KRA MFMA

Excluding 17 and 31 respondents who did not know the prevalence of non-compliance among local fishers and outsiders respectively, the majority of respondents (88%) reported that rule-breaking was low among local fishers, whereas 68% reported it as medium or high among outsiders (Cambodians from the mainland, Vietnamese, and Thai) (Table 2). Similarly, all key informants reported low or average levels of illegal fishing among locals but average to high levels among outsiders. One participant supported his statements by showing videos and pictures of non-Cambodian fishers using illegal techniques and fishing in restricted areas.

The perceptions of fishers significantly differed from other respondents (outsider compliance χ^2=13.24, p<0.01; local compliance: F=10.26, p<0.01), with fishers reporting a higher prevalence of illegal fishing. However, the majority of both groups reported that non-compliance is rare among locals (72% of fishers and 93% of other respondents) and occasional or frequent among outsiders (94% and 60%, respectively) (Table 2).

Ranger patrols recorded 38 fishing offences within the MFMA during the study period. According to the SMART database for the MFMA, offenders originated from Sihanoukville Province (n=31), Koh Kong Province (n=3), unknown origin (n=1), and "other" (n=1). The two remaining records lacked information on the origin of the offenders.

Drivers of compliance and non-compliance

A total of 140 and 111 respondents shared their perceptions on the drivers of compliance and non-compliance, respectively (Fig. 2). Thus, 21 respondents reported to not be aware of the factors driving compliance, 35 reported to not know what drives non-compliance, whereas 15 participants did not believe that non-compliance existed in the KRA MFMA.

Legitimacy of the MFMA rules was by far the most reported driver of compliance in the KRA MFMA (82.1% of respondents). Law enforcement through sanctions was the next most cited driver for compliance (29.3%). Norms and morals and economic and livelihood-related incentives were mentioned only occasionally as reasons for compliance. However, economic and livelihood incentives were the most frequently cited drivers of non-compliance (cited by nearly half of respondents), followed by lack of knowledge of the rules, norms and

Table 2 Perceived prevalence of illegal fishing by outside and local fishers in the Koh Rong Archipelago Marine Fisheries Management Area. Figures represent percentages of the number of respondents.

	Illegal fishing by outsiders			Illegal fishing by locals		
	Fishers (n=31)	Others (n=101)	Total (n=132)	Fishers (n=32)	Others (n=114)	Total (n=143)
Low	6.5	39.6	31.8	71.9	93	88.4
Medium	35.5	29.7	31.1	21.9	4.4	8.2
High	58.1	30.7	37.1	6.3	2.6	3.4

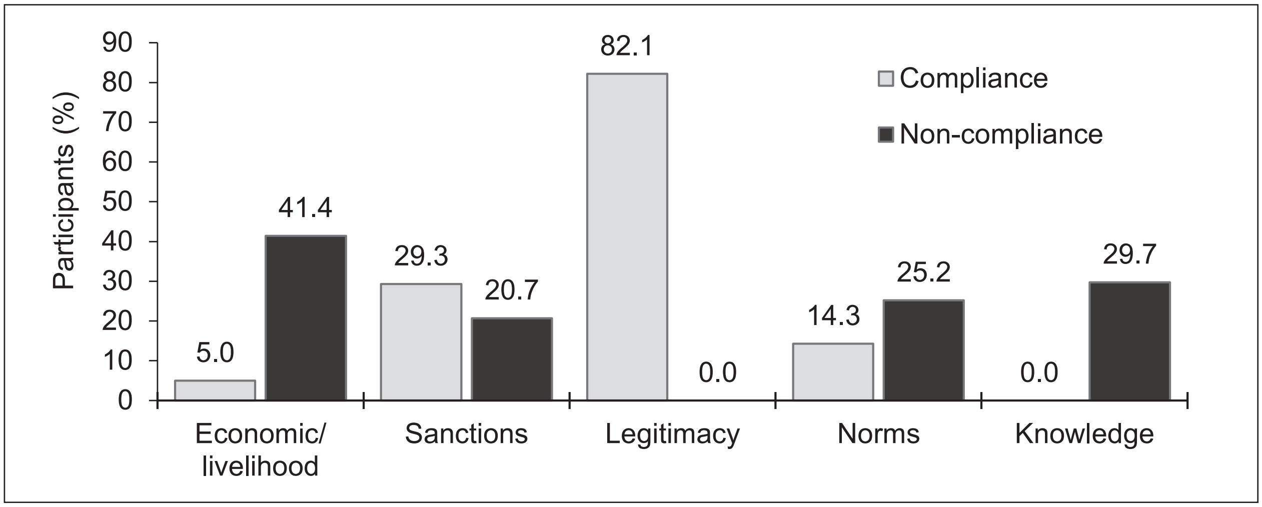

Fig. 2 Drivers of compliance (*n*=140) and non-compliance (*n*=111) among fishers as perceived by residents in the Koh Rong Archipelago Marine Fisheries Management Area.

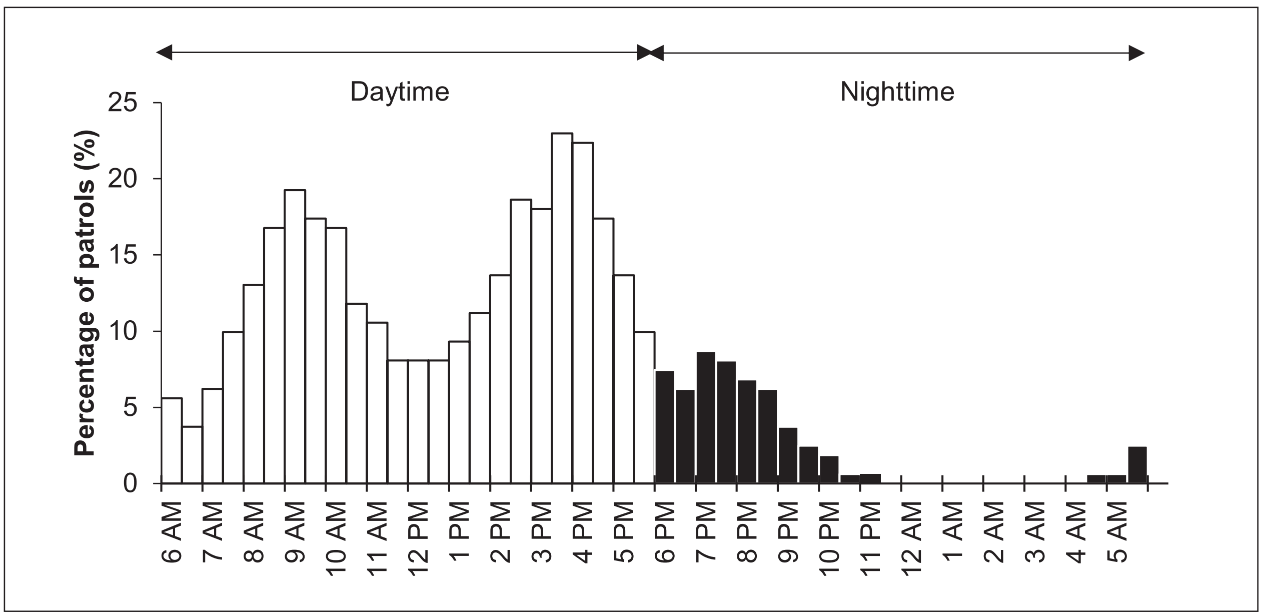

Fig. 3 Hourly distribution of patrols (*n*=94) between June 2016 and March 2017 in the Koh Rong Archipelago Marine Fisheries Management Area.

morals (e.g., "others do not follow the rules", *n*=23) and weak enforcement.

Temporal distribution of non-compliance and enforcement effort

Of 121 respondents, 80.2% believed that illegal fishing occurs mainly at night, 11.6% in daytime and 8.3% perceived no differences between night and day.

There were 161 patrols since the formal proclamation of the MFMA, but only 94 were retained in analysis of patrol timing. The temporal distribution of patrols was highly skewed, with 84.6% occurring in daytime (Fig. 3). Only 6.4% of patrols included at least one hour of night patrolling. However, these registered more than four times as many infractions per patrol hour compared to day patrols (IDPH night=0.711±0.43, IDPH day=0.15 ± 0.34; U=448.5, p=0.001).

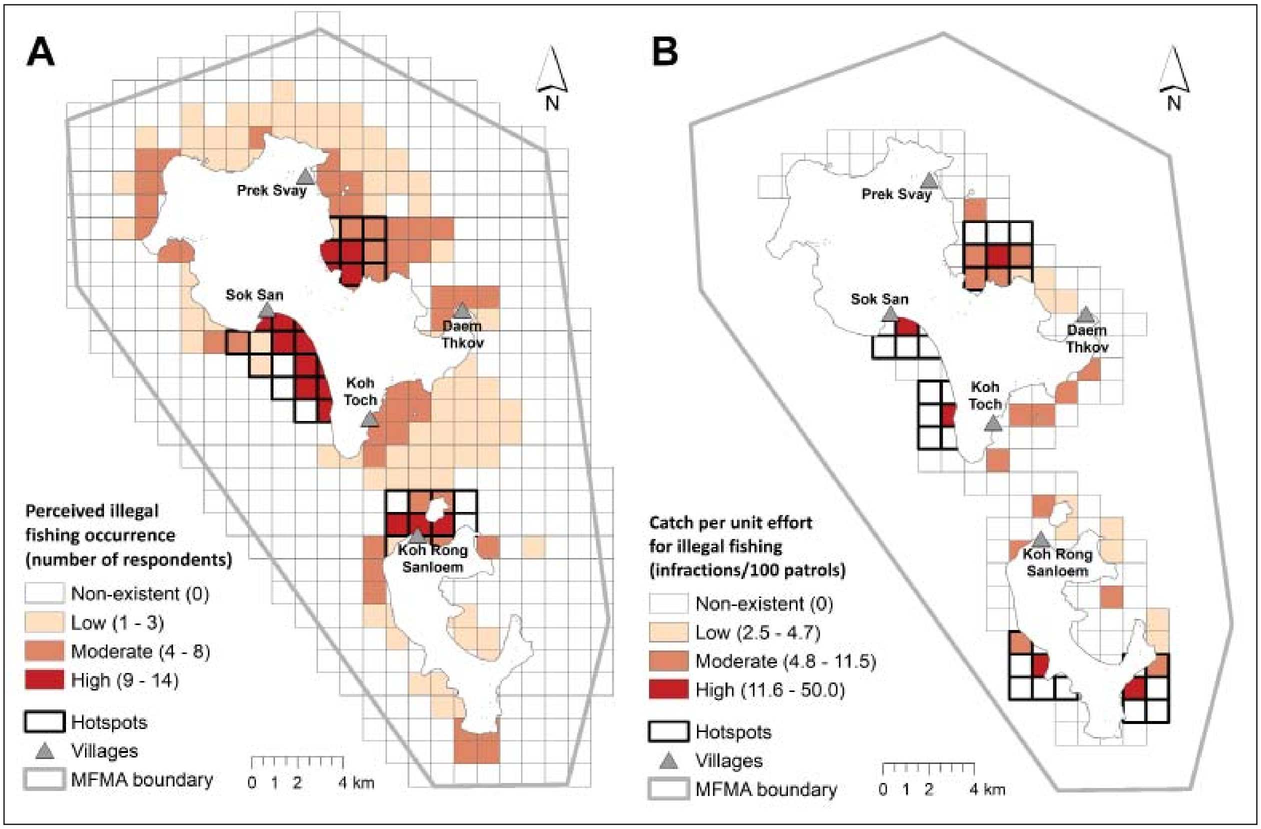

Fig. 4 Distribution of illegal fishing in the Koh Rong Archipelago Marine Fisheries Management Area according to A) local perceptions and B) patrol records.

Spatial distribution of non-compliance and enforcement effort

According to 99 respondents, areas in the vicinity of all villages and most of the coast of Koh Rong Island experienced at least moderate frequencies of illegal fishing (Fig. 4A). The highest levels of illegal fishing appeared to occur in three areas of the MFMA. Two of these were around Koh Rong Island (in the immediate vicinity of Sok San and between Prek Svay and Daem Thkov) and one around Koh Rong Sanloem Island (northern portion of the island).

Illegal fishing hotspots identified using patrol data (Fig. 4B) roughly coincided with those reported by respondents around Koh Rong Island, but no overlap of fishing hotspots around Koh Rong Sanloem Island was observed. There was no global association in the distribution of illegal fishing between patrol data and that reported by respondents (Fig. 4A and 4B; Spearman's *rho*=0.15, $p>0.05$), although hotspots showed low but significant convergence (*phi*=0.39, $p<0.001$).

Most of the 161 ranger patrols undertaken since MFMA designation occurred in the proximity of the Daem Thkov, Koh Toch and Koh Rong Sanloem villages (Fig. 5B). The vicinity of Prek Svay village experienced moderate patrol effort, as did the eastern and northwestern coast of Koh Rong Sanloem Island. Very low or no patrol effort was devoted to the rest of the seascape.

There was a moderate association between the number of people reporting high patrol effort in a grid cell with the actual number of patrols conducted there (Fig. 5A and 5B; Spearman's *rho*=0.54, $p<0.001$). The association was stronger with regard to hotspots of patrol effort and frequently cited grid cells (*phi*=0.69, $p<0.001$).

Discussion

Although understanding illegal behaviour in protected areas is crucial for the design of effective management strategies, the sensitive nature of the topic (Gavin *et al.*, 2010; Arias, 2015) and funding deficits in low-income countries (James *et al.*, 2001) pose challenges to its study and monitoring.

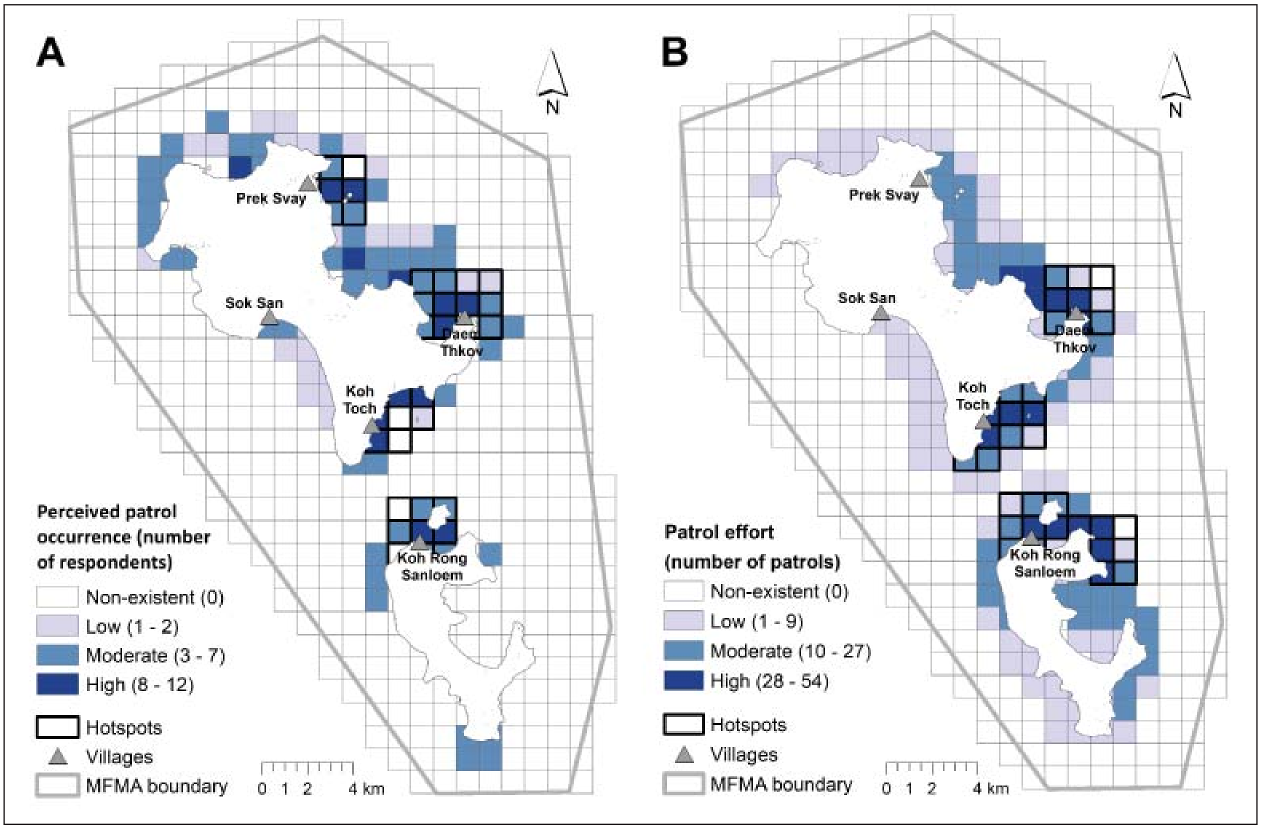

Fig. 5 Distribution of patrols in the Koh Rong Archipelago Marine Fisheries Management Area according to A) local perceptions and B) patrol records.

Our study highlights several challenges to monitoring non-compliance in marine protected areas in the global South and emphasises the need for multiple methods to overcome the weaknesses and biases of different approaches. We consequently discourage exclusive reliance on patrol records to inform management in protected areas because i) illegal activity must be well understood to inform management, including the motivations behind compliant and non-compliant behaviours, ii) the non-random distributions of patrols may lead to important biases in data, and iii) the main objective of patrols should be to deter non-compliance.

Our study is an example of how patrol data regularly collected in a standardised way can be complemented with data on local perceptions to inform strategies aimed at increasing compliance with the rules of marine protected areas. Local perceptions are a cost-effective tool for studying illegal behaviour, particularly in rarely or non-patrolled areas or during periods when patrols are not conducted. They can also be used to determine the drivers of compliant and non-compliant behaviours which are difficult to understand through patrol records alone. Our study further demonstrates that they can be used to identify weaknesses in a management systems, such as the distribution of patrol effort.

Prevalence of non-compliance in the KRA MFMA

We assessed the prevalence of violations within the KRA MFMA using local perceptions and patrol data. The results of both indicate that illegal fishing is prevalent. The large majority of participants in the survey perceived non-compliance as rare among locals but moderately to highly frequent among outsiders, both nationals and foreigners. Although the fishers we interviewed perceived offences as more prevalent than other respondents, all groups rated non-compliance among locals as rare or non-existent. Other studies have also pointed to outside fishers as being responsible for the decline of turtles in the KRA (Diamond *et al.*, 2012) and have criticized the operation of large, foreign vessels in shallow waters (Hamilton, 2012). Our analysis of patrol records reveals a similar pattern, with none of the 38 violations recorded being committed by fishers from the KRA. Greater compliance by locals can be expected due to the involvement of local communities and fishers prior to the MFMA's proclamation, as this likely resulted in higher levels of agreement and a perceived sense of legitimacy of the rules (e.g., Hatcher *et al.*, 2000; Raakjær Nielsen & Mathiesen, 2003; Viteri & Chávez, 2007). Nevertheless, our results must be interpreted cautiously as the two data sources we employed to assess the prevalence of illegal fishing risk underestimating the amount done by local fishers. Given the sensitivity of the subject and because the social survey only included the responses and perceptions of local communities, these could have deflected blame to outsiders to some extent as this has been observed in other marine protected areas (Fabinyi, 2012; von Heland & Clifton, 2015). In addition, as patrols are conducted by local CFis, these could experience pressure to ignore or under-report offences committed by friends, family or neighbours (Abbot & Mace, 1999) or be involved in illegal activities themselves. Additional surveys or key informant interviews with fishers from outside the archipelago would help to further contrast our findings.

Regardless of possible underestimation of illegal fishing by local fishers, low compliance by outside fishers appears to be a major problem for the KRA MFMA. This was supported by statements from key informants with no social ties to local fishers who reported outsiders fishing illegally in the area and provided video and photographic evidence in some instances. The illegal operation of foreign boats in Cambodian waters is also recognised as an issue at the national level and there is generally poor monitoring, control and surveillance of national and foreign vessels in Cambodian waters (Staples, 2017).

Drivers of compliance and non-compliance

Designing effective strategies to address illegal fishing requires an understanding of the factors that motivate compliant and non-compliant behaviours (Gavin *et al.*, 2010; Arias, 2015). Our results indicate that the factors underlying non-compliance in the KRA MFMA include economic and livelihood-related incentives, lack of knowledge of the rules, low influence of norms and morals, and insufficient deterrence through sanctions.

We found economic or livelihood benefits were the most commonly reported driver of illegal fishing. According to rational models of behaviour, when economic gains drive rule-breaking, law enforcement can decrease non-compliance by increasing the costs of such behaviour through economic sanctions and prison sentences (Akella & Cannon, 2004). The need for and effectiveness of law enforcement to combat non-compliance has been previously reported in marine conservation (e.g., Kelaher *et al.*, 2015), and around one-fifth of our respondents believed that the existence of patrols drove compliance within the KRA MFMA. However, to effectively deter illegal activities, enforcement systems need to create economic disincentives that exceed the economic benefits of rule-breaking (Akella & Cannon, 2004). In the case of the KRA MFMA, the limitations of the current enforcement system identified in our study (as follows) likely prevent generation of a sufficient disincentive. This was also the view of 18% of respondents who felt that insufficient enforcement deterrence explained the existence of illegal behaviours.

Lack of knowledge of the MFMA regulations and lack of demarcation were cited as the second most common driver of illegal fishing. Adequate and widespread understanding of the rules is a prerequisite for compliance, although communication-based interventions can also be effective when rules are not understood (Leisher *et al.*, 2012). Although awareness-raising meetings were conducted before and after the MFMA's designation with the local CFis and communities, these have been less frequent in villages lacking a CFi or difficult to access. Additionally, since the meetings only involved local fishers, they would not have influenced the awareness of outsiders.

Legitimacy of the MFMA rules was by far the most commonly reported driver of compliance in the KRA MFMA. This has been shown to be an important prerequisite for compliance in fisheries elsewhere (Hønneland, 2000; Raakjær Nielsen & Mathiesen, 2003; Viteri & Chávez, 2007) and can be strengthened through the involvement of local communities in formation and enforcement of regulations (Jentoft *et al.*, 1998; Pollnac *et al.*, 2001). In the KRA, the extensive consultations with the CFis during MFMA planning and the adoption of a co-management approach after its declaration likely led to high levels of perceived legitimacy and presumably high compliance among local fishers.

Social factors have been found to influence compliance in protected areas (e.g., Eggert & Ellegard, 2003; St. John *et al.*, 2014). Norms in the sense of typical actions, attitudes and expectations on the behaviour and attitude of others can significantly influence individual decisions (Axelrod, 1986). Morals, understood as "internalised norms" according to "perceptions of what is right or wrong" can similarly affect individual behaviour (Hoffman, 1977; Raakjær Nielsen & Mathiesen, 2003). In our study, morals and norms were only occasionally cited as drivers of compliance. For example, few respondents believed that social pressure or concern for future generations motivated fishers to follow the rules. However, one-fifth of respondents felt that social factors were also the cause of illegal behaviour, particularly the perception that rule-breaking was common among many other fishers (i.e., social norms). The prevalence of compliance and non-compliance perceived among peers can influence individual decision-making and encourage compliance as well as non-compliance with conservation rules (Cialdini *et al.*, 1990; Bergseth & Roscher, 2018). In other words, as non-compliance becomes more prevalent, its social acceptability may increase. Conversely, increases in compliance with the rules could lead to further increases of the same through the influence of social norms.

It should be noted that our study did not assess the perceptions of outsiders who were reported by local residents as frequently engaging in illegal activity. We therefore recommend additional key informant interviews or social surveys with outsiders to complement the findings of our work. Given the drivers of compliance and non-compliance perceived by locals, we also believe that illegal behaviours must be addressed through a combination of improved awareness of the rules, clear demarcation of fishing-restricted areas, sustained participation of local communities in MFMA management and effective law enforcement. Although enforcement alone is unlikely to be successful, it is crucial to address commercial-scale illegal activities (Akella & Cannon, 2004) and illegal fishing by outsiders who are difficult to reach in campaigns aimed at increasing awareness and perceived legitimacy of the rules. Moreover, an effective enforcement system could offer fast results by counteracting the economic incentives of illegal fishing while allowing time for other strategies to come into effect (Arias, 2015).

Spatial and temporal distributions of non-compliance and enforcement effort

The effectiveness of enforcement depends on the probability of detection, severity of penalties and chances of prosecution and conviction (Akella & Cannon, 2004). While the latter rely more on legal and political jurisdictions that can be difficult to influence, the probability of detection is mainly technical and site-specific (Arias *et al.*, 2016) and thus more easily managed at the protected area level. This can be improved through greater or more efficient effort. However, patrol effort is often constrained by the associated costs (e.g., McCook *et al.*, 2010) and the limited resources and personnel available in marine protected areas such as the KRA MFMA. Therefore, efforts to increase the efficiency of patrols by better targeting these in space and time must be prioritised.

Identifying the spatial distribution of illegal activities is crucial to target limited enforcement resources to the areas most severely affected. Patrol records are an attractive information source in this regard, being cheap and readily available (Keane *et al.*, 2011). We used patrol records collected since MFMA designation to calculate the number of infractions per patrol and mapped these to identify hotspots that patrols should target. However, some hotspots were located in rarely patrolled areas and therefore might have been erroneously identified due to biases associated with small sample sizes. Moreover, hotspots of illegal fishing may have been overlooked in unpatrolled areas.

The reliability of patrol data can be severely limited when patrol effort is not uniformly distributed (Keane *et al.*, 2011). As the distribution of patrols in the KRA MFMA is highly uneven, with most effort undertaken near villages with operational patrol teams and some areas rarely or never visited, we incoporated the perceptions of local stakeholders—a source of information increasingly recognised by conservation managers (Treves *et al.*, 2006)—in analysis. Assuming that areas that experience greater illegal fishing would be reported by more people, we mapped the perceived distribution of illegal fishing (Fig. 4A) and detected several hotspots, some of which roughly coincided with areas detected by patrols as experiencing high non-compliance (Fig. 4B). However, some incongruencies were apparent between maps based on perception and patrol data. For example, perception data indicated that moderate levels of illegal fishing occur in areas never visited by patrols and therefore not detected by the latter (Fig. 4A vs. Fig. 5B). Additionally, some areas identified as non-compliance hotspots in patrol data were not apparent in perception data. For example, whereas all villages appeared to frequently experience illegal fishing, IDPP values surrounding these were generally low according to patrol data. It is to be expected that areas better known or more visible to respondents such as the vicinity of villages would be reported more frequently than areas rarely visited. This is demonstrated by the perceived low prevalence of illegal fishing in the southern and less accessible part of the MFMA which is remote from the main villages (Fig. 4A). In addition, perceptions may be biased towards conspicuous infractions or those that are known to be illegal (e.g., trawling) by more people. Because perception data are based on personal experiences and second-hand stories from acquaintances (Treves *et al.*, 2006), they must also be interpreted with caution.

We also used local perceptions and participatory mapping to assess the predictability of patrols. These revealed that when an area is patrolled more often, more people become aware of this (Figs 5A & 5B). It consequently follows that if patrol distributions become known to local fishers, these could adjust their activities to avoid highly patrolled areas. However, areas not patrolled in the previous year but patrolled prior to that were also reported as highly patrolled by respondents, suggesting that creation of a deterrence effect may not require continuous patrols.

The temporal distribution of patrols also requires careful planning because fishing may be undertaken at certain times of day to evade detection. Our data indicates that most local respondents believe that illegal fishing mainly occurs at night-time. This could be to evade detection under the cover of darkness or be due to the limited presence of law enforcement teams at this time, or both (Islam *et al.*, 2017). At present however, we cannot determine if the timing of legal fishing differs from illegal fishing. New approaches are being explored to address the limited capacity and infrastructure for fisheries monitoring and management in Cambodia, which will hopefully improve understanding of fishing trends, legal and illegal. Several factors currently prevent night patrols in the KRA MFMA. These include a lack of appropriate equipment and the rare availability of the Royal Navy to ensure the security of local rangers. Our patrol data indicates that just over 5% of patrols included some effort at night and that 85% of patrol hours occurred during the day. Although our data on night patrols were insufficient to draw firm conclusions, it nonetheless suggests that a high percentage of illegal fishing occurs at night. As a consequence, we believe that an increase in the number of night patrols would improve the efficiency and effectiveness of law enforcement in the KRA MFMA. For this to occur however, measures would be required to improve the capacity and ensure the safety of CFi patrol teams.

Overall, our study demonstrates that the effectiveness of law enforcement in the KRA MFMA is limited by a lack of resources and uneven patrol effort. We consequently recommend periodic assessment of patrol records complemented by information from key informants to monitor the distribution of illegal activity and target patrol effort to the greatest effect. Because local communities quickly learn where patrols are undertaken, we also recommend reducing their predictability and maximising patrol areas to prevent displacement of illegal activity to unpatrolled areas. This would also improve the quality of patrol records. Patrols of additional areas may not need to be intensive, as our results suggest that areas frequently visited in the past are still perceived to be highly patrolled by many people.

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References

Abbot, J.I.O. & Mace, R. (1999) Managing Protected Woodlands: Fuelwood Collection and Law Enforcement in Lake Malawi National Park. *Conservation Biology*, **13**, 418–421.

Akella, A.S. & Cannon, J.B. (2004) *Strengthening the Weakest Link: Strategies for Improving the Enforcement of Environmental Law Globally*. Unpublished report, Centre for Conservation and Government, Conservation International, Washington, USA.

Arias, A. (2015) Understanding and managing compliance in the nature conservation context. *Journal of Environmental Management*, **153**, 134–143.

Arias, A., Pressey, R.L., Jones, R.E., Álvarez-Romero, J.G. & Cinner, J.E. (2016) Optimizing enforcement and compliance in offshore marine protected areas: a case study from Cocos Island, Costa Rica. *Oryx*, **50**, 18–26.

Axelrod, R. (1986) An evolutionary approach to norms. *American Political Science Review*, **80**, 1095–1111.

Bergseth, B.J. & Roscher, M. (2018) Discerning the culture of compliance through recreational fisher's perceptions of poaching. *Marine Policy*, **89**, 132–141.

Bergseth, B.J., Russ, G.R. & Cinner, J.E. (2015) Measuring and monitoring compliance in no-take marine reserves. *Fish and Fisheries*, **16**, 240–258.

Bay of Bengal Large Marine Ecosystem Project [BOBLME] (2015) *Review of Impacts of Illegal, Unreported and Unregulated Fishing on Developing Countries in Asia*. Final report to BOBLME-2015-Governance-1.

Brown, G., Strickland-Munro, J., Kobryn, H. & Moore, S.A. (2017) Mixed methods participatory GIS: an evaluation of the validity of qualitative and quantitative mapping methods. *Applied Geography*, **79**, 153–166.

Campbell, S.J., Hoey, A.S., Maynard, J., Kartawijaya, T., Cinner, J., Graham, N.A.J. & Baird, A.H. (2012) Weak compliance undermines the success of no-take zones in a large government-controlled marine protected area. *PLoS ONE*, **7**, 1–12.

Chape, S., Harrison, J., Spalding, M. & Lysenko, I. (2005) Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **360**, 443–455.

Cialdini, R.B., Reno, R.R. & Kallgren, C.A. (1990) A focus theory of normative conduct: recycling the concept of norms to reduce littering in public places. Journal of Personality and Social Psychology, **58**, 1015–1026.

Convention on Biological Diversity [CBD] (2010) *COP 10 Decision X/2. The Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets*. Http://www.cbd.int/decision/cop/default.shtml?id=12268 [accessed 20 June 2017].

Diamond, J., Blanco, V. & Duncan, R. (2012) Knowing sea turtles: local communities informing conservation in Koh Rong Archipelago, Cambodia. *Cambodian Journal of Natural History*, **2012**, 131–140.

Eggert, H. & Ellegard, A. (2003) Fishery control and regulation compliance: a case for co-management in Swedish commercial fisheries. *Marine Policy*, **27**, 525–533.

Fabinyi, M. (2012) *Fishing for Fairness: Poverty, Morality and Marine Resource Regulation in the Philippines*. Australia National University Press, Canberra, Australia.

Fisher, R.J. (1993) Social desirability bias and the validity of indirect questioning. *Journal of Consumer Research*, **20**, 303.

Fisheries Administration [FiA] (2007) *Law on Fisheries*. Unofficial translation supported by ADB/FAO TA Project on Improving the Regulatory and Management Framework for Inland Fisheries, World Wide Fund for Nature and United Nations Development Programme, Phnom Penh, Cambodia.

Gavin, M.C., Solomon, J.N. & Blank, S.G. (2010) Measuring and monitoring illegal use of natural resources. *Conservation Biology*, **24**, 89–100.

Hamilton, M. (2012) Perceptions of fishermen towards marine protected areas in Cambodia and the Philippines. *Bioscience Horizons: The International Journal of Student Research*. Doi 10.1093/biohorizons/hzs007

Hatcher, A., Jaffry, S., Thébaud, O., Bennett, E., Thibaud, O., Thebaud, O. & Bennett, E. (2000) Normative and social influences affecting compliance with fishery regulations. *Land Economics*, **76**, 448–461.

von Heland, F. & Clifton, J. (2015) Whose threat counts? Conservation narratives in the Wakatobi National Park, Indonesia. *Conservation and Society*, **13**, 154–165.

Hoffman, M.L. (1977) Moral internalization: current theory and research. In *Advances in Experimental Social Psychology*, Vol 10 (ed L. Berkowitz), pp. 85–133. Academic Press, New York, USA.

Hønneland, G. (2000) Compliance in the Barents Sea fisheries. How fishermen account for conformity with rules. *Marine Policy*, **24**, 11–19.

Islam, M.M., Shamsuzzaman, M.M., Hoque Mozumder, M.M., Xiangmin X., Ming Y. & Abu Sayed Jewel, M. (2017) Exploitation and conservation of coastal and marine fisheries in Bangladesh: do the fishery laws matter? *Marine Policy*, **76**, 143–151.

James, A., Gaston, K.J. & Balmford, A. (2001) Can we afford to conserve biodiversity? *BioScience*, **51**, 43–52.

Jentoft, S., McCay, B.J. & Wilson, D.C. (1998) Social theory and fisheries co-management. *Marine Policy*, **22**, 423–436.

St. John, F.A.V., Edwards-Jones, G., Gibbons, J.M. & Jones, J.P.G. (2010) Testing novel methods for assessing rule breaking in conservation. *Biological Conservation*, **143**, 1025–1030.

St. John, F.A.V., Mai C.H. & Pei K.J.C. (2014) Evaluating deterrents of illegal behaviour in conservation: carnivore killing in rural Taiwan. *Biological Conservation*, **189**, 86–94.

Keane, A., Jones, J.P.G. & Milner-Gulland, E.J. (2011) Encounter data in resource management and ecology: pitfalls and possibilities. *Journal of Applied Ecology*, **48**, 1164–1173.

Kelaher, B.P., Page, A., Dasey, M., Maguire, D., Read, A., Jordan, A. & Coleman, M.A. (2015) Strengthened enforcement enhances marine sanctuary performance. *Global Ecology and Conservation*, **3**, 503–510.

Lavrakas, P. (2008) *Encyclopedia of Survey Research Methods*. Sage Publications, California, USA.

Leisher, C., Mangubhai, S., Hess, S., Widodo, H., Soekirman, T., Tjoe, S., Wawiyai, S., Larsen, S.N., Rumetna, L., Halim, A. & Sanjayana, M. (2012) Measuring the benefits and costs of community education and outreach in marine protected areas. *Marine Policy*, **36**, 1005–1011.

Leng P., Schneider, H. & West, K. (2017) *Socio-economic Baseline Assessment - Koh Rong and Koh Rong Sanloem, December 2014*. Unpublished report to Fauna & Flora International Cambodia Programme, Phnom Penh, Cambodia.

McCook, L.J., Ayling, T., Cappo, M., Choat, J.H., Evans, R.D., De Freitas, D.M., Heupel, M., Hughes, T.P., Jones, G.P., Mapstone, B., Marsh, H., Mills, M., Molloy, F.J., Pitcher, C.R., Pressey, R.L., Russ, G.R., Sutton, S., Sweatman, H., Tobin, R., Wachenfeld, D.R. & Williamson, D.H. (2010) Adaptive management of the Great Barrier Reef: a globally significant demonstration of the benefits of networks of marine reserves. *Proceedings of the National Academy of Sciences*, **107**, 18278–18285.

Mizrahi, M., Vibol O., West, K., Chea P. & Sokha K. (2016) *Management Plan for the Koh Rong Archipelago Marine Fisheries Management Area 2016–2020*. Fauna & Flora International Cambodia Programme, Fisheries Administration of Cambodia, Phnom Penh, Cambodia.

Marine Resources Assessment Group [MRAG] (2005) *Review of Impacts of Illegal, Unreported and Unregulated Fishing on Developing Countries, Final Report*. Marine Resources Assessment Group, London, UK.

Mulligan, B. & Longhurst, K. (2014) *Research and Recommendations for a Proposed Marine Fisheries Management Area in the Koh Rong Archipelago*. Unpublished report, Fauna & Flora International Cambodia Programme and Coral Cay Conservation, Phnom Penh, Cambodia.

Nuno, A., Bunnefeld, N., Naiman, L.C. & Milner-Gulland, E.J. (2013) A novel approach to assessing the prevalence and drivers of illegal bushmeat hunting in the Serengeti. *Conserva-*

tion Biology, **27**, 1355–1365.

Nuno, A. & St. John, F.A.V. (2014) How to ask sensitive questions in conservation: a review of specialized questioning techniques. *Biological Conservation*, **189**, 5–15.

Patton, M. (1990) *Qualitative Evaluation and Research Methods*. Sage Publications, California, USA.

Pieraccini, M., Coppa, S. & De Lucia, G.A. (2017) Beyond marine paper parks? Regulation theory to assess and address environmental non-compliance. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **27**, 177–196.

Pollnac, R.B., Crawford, B.R. & Gorospe, M.L.G. (2001) Discovering factors that influenced the success of community-based marine protected areas in the Visayas, Philippines. *Ocean & Coastal Management*, **44**, 683–710.

Raakjær Nielsen, J. & Mathiesen, C. (2003) Important factors influencing rule compliance in fisheries lessons from Denmark. *Marine Policy*, **27**, 409–416.

Roberts, C.M., Hawkins, J.P. & Gell, F.R. (2005) The role of marine reserves in achieving sustainable fisheries. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **360**, 123–132.

Royal Government of Cambodia [RGC] (2005) Sub-decree on Community Fisheries Management. Legal document of the Kingdom of Cambodia, Phnom Penh, Cambodia.

Schaeffer, N.C. & Presser, S. (2003) The science of asking questions. *Annual Review of Sociology*, **29**, 65–88.

Solomon, J.N., Gavin, M.C. & Gore, M.L. (2015) Detecting and understanding non-compliance with conservation rules. *Biological Conservation*, **189**, 1–4.

Staples, D. (2017) *National Plan of Action (NPOA) to Combat Marine Illegal, Unreported and Unregulated (IUU) Fishing in Cambodia*. Unpublished report to the Fisheries Administration of Cambodia, Phnom Penh, Cambodia.

Treves, A., Andriamampianina, L., Didier, K., Wilkie, D., Gibson, J., Plumptre, A. & Zahler, P. (2006) A simple, cost-effective method for involving stakeholders in spatial assessments of threats to biodiversity. *Human Dimensions of Wildlife*, **11**, 43–54.

United Nations [UN] (2015) *Sustainable Development Goals*. Https://sustainabledevelopment.un.org/?menu=1300 [accessed 22 January 2018].

Van Cayzeele, C. (2017) *Understanding the spatiotemporal patterns of poaching from ranger patrol data in Golestan National Park, Iran*. MSc thesis, Georg-August-Universität Göttingen, Germany.

Viteri, C. & Chávez, C. (2007) Legitimacy, local participation, and compliance in the Galápagos Marine Reserve. *Ocean and Coastal Management*, **50**, 253–274.

Warner, S.L. (1965) Randomized response: a survey technique for eliminating evasive answer bias. *Journal of the American Statistical Association*, **60**, 63–69.

Wood, L.J., Fish, L., Laughren, J. & Pauly, D. (2008) Assessing progress towards global marine protection targets: shortfalls in information and action. *Oryx*, **42**, 340–351.

Appendix 1 Categories for responses on perceived drivers of compliance (+) and non-compliance (-)

Category	**+/-**	**Response**
Economic/livelihood	+	They are afraid [illegal fishing] will impact tourism.” “[Complying with the rules] will lead to increases in income and jobs.” “They do not need to do illegal fishing because their income has diversified and is obtained through various sectors.” “They cannot afford illegal gear.”
	-	“There are more or more profitable resources in restricted areas.” “Illegal gear is more efficient than legal gear.” “Fishing legally is not profitable.” “The prices of fish are high and want to maximise catch to maximise benefits.” “They want the personal (economic) benefit.” “There is a higher demand for fish.” “They receive pressure from their bosses.” “They are poor and have no alternative.”
Sanctions & deterrence	+	“They are scared of being caught by the patrols.”
	-	“There is a low probability of being caught/being punished.” “They are not scared of patrols because they have the support of powerful men.”
Legitimacy of rules	+	“They support and accept the rules.”
	-	

Appendix 1 Continued

Category	+/-	Response
Norms and morals	+	"Other people comply with the rules." "Illegal fishing is not accepted by the community." "They want to protect resources for the coming generations."
	-	"The resources will not end." "It is their way of living, and they do not care." "They do whatever they want, they do not care, they are thieves." "Other fishers do not follow the rules."
Knowledge of the rules	+	
	-	"They did not participate in the information meetings." "They do not know the rules."

Fish species diversity and assemblage structure in seasonal wetlands in the dry dipterocarp forests of Kulen Promtep Wildlife Sanctuary, Cambodia

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មូលន័យសង្ខេប

ព្រៃរបោះ (Dipterocarp forest) ជាព្រៃដែលគេប្រទះឃើញមានច្រើននៅទំនាបភាគខាងជើងនៃប្រទេសកម្ពុជា ប៉ុន្តែមានការយល់ដឹងតិចតួចនៅឡើយអំពីមច្ឆជាតិដែលរស់នៅតាមរដូវ នៅតាមដីសើមនៃព្រៃប្រភេទនេះ។ ជាមួយនឹងសម្ពាធកើនឡើងទៅលើធនធានតំបន់ដីសើមនៅក្នុងប្រទេសកម្ពុជា ព័ត៌មានស្តីពីតម្លៃនៃតំបន់ដីសើមទំហំតូចគឺជាភាពចាំបាច់។ យើងបានពិពណ៌នាពីសមាសភាពត្រីនៅតំបន់ដីសើមក្នុងដែនជម្រកសត្វព្រៃគូលែនព្រហ្មទេព ដោយផ្អែកលើការប្រមូលទិន្នន័យនៅដើមរដូវវស្សា ក្នុងរដូវវស្សា និង រដូវប្រាំងនាអំឡុងឆ្នាំ២០១៥ ដល់ ២០១៦។ ចំនួនត្រីសរុប១៨៩៥ក្បាល ត្រូវជា៥៣ប្រភេទ និង ១៧អម្បូរត្រូវបានចាប់។ សមាសភាពរបស់ត្រីមានភាពសម្បូរបំផុតនៅអំឡុងរដូវវស្សា ផ្អែកលើការវិភាគទិន្នន័យតាមម្មវិធី Shannon-Weiner index និង Species richness។ យើងមិនអាចធ្វើការញែកអំពីសមាសភាពត្រីក្នុងរដូវផ្សេងគ្នាបានទេ តាមកម្មវិធីវិភាគទិន្នន័យ non-metric multi-dimensional scaling ដោយសារភាពខុសគ្នាក្នុងដំណើរការប្រមូលទិន្នន័យរវាងរដូវប្រាំង និង រដូវវស្សា។ គ្មានភាពទំនាក់ទំនង(correlation)គ្នាគួរឲ្យកត់សម្គាល់ទេ រវាងតំបន់ដីសើម(log-transformed wetland areas) និង នានាភាពដែលបានវាស់វែង(diversity measure) ទោះបីជាជម្រៅទឹកអតិបរមា និង នានាភាពមានទំនាក់ទំនងគ្នាគួរឲ្យកត់សម្គាល់ និង ជាវិជ្ជមានក៏ដោយ។ ម៉ូឌែលBinomial generalized linear models ត្រូវបានប្រើដើម្បីកំណត់ឲ្យដឹងថា តើរដូវ ភាពភ្ជាប់ជាមួយនឹងប្រភពទឹកជាអចិន្ត្រៃយ៍ ឬ ជម្រៅទឹកអតិរមាមានភាពជាប់ទាក់ទងទៅនឹងត្រីទាំងប្រាំប្រភេទដែលសម្បូរជាងគេឬទេ។ គ្មានម៉ូឌែលណាមួយបានបង្ហាញពីភាពមានទំនាក់ទំនងគ្នាគួរឲ្យកត់សម្គល់នោះទេ បើទោះជាជម្រៅទឹកគឺជាម៉ូឌែលដែលបង្ហាញពីភាពមានទំនាក់ទំនងគ្នាសម្រាប់ប្រភេទត្រីនីមួយៗក៏ដោយ។ លទ្ធផលនៃការសិក្សានេះបង្ហាញថា ជម្រៅទឹកអាចជាកត្តាមួយយ៉ាងសំខាន់ដែលមានឥទ្ធិពលទៅដល់ភាពសម្បូរបែបនៃសមាសភាពត្រី និង វត្តមានរបស់ប្រភេទដែលសម្បូរទាំងឡាយនៅក្នុងតំបន់ដីសើមតាមរដូវ។ វិធីសាស្ត្រប្រមូលទិន្នន័យសាកល្បងរបស់យើង ក៏អាចបង្ហាញពីវិធីសម្រាប់ធ្វើការវាយតម្លៃតំបន់ដីសើមតូចៗនៅក្នុងតំបន់ ហើយយើងផ្តល់នូវអនុសាសន៍សម្រាប់ធ្វើការកែលម្អវិធីសាស្ត្រទាំងនេះឱ្យកាន់តែល្អប្រសើរ។

Abstract

Dipterocarp forests are common in the northern plains of Cambodia, but little is known about the fish that occupy seasonal wetlands in these. With pressures increasing on Cambodian wetland resources, more information is needed on the value of small wetlands. We describe fish assemblages in seasonal wetlands in Kulen Promtep Wildlife Sanctuary based on sampling completed during the early-wet, wet and dry seasons in 2015–2016. A total of 1,895 fish were captured, representing 53 species in 17 families. Fish assemblages were most diverse during the wet season according to the Shannon-Weiner index and species richness. We were not able to identify distinct seasonal assemblages using non-

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metric multi-dimensional scaling, which may have been due to differences in sampling effort between seasons. There was no significant correlation between log-transformed wetland area and diversity measures, although correlations between maximum water depth and diversity were significant and positive. Binomial generalized linear models were used to examine whether season, connectivity to permanent water bodies (categorical) and maximum water depth were related to presence of the five most common species. None of the models revealed significant relationships, although depth was in the best fit model for each species. These results indicate that water depth may be important in influencing the diversity of fish assemblages and presence of common species in seasonal wetlands. Our pilot of rapid sampling methods can inform protocols for assessing small wetlands in the region and we provide recommendations for improving these methods.

Keywords Forest, intermittent wetlands, Shannon–Weiner diversity index, species richness.

Introduction

Over 30% of Cambodia is covered by wetlands (Kosal, 2004) which are important habitats for humans and wildlife. Cambodian wetlands provide numerous ecosystem services including food, medicines, firewood, irrigation water, aquaculture, tourism, transportation, flood protection and habitat for endangered species (Kol, 2003; Loeung *et al.*, 2015). Freshwater fish and fish products account for a relatively high portion of total protein consumed in Cambodia (Needham & Funge-Smith, 2015) and seasonally-inundated wetlands provide breeding, nursery and feeding habitats for these. Wetland fish also provide ecosystem services beyond food security (Cowx & Portocarrero Aya, 2011), such as supporting piscivorous wildlife. The rapid development and land use changes currently occurring in Cambodia are increasing pressures on wetland resources and highlight the need for more information on their values.

The lower Mekong River Basin has a monsoonal climate with a dynamic annual flood pulse and the productivity of wetlands in the region depends on the substantial differences between the wet and dry seasons (Kosal, 2004). During the wet season, flooding occurs in forested areas of Cambodia and receding waters are retained in seasonal wetlands that persist into the dry season (Kol, 2003). Deciduous dipterocarp forests in Cambodia are generally understudied and under-protected (Wohlfart *et al.*, 2014), but are common across the Northern Plains where an estimated 12,000 wetlands exist (Barzen, 2004). While descriptions of fish assemblages exist for the floodplains of the Tonle Sap Lake (e.g., Campbell *et al.*, 2006) and flooded forest habitats adjacent to the Mekong River (e.g., Baird, 2007), little information is available for the many seasonal wetlands scattered across the Northern Plains.

Understanding what influences the structure of wetland fish assemblages is valuable because they may not form a single management unit and a large variety of wetlands may need to be conserved to adequately represent fish species diversity within a region (Pazin *et al.*, 2006). Seasonal wetlands can become harsh environments for fish if they are disconnected during the dry season (e.g., low oxygen, high water temperatures, exposure to predation, complete loss of water) and these stresses can structure aquatic communities. Studies of habitat relationships with fish assemblages in seasonal wetlands have had mixed results. For instance, Fernandes *et al.* (2010) examined the influence of depth, vegetation biomass and distance from permanent water bodies on fish in temporary wetlands in Pantanal, Brazil and found a positive relationship between water depth and species richness, but no relationship with the linear distance from the nearest permanent water body. Another study of seasonal wetlands in Florida revealed that connectivity with permanent water bodies was the dominant influence on fish assemblages, but that correlated variables such as depth and hydro-period were also important (Baber *et al.*, 2002). In artificial and natural depressions adjacent to the Oueme River in Africa, fish communities were dominated by piscivores tolerant of hypoxia during low water periods, indicating that these communities were likely influenced by dissolved oxygen and predation or both. Consequently, understanding the relationships between wetland characteristics and fish assemblages can help to determine how human activities that influence these characteristics may also affect fish and their ecosystem services.

This paper was prepared as part of a multi-disciplinary project that sought to advance understanding of the value of wetland ecological functions and ecosystem services through a rapid assessment of seasonal wetlands in the dry dipterocarp forests of Cambodia and Vietnam. The purpose of project in Cambodia was to provide managers at the Ministry of the Environment and the Kulen Promtep Wildlife Sanctuary with baseline information to inform effective management and establish a basis for more extensive studies in the future.

Our study had three objectives: 1) to describe the fish diversity and assemblages of wetlands sampled, 2) to explore how variations in wetland size (area and maximum water depth) and connectivity (isolated or connected) influence fish diversity and the presence of the most common fish species, and 3) to pilot rapid sampling methods that could be used in protocols for sampling small, seasonal wetlands throughout the Mekong River Basin. We are unaware of any previous systematic surveys of fish in the seasonal dry forest wetlands in Cambodia, and so our overall aim was to improve understanding of the value of this ecosystem and inform its management.

Methods

Study Area

Our study was undertaken in Kulen Promtep Wildlife Sanctuary (KPWS), Cambodia's largest protected area, which is located in the country's Northern Plains (Edwards, 2012; Fig. 1). The sanctuary covers 4,099 km^2 and is managed by the Ministry of Environment with assistance from the Wildlife Conservation Society, which has supported ecotourism and efforts to improve livelihoods of communities inside the sanctuary through conservation-friendly rice cultivation (Souter *et al.*, 2016). The wildlife sanctuary is situated in the upper Stung Sen River catchment, a tributary of the Tonle Sap Lake.

We used rapid sampling techniques to gather data on wetlands in KPWS. Fish sampling was conducted near four communities (Tmart Boey, Rum Check, Sambour and Prey Veng) within the sanctuary in Preah Vihear Province. Landcover in this part of Preah Vihear mainly comprises open deciduous dipterocarp forests, grassland savannah and seasonal wetlands. Wetlands for sampling were selected to cover a range of habitat types based on interviews with village leaders.

Sampling was undertaken in June 2015 (early-wet season), October 2015 (wet season) and January 2016 (dry season). The wet season was considered to occur from June through October and the dry season from November through May. Sampling in June 2015 and January 2016 included our entire team, whereas October 2015 comprised sampling for fish diversity only. Consequently, some our analyses are limited to the early-wet and dry seasons when broader datasets were gathered.

Fish collection

Wetlands are dynamic environments that can be difficult to sample for fish (Kaller *et al.*, 2013). Those with underwater vegetation are especially difficult to sample because the vegetation can get in the way and capture

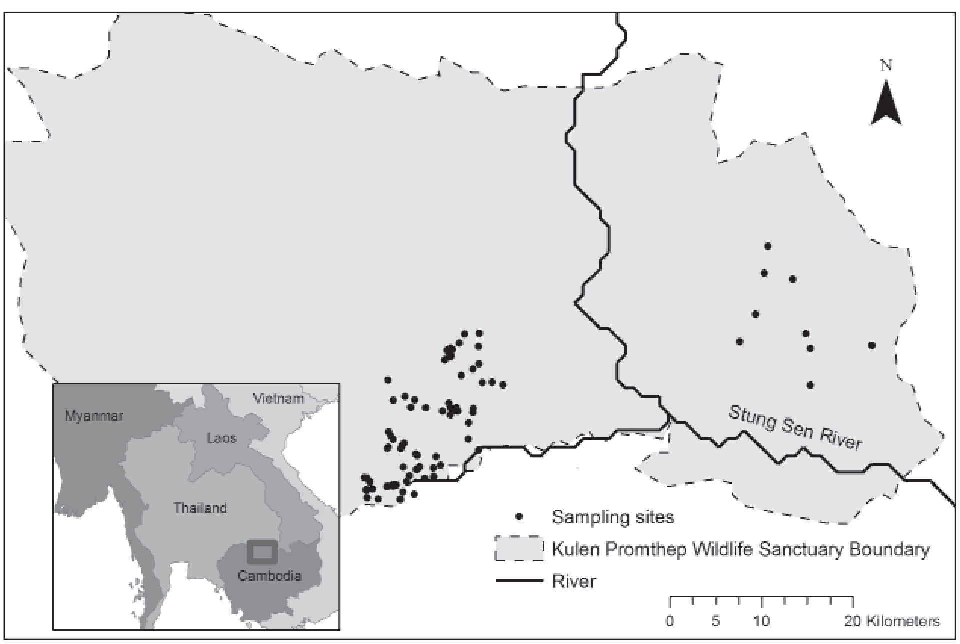

Fig. 1 Sampling sites at Kulen Promtep Wildlife Sanctuary for which GPS data were available.

efficiency can vary by gear type (Knight & Bain, 1996). We used a combination of gear types to address these challenges and employed a rapid survey approach with active sampling methods because each wetland was typically visited for one hour or less due to time constraints. Consequently, active gear methods were used at all wetlands where water was found and passive sampling gear was used opportunistically where time permitted.

In active sampling, we first used backpack electrofishing for up to 10 minutes in each wetland, depending on the size of the water body. As some were very small (i.e., less than 2 m^2 in area), less than ten minutes was considered sufficient for sampling. In shallow wetlands where researchers could wade, electrofishing was undertaken in zig-zag transect lines across the centre of the wetland from one end to the other. For deeper wetlands where researchers could not wade, electrofishing was confined to areas along the shoreline. Start and end times were recorded to calculate the associated effort. Second, we also used a 1.2 x 3.7 m polyethylene fibre seine net with 0.64 cm mesh (Frabill, Plano, USA) to sweep-sample each wetland. To this end, two people completed a five-metre pass adjacent to the shoreline which was undertaken three times at each site, for a total seine distance of 15 m, covering different areas each time where possible. While some of the sampling gear we employed is prohibited for fishing in Cambodia, its use was permitted in our study by the Inland Fisheries Research and Development Institute (IFReDI) and KPWS and staff from both organisations participated in the sampling.

Our survey was intended to be rapid, but where time allowed, passive sampling gear (i.e., gill nets and minnow traps) were deployed at sites with a water depth of >30 cm to obtain further data on species presence. As these gears were not consistently used, the data are not included in analysis apart from summary information on overall species richness and total abundance of each species. Gill nets (mesh size 1.5 cm and 1.25 cm) were set across the deepest parts of wetlands if these were small, or in waist-deep water near the shore if they were large. The gill nets were left in the water for at least 30 minutes. Four minnow traps (Primer TR-501; 25.4 x 25.4 x 45.7 cm; Gardena, USA) were set in wetlands sufficiently deep to submerge the trap opening. Each trap had two entrances (6.35 cm in width) and a piece of bread or ball of sticky rice was placed into the bait pocket inside. Where possible, wetlands sampled with the traps were divided into four approximately equal quadrants with one minnow trap placed in the centre of each. If the wetland was prohibitively large, individual traps were deployed at least 5 m apart along the shore line, close to where active sampling took place. Traps were left to soak for at least 30 minutes. The start and end times of gill net and minnow trap deployments were recorded.

Sample processing

Fish were collected alive and processed separately by sampling gear at each site. Each fish was identified to species based on Rainboth (1996), Vidthayanon (2008), and an unpublished IFReDI fish identification guide. Where species identification was uncertain, the individual was preserved in ethanol for later identification at the IFReDI laboratory. All other fish were released alive into the wetlands following processing, which included photographs of individuals of most species. Fish names in this study follow valid species names in Eschmeyer *et al.* (2016).

Habitat characteristics

Data on wetland size and connectivity were recorded at each wetland during the June 2015 (early wet season) and January 2016 (dry season) sampling.

Wetland length and width were measured in metres in the field (longest diameter either way) for smaller wetlands. These measurements were multiplied to give an estimate for wetland area. When too large to measure this way, the surface area of wetlands was derived from GPS tracks of the boundary or from satellite images. Water depth was measured in centimetres at one metre intervals along a profile transect from the edge to the centre of each wetland. The deepest point along the transect was taken as the maximum depth for a wetland. Wetlands deeper than approximately 1.5 m were not measured further for depth. Wetlands were recognized as either ‘connected‘ (via channel or sheet flow from a nearby river) or ‘isolated’. In the early wet season, connectivity was determined through site-based observations. As this was not always clear during the dry season however, connectivity with a permanent water body during this period was sometimes assigned using information obtained from local villagers or field guides familiar with the site.

Analysis

The extent of fish occupation in each season was determined by comparing the percentage of inhabited wetlands between the three sampling periods. The relative abundance of each wetland was calculated as the combined total of fish recorded from the two active sampling methods (electrofishing and seine nets) undertaken at every site.

We calculated species diversity metrics for all three sampling periods, although analyses of relationships between diversity and wetland characteristics were confined to the early-wet and dry season sampling events (when these data were collected). Species diversity was examined using two metrics based on data from electrofishing and seine netting: species richness (total number of species per wetland) and the Shannon–Weiner diversity index (*H*'). The Shannon-Weiner index was calculated for all wetland sites where fish were collected using the Vegan package in the R statistical programme (R Core Team, Austria). Pearson's correlations were used to explore relationships between wetland size and diversity metrics.

Use of a linear mixed-effect regression model was initially considered in analysis, but plots of relationships between species diversity, richness and wetland size and depth did not indicate any patterns for isolated and connected wetlands that warranted such a model. Binomial generalized linear models were consequently employed to examine whether sampling season, wetland connectivity and depth were related to the presence and absence of the five most common fish species. These species were selected because they represented the vast majority of the catch and were the only species that individually comprised >5% of the total catch. Sample sizes for other species were too small to justify such analysis.

Prior to model development, correlation analysis was undertaken to test for multi-collinearity between wetland size and depth. A positive correlation was found between maximum depth and the log-transformed wetland size (Pearson's correlation: df=15, r=0.66, p=0.004). Wetland area was not necessarily a good indicator of water volume because different approaches were used to generate these data and water depth measurements might better reflect the water volume of a wetland during sampling. Because the two variables were correlated, depth was employed in candidate models. Because depth data were not collected from a few sites where fish were sampled, our dry season analysis was confined to 17 sites where both types of data were available (Table 1). Eight candidate models were tested for each species: 1) null, 2) season, 3) connectivity, 4) depth, 5) connectivity + depth, 6) season + depth, 7) season + connectivity, and 8) season + connectivity + depth. Model selection was performed using Akaike's Information Criterion (AIC) to determine the best model or set of models for each species. The AIC scores were used to quantitatively rank each model and the model with the lowest AIC value (AICmin) was considered the best. Differences in using Akaike's Information Criterion (AIC) from the lowest value were calculated as Δi=AICi−AICmin.

Non-metric Multidimensional Scaling (NMDS) was applied using the 'metaMDS' function in the Vegan package of R software to visualize differences in species assemblages between sampling sites based on Bray-Curtis dissimilarity values. This analysis was confined to data from active sampling methods and only included species found in more than two sites. Clusters of similar assemblages were defined in the visual analysis to distinguish the separate seasons. Three dimensions produced adequate configuration between observed dissimilarity and ordination stress.

Cluster analysis was used to examine whether certain species assemblages occurred due the connectivity categories of the wetland (connected vs. isolated). Bray-Curtis dissimilarities were calculated using data from the January 2016 dry season using the 'vegdist' function in the Vegan package of R software. An agglomerative hierarchical clustering analysis using the 'hclust' function in R with a complete-linkage algorithm was used to characterize fish assemblages in the dry season alone based on log-transformed abundance data from active sampling (n=20 sites). This was done because our early-wet season sample size was too small to analyze this way and because our wet season dataset lacked connectivity data. Complete-linkage looks at similarity between a sample and the farthest member of its cluster, which

Table 1 Summary characteristics of wetlands sampled at Kulen Promtep Wildlife Sanctuary. Area and depth data were not collected at all sites (sample sizes are given in parentheses). [1] Three sites had water deeper than 100 cm.

Season	No. of sample sites	No. of sites with fish	Connected / isolated	Size (m^2)	Maximum depth (cm)
Early-wet (June 2015)	5	4	2 / 3	896–12,821 (4)	28–63 (3)
Wet (October 2015)	13	12	n/a	n/a	n/a
Dry (January 2016)	23	20	12 / 11	305–425,258 (17)	10–124 (17[1])
Total	41	36			

tends to produce tight, compact clusters (Krebs, 1999). Isolated sites were labelled separately and the data were visually examined using a dendrogram to identify clear groupings of assemblages that corresponded to our connectivity categories.

Results

Species composition and relative abundance

A total of 41 sites were sampled in KPWS for fishes during the early-wet (*n*=5), wet (*n*=13) and dry (*n*=23) seasons (Table 1). We were not able to sample all sites visited, because although 56 sites were visited during the early-wet season, most did not contain water yet. Fish were present in 80%, 92%, and 87% of wetlands sampled in the early-wet, wet and dry seasons, respectively. The mean relative abundance of fish (combined data for all species from active sampling methods) was highest in the early-wet season with 56 fish per wetland (SD=56.53; Table 2), which was highly influenced by a single wetland which included 120 individuals of *Trichopodus trichopterus*. In general, there was high variability in fish abundance between wetlands in all seasons.

Combining data from all sampling methods (passive and active), a total of 53 species arranged in 32 genera and 17 families were represented among the 1,895 fish captured (Table 3). All species recorded were native to Cambodia and included one Near Threatened (*Clarias macrocephalus*) and one Vulnerable (*Oxygaster pointoni*) taxon according to the IUCN Red List, in addition to one species considered rare in Cambodia (*Puntigrus partipentazona*). *Trichopodus trichopterus* was found in the greatest number of wetlands (85% of sites sampled) and was captured in all seasons. This was also the most common species encountered, comprising 22.3% of all fish, particularly during the early-wet season. *Trichopsis vittata* was also common in the wet (October) and dry (January) seasons and occasionally in the early-wet season. This occurred at 83% of sites and comprised 11.8% of all individuals. *Esomus metallicus* (present at 66% of sites) and *Rasbora paviana* (68%) were similarly common, comprising 13.7% and 13.4% of all individuals respectively, although neither was captured in the early-wet season. Following these, *Rasbora borapetensis* comprised 7.4% of all individuals (present 34% of sites) and *Anabas testudineus* was frequently encountered in all seasons (at 66% of sites), although at lower abundances (3.6% of all individuals).

Ordination results (NMDS stress=0.123; Fig. 2) based on the standardized abundance of fish species recorded in active sampling did not exhibit distinct seasonal clusters and differences were mostly driven by sites dominated by a single species. The early-wet season contained the most distinctive group, but this was driven mainly by one site (KP28) where a single *Monopterus albus* was captured. The early-wet season also had a very low sample size (four sites where fish were captured) compared to other seasons. One dry season site (KP103) only had abundant *A. testudineus*, while another (KP92) contained many *T. vittata*. In the wet season, three sites (KP122, KP123, KP124) each contained *E. metallicus* and different *Trichopsis taxa*, although *E. metallicus* was found in both the wet and dry seasons. Our analysis included species captured at three or more sites, but when all species were included the resulting clusters were even less distinct by season. Excluding sites with a single species (*n*=3), ordination results (NMDS stress = 0.133; Figs 3–4) appeared as concentric polygons, the largest of which was the dry season which had the greatest variation in species. However, this was also the season with the greatest number of samples, whereas the season with the least variability also had the lowest number of samples (early-wet season).

Fish richness and diversity

Based on active sampling methods, the maximum species richness per wetland was 12, 15 and 15 species in the early-wet, wet and dry seasons respectively. Individual

Table 2 Fish abundance, species richness and diversity (Shannon-Weiner *H'*) of wetlands in Kulen Promtep Wildlife Sanctuary by season. Figures given in parenthesis represent standard deviation.

Season	Abundance		Diversity		Species richness	
	Mean	Range	Mean	Range	Mean	Range
Early-wet (June 2015)	56.00 (56.53)	1–135	1.01 (0.93)	0.00–2.07	6.25 (4.50)	1–12
Wet (October 2015)	30.25 (20.69)	2–80	1.39 (0.72)	0.16–2.43	7.50 (4.81)	2–15
Dry (January 2016)	45.70 (77.77)	2–362	1.10 (0.61)	0.00–2.36	5.40 (3.66)	1–15

Table 3 Fish species richness and abundance by season in Kulen Promtep Wildlife Sanctuary based on active and passive sampling methods. Status: LC=Least Concern, DD=Data Deficient, NA=Not Assessed, NT=Near Threatened, VU=Vulnerable.

No.	Family, Species	Status	Season			Total
			Early-Wet	Wet	Dry	
	Ambassidae					
1	*Parambassis apogonoides*	LC			1	1
	Anabantidae					
2	*Anabas testudineus*	DD	7	15	47	69
	Bagridae					
3	*Mystus atrifasciatus*	LC		1		1
4	*Mystus multiradiatus*	LC			9	9
5	*Mystus mysticetus*	LC		7	5	12
	Balitoridae					
6	*Nemacheilus pallidus*	LC			1	1
	Belonidae					
7	*Xenentodon* sp.	N/A		1	1	2
	Channidae					
8	*Channa gachua*	LC	1	2		3
9	*Channa striata*	LC	6	4	5	15
	Clariidae					
10	*Clarias batrachus*	LC			2	2
11	*Clarias macrocephalus*	NT			1	1
	Cobitidae					
12	*Lepidocephalichthys hasselti*	LC	3	3	26	32
	Cyprinidae					
13	*Amblypharyngodon chulabhornae*	LC		1	3	4
14	*Barbodes aurotaeniatus*	LC	4	19	67	90
15	*Cyclocheilichthys apogon*	LC		7	4	11
16	*Cyclocheilichthys armatus*	LC		6	6	12
17	*Cyclocheilichthys lagleri*	LC			6	6
18	*Esomus longimanus*	DD		2		2
19	*Esomus metallicus*	LC		48	212	260
20	*Henicorhynchus lobatus*	LC			2	2
21	*Henicorhynchus siamensis*	N/A	1		8	9
22	*Labiobarbus leptocheilus*	N/A	3	2		5
23	*Labiobarbus siamensis*	LC			1	1
24	*Laubuka caeruleostigmata*	N/A		1		1
25	*Laubuka lankensis*	N/A		10	1	11
26	*Osteochilus lini*	LC			7	7
27	*Osteochilus vittatus*	LC	10	2	2	14
28	*Oxygaster anomalura*	LC		8		8
29	*Oxygaster pointoni*	VU		6	4	10
30	*Parachela maculicauda*	LC			1	1
31	*Parachela oxygastroides*	LC		6		6

Table 3 Continued.

No.	Family, Species	Status	Season: Early-Wet	Season: Wet	Season: Dry	Total
32	*Parachela siamensis*	LC			4	4
33	*Puntius brevis*	LC		8	37	45
34	*Puntigrus partipentazona*	LC		1		1
35	*Rasbora aurotaenia*	LC			10	10
36	*Rasbora borapetensis*	LC	10	3	127	140
37	*Rasbora paviana*	LC		121	133	254
38	*Rasbora trilineata*	LC		16		16
39	*Rasbosoma spilocerca*	N/A	2			2
40	*Systomus orphoides*	N/A		10	1	11
41	*Thynnichthys thynnoides*	LC			25	25
	Eleotridae					
42	*Oxyeleotris marmorata*	LC			1	1
	Hemiramphidae					
43	*Dermogenys siamensis*	LC	4	16	6	26
	Mastacembelidae					
44	*Macrognathus siamensis*	LC			1	1
	Nandidae					
45	*Pristolepis fasciata*	LC		4		4
	Notopteridae					
46	*Notopterus notopterus*	LC			1	1
	Osphronemidae					
47	*Trichopodus microlepis*	LC	5	2	37	44
48	*Trichopodus trichopterus*	LC	123	59	240	422
49	*Trichopsis pumila*	LC	12	4	21	37
50	*Trichopsis vittata*	LC	31	32	161	224
	Siluridae					
51	*Ompok siluroides*	N/A		8	5	13
52	*Ompok eugeneiatus*	N/A			3	3
	Synbranchidae					
53	*Monopterus albus*	LC	2	1		3
	Abundance		1235	224	436	1895
	Species richness		16	34	41	53

wetlands in the wet season had higher species richness and were most diverse (Table 2; Fig. 5), although overall species richness for all sites combined was highest in the dry season (Table 3). There was a significant correlation between log-transformed total abundance and log-transformed species richness (Pearson's correlation: df=38, r=0.80, p<0.001; Fig. 6) for all seasons combined, indicating that more species were generally found in wetlands with a greater abundance of fish.

Wetlands characteristics and fish diversity

Sites surveyed for wetland characteristics were well balanced between the connected and isolated categories (Table 1). Individual wetlands ranged in size from 305 m^2

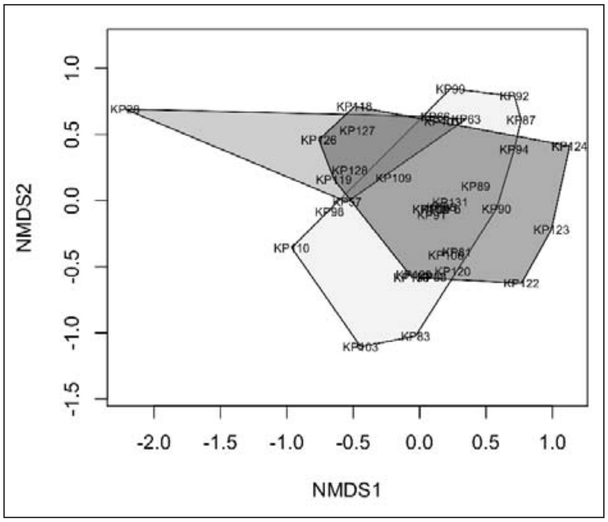

Fig. 2 Non-metric multidimensional scaling ordination plot of sampling sites based on standardized fish species abundance in the early-wet (mid-grey), wet (dark grey) and dry (light grey) seasons for taxa at ≥3 sites in Kulen Promtep Wildlife Sanctuary.

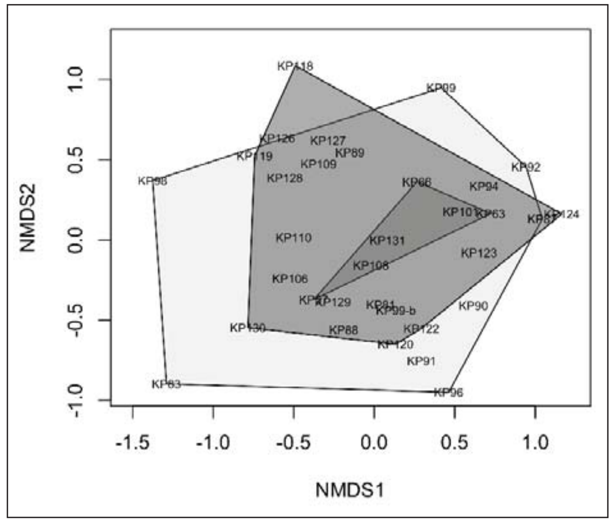

Fig. 3 Non-metric multidimensional scaling ordination plot of sampling sites based on standardized fish species abundance in the early-wet (mid-grey), wet (dark grey) and dry (light grey) seasons for taxa at ≥3 sites and sites with >1 taxon in Kulen Promtep Wildlife Sanctuary.

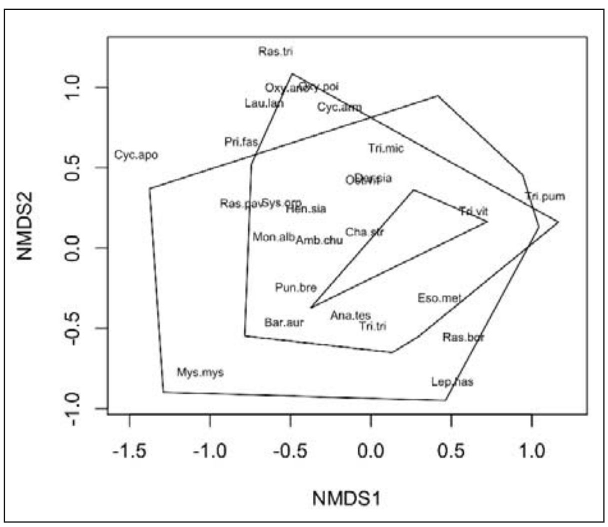

Fig. 4 Non-metric multidimensional scaling (NMDS) ordination plot of sampling sites based on standardized fish species (labeled) abundance in the early-wet, wet and dry seasons for taxa at ≥3 sites and sites with >1 taxon in Kulen Promtep Wildlife Sanctuary. The polygons define the same seasons depicted in Fig. 3.

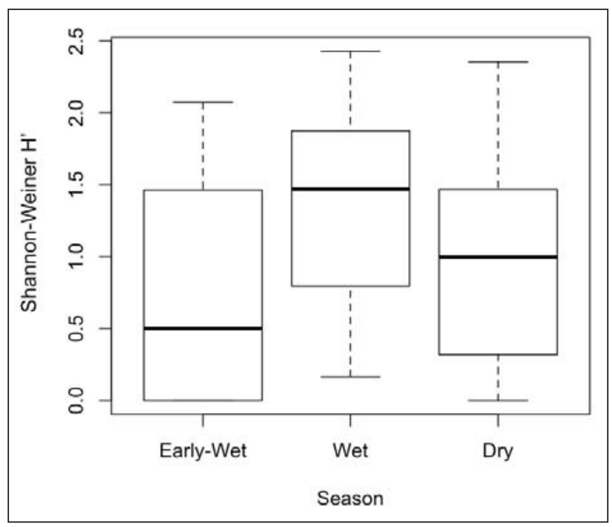

Fig. 5 Box plot of species diversity by season based on active sampling of sites in early-wet (*n*=4), wet (*n*=12) and dry (*n*=20) season in Kulen Promtep Wildlife Sanctuary.

to 425,258 m^2 (mean=28,637 m^2) and in depth from 10 cm to >100 cm (mean=46 cm for precisely measured depths). There was no significant correlation between log-transformed wetland area and log-transformed species richness (Pearson's correlation: *df*=20, *r*=0.12, *p*=0.589; Fig. 7) or between log-transformed wetland area and *H'* (Pearson's correlation: *df*=20, *r*=0.23, *p*=0.298; Fig. 8). The same was true for log-transformed maximum depth and log-transformed species richness (Pearson's correlation: *df*=18, *r*=0.40, *p*=0.080) and for log-transformed depth and *H'* (Pearson's correlation: *df*=18, *r*=0.38, *p*=0.101).

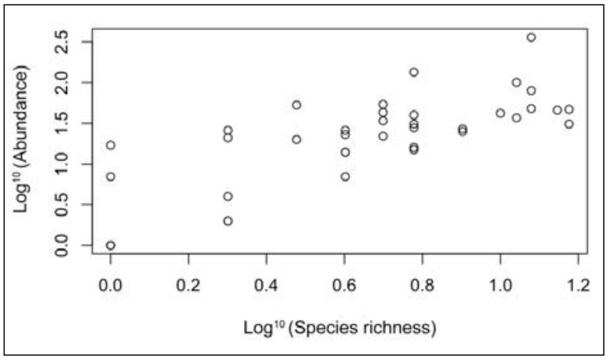

Fig. 6 Relationship between log-transformed abundance and species richness for all seasons (active sampling only) in Kulen Promtep Wildlife Sanctuary.

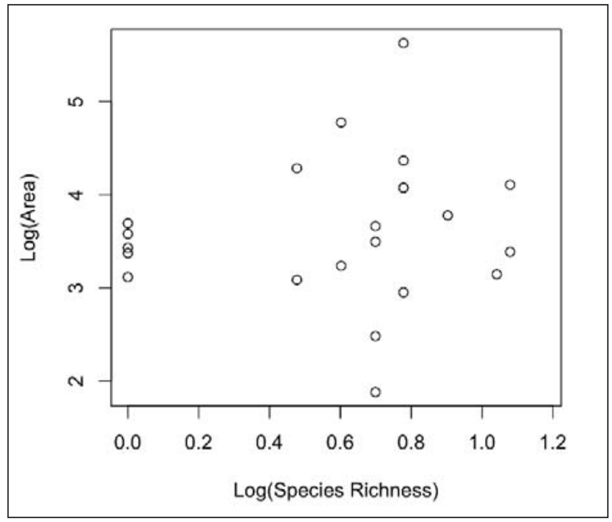

Fig. 7 Relationship between log-transformed wetland area and species richness for all seasons (active sampling only) in Kulen Promtep Wildlife Sanctuary.

However, maximum depth and species richness (all connectivity levels and seasons combined) were significantly correlated, although this was heavily influenced by a single outlier (Pearson's correlation: *df*=18, *r*=0.48, *p*=0.032; Fig. 9). There was also significant correlation between maximum depth and *H′* (Pearson's correlation: *df*=18, *r*=0.53, *p*=0.015; Fig. 9).

No patterns related to the wetland connectivity were apparent in the dendrogram characterizing fish assemblages actively sampled in the dry season. However, the dendrogram indicated that geographically closer sites and those sampled closer in time were more similar, suggesting potential issues of spatial or temporal autocorrelation.

Species-habitat associations

None of the eight regression models we fitted for each of the five most common species (*T. trichopterus*, *E. metallicus*, *T. vittata*, *A. testudineus* & *R. paviana*) appeared to have strong support. However, the models based on depth alone were most supported according to AIC fit (except for *E. metallicus*, for which the best model was depth + season), although coefficient estimates indicated the depth variable was never significant (Appendix 1).

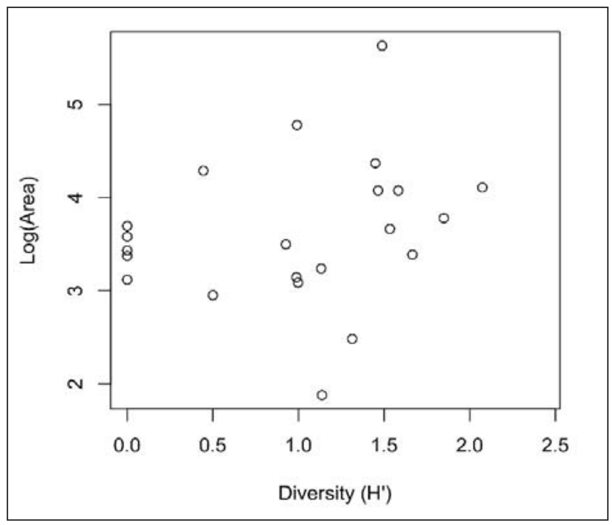

Fig. 8 Relationship between log-transformed wetland area and species diversity for all seasons (active sampling only) in Kulen Promtep Wildlife Sanctuary.

Discussion

Fish assemblages in seasonal wetlands of KPWS

Fish assemblages in the seasonal wetlands of KPWS were dominated by common species native to Cambodia. For example, *T. trichopterus* and *T. vittata* are known to seasonally occupy shallow, sluggish or standing water habitats and *E. metallicus* moves into seasonally flooded habitats like rice paddies, canals and ditches (Rainboth, 1996). In all seasons, most wetlands sampled (>80%) were occupied by fish and some contained at least 15 species, indicating that these sites can provide valuable fish-related ecosystem services such as food for piscivorous wildlife (e.g., endangered water birds) and humans, even in the dry season and early-wet season. It was not possible in our visual analysis of ordination results to describe separate fish assemblages or define groups of indicator species based on season. Differences in sample

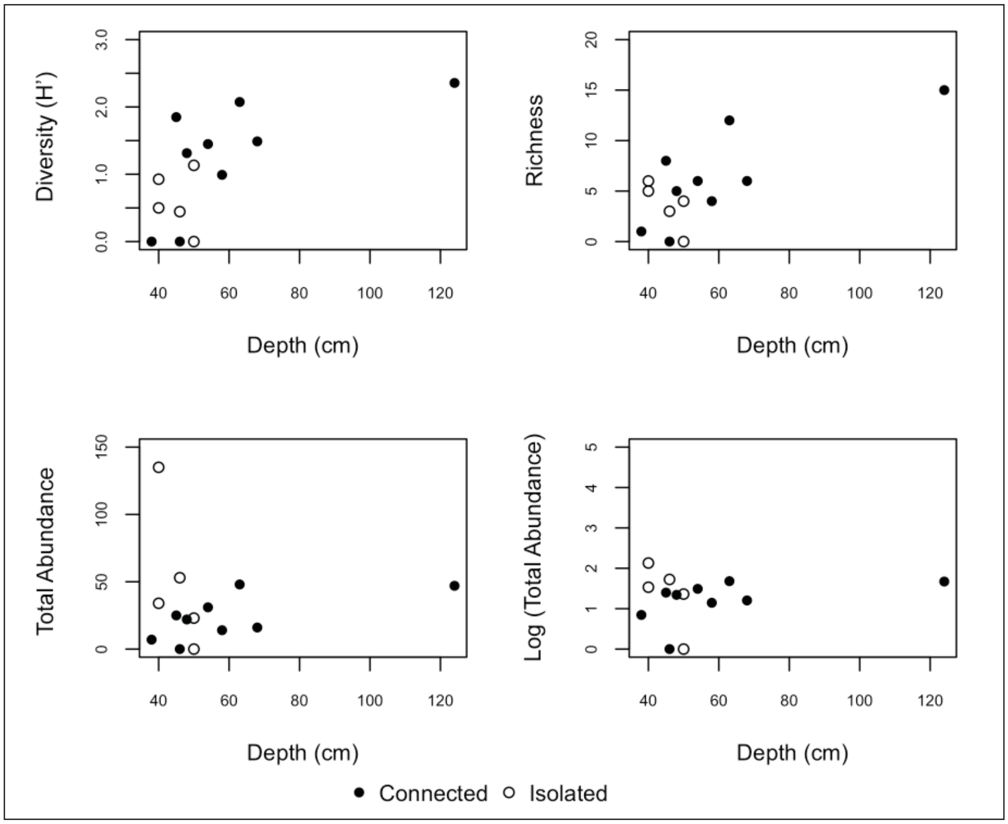

Fig. 9 Relationships between maximum depth (cm) and fish diversity (top left), species richness (top right), total abundance (bottom left) and log-transformed total abundance (bottom right) for isolated (empty symbols) and connected (solid symbols) wetlands at Kulen Promtep Wildlife Sanctuary.

size between season may have confounded interpretation. While a few species were only collected in the dry season (e.g., *Parachela maculicauda*, *Oxyeleotris marmorata* & *Parambassis apogonoides*), these were only encountered at one or two sites and this may reflect greater sampling effort.

We found several species that were well adapted to drying or low oxygen conditions, such as *Clarias batrachus*, which can survive in poorer quality water. Similarly, *A. testudineus*, which was captured in all seasons, is commonly found in ponds, swamps and wetlands throughout Southeast Asia and tolerates stagnant water conditions (Rainboth, 1996). This species can hibernate in mud, has special organs that allow it to breathe air and can walk on land using spines on its gill plates. It is also easier to transport to markets from remote areas because the species can stay alive for days in water containers (Valbo-Jørgensen *et al.*, 2009). Needham & Funge-Smith (2015) reported that air-breathing "black fish" species including *A. testudineus* are common in the diet of Cambodians, comprising 30% of total consumption. Jackson *et al.* (2013) found that artificial and natural floodplain depressions adjacent to an African river had a higher percentage of fishes that could tolerate dissolved oxygen than nearby river channels, indicating that the water quality in these isolated pools likely influences assemblage structure. Jackson *et al.* (2013) also found that piscivores dominated isolated, seasonal ponds during low water periods in the Oueme River in Africa. We similarly found that where only one species was encountered in a wetland, the species was almost always *A. testudineus*, a known piscivore.

Relationships between wetland characteristics and fish

We examined whether wetland size (area and maximum water depth) and connectivity (isolated or connected) influenced fish diversity, but did not find a significant correlation between area and species richness or diversity (*H'*). This accords with the findings of similar studies. Snodgrass *et al.* (1996), although not studying a tropical system, found no correlation between wetland size and species richness. Similarly, Tondato *et al.* (2013) found that while depth was one of the most important variables influencing species occurrence and that wetland area had no effect. In contrast, Pazin *et al.* (2006) found that species richness was positively related to area, canopy cover, hydro-period and conductivity, but not to depth. However, this might be because the temporary wetlands studied by Pazin *et al.* (2006) were much smaller (mean area=2.42 m^2) and shallower (mean depth=8.1 cm) compared to our study (mean area=28,637 m^2) and Tondato *et al.* (2013) (mean area=1,591 m^2). Furthermore, our measurements of wetland size might not have been a good indicator of water volume at the time of sampling. Due to the large variation in the size of the wetlands sampled, their area was either estimated from length and width measurements in the field or calculated from GPS tracks or satellite images of the wetland boundary. As a consequence, depth may have been a better indicator of total water volume at the wetland during sampling.

Although none of our models found a significant relationship between presence of a given fish species and depth, depth was in the best model for each of the five most common species. Likewise, maximum depth was also correlated with overall species richness and diversity. This suggests that water depth may be an important factor influencing the diversity of fish assemblages and presence of common species in KPWS. It has also been found to be important in determining fish communities in many small, seasonal wetlands (Escalera-Vazquez & Zambrano, 2010; Tondato *et al.*, 2013; Fernandes *et al.*, 2015). For instance, Fernandes *et al.* (2015) found that fish abundance and species richness were generally higher in deeper and more connected wetland patches. Our findings collectively suggest that a more comprehensive study of the influence of wetland inundation patterns and depth on fish diversity could provide useful information for conservation efforts, as described below.

One strategy that has been proposed for wildlife conservation in the dry forest habitats of Cambodia is to physically deepen wetlands so that they maintain water year-round, thereby converting seasonal wetlands to permanent wetlands (Gray *et al.*, 2015). While we found a correlation between maximum depth and fish diversity, we caution that limited conclusions can be drawn from our rapid survey. Escalera-Vazquez and Zambrano (2010) suggest that different communities in temporary and permanent wetlands may help to maintain diversity at a landscape level. Deepening wetlands to create permanently inundated habitats may increase species richness in those wetlands, but could also lead to homogeneity in species assemblages among modified wetlands. Conversely, maintaining a variety of depths may support greater diversity overall. We therefore recommend further examination of the effects of such wetland modifications on fish assemblages to determine potential benefits or negative impacts on fish resources and diversity.

We also found indications that wetlands closer to each other may have more similar fish assemblages. To protect greater fish diversity, it could therefore prove valuable to select scattered rather than clustered wetlands for conservation purposes. Further research to improve understanding of the spatial distribution of fish assemblages would help site managers direct resources towards areas with higher biodiversity and ecosystem services.

Rapid sampling methods

Further data on wetland distribution, biodiversity and ecosystem services is needed to demonstrate the importance of wetland conservation to decision makers (Kingsford *et al.*, 2016). The swift pace of development in Cambodia emphasizes the need to gather this information rapidly to support conservation and we sought to test a rapid method for collecting basic data on fish in small wetlands. The methods we used were effective as a rapid sampling technique and could be incorporated into future protocols for wetland assessments. In this context, we describe challenges and lessons learnt regarding our approach.

To balance the need for rapid sampling and adequate levels of effort, our methods could be improved by repeatedly sampling the same wetlands and developing species accumulation curves to determine the level of effort (electrofishing time or number of seine passes) required to accurately estimate species richness. In our study, we were limited to using a similar level of effort at each wetland, irrespective of their size.

While we did not examine the influence of aquatic vegetation, this may also play a role in structuring fish assemblages in seasonal wetlands. For example, Tondato *et al.* (2013) found that macrophyte richness and cover were important in influencing fish species occurrence. Escalera-Vazquez & Zambrano (2010) also found that community structure was related to macrophyte cover, in addition to water temperature, depth and pH. Jackson *et al.* (2013) found greater macrophyte coverage in artificial depressions compared to natural depressions, which led to differences in dissolved oxygen and consequently also in fish assemblages. We therefore recommend measurement of aquatic plant cover in future wetland studies, alongside instantaneous water quality characteristics such as temperature, pH, dissolved oxygen and conductivity. Given the presence of fish that are known to tolerate hypoxia, dissolved oxygen likely plays a role in structuring species assemblages in the dry season in smaller wetlands (e.g., Jackson *et al.* 2013).

We also did not explicitly address spatial autocorrelation, although our cluster analysis suggested that wetlands closer together may be more similar in fish composition than distant wetlands. Although few researchers quantify and adjust for spatial autocorrelation (Tondato *et al.*, 2013), we recommend its consideration in future wetland studies. This could be achieved by including a measure of the degree of spatial correlation in analysis based on the coordinates for each wetland.

We recognize that our methods are biased towards species associated with shallower waters because we did not sample the deeper waters of larger wetlands. Future studies would benefit from access to deeper wetland locations to deploy traps and nets and accurately measure all depths (e.g., using a small lightweight boat and a weighted rope). In addition, an electronic range finder could be used to measure the length and width of smaller wetlands. Our study would also have been strengthened by quantitative data on connectivity, rather than a simple qualitative (i.e., isolated or connected) category based on direct observation and local knowledge.

Our results can be used to develop specific research questions about the environmental characteristics of wetlands that influence the structure of the fish communities. To expand on our work, research on the effects of changes in connectivity would shed light on the potential influence of changes to hydrology due to development or climate change. In this context, wetlands could be selected for a year-long study where these are resampled monthly for water depth and connectivity to determine the influence of specific inundation and duration patterns (e.g., Baber *et al.*, 2002) on fish assemblages. This would improve understanding of how fish assemblages form and change during the dry season when the wetlands begin to dry up. Source river populations could also be sampled to learn how the species assemblages in wetlands compare to those of their source rivers (e.g., Jackson *et al.*, 2013). The results of such studies would help site managers understand the importance of connectivity and flood-timing on fish diversity and resources in small wetlands, because these may be altered by water management and land use changes in a watershed.

Acknowledgements

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References

Baber, M.J., Childers, D.L., Babbitt, K.J. & Anderson, D.H. (2002) Controls on fish distribution and abundance in temporary wetlands. *Canadian Journal of Fisheries and Aquatic Sciences*, **59**, 1441–1450.

Baird, I.G. (2007) Fishes and forests: the importance of seasonally flooded riverine habitat for Mekong River fish feeding. *Natural History Bulletin of the Siam Society*, **55**, 121–148.

Barzen, J. (2004) *An Aerial Survey of Wetlands in Northern Cambodia 2001*. Report, International Crane Foundation, Phnom Penh, Cambodia.

Campbell, I.C., Poole, C., Giesen, W. & Valbo-Jorgensen, J. (2006) Species diversity and ecology of Tonle Sap Great Lake, Cambodia. *Aquatic Sciences*, **68**, 355–373.

Cowx, I.G. & Portocarrero Aya, M. (2011) Paradigm shifts in fish conservation: moving to the ecosystem services concept. *Journal of Fish Biology*, **79**, 1663–1680.

Edwards, S. (2012) Small carnivore records from the Oddar Meanchay sector of Kulen–Promtep Wildlife Sanctuary, northern Cambodia. *Small Carnivore Conservation*, **46**, 22–25.

Escalera-Vazquez, L.H. & Zambrano, L. (2010) The effect of seasonal variation in abiotic factors on fish community structure in temporary and permanent pools in a tropical wetland. *Freshwater Biology*, **55**, 2557–2569.

Eschmeyer, W.N., Fricke, R. & van der Laan, R. (2016) *Catalog of Fishes: Genera, Species, References*. California Academy of Sciences, San Francisco, USA.

Fernandes, I., Penha, J. & Zuanon, J. (2015) Size-dependent response of tropical wetland fish communities to changes in vegetation cover and habitat connectivity. *Landscape Ecology*, **30**, 1421–1434.

Fernandes, I.M., Machado, F.A. & Penha, J. (2010) Spatial pattern of a fish assemblage in a seasonal tropical wetland: effects of habitat, herbaceous plant biomass, water depth, and distance from species sources. *Neotropical Ichthyology*, **8**, 289–298.

Gray, T.N.E., McShea, W.J., Koehncke, A., Sovanna P. & Wright, M. (2015) Artificial deepening of seasonal waterholes in Eastern Cambodia: impact on water retention and use by large ungulates and waterbirds. *Journal of Threatened Taxa*, **7**, 7189–7195.

Jackson, A. T., Adite, A., Roach, K. A. & Winemiller, K. O. (2013) Fish assemblages of an African river floodplain: a test of alternative models of community structure. *Ecology of Freshwater Fish*, **22**, 295–306.

Kaller, M.D., Kelso, W.E. & Trexler, J.C. (2013) Wetland Fish Monitoring and Assessment. In *Wetland Techniques* (eds. J.T. Anderson & C.A. Davis), pp. 197–263. Springer, New York, USA.

Kingsford, R.T., Basset, A. & Jackson, L. (2016) Wetlands: conservation's poor cousins. *Aquatic Conservation-Marine and Freshwater Ecosystems*, **26**, 892–916.

Knight, J.G. & Bain, M.B. (1996) Sampling fish assemblages in forested floodplain wetlands. *Ecology of Freshwater Fish*, **5**, 76–85.

Kol V. (2003) *Review of Wetland and Aquatic Ecosystem in the Lower Mekong River Basin of Cambodia*. Report, Cambodian National Mekong Committee Secretariat and The Mekong River Commission Secretariat, Phnom Penh, Cambodia.

Kosal M. (2004) Biodiversity of Cambodia's Wetlands. In *Wetlands Managment in Cambodia: Socioeconomic, Ecological and Policy Perspectives* (M. Torell, A.M. Salamanca & B.D. Ratner), pp. 14–16. Worldfish Center, Phnom Penh, Cambodia.

Krebs, C.J. (1999) *Ecological Methodology*. Benjamin Cummings, New York, USA.

Loeung K., Schmidt-Vogt, D. & Shivakoti, G.P. (2015) Economic value of wild aquatic resources in the Ang Trapeang Thmor Sarus Crane Reserve, North-western Cambodia. *Wetlands Ecology and Management*, **23**, 467–480.

Needham, S. & Funge-Smith, S. (2015) *The Consumption of Fish and Fish Products in the Asia-Pacific Region based on Household Surveys*. Regional Office for Asia and the Pacific, Food and Agriculture Organization of the United Nations, Bangkok, Thailand.

Pazin, V.F.V., Magnusson, W.E., Zuanon, J. & Mendonca, F.P. (2006) Fish assemblages in temporary ponds adjacent to 'terra-firme' streams in Central Amazonia. *Freshwater Biology*, **51**, 1025–1037.

Rainboth, W.J. (1996) *Fishes of the Cambodian Mekong*. Food and Agriculture Organization of the United Nations, Rome, Italy.

Snodgrass, J.W., Bryan, A.L., Lide, R.F. & Smith, G.M. (1996) Factors affecting the occurrence and structure of fish assemblages in isolated wetlands of the upper coastal plain, USA. Canadian *Journal of Fisheries and Aquatic Sciences*, **53**, 443–454.

Souter, N.J., Simpson, V., Mould, A., Eames, J.C., Gray, T.N.E., Sinclair, R., Farrell, T., Jurgens, J.A. & Billingsley, A. (2016) Will the recent changes in protected area management and the creation of five new protected areas improve biodiversity conservation in Cambodia? *Cambodian Journal of Natural History*, **2016**, 1–5.

Tondato, K.K., Fantin-Cruz, I., Pedrollo, O.C. & Suarez, Y.R. (2013) Spatial distribution of fish assemblages along environmental gradients in the temporary ponds of Northern Pantanal, Brazil. *Journal of Limnology*, **72**, 95–102.

Valbo-Jørgensen, J., Coates, D. & Hortle, K. (2009) Fish diversity in the Mekong River Basin. In *The Mekong: Biophysical Environment of an International River Basin* (ed I.C. Campbell). pp. 161–196. Academic Press, San Diego, USA.

Vidthayanon, C. (2008) *Field Guide to Fishes of the Mekong Delta*. Mekong River Commission, Vientiane, Lao PDR.

Wohlfart, C., Wegmann, M. & Leimgruber, P. (2014) Mapping threatened dry deciduous dipterocarp forest in South-East Asia for conservation management. *Tropical Conservation Science*, **7**, 597–613.

Appendix 1 Model relationships between sampling season, wetland connectivity, water depth and the presence and absence of the five most common fish species at Kulen Promtep Wildlife Sanctuary

Species	Model	Residual deviance	Residual degrees of freedom	AIC	Δ AIC	*p*
Trichopodus trichopterus	1) Null	54.548	39	56.55	26.3	
	2) Season	52.067	37	58.07	27.8	
	3) Connectivity	36.498	26	40.50	10.3	
	4) Max. Depth	26.226	18	30.23	0.0	Intercept 0.260, depth 0.308
	5) Max. Depth + Connectivity	24.334	17	30.33	0.1	

Appendix 1 Continued

Species	Model	Residual deviance	Residual degrees of freedom	AIC	Δ AIC	*p*
	6) Max. Depth + Season	26.057	17	32.06	1.8	
	7) Season + Connectivity	36.361	25	42.36	12.1	
	8) Season + Connectivity + Max. Depth	24.245	16	32.25	2.0	
Esomus metallicus	1) Null	55.352	39	57.35	29.8	
	2) Season	48.142	37	54.14	26.6	
	3) Connectivity	38.243	26	42.24	14.7	
	4) Max. Depth	26.551	18	30.55	3.0	
	5) Max. Depth + Connectivity	26.49	17	32.49	4.9	
	6) Max. Depth + Season	21.568	17	27.57	0.0	Intercept 0.207, Depth 0.292, Season 0.996
	7) Season + Connectivity	31.794	25	37.79	10.2	
	8) Season + Connectivity + Max. Depth	21.566	16	29.57	2.0	
Trichopsis vittata	1) Null	54.548	39	56.55	24.8	
	2) Season	54.523	37	60.52	28.8	
	3) Connectivity	37.657	26	41.66	9.9	
	4) Max. Depth	27.726	18	31.73	0.0	Intercept 0.993, Depth 0.992
	5) Max. Depth + Connectivity	27.413	17	33.41	1.7	
	6) Max. Depth + Season	27.326	17	33.33	1.6	
	7) Season + Connectivity	37.652	25	43.65	11.9	
	8) Season + Connectivity + Max. Depth	27.068	16	35.07	3.3	
Anabas testudineus	1) Null	53.841	39	55.84	24.8	
	2) Season	53.82	37	59.82	28.7	
	3) Connectivity	36.16	26	40.16	9.1	
	4) Max. Depth	27.072	18	31.07	0.0	Intercept 0.436, Depth 0.515
	5) Max. Depth + Connectivity	26.739	17	32.74	1.7	
	6) Max. Depth + Season	26.896	17	32.90	1.8	
	7) Season + Connectivity	36.154	25	42.15	11.1	
	8) Season + Connectivity + Max. Depth	26.600	16	34.60	3.5	
Rasbora paviana	1) Null	51.796	39	53.80	32.2	
	2) Season	41.679	37	47.68	26.1	
	3) Connectivity	25.454	26	29.45	7.8	
	4) Max. Depth	17.614	18	21.61	0.0	Intercept 0.0324*, Depth 0.1727
	5) Max. Depth + Connectivity	17.224	17	23.22	1.6	
	6) Max. Depth + Season	16.283	17	22.28	0.7	
	7) Season + Connectivity	23.003	25	29.00	7.4	
	8) Season + Connectivity + Max. Depth	15.907	16	23.90	2.3	

Significance values are provided for best fit model only (* indicates significant value).

Recent Master's Theses

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

Effectiveness of nest protection methods and nesting preferences of three Cambodian vulture species

NY Naiky

មូលន័យសង្ខេប

ប្រទេសកម្ពុជាគឺជាទីតាំងយ៉ាងសំខាន់មួយសម្រាប់វត្តមានរបស់សត្វត្មាតចំនួនបីប្រភេទ ដែលកំពុងរងគ្រោះថ្នាក់ជិតផុតពូជជាសកល។ ប្រភេទទាំងបីរួមមាន៖ ត្មាតផេះ(*Gyps bengalensis*) ត្មាតភ្លើង(*Sarcogyps calvus*) និង ត្មាតត្នោត(*Gyps tenuirostris*)។ កន្លងមក ត្មាតទាំង៣ប្រភេទនេះធ្លាប់មានចំនួនច្រើននៅក្នុងតំបន់អាស៊ីអាគ្នេយ៍ ប៉ុន្តែបច្ចុប្បន្នចំនួនរបស់វាបានថយចុះយ៉ាងខ្លាំង និងត្រូវបានគេជឿជាក់ថាបានផុតពូជពីប្រទេសម៉ាឡេស៊ី វៀតណាម ថៃ និង ប្រទេសឡាវ។ នៅប្រទេសកម្ពុជា កត្តាគំរាមកំហែងទៅលើការរស់នៅរបស់ត្មាតមានដូចជា៖ ការបាត់បង់ទីជម្រក ការបង្កកំណើតមិនសូវបានជោគជ័យ ការបំពុលដោយប្រយោល និងអាហារមិនគ្រប់គ្រាន់ ដោយសារការថយចុះនៃប៉ូពុយឡាស្យុងថនិកសត្វធំនៅក្នុងព្រៃ។ ការសិក្សារបស់ខ្ញុំ បានវាយតម្លៃអំពីទំនោរនៃការជ្រើសរើសទីតាំងធ្វើសំបុករបស់ត្មាតទាំងបីប្រភេទ ដោយប្រើទិន្នន័យរយៈពេលពីរឆ្នាំស្តីពីភូមិសាស្ត្រ និង ពត៌មានលម្អិតនៃទីជម្រក ទាក់ទងនឹងអកប្បកិរិយានៃការធ្វើសំបុករបស់សត្វត្មាត ក្នុងដែនជម្រកសត្វព្រៃឆែបក្នុងខេត្តព្រះវិហារ និង សៀមប៉ាងខាងលិចក្នុងខេត្តស្ទឹងត្រែង។ ខ្ញុំក៏បានថ្លឹងថ្លែងពីប្រសិទ្ធភាពនៃវិធីសាស្ត្រការពារសំបុកត្មាតនៅតាមទីតាំងនីមួយៗ ដើម្បីវាយតម្លៃលើកម្រិតជោគជ័យរវាងសំបុកដែលបានការពារដោយសហគមន៍ និង សំបុកដែលមិនបានការពារ ប៉ុន្តែបានពិនិត្យតាមដានជាប្រចាំ។ តាមលទ្ធផលបង្ហាញថា ត្មាតត្នោតចូលចិត្តដើមឈើដែលមានកម្ពស់ទាប នៅតាមព្រៃរបោះដែលស្រឡះ គេតែងប្រទះឃើញវាកាច់សំបុកលើមែកឈើណាដែលមានទំហំធំជាងគេ និង នៅក្បែរដើម ចំណែកឯត្មាតផេះ វាចូលចិត្តកម្ពស់ដើមឈើប្រហាក់ប្រហែលនឹងត្មាតត្នោតដែរ ប៉ុន្តែជាព្រៃស្តុកជាង ហើយវាកាច់សំបុកនៅទីតាំងបែកមែកឈើ។ ទីតាំងកាច់សំបុករបស់សត្វត្មាតទាំងពីរប្រភេទនេះមានទំនាក់ទំនងជាមួយនឹងទីតាំងលំនៅដ្ឋាន និង តំបន់កសិកម្មដែលមានចំនួនមនុស្ស និង គោក្របីច្រើន។ ត្មាតភ្លើងមាន លក្ខណៈខុសគេ គឺមានទំនោររស់នៅក្នុងព្រៃស្តុកដែលមានចម្ងាយឆ្ងាយពីលំនៅដ្ឋានរបស់មនុស្ស និង កាច់សំបុកនៅលើមែកឈើតូចៗផ្នែកខាងចុងឈើ និង ប្រើប្រាស់មែកឈើតូចៗសម្រាប់កាច់សំបុក បើប្រៀបធៀបនឹងត្មាតពីរប្រភេទខាងលើ។ ខ្ញុំសន្និដ្ឋានថា រៀងរាល់ឆ្នាំ ការការពារសំបុកត្មាតគឺមានសារសំខាន់ខ្លាំងណាស់ ក្នុងការការពារសត្វត្មាតទាំង៣ប្រភេទពីបញ្ហាប្រឈមភ្លាមៗ ដែលកពុងកើតមានឡើងដូចជា៖ ការកាប់ឈើខុសច្បាប់ និង ការរំខានដោយមនុស្ស៕

Abstract

Cambodia supports important populations of three globally endangered vulture species: white-rumped vulture *Gyps bengalensis*, red-headed vulture *Sarcogyps calvus* and slender-billed vulture *Gyps tenuirostris*. These were historically abundant in the region but have declined dramatically in recent decades and are now believed to be extinct in Malaysia, Vietnam, Thailand and Laos. Threats to their survival in Cambodia include habitat loss, low breeding success, incidental poisoning and insufficient food availability due to declines in wild large ungulate populations. My study evaluated the nesting preferences of the three species using two-year datasets on geographical and microhabitat variables related to nesting behaviour from Chheab Wildlife Sanctuary in Preah Vihear Province and Prey Siem Pang Kang Lech Wildlife Sanctuary in Stung Treng province. I also explored the effectiveness of nest protection methods applied at each site to evaluate differences in nesting success between nests with community guardians and nests without guardians that were regularly monitored. My results suggest that slender-billed vultures preferred shorter trees in very open dry forests and mostly built their nests in the largest branches adjacent to tree trunks, whereas white-rumped vultures preferred taller trees in similar but denser habitats and built their nests on three branch formations. Nest locations for both species were associated with residential and agricultural areas with higher populations of humans and domestic livestock. Red-headed vultures differed in preferring locations further from residential areas in dense forest patches where they nested on the edge of the tree canopy on small branches and used smaller nesting material compared to the

other species. I conclude that nest protection is essential each year to safeguard the three vulture species from rapidly emerging issues such as illegal logging and human persecution.

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The impact of question formats in conservation research: a comparison of specialized techniques applied in a Cambodian context

ROTH Vichet

មូលន័យសង្ខេប

ការបរបាញ់ ការបំផ្លាញទីជម្រក ការរំខានដោយមនុស្ស និង ការប្រើប្រាស់ធនធានខុសច្បាប់សុទ្ធតែជាកត្តាគំរាមកំហែងដ៏ធ្ងន់ធ្ងរដល់សត្វព្រៃនៅក្នុងប្រទេសកម្ពុជា។ ទោះជាការប៉ាន់ប្រមាណអោយបានជាក់លាក់ពីទំហំនៃការប្រើប្រាស់ធនធានខុសច្បាប់នៅតែជាបញ្ហាប្រឈម តែវិធីសាស្ត្រប្រមូលទិន្នន័យបែបអនាមិកដូចជា Randomized Response Technique (RRT), Unmatched Count Technique (UCT) និង Nominative Technique (NT) ត្រូវបានគេចាត់ទុកថាជាវិធីសាស្ត្រដ៏មានប្រសិទ្ធភាព ពីព្រោះវាធ្វើអោយអ្នកឆ្លើយសំណួរអាចឆ្លើយតបដោយគ្មានការភ័យខ្លាច ព្រមទាំងអាចកាត់បន្ថយភាពលម្អៀងដែលកើតមានដោយសារកត្តាសង្គម និង ភាពលម្អៀងដោយការមិនឆ្លើយតប។ ការសិក្សារបស់ខ្ញុំមានគោលបំណងវាយតម្លៃលើបច្ចេកទេសទាំងបីខាងលើដែលអនុវត្តនៅក្នុងបរិបទប្រទេសកម្ពុជា និង ប្រើលទ្ធផលពីការសិក្សានេះដើម្បីអភិវឌ្ឍការតាមដានអោយកាន់តែមានប្រសិទ្ធភាពសម្រាប់ត្រួតពិនិត្យការប្រើប្រាស់ផលិតផល និង សរីរាង្គរបស់សត្វខ្លាឃ្មុំ។ ការស្រាវជ្រាវនេះត្រូវបានធ្វើឡើងនៅចន្លោះខែមីនា និង ខែមិថុនា ឆ្នាំ២០១៧ នៅក្នុងឃុំចំនួន៦ដែលស្ថិតនៅជិតតំបន់ការពារជួរភ្នំក្រវាញកណ្តាលភាគនិរតីនៃប្រទេសកម្ពុជា។ គំរូតាងរបស់ខ្ញុំ រួមមានទិន្នន័យប្រមូលបានពីគ្រួសារចំនួន៦៥០ ដោយប្រើប្រាស់បច្ចេកទេសទាំងបីខាងលើ និង បច្ចេកទេសមួយផ្សេងទៀតដើម្បីប្រមូលព័ត៌មានទូទៅ និង ព័ត៌មានរសើបដែលទាក់ទងទៅនឹងការប្រើប្រាស់សរីរាង្គផ្សេងៗនៃសត្វខ្លាឃ្មុំពីអ្នកឆ្លើយសំណួរ។ ចំនួនគ្រួសារប្រហែល២.៧% ទៅ ២២.៧%នៅក្នុងឃុំនីមួយៗត្រូវបានជ្រើសរើសជាសំណាកគំរូ។ ការវិភាគទិន្នន័យបានរកឃើញថាមានភាពខុសដាច់នៅក្នុងការប៉ាន់ប្រមាណអំពីការប្រើប្រាស់ទឹកប្រមាត់សត្វខ្លាឃ្មុំរវាងបច្ចេកទេសទាំងបួន។ បច្ចេកទេសសួរសំណួរ NT បង្ហាញពីកម្រិតខ្ពស់ដាច់នៃប្រេវ៉ាឡង់ (prevalence) ធៀបទៅនឹងការសួរសំណួរដោយផ្ទាល់UCT និង RRT។ UCT ក៏បង្ហាញពីកម្រិតខ្ពស់ដាច់នៃប្រេវ៉ាឡង់ធៀបនឹងRRT ប៉ុន្តែវាមិនមានភាពខុសគ្នាពីការប៉ាន់ប្រមាណដោយប្រើសំណួរដោយផ្ទាល់ទេ ឯការសួរសំណួរដោយផ្ទាល់បានបង្ហាញពីកម្រិតខ្ពស់ដាច់នៃប្រេវ៉ាឡង់ធៀបនឹងRRT។ ភាពខុសគ្នាដាច់ក៏ត្រូវបានរកឃើញផងដែររវាងភេទប្រុស និង ភេទស្រីទៅលើប្រេវ៉ាឡង់នៃការប្រើប្រាស់ទឹកប្រមាត់សត្វខ្លាឃ្មុំ តាមរយៈប្រើប្រាស់បច្ចេកទាំងបួន។ ខ្ញុំសូមផ្តល់យោបល់ឲ្យមានការសិក្សាបន្ថែមទៀត ទាំងនៅតំបន់ជនបទ និង នៅទីក្រុង ដើម្បីបង្កើនការយល់ដឹងបន្ថែមទៀតទាក់ទងទៅនឹងការប្រើប្រាស់បច្ចេកទេសទាំងបួន សម្រាប់ការស្រាវជ្រាវពីសង្គមនៅប្រទេសកម្ពុជា។ ការស្រាវជ្រាវដោយប្រើវិធីសាស្ត្រផ្សេងទៀតក៏មានភាពចាំបាច់ដែរក្នុងការអភិវឌ្ឍវិធីសាស្ត្រដ៏មានប្រសិទ្ធភាព ដើម្បីប្រមូលព័ត៌មានរសើបទាក់ទងនឹងការប្រើប្រាស់ធនធានធម្មជាតិដោយកាត់បន្ថយភាពលម្អៀងកើតមានដោយសារកត្តាសង្គម និង ភាពលម្អៀងដោយការមិនឆ្លើយតប៕

Abstract

Hunting, habitat destruction, human disturbance and illegal resource use present serious threats to wildlife in Cambodia. Although accurate estimation of the scale of illegal resource use is challenging, anonymous data collection methods such as randomized response (RRT), unmatched count (UCT) and nominative (NT) techniques are thought to be effective because they enable interviewees to respond without fear of punishment and reduce bias due to social desirability and non-responses. My study aimed to assess the utility of these techniques in a Cambodian context and to employ the results to improve the effectiveness of monitoring efforts regarding the use of bear parts and products. My research was undertaken between March and June 2017 in six communes adjacent to the Central Cardamom Mountains region in southwestern Cambodia. My sample comprised data collected from 650 households using the three techniques and one questionnaire to gather general data and sensitive information relating to bear part usage on the part of respondents. Between 2.7 and 22.7% of households in each commune were sampled. Analysis revealed significant differences in estimates of the prevalence of bear bile use between the four techniques. The nominative technique provided a significantly higher estimate of prevalence compared to direct questioning, RRT and UCT. The unmatched count technique also provided a significantly higher prevalence estimate than RRT but did not differ from direct questioning, whereas the latter provided a significantly higher prevalence estimate compared to RRT. Significant differences were also found between male and female respondents in prevalence estimates for bear bile usage with the four techniques. I suggest additional studies in rural and urban areas are needed to improve understanding of the utility of the four techniques for social research in Cambodia. Research on other approaches is also needed to develop effective methods for gathering sensitive information on natural resource use that reduce bias from social desirability and non-responses.

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Activity of insectivorous bats over rice fields surrounding free-range bat farms in two provinces of Cambodia

SEK Pisey

មូលន័យសង្ខេប

ប្រចៀវស៊ីសត្វល្អិតជាក្រុមសត្វរំពា ដែលស៊ីអាហារបានច្រើន រួមទាំងក្រុមសត្វល្អិតចង្រៃដែលបំផ្លាញផលកសិកម្មនៃពិភពលោក។ មានឯកសារតិចតួចនៅឡើយស្តីពីប្រចៀវ ដែលរស់នៅដោយសេរីនៅតាមដើមត្នោត(*Scotophilus kuhlii*) ពួកវាមានតួនាទីជាអ្នកគ្រប់គ្រងសត្វល្អិតចង្រៃក្នុងប្រព័ន្ធកសិកម្មនៅកម្ពុជា។ ដូច្នេះការសិក្សារបស់ខ្ញុំ មានគោលបំណងស្វែងយល់ពីសកម្មភាពប្រចៀវនៅតាមវាលស្រែ ដែលស្ថិតនៅជុំវិញកសិដ្ឋានប្រចៀវ និង ដើម្បីអង្កេតថាតើការគ្រប់គ្រងដំណាំដោយប្រើថ្នាំសម្លាប់សត្វល្អិត ការបាត់បង់ជម្រកធម្មជាតិ និង ការបរបាញ់ធ្វើជាអាហារ អាចគំរាមកំហែងដល់ប្រចៀវក្នុងតំបន់ទាំងនោះឬទេ? សកម្មភាពសត្វប្រចៀវត្រូវបានធ្វើគំរូតាងតាមខែនីមួយៗគឺមាន៖ មុនពេល អំឡុងពេល និង ក្រោយពេលនៃវដ្តរដូវកសិកម្មមួយ (៦ខែ) ក្នុងចម្ងាយខុសៗគ្នា (A: 0–1 km, B: 2–3 km, C: 4–5km) គិតចាប់ពីកសិដ្ឋានប្រចៀវក្នុងខេត្តទាំងពីរ (កណ្តាលនិងតាកែវ)។ ម្ចាស់កសិដ្ឋានប្រចៀវ (*n*=15) និង កសិករធ្វើស្រែ (*n*=60) នៅក្នុងខេត្តទាំងពីរត្រូវបានសម្ភាសន៍ ដើម្បីកំណត់ពីរបៀបដាំដុះ និង ការគ្រប់គ្រងសត្វល្អិត។ សកម្មភាពជាមធ្យមប្រចាំខែនៃប្រចៀវ និងភាពសម្បូរនៃប្រភេទ (species richness) គឺមានភាពខ្ពស់ដាច់នៅក្នុងតំបន់A បើធៀបនឹងតំបន់B និង C នៅក្នុងខេត្តទាំងពីរ ប៉ុន្តែគ្មានភាពខុសគ្នាដាច់ទេរវាងតំបន់B និងC នៃខេត្តនីមួយៗ។ សកម្មភាពប្រចៀវក៏មានការប្រែប្រួលគួរឲ្យកត់សម្គាល់ផងដែរទៅតាមពេល។ ពាក់កណ្តាលនៃម្ចាស់កសិដ្ឋានប្រចៀវ និង បីភាគបួននៃកសិករធ្វើស្រែ ដែលត្រូវបានសម្ភាសន៍រាយការណ៍ថា ប៉ូពុយឡាស្យុងប្រចៀវមានការថយចុះនៅក្នុងតំបន់ ក្នុងអំឡុងដប់ឆ្នាំចុងក្រោយ។ ទិន្នន័យនៃការសម្ភាសន៍បានបង្ហាញថា ការប្រើថ្នាំសម្លាប់សត្វល្អិត ការបាត់បង់ដើមត្នោតដែលជាជម្រក និង ការបរបាញ់ប្រចៀវ ប្រហែលជាបាននឹងកំពង់គំរាមកំហែងប៉ូពុយឡាស្យុងប្រចៀវនៅក្នុងតំបន់សិក្សា ទោះបីជាការគំរាមកំហែងដោយការបរបាញ់បច្ចុប្បន្ន អាចនឹងប៉ះពាល់ធ្ងន់ធ្ងរជាងកត្តាទាំងពីរខាងដើមក៏ដោយ។ ការសិក្សាបន្តទៀត គឺជាការចាំបាច់ដើម្បីបង្កើនការយល់ដឹងពីបុព្វហេតុបណ្តាលឲ្យមានការថយចុះនូវចំនួនប៉ូពុយឡាស្យុង និង ដើម្បីកំណត់ពីវិធីសាស្ត្រល្អបំផុត ដែលអាចធ្វើឲ្យប៉ូពុយឡាស្យុងប្រចៀវទាំងនោះ បានប្រសើរដូចដើមវិញនៅក្នុងខេត្តទាំងពីរ៕

Abstract

Insectivorous bats are voracious predators of economically-relevant pest species in many of the world's agro-production systems. Because the role that lesser Asian house bats *Scotophilus kuhlii* inhabiting free-range bat farms play as a pest control agents in Cambodian rice agro-systems is undocumented, my study aimed to quantify bat activity over rice fields surrounding bat farms and to investigate whether pesticide-based insect controls, loss of natural roosts and/or hunting for bush meat consumption may threaten bats in these areas. Bat activity was acoustically sampled each month before, during and after the entire cultivation cycle of one rice crop (six months) over a distance gradient (A: 0–1 km, B: 2–3 km, C: 4–5km) from central clusters of bat farms in two provinces (Kandal and Takeo). Bat farmers (*n*=15) and rice farmers (*n*=60) in both provinces were interviewed to determine their related farming and pest-management practices. Mean-monthly bat activity and species richness were significantly greater in Zone A compared to Zone B and Zone C in both provinces, but did not differ significantly between the latter zones in either province. Bat activity also varied markedly over time between provinces. Half of the bat farmers and over three-quarters of rice farmers interviewed reported declines in bat populations in their areas over the last decade. Interview data collectively suggested that pesticide use, loss of palm roost trees and bat hunting may threaten bat populations at the study sites, although the threat posed by hunting may now be outweighed by the former. Further studies are warranted to improve understanding of the causal mechanisms of the reported population declines and determine the best means of reversing these within the two provinces.

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Surveillance and characterization of avian influenza virus in Cambodia

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វីរុសគ្រុនផ្តាសាយប្រភេទAដែលឆ្លងរាលដាលបក្សីនៅកម្ពុជា គឺជាទម្រង់នៃវីរុសគ្រុនផ្តាសាយបក្សីH5N1 ដែលត្រូវបានគេស្គាល់ដំបូងក្នុងឆ្នាំ២០០៤។ ការឆ្លងរាលដាលនៃជំងឺផ្តាសាយបក្សីបាននឹងកំពុងកើតឡើងជាបន្តបន្ទាប់ ចាប់តាំងពីពេលគេរកឃើញវត្តមានរបស់វា ហើយមានមនុស្សចំនួន៥៦នាក់ត្រូវបានរកឃើញថាបានឆ្លងជំងឺនេះរហូតមកដល់ពេលបច្ចុប្បន្ន ហើយមានមនុស្សចំនួន៣៧នាក់បានស្លាប់។ ការតាមដាននៃវីរុសគ្រុនផ្តាសាយA/H5N1នៅក្នុងប្រទេសកម្ពុជាក្នុងឆ្នាំ២០១១ និង ២០១៣បានបង្ហាញពីអត្រាប្រេវ៉ាឡង់ខ្ពស់នៅក្នុងទីផ្សារលក់បក្សីរស់។ ការសិក្សាស្រាវជ្រាវរបស់ខ្ញុំ រួមមានការតាមដាន ឃ្លាំមើលទៅលើវីរុសគ្រុនផ្តាសាយបក្សីនៅក្នុងបសុបក្សី និង ពីបរិស្ថាន តាមរយៈសំណាកប្រមូលបានពីផ្សារអូឫស្សី នៅទីក្រុងភ្នំពេញ ចាប់ពីខែមករា ដល់ ខែមេសា ឆ្នាំ២០១៧។ ការធ្វើតេស្តដោយឧបករណ៍ RT-PCR វីរុសគ្រុនផ្តាសាយបក្សីត្រូវបានរកឃើញរហូតដល់៥២%នៃ២៩២សំណាកដែលប្រមូល។ អត្រានៃការរកឃើញមានពី៤៥%(ទា) ទៅ ៩៩%(មាន់) នៅក្នុងឧបករណ៍ជូត(swab) ហើយរហូតដល់១០០% ពីសំណាកទឹក ដែលប្រើដើម្បីលាងសម្អាតបក្សីដែលសម្លាប់រួច។ វីរុសគ្រុនផ្តាសាយA/H5N1 ត្រូវបានរកឃើញក្នុង១២%នៃសំណាកដែលគេដឹងថាមានវីរុសគ្រុនផ្តាសាយប្រភេទA និង មាន៦%នៃគ្រប់សំណាក ដែលបានប្រមូលពីទីផ្សារ។ វីរុសគ្រុនផ្តាសាយA/H9N2 ក៏ត្រូវបានរកឃើញពី២៥%នៃសំណាកដែលគេដឹងថាមានវីរុសគ្រុនផ្តាសាយប្រភេទA ហើយមាន១៣%នៃគ្រប់សំណាកទាំងអស់។ ចំណែកវីរុសH7 មិនបានរកឃើញឡើយ។ ក្នុង១០០%នៃសំណាកដែលគេដឹងថាមានវីរុសគ្រុនផ្តាសាយប្រភេទA ទឹកលាងបក្សីត្រូវបានរកឃើញថាមានការឆ្លងខ្ពស់បំផុត នៅខណៈវីរុសH5N1ត្រូវបានរកឃើញពី៤៥%នៃសំណាកដែលគេដឹងថាមានវីរុស និង H9N2 ត្រូវបានរកឃើញពី២៨%នៃសំណាកបានពីឧបករណ៍ជូត។ ការរីករាលដាលនៃវីរុសគ្រុនផ្តាសាយប្រភេទ A មានចំនួនច្រើននៅក្នុងសំណាកក្នុងអំឡុងពេលចូលឆ្នាំចិន ខណៈដែលអត្រានៃជំងឺគ្រុនផ្តាសាយបក្សីH5N1 និង H9N2បានកើនឡើងខ្ពស់ក្នុងអំឡុងពេលចូលឆ្នាំខ្មែរ ដែលនេះត្រូវគ្នានឹងពេលវេលានៃការផ្ទុះជំងឺ ដែលបានកត់ត្រាក្នុងឆ្នាំ២០១១ និង ២០១៣ ហើយចរាចរនៃវីរុសហាក់ដូចជាកើនឡើងជារៀងរាល់ឆ្នាំ។ ខ្ញុំសន្និដ្ឋានថា ការតាមឃ្លាំមើលទីផ្សារបក្សី គឺជាមធ្យោបាយដ៏មានប្រសិទ្ធភាព ក្នុងការតាមដានវីរុសគ្រុនផ្តាសាយបក្សី និង វីរុសគ្រុនផ្តាសាយដទៃទៀត ដែលមានសក្តានុពលតិចតួចដល់បសុបក្សីកម្ពុជា៕

Abstract

The Influenza A virus which infects birds in Cambodia is a form of the H5N1 bird flu virus that was first recognized in 2004. Continuous outbreaks of bird flu have occurred since its discovery and 56 people have been infected to date, 37 of whom have died. Surveillance for influenza A/H5N1 virus in Cambodia in 2011 and 2013 has also demonstrated high prevalence in the country's live bird markets. My study comprised surveillance for avian influenza viruses in poultry and environmental samples collected from O'Russei market in Phnom Penh from January to April 2017. In real-time RT-PCR testing, avian influenza viruses were detected in 52% of 242 samples collected during the sampling period. Detection rates ranged from 45% to 49% in swabs from ducks and chickens respectively, to 100% in samples of water used to wash bird carcasses. Influenza A/H5N1 virus was detected in 12% of samples positive for influenza A virus and in 6% of all samples collected from the market. Influenza A/H9N2 virus was also detected in 25% of samples positive for influenza A virus and in 13% of all samples. The H7 virus was not detected. With 100% of samples positive for influenza A virus, carcass wash water was most contaminated, whereas H5N1 virus was detected in 45% of all positive samples and H9N2 was detected in 28% of all chicken swab samples. The prevalence of influenza A virus was greater in samples during the Chinese new year period, whereas the prevalence of H5N1 and H9N2 was greater during the Khmer new year period. This matches the timing of outbreaks documented in 2011 and 2013 and circulation of the virus appears be increasing each year. I conclude that surveillance of live bird markets is an effective way of monitoring for the highly pathogenic H5N1 virus and for other avian influenza viruses with low pathogenic potential in Cambodian poultry.

Citation: Sun S. (2018) Surveillance and characterization of avian influenza virus in Cambodia. *Cambodian Journal of Natural History*, **2018**, 42–43.

Diversity and relative abundance of mosquito vectors of dengue virus in 24 primary schools in Kampong Cham and Tboung Khmum province, Cambodia

YEAN Sony

មូលន័យសង្ខេប

មានសត្វមូសចំនួន២៩៣ប្រភេទ ស្ថិតក្នុង២០ពួក ត្រូវបានគេធ្វើកំណត់ត្រានៅក្នុងប្រទេសកម្ពុជា។ ករណីវីរុសគ្រុនឈាមជាច្រើនកើតឡើងជារៀងរាល់ឆ្នាំនៅក្នុងខេត្ត-ក្រុងទាំង២៥នៃប្រទេស ដែលមូស*Aedes aegypti* គឺជាវ៉ិចទ័រសំខាន់ក្នុងការចម្លងវីរុសគ្រុនឈាមទៅមនុស្ស ចំណែកឯ*A. albopictus* ត្រូវបានគេចាត់ទុកជាវ៉ិចទ័រសំខាន់ទីពីរ។ ការសិក្សានេះ មានគោលបំណងកំណត់នានាភាព និង ប្រភេទនៃវ៉ិចទ័ររបស់ជំងឺគ្រុនឈាម នៅក្នុងសាលាបឋមសិក្សាទាំង១៩នៃខេត្តកំពង់ចាម និង ៥សាលានៅខេត្តត្បូងឃ្មុំ។ អន្ទាក់ប្រភេទ BG-sentinel និង អន្ទាក់ពន្លឺCDC light ត្រូវបានប្រើដើម្បីប្រមូលសត្វមូសក្នុងខែមីនា និង សីហា ឆ្នាំ២០១៧។ ជាលទ្ធផលចាប់បានមូសចំនួន១០.៩៦៩ក្បាល ដែល៣.៩៦៩ក្បាលត្រូវបានចាប់នៅខែមិនា និង៦.៥២៨ក្បាលទៀតចាប់នៅខែសីហា។ មូសចំនួន៥៩ប្រភេទបានមកពី១១ពួក ត្រូវបានធ្វើអត្តសញ្ញាណដោយប្រើសំណាកដែលបានប្រមូលបាន ទោះបីជាមូសមួយចំនួនតូចអាចកំណត់អត្តសញ្ញាណបានត្រឹមពួកប៉ុណ្ណោះ។ មានមូសបីប្រភេទតំណាងឲ្យ៦៣.៥% នៃសំណាកប្រមូលទាំងអស់ គឺ *Culex vishnui, C. quinquefasciatus* និង *Anopheles indefinitus*។ មានមូសតិចជាងនៅខែឧសភា (n=40) បើធៀបនឹងខែ សីហា (n=46) ហើយចាប់បានច្រើនដោយអន្ទាក់CDC light (n=54) ធៀបទៅនឹងBG-sentinel (n=20)។ ទោះជាយ៉ាងណាក៏វត្តមានមូស*A. aegypti* មិនមានភាពខុសគ្នាដាច់ រវាងសាលាដែលមានការប្រើថ្នាំសម្លាប់សត្វល្អិតដោយគម្រោងECOMORE 2 និងសាលាដែលមិនមានការប្រើថ្នាំ។ *A. aegypti*ញីចំនួន១៨៣ក្បាល (១.៧%នៃសំណាក) និង *A. albopictus*ញីចំនួន ១១៦ក្បាល (១%)ត្រូវបានធ្វើកំណត់ត្រា មូសជាវ៉ិចទ័ររបស់វីរុសគ្រុនឈាម មិនមែនជាប្រភេទដែលសម្បូរជាងគេទេ។ ទោះជាយ៉ាងណាក៏ដោយ វ៉ិចទ័ររបស់វីរុសJapanese encephalitis ដូចជា *C. vishnui* និង *C. quinquefasciatus* មានចំនួនច្រើន និង អាចចម្លងទៅមនុស្សដែលរស់នៅជិតៗសាលានោះនៅពេលយប់។ លទ្ធផលនៃការសិក្សានេះបង្ហាញថា នានាភាព និង ចំនួននៃសត្វមូសមានភាពខុសគ្នាអាស្រ័យទៅលើទីជម្រក រដូវ និង កន្លែងដែលវានៅ។ សរុបមកការគ្រប់គ្រងវ៉ិចទ័រមានភាពចាំបាច់ណាស់ ដើម្បីការពារក្មេងៗ និង អ្នកស្រុកពីការឆ្លងរោគផ្សេងៗដោយសារមូស។

Abstract

Two hundred and forty-three mosquito species belonging to 20 genera have been recorded in Cambodia. Cases of dengue virus occur every year in 25 provinces of the country and *Aedes aegypti* is the main vector for dengue virus transmission to humans, whereas *A. albopictus* is considered the second most important vector. My study aimed to determine the diversity and relative abundance of dengue vectors in 19 primary schools in Kampong Cham province and five primary schools in Tboung Khmum province. BG-sentinel traps and CDC light traps were used to collect mosquitoes at these in May and August 2017. This resulted in the capture of 10,793 mosquitoes, 3,969 of which were caught in May and 6,824 in August. Fifty-four species of mosquito arranged in 11 genera were identified from the material collected, although a few other species were identified only to genus. Three species represented 63.5% of all mosquitoes collected: *Culex vishnui* (group), *C. quinquefasciatus* and *Anopheles indefinitus*. Fewer mosquito species were caught in May (*n*=40) than August (*n*=46) and more were caught in CDC light traps (*n*=54) compared to BG-sentinel traps (*n*=20). There was also no significant difference in numbers of *A. aegypti* mosquitoes present in schools selected for insecticide treatment by the ECOMORE 2 project and schools which would not be treated. With 183 female *A. aegypti* (1.7% of captures) and 116 female *A. albopictus* (1%) recorded, the major vectors for dengue virus were not the most abundant species. However, vectors for Japanese encephalitis virus such as *C. vishnui* (group) and *C. quinquefasciatus* were abundant and could infect humans living nearby the schools at night. My results suggest that mosquito diversity and their relative species abundances variably depend on habitat, season and places for rest. I conclude that vector control is needed to protect children and other local residents from associated disease infections.

Citation: Yean S. (2018) Diversity and relative abundance of mosquito vectors of dengue virus in 24 primary schools in Kampong Cham and Tboung Khmum province, Cambodia. *Cambodian Journal of Natural History*, **2018**, 43–44.

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).

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New species & taxonomic reviews

Bayarsaikhan, U., Bucsek, K. & Bae, Y-S. (2018) A review of the genus *Eugoa* Walker (Lepidoptera, Erebidae, Arctiinae, Lithosiini) in Cambodia, with the description of a new species. *Zootaxa*. DOI 10.11646/zootaxa.4403.3.3

The authors review the *Eugoa* moth genus in Cambodia which comprises 20 species, including one new species to science that they describe (*E. arguta*) and first records of three species: *E. vasta*, *E. formosicola* and *E. kuznetzovi*. A key to the species in the genus in Cambodia is provided, including illustrations of adults and genitalia. Author: uug228@yahoo.com

Kosterin, O.E. & Kompier, T. (2018) *Amphicnemis valentini* sp. nov. from the Cardamom ecoregion in Cambodia and Vietnam (Odonata: Coenagrionidae). *Zootaxa*. DOI 10.11646/zootaxa.4429.2.4

Describes a new species of *Amphicnemis* to science from the Ream Peninsula of Cambodia (Preah Sihanouk Province) and Phú Quốc Island, Vietnam. The new species is similar to *A. gracilis*, which occurs in Peninsular Malaysia and Sumatra, but differs in having a long process on the male prothorax. Author: kosterin@bionet.nsc.ru

Neang T., Chan S. & Poyarkov, N.A. (2018) A new species of smooth skink (Squamata: Scincidae: Scincella) from Cambodia. *Zoological Research*, **39**, 220–240.

The authors use morphological and genetic data to describe a new species of smooth skink to science from Keo Seima Wildlife Sanctuary, Mondulkiri Province. Named *Scincella nigrofasciata*, the new species is forest-dwelling and can be distinguished from all other Southeast Asian congeners by a combination of morphological characters. Author: thyneang9@gmail.com

Jia Y., Wang S. & Bae, Y-S. (2018) The genus *Promalactis* Meyrick (Lepidoptera: Oecophoridae) in Cambodia, with description of eight new species. *Zootaxa*. DOI 10.11646/zootaxa.4422.1.6

Describes nine species of the *Promalactis* moth genus from Cambodia, including eight species new to science and one new record for the country. Photographs of adults and genitalia are provided. Author: uug228@yahoo.com

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.

This study presents new data recorded on 33 new or rare species with the *Hoya* plant genus in eastern Indochina between 2012–2017, including eight species from Cambodia. Including the new data, the flora of eastern Indochina comprises at least 45 species within the genus. Author: av_leonid@mail.ru

Bayarsaikhan, U., Lee D-J. & Bae, Y-S. (2018) A review of *Barsine* Walker, 1854 (Lepidoptera: Erebidae, Arctiinae) in Cambodia, with a new record. *Journal of Asia-Pacific Biodiversity*. DOI 10.1016/j.japb.2018.05.003

The authors review the *Barsine* moth genus in Cambodia, documenting the occurrence of 12 species including the first country record for one: *B. sieglindae*. They also provide a key to *Barsine* species in Cambodia with illustrations of adults and genitalia. Author: uug228@yahoo.com

Chan B.P.L. & Li F. (2017) Significant records of three bunting species from Cambodia, including a first country record. *BirdingASIA*, **28**, 54–55.

Describes observations of three bird species (little bunting *Emberiza pusilla*, black-headed bunting *E. melanocephala* & yellow-breasted bunting *E. aureola*) in Kratie Province in 2017. The observation of black-headed bunting may be the first unequivocal record of the species in the wild in Cambodia. Author: boscokf@kfbg.org

Kosterin, O.E. (2016) A survey of Odonata of Mondulkiri, the elevated eastern province of Cambodia, for ten days in June 2014. *International Dragonfly Fund*, **98**, 1–85.

The author presents the results of a dragonfly survey in eastern Mondulkiri in 2014. Of the 106 species encountered, 97 were assigned to previously described taxa, including 15 which represent first records for Cambodia. Remarks on taxonomy and habitats are provided. Author: kosterin@bionet.nsc.ru

Matalin, A.V. (2018) New records of tiger beetles (Coleoptera, Carabidae: Cicindelinae from Cambodia. *Far Eastern Entomologist*, **356**, 9–16.

Describes four tiger beetle species recorded from Cambodia for the first time: *Naviauxella labiosa*, *Cylindera* (Ifasina) *viridilabris*, *C.* (*Eugrapha*) *biprolongata* and *C.* (*E.*) *mutata*. New records of three additional species are also reported for the Kampot, Preah Sihanouk and Pursat provinces. Author: andrei-matalin@yandex.ru

Ohtaka A. (2018) Aquatic oligochaete fauna (Annelida, Clitellata) in Lake Tonle Sap and adjacent waters in Cambodia. *Limnology*. DOI 10.1007/s10201-018-0543-5

This study presents the results of surveys of aquatic oligochaetes in and adjacent to the Tonle Sap Lake between 2000 and 2005. Thirty-nine taxa were recorded, which mainly comprised widely distributed species. Author: ohtaka@hirosaki-u.ac.jp

Species ecology & status

Claassen, A.H., Forester, J.D., Arnold, T.W. & Cuthbert, F.J. (2018) Consequences of multi-scale habitat selection on reproductive success of riverine sandbar-nesting birds in Cambodia. *Avian Biology Research*, **11**, 108–122.

Habitat selection occurs at multiple spatial scales and affects demographic processes such as reproductive success. The authors investigated the consequences of habitat selection on the reproductive success of four riverine sandbar-nesting bird species in Cambodia. All four species generally selected larger habitat patches in territories with higher proportions of bare ground substrates, including gravel and dry mud. Vegetation generally had a negative effect on reproductive success, which was likely due to the reduced ability of incubating birds to detect predators, or increased cover or foraging efficiency of predators. Proximity to the river channel also reduced nest success, as nests near the channel had a higher risk of flooding. Author: claas004@umn.edu

Eam S.U., Chantha N., Hang C., Thaung R. & Frechette, J. (2018) Camera trapping in the Cardamom Mountain Landscape, Cambodia, reveals Asian elephant calves with severe injuries from wire snares. *Oryx*, **52**, 409.

The authors summarize the results of camera trapping efforts which suggest that wire snares could be causing unnaturally high calf mortality among elephant populations in the Cardamom Mountains of southwestern Cambodia. Although efforts to remove wire snares are ongoing in the region, the practice of snaring appears to be increasing. Author: jackson.frechette@fauna-flora.org

Gray, T.N.E. (2018) Monitoring tropical forest ungulates using camera-trap data. *Journal of Zoology*. DOI 10.1111/jzo.12547

Despite their ecological and conservation importance, tropical forest ungulates are poorly known with few studies on their density and abundance. This study estimated densities of lesser oriental chevrotain *Tragulus kanchil* in the Southern Cardamom National Park using camera-trap encounter rates and a random encounter model (REM) that does not require individual identification of animals. Random deployment of camera-traps, a prerequisite of the REM, did not prevent detection of most of the ground-dwelling large mammal species likely present. The author concludes the REM has potential for monitoring tropical ungulates, particularly in dense evergreen forest where other methods are unsuitable. Author: gray@wildlifealliance.org

Gray, T.N.E., Hughes, A.C., Laurance W.F., Long, B., Lynam, A.J., O'Kelly, H., Ripple, W.J., Seng T., Scotson, L. & Wilkinson N.M. (2018) The wildlife snaring crisis: an insidious and pervasive threat to biodiversity in Southeast Asia. *Biodiversity Conservation*. DOI 10.1007/s10531-017-1450-5

Southeast Asia supports more threatened species than any comparable continental area and is in the midst of a conservation crisis due to hunting. This article reviews the threat posed by the use of wire snare traps which have resulted in many largely intact forest areas losing much of their former vertebrate diversity and abundance. Because snares are easily and cheaply replaced, removal efforts alone will not solve the problem. The authors reccommend actions to address the issue including the proactive search, arrest and prosecution of snare-setters, development and enforcement of legislation criminalizing the possession of snares and measures to reduce the demand for wildlife products in Southeast Asia. Author: gray@wildlifealliance.org

Hon N., Behie, A.M., Rothman, J.M. & Ryan, K.G. (2018) Nutritional composition of the diet of the northern yellow-cheeked crested gibbon (*Nomascus annamensis*) in northeastern Cambodia. *Primates*. DOI 10.1007/s10329-018-0663-x

The authors measured the nutritional composition of food items consumed by a group of northern yellow-cheeked crested gibbons for four months during the dry season in northeastern Cambodia. The gibbons spent spent the most of their time feeding on fruit, followed by young leaves, flowers and mature leaves. Details of the nutritional composition of these items are provided and may contribute to captive feeding programmes, ultimately assisting conservation of the species. Author: navenhon@yahoo.com

Lim T., Cappelle, J., Hoem T. & Furey, N.M. (2018) Insectivorous bat reproduction and human cave visitation in Cambodia: a perfect conservation storm? *PLOS ONE*, **13**, e0196554.

Cave roosting bats represent an important component of Southeast Asian bat diversity and are vulnerable to human disturbance during reproductive periods. Because dramatic growth of cave tourism in the region has raised concerns about impacts on cave bats, the authors assessed the reproductive phenology of two species and patterns of human-cave visitation in southern Cambodia. Their results indicate that major birth peaks for the bats coincide with the time of greatest cave visitation each year (April) and therefore raise a conservation concern. Because growing evidence suggests that insectivorous cave bats exhibit reproductive synchrony across mainland Southeast Asia where countless cave shrines are heavily frequented during April in Theravada Buddhist countries, their findings may have wider applicability in the region. Authors: lim.thona@yahoo.com, neil.m.furey@gmail.com

Moody, J.E. (2018) *Population genetics, biogeography, and conservation of the Indochinese silvered langur, Trachypithecus germaini, in Cambodia: is the Mekong River a taxonomic boundary?* PhD thesis, Fordham University, New York, USA.

Indochinese silvered langurs are traditionally considered a single species whose distribution spans the Mekong River, although recent data suggest the river divides two separate species. This study used genetic data, ecological niche models, acoustic and pelage data to evaluate the Mekong barrier hypothesis. The results provide support for the existence of two silvered langur species in Indochina (*Trachypithecus germaini* and *T. margarita)*, which likely diverged as a result of isolation in rainforest refugia during the Pleistocene. The author suggests that future studies of silvered langurs in Indochina should focus on clarifying the limits between the two species and estimating population sizes in certain landscapes.

Rostro-García, S., Kamler, J.F., Crouthers, R., Sopheak K., Prum S., In V., Pin C., Caragiulo, A. & Macdonald, D.W. (2018) An adaptable but threatened big cat: density, diet and prey selection of the Indochinese leopard (*Panthera pardus delacouri*) in eastern Cambodia. *Royal Society Open Science*, **5**, 171187.

The authors studied Indochinese leopards *Panthera pardus delacouri* in Srepok Wildlife Sanctuary to determine their density, diet, prey selection and predation impact. The density revealed was one of the lowest ever reported in Asia and dietary analysis confirmed 13 prey species, although ungulates (banteng *Bos javanicus*, wild pig *Sus scrofa* & muntjac *Muntiacus vaginalis*) represented most of the biomass consumed and important differences existed in diet and prey selection between sexes. Predation impact was low for the three ungulate species. The authors conclude that leopard is an important apex predator in Srepok Wildlife Sanctuary but will soon be eradicated unless effective protection is provided. Author: rostro.susana@gmail.com

Trisurat, Y. & Bhumpakphan, N. (2018) Effects of land use and climate change on Siamese eld's deer (*Rucervus eldii siamensis*) distribution in the transboundary conservation area in Thailand, Cambodia, and Lao PDR. *Frontiers in Environmental Science*. DOI 10.3389/fenvs.2018.00035

This study used occurrence data to predict the distribution of Siamese eld's deer in the transboundary area of Thailand, Cambodia and Laos and determine potential shifts in suitable habitats due to different land use and climate change scenarios in 2030. Predicted habitats were concentrated in the protected areas of lowland Cambodia and Laos. Land use change alone did not affect the distribution of the species, whereas climate change affected it substantially. The authors provide recommendations for cooperation in conservation efforts among the three countries, habitat protection and ex-situ conservation. Author: fforyyt@ku.ac.th

Coasts, wetlands and aquatic resources

Althor, G., Mahood, S., Witt, B., Colvin, R.M. & Watson, J.E.M. (2018) Large-scale environmental degradation results in inequitable impacts to already impoverished communities: a case study from the floating villages of Cambodia. *Ambio*. DOI 10.1007/s13280-018-1022-2

Subsistence communities within the Tonle Sap Lake area rely on resource extraction from the lake for their livelihoods and potentially face serious challenges due to climate change and hyrdrological changes related to dam construction in the Mekong Basin. The authors interviewed subsistence fishers across five floating villages on the lake in 2015 and found that the fishery system is undergoing a rapid ecological decline, with available fish stocks increasingly experiencing reductions. The implications of these losses for the future of floating village communities on the lake are considered. Author: g.althor@uq.edu.au

Heng K., Chevalier, M., Lek S. & Laffaile, P. (2018) Seasonal variations in diet composition, diet breadth and dietary overlap between three commercially important fish species within a flood-pulse system: the Tonle Sap Lake (Cambodia). *PLOS One*, **13**, e0198848.

Tropical lakes and their associated floodplains are dynamic habitats strongly influenced by seasonal variations in hydrological conditions. The authors investigated whether seasonal changes in the water level of the Tonle Sap Lake differentially affect the diet breadth and dietary overlap of three commercially important fish species (*Anabas testudineus*, *Boesemania microplepis* & *Notopterus notopterus*) with important differences in their life-cycles e.g., seasonal migration. Their results demonstrate seasonal variation occurs in dietary breadth and overlap which suggests considerable plasticity occurs in the feeding behaviour of the three species. Author: mathieu.chevalier38@gmail.com

Oyagi H., Endoh S., Ishiwaka T., Okumura Y. & Tsukawaki S. (2017) Seasonal changes in water quality as affected by water level fluctuations in Lake Tonle Sap, Cambodia. *Geographical Review of Japan Series B*, **90**, 53–65.

The water level of the Tonle Sap Lake varied by 8 m between seasons in 2005, which caused dramatic seasonal changes in its surface area. The authors assessed water quality in the lake during the low and high water periods. They conclude that changes in lake water quality during low water periods are partly caused by the increased influence of discharge from inflowing tributaries as the volume of lake water decreases. Seasonal changes are also caused by contamination from mobile floating villages around the lake's margin. During the wet season, water quality does not appear to be affected by human activity but is significantly affected by reverse inflow from the Mekong River. Author: oyagi.hideo@nihon-u.ac.jp

Forests and forest resources

Lonn P., Mizoue N., Ota T., Kajisa T. & Yoshida S. (2018) Biophysical factors affecting forest cover changes in community forestry: a country scale analysis in Cambodia. *Forests*, **9**, 273.

Community forestry is increasingly used in developing countries to achieve poverty reduction and ecological outcomes. The authors used a nationwide dataset of 197 community forestry projects established between 1994 and 2005 across Cambodia to identify biophysical factors that affected forest cover changes from 2005 to 2016. Their results indicate that deforestation was likely to increase with increasing size of the community forestry area at lower elevations and on gentler slopes. Deforestation also increased if the community forestry area was located close to villages, markets and community forestry boundaries, but further away from main roads. Author: mizouenn@gmail.com

Sakkhamduang, J., Miwa K. & Mihara M. (2017) Resin trees: a vital source of the Phnong people's livelihood in transition in Cambodia. In *Sustainable Livelihoods in Socio-ecological Production Landscapes and Seascapes* (eds S.M. Subramanian, S. Chakraborty, B. Leimona, Y. Amano & K. Ichikawa), pp. 58–66. United Nations University Institute for the Advanced Study of Sustainability, Tokyo.

The Phnong people account for as much as 80% of the population of Mondulkiri Province and depend on self-sufficient agriculture for their livelihoods. Resin trees provide an important income source during rice shortages but are threatened by illegal logging and changes in land use due to economic land concessions. This study explores the causes and effects of the decrease in resin trees upon the livelihoods of the Phnong and ways in which they cope with the challenge. Solutions are proposed including the involvement of resin tree stands in REDD+ or carbon mitigation programmes and increasing agricultural productivity to enhance food security. Author: j.sakkhamduang@gmail.com

Scheidel, A. & Work, C. (2018) Forest plantations and climate change discourses: new powers of 'green' grabbing in Cambodia. *Land Use Policy*, **77**, 9–18.

Efforts to combat global climate change through forestry plantations intended to sequester carbon and promote sustainable development are increasing. The authors analyze Cambodia´s first large-scale reforestation project awarded within the context of climate change mitigation. Through their case study, they conclude that current climate change discourses, forestry agendas and their underlying assumptions require critical revision in global policy discussions to forestall the growing problem of green grabbing in land use. Author: arnim.scheidel@gmail.com

Turreira-García, N., Meilby, H., Brofeldt, S., Argyriou, D. & Theilade, I. (2018) Who wants to save the forest? Characterizing community-led monitoring in Prey Lang, Cambodia. *Environmental Management*, **61**, 1019–1030.

Community monitoring is sometimes thought to succeed only where sustained funding, legislation for communities to enforce rules, clear tenure rights and a state-created enabling environment exist. The authors present a case-study of a grassroots-monitoring network that protected forest where no external incentives or rule enforcement power were provided. Despite this, and a lack of land-ownership rights and enduring threats of violence and conflicts, their results show that autonomous community monitoring can take place when members are sufficiently motivated by the risk of losing their resources. Author: ntg@ifro.ku.dk

Environmental policy & practice

Beauchamp, E., Woodhouse, E., Clements, T. & Milner-Gulland, E.J. (2018) "Living a good life": conceptualizations of well-being in a conservation context in Cambodia. *Ecology and Society*, **23**, 28. DOI 10.5751/ES-10049-230228

Conservation practice is sometimes criticized for relying on simplistic assumptions about social contexts in natural resource management. The authors provide one of the first examinations of local conceptualizations of well-being in a conservation context, using mixed methods to examine these at three sites in northern Cambodia. Taken together, their results suggest that conservation incentives that mirror people's aspirations can balance out negative trade-offs linked to compliance and contribute to well-being. Author: emilie.beauchamp@zoo.ox.ac.uk

Flor, R.J. Chhay K., Sorn V., Maat, H. & Hadi, B.A.R. (2018) The technological trajectory of integrated pest management for rice in Cambodia. *Sustainability*, **10**, 1732.

While the efficacy of integrated pest management has been demonstrated in Cambodia, its dissemination and sustained adoption has not met with similar success. The authors explore technological systems and pest management trends that have influenced this by examining connections between pest management options at the farmer level and conditions in the technological system. Although programs have targeted change by increasing knowledge of integrated pest management, they conclude that many of the systemic conditions in place sustain the current reliance on pesticides. Authors: r.flor@irri.org

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

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:

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

Books and chapters:

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

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

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

Reports:

Lic V., Sun H., Hing C. & Dioli, M. (1995) *A Brief Field Visit to Mondolkiri Province to Collect Data on Kouprey* (Bos sauveli), *Rare Wildlife and for Field Training.* Unpublished report to Canada Fund and IUCN, Phnom Penh, Cambodia.

Theses:

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

Websites:

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

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Cambodian Journal of Natural History

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