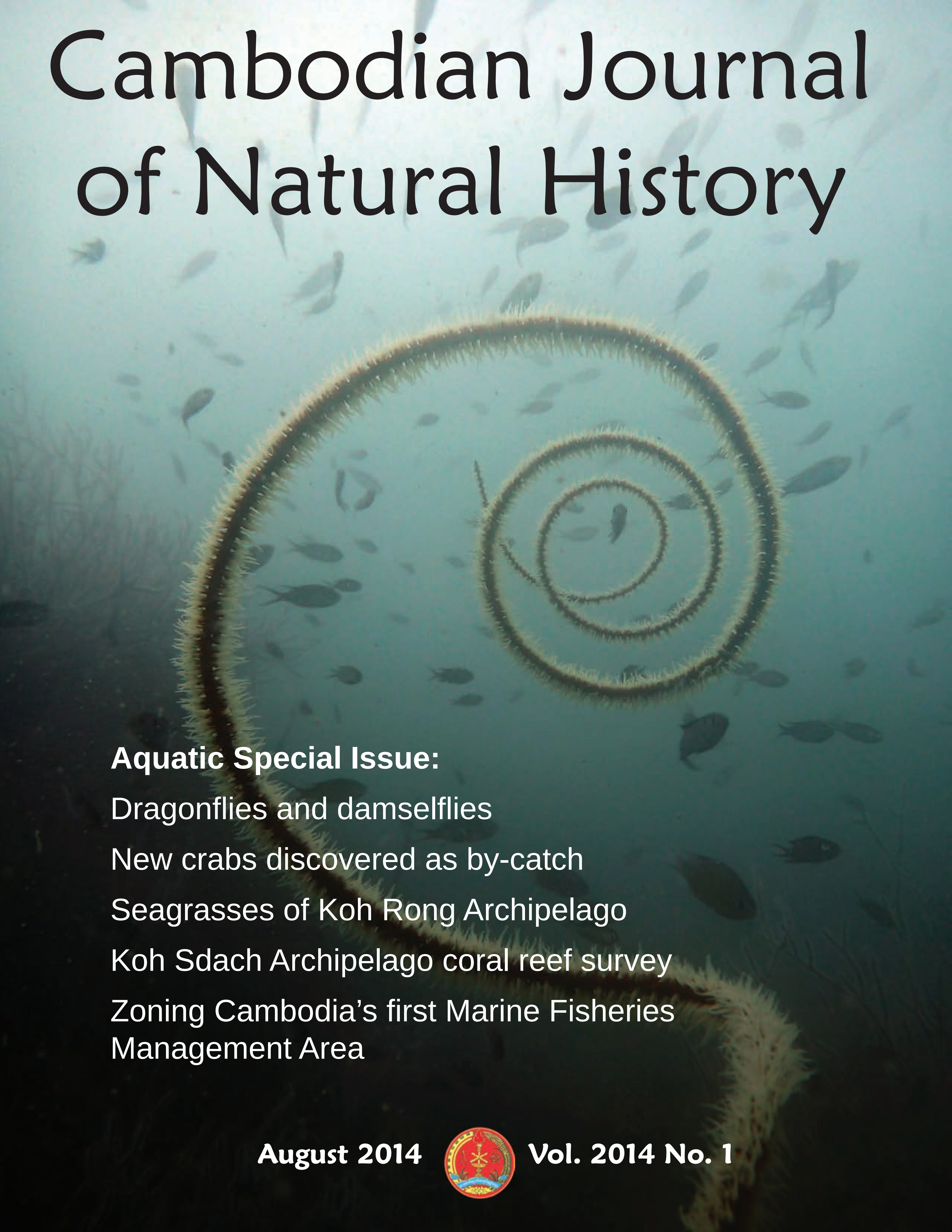
Cambodian Journal of Natural History



Aquatic Special Issue:

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New crabs discovered as by-catch

Seagrasses of Koh Rong Archipelago

Koh Sdach Archipelago coral reef survey

Zoning Cambodia's first Marine Fisheries Management Area

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Cover photo: A sea whip (order Alcyonacea) near Koh Bong in the Song Saa Marine Reserve (© Jelena Vukosavljevic, Song Saa Private Island). The reserve is within the proposed Koh Rong Archipelago Marine Fisheries Management Area, the focus of papers in this issue led by Cambodian scholars Leng Phalla and Boon Pei Ya.

Guest Editorial—Lots of information collected about marine living resources, but where is it? And can it be trusted?

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"Out of sight—out of mind", is an excuse that has often been used to explain why so little is known about biodiversity in the sea. With the exception of what washes up on the beach and what can be seen in the fish market, marine biodiversity remains largely hidden from human eyes. This means we have to remind ourselves—or be reminded—that marine biodiversity needs our attention, care and protection, just like that of forests, mountains and wetlands.

Cambodia has one of the world's largest inland fisheries and naturally the focus of international organizations, as well as the national government, has been largely on the conservation and sustainable use of freshwater fisheries resources. The unique hydrological features associated with the seasonal reversal of flow to and from the Tonle Sap Lake have intrigued scientists from all over the world, and there is great concern about the potential damage caused by constructing hydro-electric power plants across the Lower Mekong water course (see e.g. Hogan *et al.*, 2004; Campbell *et al.*, 2006; Baran & Myschowoda, 2009).

Much less attention has been given to the marine biodiversity of Cambodia. Marine capture fisheries, though increasing, remain less than 20% the size of the inland fisheries, and hence fewer resources have been allocated to this field. Over the years, numerous international projects have operated in the Cambodian coastal zone, and much information has been gathered about vulnerable ecosystems, the socio-economics of coastal residents, and the impacts of legislation relating to environmental degradation and use of fisheries resources.

One of the largest projects, usually called the UNEP South China Sea Project for short, involved seven countries surrounding the South China Sea, over 16 million dollars in direct funding, and about the same amount in local "in-kind" contributions, and lasted from 2002 through 2008 (Vo & Pernetta, 2010). The results from this project have entered the international scientific literature (e.g. Vo *et al.*, 2013), and provided government agencies with national reports, trained staff members, established demonstration sites for the general public (e.g. UNEP, 2007) and published posters and booklets on various ecosystems (e.g. UNEP, 2004).

For Cambodia, this project funded assessments of coral reef, seagrass and mangrove habitats. We now have a fair knowledge of the size of these vulnerable ecosystems and, equally importantly, where they are located. This information constituted the baseline information for developing a *National Action Plan for Coral Reef and Seagrass Management in Cambodia 2006–2015* (FiA, 2006). The project also funded the publication of a bilingual field guide to the marine living resources in Cambodia, which unfortunately was printed in far too few copies (Ing *et al.*, 2006).

Smaller projects have taken over and carry out Reef Check and Seagrass Watch procedures to monitor the state of selected reefs and seagrass beds. Some of these projects are carried out by local Cambodian government employees, but most use foreign volunteers, often marine biology students. Few Cambodians have diving skills or can afford the equipment and other associated costs. However, dive shops exist for tourists, and the staff and boats from these shops have been involved in several projects.

Every NGO has its own "mission and vision", but this may seem like semantics when applying for foreign grants: you put your pen where the money

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is. If the donor wants you to include gender issues, you include them in your application; if they focus on sustainability, you make this a priority goal; and so on. One project may be specifically dedicated to seahorses—small threatened fish used in traditional medicine. Another project may focus on the economic costs and benefits of tourism in coral reef areas. Other projects may focus on socioeconomics and the development of small-scale fisheries. In spite of this diversity in aims and goals, there is a lot of overlap in the reports that result from these projects. Many socioeconomic questionnaires containing basically the same questions are presented to basically the same people by different projects. Similarly, the same coral reef may be surveyed by transects, manta-tows and random quadrat photography. Unfortunately there are sometimes conflicting results among reports.

The information gathered from this multitude of projects is valuable and useful, but often difficult to locate. In many cases, project teams write status reports for their funding bodies only. Most finish their projects with impressive reports on glossy paper, but rarely with an ISBN identification number, and rarely have these reports been subject to peer-review. Some information is available in Environmental Impact Assessment reports in connection with major development projects, usually in the private sector, but EIA reports are often inaccessible to the public, including scientists, because they are considered the private property of the company. Other information is available only in Khmer-language internal government reports, such as most fisheries statistics. There is a great need for a comprehensive review of the available data, and to improve the quality and reliability of the data from different studies.

The staff of government agencies, both national and local, try their best to keep up with all the findings from the various projects, but it often looks as if legislation is drafted, implemented and enforced at the same time as the field data are collected. One could say that Cambodia implements the holistic, integrated approach from need rather than choice, and "citizen science" was in use here years before it became fashionable in western countries (after the economic crisis drastically cut funding for science).

Government staff depend on scientific information to draft meaningful and effective regulations. Cambodian fisheries officers, however, usually have to collect field data at the same time they draft management measures, such as the *National Plan of Action for Sharks* (Ing *et al.*, 2004). Fortunately international organizations provide guidelines, but data still have to be collected. Although an increasing number of Cambodian ministerial officers have received upper level academic degrees (MSc and PhD), they rarely get the opportunity to be involved in basic research or participate in research publications. There is a need for collaboration between universities and government agencies that goes beyond supervising graduate thesis projects.

Cambodia is a signatory party to several international conventions related to marine biodiversity (Nao *et al.*, 2013). This means that Cambodia is expected to participate in meetings, submit national reports, and most importantly, comply with international regulations. This has occasionally led to awkward situations. At one time, Cambodia was urged to take measures against illegal fishing vessels, which were fishing tuna in the Atlantic Ocean. Obviously no Cambodian fishermen own vessels capable of fishing tuna in the Atlantic, but somehow these vessels had been registered in Cambodia and were flying the flag of Cambodia, but without a Cambodian license to fish. Recently, the European Union imposed an embargo on fisheries goods from Cambodia because "despite several warnings" the country had not taken sufficient measures to prevent illegal, unreported and unregulated (IUU) fishing. Cambodia is working on a National Action Plan to prevent, deter and eliminate illegal, unreported and unregulated fishing (NPOA-IUU fishing), but this takes time and requires funding.

Cambodia has four nationally protected areas in the coastal zone: Three National Parks (Bokor, Kep and Ream), and one Wildlife Sanctuary (Peam Krasop, part of which—Koh Kapik—is also a Ramsar Wetland of International Importance). These are all land-based but have a marine component. In addition, the UNEP South China Sea Project introduced a new concept for conserving critical habitats of certain species—Fisheries Refugia—and the South-East Asian Fisheries Development Center (SEAFDEC) assisted Cambodia to implement marine refugia (Ing *et al.*, 2010). A real Marine Protected Area, however, has yet to be formally established in Cambodia. The underwater area surrounding the islands of the Koh Rong Archipelago has been mentioned several times, and many reef areas have been surveyed again and again. In spite of all the information available, however, conflicting interests have so far stalled the formal establishment of a Marine Fisheries Management Area.

One of the latest government targets of the *Strategic Planning Framework for Fisheries 2010–2019*, is to increase aquaculture production by 15% annually. One can only guess at the impacts to vulnerable

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coastal environments of such an immense enterprise. Once again, it appears that research and policy development are carried out simultaneously with cutting mangroves and digging ponds. Moreover, this is happening at a time when most western countries are trying to ban imports of cultured fish and shrimps from countries that use wild-caught trash-fish for feed.

In Cambodia, conservation issues, which are often supported by small NGOs, have to compete with development projects, which are often supported by wealthy private companies. Unfortunately, the economy usually wins over ecology. The coastal marine waters of Cambodia house a diverse and possibly unique marine life, and it is important that this resource be protected for future generations (as well as to attract tourists). Having multiple NGO-supported projects without much coordination of their efforts has created a lot of information, but has had little or no lasting effect on the conservation or management of marine resources. The action plans remain plans without action.

It is time for someone in Cambodia to review the existing information and extract data from available reports that might be used for knowledge-based selection of sites to be protected. Also, NGO and international projects should be required to make their final results publicly available at a common website repository in Cambodia. The existing websites that contain some of this information should be urged to collaborate. The conservation of Cambodia's marine biodiversity is too important to end up as a pile of glossy paper reports on bookshelves in government offices.

References

Baran, E. & Myschowoda, C. (2009) Dams and fisheries in the Mekong Basin. *Aquatic Ecosystem Health & Management*, **12,** 227–234.

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

FiA—Fisheries Administration (2006) *National Action Plan for Coral Reef and Seagrass Management in Cambodia 2006–2015*. Ministry of Agriculture, Forestry and Fisheries, Fisheries Administration, Phnom Penh, Cambodia.

Hogan, Z.S., Moyle, P.B., May, B., Vander Zanden, M.J. & Baird, I.G. (2004) The imperiled giants of the Mekong. *American Scientist*, **92,** 228–237.

Ing T., Jensen, K.R., Pich S. & Va L. (2004) Shark and ray fisheries in Cambodia: a review of national management activities. *Fish for the People*, **2,** 24–31.

Ing T., Jensen, K.R. & Va L. (2006) *Field Guide to the Marine Living Resources of Cambodia*. Fisheries Administration, Phnom Penh, Cambodia.

Ing T., Etoh, S. & Sornkliang, J. (2010) The role of fishers' group in the establishment and management of a refugia system: experience of Cambodia. *Fish for the People*, **8,** 32.

Nao T., Ing T. & Jensen, K.R. (2013) Relevant international and regional instruments for sustainable development of small-scale marine fisheries: significance to Cambodia. *Fish for the People*, **11,** 24–31.

UNEP—United Nations Environment Programme (2004) *Coral Reefs in the South China Sea.* UNEP/GEF/SCS Technical Publication No. 2., United Nations Environment Programme, Bangkok, Thailand.

UNEP—United Nations Environment Programme (2007) *Seagrass Demonstration Sites in the South China Sea.* UNEP/GEF/SCS Technical Publication No. 6., United Nations Environment Programme, Bangkok, Thailand.

Vo, S.T. & Pernetta, J.C. (2010) The UNEP/GEF South China Sea Project: lessons learnt in regional cooperation. *Ocean & Coastal Management*, **53,** 589–596.

Vo, S.T., Pernetta, J.C. & Paterson, C.J. (2013) Status and trends in coastal habitats of the South China Sea. *Ocean & Coastal Management*, **85,** 153–163.

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Short Communication

A range extension for the new plant species *Solanum sakhanii* Hul, and its medicinal uses in a Bunong community in Mondulkiri Province

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Thanks to its wide range of ecosystems (Tan, 1952), including evergreen forests, deciduous dry forests, grasslands, mangroves, coral reefs, swamp forests, seagrass meadows, and wetlands, Cambodia harbours a rich floristic diversity. The country is home to about 2,308 known vascular plant species belonging to 852 genera in 164 families, including 214 endemic species (Dy Phon, 1982; Ministry of Environment, 2010). In the 1990s, Ashwell (1997) estimated that with a complete and systematic study, the flora would exceed 3,000 species. The total number of vascular plants remains unknown, but we now estimate that Cambodia has as many as 5,000 vascular plant species (Hul, unpublished data).

Cambodia's native flora has fascinated scientists through the ages (e.g. Loureiro, 1790; Pierre, 1879–1899; Lecomte, 1907–1951; Aubréville, 1960 onwards; Vidal *et al*., 1969; Martin, 1971; Matras & Martin, 1972), and botanists, ethnobotanists and biologists continue to take a keen interest in it to this day. With research over the past five years, the number of plant species recorded in Cambodia has increased, and 20 new vascular plants species have been described: *Acampe hulae* Telepova (Telepova, 2009), *Aeschynanthus cambodiensis* D.J. Middleton (Middleton, 2009), *Alocasia jiewhoei* V.D. Nguyen (Nguyen *et al*., 2010), *Amorphophallus hemicrypticus* Hetterscheid (Maxwell, 2009), *Areca riparia* Heatubun (Heatubun, 2011), *Ceratopteris oblongiloba* Masuyama & Watano (Masuyama & Watano, 2010), *Curculigo fabrei* Hul (Leti *et al*., 2013), *Dasymaschalon acuminatum* Wang & Saunders (Wang *et al*., 2009), *Doritis boulbetii* Telepova (Telepova, 2013), *Doritis pulcherrima f. cinnabarina* Telepova (Telepova, 2013), *Exacum darae* Hul (Hul, 2010), *Lagerstroemia kratiensis* W.J. de Wilde & Duyfjes (de Wilde & Duyfjes, 2013), *Lespedeza cambodianum* V.D. Nguyen (de Kok & Nguyen, 2013), *Miliusa cambodgensis* Chaowasku & Kessler (Chaowasku & Keßler, 2014), *Nepenthes bokorensis* Mey (Mey, 2009), *Nepenthes holdenii* Mey (Mey *et al*., 2010), *Peliosanthes cambodiana* Aver. & N. Tanaka (Averyanov *et al*., 2013), *Peliosanthes triandra* Aver. & N. Tanaka (Averyanov *et al*., 2014), *Solanum sakhanii* Hul (Leti *et al*., 2013) and *Syzygium bokorense* W.K. Soh & J. Parn. (Soh & Parnell, 2011).

These findings have contributed to a better understanding of the country's flora, but suggest that many species remain to be discovered.

In Northeast Cambodia, near the Vietnamese border, lies the province of Mondulkiri. This province has been studied primarily by zoologists, whose research has proved that the area's wide range of habitats supports an exceptionally high diversity of fauna (Walston *et al*., 2001; Rawson *et al*., 2009; Phan *et al*., 2010). Although its rich diversity of habitats also

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makes Mondulkiri an extremely interesting subject for botanists, only a handful of surveys have been conducted thus far (Jung *et al.*, 2014).

The province's largest ethnic group is the indigenous Bunong, one of the highland minorities who are considered to be among the first inhabitants of Cambodia. Over time, the Bunong people have developed a strong relationship with their natural environment (Bourdier, 2006). They are known for their extensive knowledge of plants, which they use for various purposes, such as medicine, food, building and hunting (Laval *et al.*, 2011). Their local knowledge has already been advantageous for ecological assessments of mammal species (Starr *et al.*, 2011) and we predicted this could also be used as a basis for botanical field studies, potentially helping to uncover new plant species.

The results of an ethnobotanical survey carried out in 2013 and 2014 with the Bunong people have enhanced our understanding of Mondulkiri's flora (Chassagne, in prep.). It is thanks to the knowledge of the Bunong that we discovered the newly described plant species *Solanum sakhanii* Hul during our investigation. The villagers of Dak Dam Commune (O'Reang District) have long known and used this plant as a traditional treatment for malaria and fevers. The plant grows on dry rice fields during the rainy season. The Bunong people collect the whole plant and cut it into small pieces, which are boiled for 15 minutes. The patient drinks this remedy four to six times per day until his condition has improved. It is also possible to make a steam bath with the boiling water.

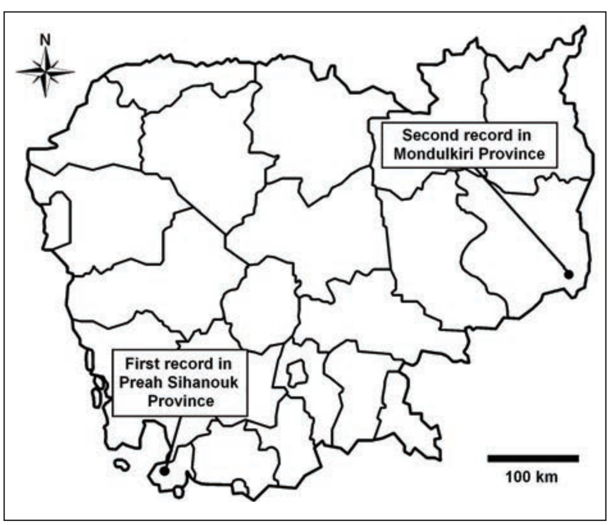

Fig. 1 Cambodia, showing the locations of the two records of *Solanum sakhanii* Hul.

This is the first paper to describe the plant *Solanum sakhanii* Hul as having medicinal uses, and also confirms the first record in Mondulkiri, and only the second record of this species in Cambodia and Southeast Asia.

Solanum sakhanii Hul is a small herb that was first discovered in 2008 and published in 2013 by Leti *et al.* (Chéng, Hul & David CL 929; holotype, P00836398; isotypes, P00836399, P00836400) near Kbal Chhay in Preah Sihanouk Province (10°39′23″N, 103°36′ 57″E, elevation 60 m) (Figs 1 and 2). It is a creeping, stoloniferous plant, which grows in open, humid environments or in the understory of dense forests. Other characteristics are listed as follows: Leaves are solitary or unequally paired; lamina ovate-elliptic, 4–7 × 2.5–4.0 cm, margin 3–5-sinuate lobed, pubescent with stellate hairs adaxially and abaxially, prickly along main veins on both surfaces. Inflorescences extra-axillary, scorpioid-racemose, 1–4-flowered. Flowers 5-merous, 10–12 mm long; pedicel pubescent with stellate hairs, prickly. Calyx of 5 sepals, pubescent with stellate hairs, prickly abaxially. Corolla of 5 petals, pale blue or purplish, pubescent with stellate hairs abaxially. Stamens 5, filaments 1–1.5 mm long; anthers narrow. Fruits: berries globose or subglobose, 1–1.5 cm in diameter, glabrous, ± included in the accrescent calyx, greenish-white to yellow.

We collected *Solanum sakhanii* Hul (Chassagne 138, P00723707) on 27 October 2013. This species was found to be very common in an upland rice field on red clay soil, in a disturbed area near an evergreen forest, in Dak Dam Commune, O'Reang District, Mondulkiri Province (12°24′37″N, 107°19′25″E, elevation 785 m) (Fig. 1). Specimens have been deposited in the National Herbarium of Cambodia (RUPP) in the Department of Biology, Faculty of Science, Royal University of Phnom Penh, and in the Paris Herbarium in France.

This record in Mondulkiri Province, in a different habitat (with red clay soil rather than sandy soil) and at a much higher altitude (785 m) than the type locality in Preah Sihanouk Province, indicates that the species *Solanum sakhanii* could be widely distributed. Further investigations in neighbouring countries, especially Vietnam and Laos, could be helpful to assess its presence in these countries. Moreover, the discovery that this plant is considered by the Bunong as having medicinal uses could be used for future phytochemical and pharmaceutical investigations.

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Fig. 2 *Solanum sakhanii* Hul, in its type locality in Preah Sihanouk Province (© B. David).

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References

Ashwell, D.A. (1997) *Cambodia: A National Biodiversity Prospectus.* Report to United Nations Development Program and Ministry of Environment, Phnom Penh, Cambodia.

Aubréville, A. (first editor) (1960 onwards) *Flore du Cambodge, du Laos et du Viêtnam*. Muséum National d'Histoire Naturelle, Paris, France. In 32 volumes.

Averyanov, L.V., Tanaka, N. & Luu H.T. (2013) New species of *Ophiopogon* and *Peliosanthes* (Asparagaceae) from Cambodia and Vietnam. *Taiwania*, **58,** 233–241.

Averyanov, L.V., Tanaka, N. & Nguyen S.K. (2014) New species of *Peliosanthes* and *Rohdea* (Asparagaceae) from Eastern Indochina. *Taiwania*, **59,** 18–25.

Bourdier, F. (2006) *The Mountain of Precious Stones (Ratanakiri, Cambodia).* Center for Khmer Studies (CKS), Phnom Penh, Cambodia.

Chaowasku, T. & Keßler, P.J.A. (2014) *Miliusa cambodgensis* sp. nov. (Annonaceae) from Cambodia and *M. astiana, M. ninhbinhensis* spp. nov. from Vietnam. *Nordic Journal of Botany,* **32,** 298–307.

Dy Phon, P. (1982) Végétation du Cambodge: endémisme et affinités de sa flore avec les régions voisines. *CR, Socio Biogéographie,* **58,** 135–144.

Heatubun, C.D. (2011) Seven new species of *Areca* (Arecaceae). *Phytotaxa*, **28,** 6–26.

Hul, S. (2010) Two new species of Gentianaceae from Indochina. *Edinburgh Journal of Botany*, **67,** 155–160.

Jung, J., Ryu, Y., Won, H. & Choi, H. K. (2014) Morphological and molecular characterization of a new record of *Isoëtes coromandelina* subsp. *coromandelina* from Cambodia. *Plant Systematics and Evolution*, **300,** 43–50.

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

Laval, P., Rakotoarison, H., Savajol, N. & Toun V. (2011) The contribution of wild medicinal plants towards poverty alleviation and health improvements: a case study in two villages in Mondulkiri Province, Cambodia. *Cambodian Journal of Natural History*, **2011,** 29–39.

Lecomte, H. (first editor) (1907–1951) *Flore Générale de l'Indochine*. Masson, Paris, France. In 9 volumes + 9 supplements.

Leti, M., Hul, S., Fouché, J.G., Cheng S.K. & David, B. (2013) *Flore Photographique du Cambodge.* Éditions Privat, Toulouse, France.

de Loureiro, J. (1790) *Flora Cochinchinensis*. Ulyssupone Typis, et Expensis Academicis, Lisbon, Portugal.

Masuyama, S. & Watano, Y. (2010) Cryptic species in the fern *Ceratopteris thalictroides* (L.) Brongn. (Parkeriaceae): IV. taxonomic revision. *Acta Phytotaxonomica et Geobotanica*, **61,** 75–86.

Martin, M.A. (1971) *Introduction à l'ethnobotanique du Cambodge.* PhD thesis, Faculty of Sciences, University of Paris, France.

Matras, J. & Martin, M.A. (1972) Contribution à l'ethnobotanique des Brou (Cambodge—Province de Ratanakiri). *Journal d'Agriculture tropicale et de Botanique appliquée*, **19,** 1–97.

Maxwell, J.F. (2009) Vegetation and vascular flora of the Mekong River, Kratie and Steung Treng Provinces, Cambodia. *Maejo International Journal of Science and Technology*, **3,** 143–211.

Mey, F.S. (2009) *Nepenthes bokorensis*, a new species of Nepenthaceae from Cambodia. *Carniflora Australis*, **7,** 6–15.

Mey, F.S., Catalano, M., Clarke, C., Robinson, A., Fleischmann, A. & McPherson, S. (2010) *Nepenthes holdenii* (Nepenthaceae), a new species of pyrophytic pitcher plant from the Cardamom Mountains of Cambodia. In *Carnivorous Plants and their Habitats: Volume 2* (ed. S.R. McPherson), pp. 1306–1331. Redfern Natural History Productions, Poole, UK.

Middleton, D.J. (2009) A revision of *Aeschynanthus* (Gesneriaceae) in Cambodia, Laos and Vietnam. *Edinburgh Journal of Botany*, **66,** 391–446.

Ministry of Environment (2010) *Fourth National Report to the Convention of Biological Diversity*. Ministry of Environment, Phnom Penh, Cambodia.

Nguyen V.D., Regalado, J.C. & Chinh V.T. (2010) A new species of *Alocasia* (Araceae-Colocasieae). *Gardens' Bulletin Singapore*, **62,** 121–126.

Phan C., Prum S. & Gray, T.N. (2010) Recent camera trap records of globally threatened species from the Eastern Plains Landscape, Mondulkiri. *Cambodian Journal of Natural History*, **2010,** 89–93.

Pierre, J.B.L. (1879–1899) *Flore Forestière de Cochinchine*. Doin, Paris, France (5 volumes, index, and 400 plates).

Rawson, B.M., Clements, T. & Hor N.M. (2009) Status and conservation of yellow-cheeked crested gibbons (*Nomascus gabriellae*) in the Seima Biodiversity Conservation Area, Mondulkiri Province, Cambodia. In *The Gibbons: New Perspectives on Small Ape Socioecology and Population Biology* (eds S. Lappan & D.J. Whittaker), pp. 387–408. Springer New York, USA.

Soh W. K. & Parnell, J. (2011). Three new species of *Syzygium* (Myrtaceae) from Indochina. *Kew Bulletin*, **66,** 557–564.

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

Tan K.H. (1952) *Géographie du Cambodge et de l'Asie des Moussons*. Imprimerie Henry, Phnom Penh, Cambodia.

Telepova, M. (2009) *Acampe hulae* Telepova (Orchidaceae), une nouvelle espèce du Cambodge et du Laos. *Adansonia*, **31,** 267–272.

Telepova, M. (2013) *Doritis boulbetii* Telepova sp. nov., *Doritis pulcherrima f. cinnabarina* Telepova f. nov., deux nouveaux taxons lithophytes du Cambodge. *Rhône-Alpes Orchidées*, **50,** 6–15.

Vidal, J.E., Martel, G. & Lewitz, S. (1969) Notes ethnobotaniques sur quelques plantes en usage au Cambodge. *Bulletin de l'Ecole française d'Extême-Orient*, **55,** 171–232.

Walston, J., Davidson, P. & Men S. (2001) *A Wildlife Survey in Southern Mondulkiri Province, Cambodia*. Wildlife Conservation Society: Cambodia Program, Phnom Penh, Cambodia.

Wang, J., Chalermglin, P. & Saunders, R.M.K. (2009) The genus *Dasymaschalon* (Annonaceae) in Thailand. *Systematic Botany*, **34,** 252–265.

de Wilde, W.J.J.O. & Duyfjes, B.E.E. (2013) Miscellaneous information on *Lagerstroemia* L. (Lythraceae). *Thai Forest Bulletin (Botany)*, **41,** 90–101.

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Short Communication

Two more Odonata species recorded for Cambodia

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A checklist of Odonata species recorded in Cambodia was published in the December 2012 issue of the *Cambodian Journal of Natural History* (Kosterin *et al.*, 2012a), but was estimated to comprise only about a half of the country's actual species. The paper included dragonfly and damselfly species registered in the Cardamom Mountains foothills—specifically in Tatai Commune—by the resident second author over a number of years. Since that publication, the second author has recorded two more species of Odonata that are new records for Cambodia. They are published herein, along with additional new data from the same area.

Gerard Chartier has compiled photographic records of Odonata using a Canon EOS 500D camera with 18–55 mm and 55–250 mm lenses during his regular excursions in Tatai Commune, Koh Kong Province, within the area encompassed by the following points: Rainbow Lodge on the Stoeng Kep River ("Left Tatai River"), 1.6 km north of Phum Doung Bridge in Tatai Village (11.580˚N, 103.127˚E), the "lake area" of the Stoeng Sala Munthun River ("Right Tatai River"), 3.9 km north-northwest of Phum Doung Bridge (11.599–11.601˚N, 103.120–121˚E), and the Tatai Waterfall at the same river, 4 km northwest of Phum Doung Bridge (11.586˚N, 103.097˚E). This area is covered by evergreen forest and bamboo thickets over a low ridge. For more details of the area see Kosterin *et al.* (2012a). Two odonate individuals were found dead in a house at Rainbow Lodge and preserved dry in a paper envelope.

Heliaeschna simplicia **(Karsch, 1891)**

A male was found dead inside a house at Rainbow Lodge (11.580˚N, 103.127˚E) on 12 March 2013 (Fig. 1), seemingly after being attracted by light.

There used to be taxonomical and nomenclatural confusion around this species, but this was resolved by Lieftinck (1940). The identification of our male was unmistakable because of the shape of its cerci (Fig. 2), which are unique for *H. simplicia* (Karsch, 1891) (see also Fig. 161 for "*H. Weelei*" in Martin, 1909; Figs 22–23 for "*H. Weelei*" in Ris, 1927; and plate 14h in Orr, 2003). Other characters matched as well.

Until now, *H. simplicia* was known only from Borneo, Sumatra (Lieftinck, 1940; 1954), the Philippines (Hämäläinen & Müller, 1997; Tsuda, 2000) and Peninsular Malaysia (Orr, 2008). Ours is the first published record of this species in Indochina and in continental (not peninsular or insular) Asia.

Epophthalmia vittigera **(Rambur, 1842) ssp.** ***bellicosa*** **Lieftinck, 1948.**

A female was photographed by Gerard Chartier at Rainbow Lodge (11.580 N, 103.127 E) on 14 June 2013 (Fig. 3a) and a male on 18 June 2013 (Fig. 3b). Another female (Fig. 4) was found dead inside a house at Rainbow Lodge on 23 June 2013. More males were observed at the same place every day until at least 30 June 2013.

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Identification of this species was reliably based on the extensive dark patches at the wing bases in both sexes, the strong subapical inward angulation of the male cerci and the epiproct of the same length, and vertex tubercles without yellow markings (Fraser, 1936; Lieftinck, 1948).

Fig. 1 *Heliaeschna simplicia* (Karsch, 1891), a male found dead in Rainbow Lodge, Tatai Commune, Koh Kong Province, 12 March 2013 (© G. Chartier).

Fig. 2 *Heliaeschna simplicia* (Karsch, 1891), anal appendages of the same male (© O. Kosterin).

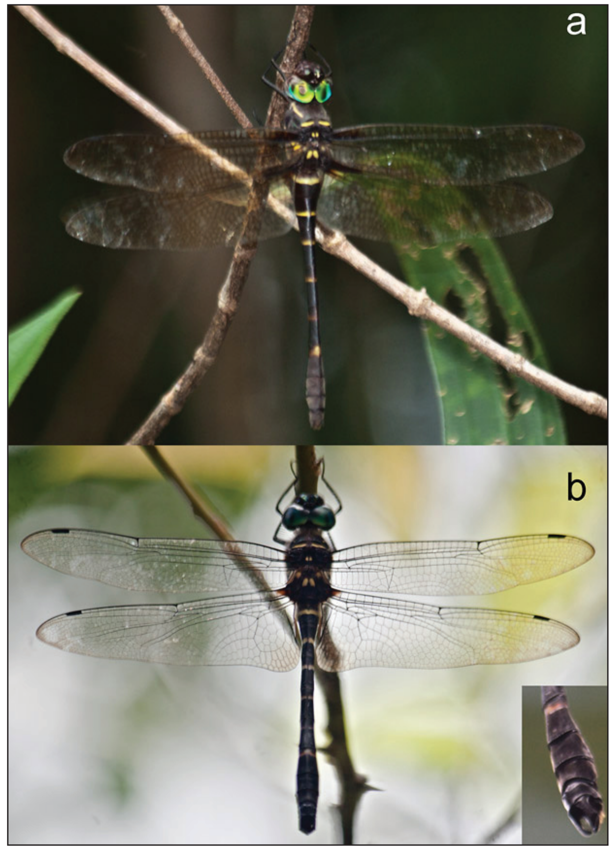

Fig. 3 *Epophthalmia vittigera bellicosa* Lieftinck, 1948, a female (a) and male (b) photographed at Rainbow Lodge, Tatai Commune, Koh Kong Province on 14 and 18 June 2013 respectively (© G. Chartier).

Fig. 4 *Epophthalmia vittigera bellicosa* Lieftinck, 1948, details of a female found at Rainbow Lodge, Tatai Commune, Koh Kong Province, 23 June 2013 (© G. Chartier).

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As to the subspecific diagnostic characters, the basal brown patches extended to antenodal 5 and 6 on the forewing and hindwing, respectively, in the female, and were vestigal on the forewing and extended to antenodal 1 in the male, which were within the range of variation indicated for the subspecies *bellicosa* Lieftinck, 1948 by Fraser (1936) and Lieftinck (1948). This subspecies is known to range across India, Myanmar, Thailand, Laos and Vietnam (Tsuda, 2000). The yellow rings on abdominal segments 2–7 were not as broad as indicated in the original description (Lieftinck, 1948) and interrupted in segments 2–6, but were within the variation indicated by Fraser (1936); their fore margins being indistinct. In the female specimen, the postclypeus missed the yellow transversal stripe mentioned by Fraser (1936) and Lieftinck (1948) and was "uniformly brownish" as characterised by Asahina (1987). Generally, the male and two females gave the impression of being aged and darkened.

Epophthalmia vittigera bellicosa was expected to occur in Cambodia, having been found in Chayaphum and Saraburi Provinces of Central Thailand (Hämäläinen & Pinratana, 1999).

Macromia chaiyaphumensis **Hämäläinen 1985.**

Two males photographed on 11 October 2011 and 19 September 2012 in the study area were not immediately identified to species, being referred to as "*Macromia* sp." and illustrated by Kosterin *et al.* (2012a) in Fig. 12 (showing the male from 19 September 2012 but erroneously captioned "April 2012"). They showed a yellow mark between the vertex pyramidal processes. Of the known Thai and Indochinese species, this trait is found only in *M. chaiyaphumensis*. The original description, based on a single male, states: "Posteriomedial slopes of pyramidal processes in frons yellow" (Hämäläinen 1985: 105), although its author did not indicate this character as diagnostic. Photographs of a male and female identified as *M. chaiyaphumensis* were uploaded by Reinthong Ruanrong to www.asia-dragonfly.net on 18 September 2013 (use the 'Global query' to find these records of this species). Ruanrong's male and female were photographed on 24 May 2013 and 20 April 2013, respectively, at the Borwee Waterfall, Sounphung, Ratchaburi Province, Thailand. They showed the aforementioned yellow mark in the frontal crevice very clearly and were obviously conspecific.

Our males from Cambodia corresponded to the male photographed by R. Ruanrong in most details, but with the following differences: yellow ring at abdominal segment 2 interrupted at auricles, anteriolateral yellow spots on S3 large (vs very small in the Ratchaburi male), dorsal and lateral yellow marks on abdominal segment 8 separated, yellow lateral spots and lateroventral dots on abdominal segment 9 absent, one less antenodal on each wing (12 on forewing and nine on hindwing vs 13 on forewing and 10 on hindwing in the Ratchaburi male). The pinkish-grey eyes and brownish-black thoracic ground colour in the Tatai males may be ascribed to their subteneral condition.

The males from the Tatai Commune and Ratchaburi Province show some common differences from the original description of *M. chaiyaphumensis* (Hämäläinen 1985: 105), as follows:

- Abdominal segment 3 with lateroventral spots (small in the Ratchaburi male and large in the Tatai males), not mentioned in the original description;
- Yellow marking on segments 3–7 seems to be larger (not depicted in *loc. cit.*), spots on segment 6 not "very small" but occupy half of segment height, mark on segment 7, however, occupies apical one-fifth rather than one-third of its segment;
- Fewer antenodals on forewing (vs 14 on forewing and nine on hindwing in the holotype);
- Two crossveins in hindwing hypertrigones (vs three in the holotype).

In spite of these not-so-large differences, which may be a matter of geographical variation, we provisionally identified the Tatai males as *M. chaiyaphumensis*. A female of this species was earlier reported from Ratanakiri Province, Cambodia, by Kosterin (2014).

Macromia ?cincta **(Rambur, 1842)**

A female was photographed on 1 July 2013. Its external characters correspond to *M. cincta*, a male of which was collected by the first author on 23 May 2013, also in Koh Kong Province. The latter record of this species, which was rather unexpected in Cambodia, was published by Kosterin (2014) without supporting arguments. These will be specially presented elsewhere in a paper devoted to Cambodian *Macromia*.

The following three species, already known from Cambodia, were added to the already quite long list of 72 species recorded in the study area by Kosterin *et al.* (2012a):

Camacinia gigantea **(Brauer, 1867).** A female photographed on 29 June 2013 at Rainbow Lodge.

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Brachydiplax farinosa **Krüger, 1902.** A male photographed on 12 June 2013 at a pond on the western bank of the Stoeng Kep River (11.582˚N, 103.130˚E).

Brachythemis contaminata **(Fabricius, 1793).** A male photographed at the same place and date as above.

The following recent findings of rare species in the study area, although already recorded in Cambodia by Kosterin *et al*. (2012a), are also worth mentioning:

Heliaeschna crassa **Krüger, 1899.** A male was photographed near Rainbow Lodge on 4 March 2013. This species was previously reported from the same area from a photograph of a female (Day, 2011).

Heliaeschna uninervulata **Martin, 1909.** A female was found alive inside a house at Rainbow Lodge and released on 2 May 2013.

Burmagomphus asahinai **Kosterin, Makbun & Dawwrueng, 2012.** A teneral female of this recently described species was found and photographed on 15 July 2013 at Tatai Waterfall (11.586˚N, 103.097˚E). Together with the data from Kosterin *et al.* (2012b), these records suggest a prolonged emergence period for imagines of this species from at least late March to mid-July.

Amphithemis curvistyla **Selys, 1891**. An immature male was photographed at Rainbow Lodge on 1 October 2013. Earlier, a female of this very rare species was reported from the same site (Kosterin *et al*., 2012a).

The new records of two species for Cambodia published herein and the recent paper by Kosterin (2014), added to the checklist published by Kosterin *et al.* (2012b), has raised the number of named Odonata species known to occur in Cambodia to 154.

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References

Asahina, S. (1987) A list of the Odonata from Thailand. Part XVIII. *Corduliidae 2. Kontû*, **55,** 699–720.

Day, L. (2011) Odonata seen in Tatai, Koh Kong Province, Cambodia. *International Dragonfly Fund Report*, **42,** 1–6.

Fraser, F.C. (1936) *The Fauna of British India, including Ceylon and Burma: Odonata, Volume III*. Taylor and Francis, London.

Hämäläinen, M. (1985) *Macromia chaiyaphumensis* sp. n. (Odonata, Corduliidae) from Northeast Thailand. *Annales Entomologici Fennici*, **51,** 105–107.

Hämäläinen, M. & Müller, R.A. (1997) Synopsis of the Philippine Odonata, with lists of species recorded from forty islands. *Odonatologica*, **26,** 249–315.

Hämäläinen, M. & Pinratana, A. (1999) *Atlas of the Dragonflies of Thailand: Distribution Maps by Provinces*. Brothers of St. Gabriel in Thailand, Bangkok, Thailand.

Kosterin, O.E. (2014) Odonata of the south-west and northeast of Cambodia as studied in early rainy season of 2013. *International Dragonfly Fund Report*, **67,** 1–94.

Kosterin, O.E., Chartier, G., Holden, J. & Mey F.S. (2012a) New records of Odonata from Cambodia, based mostly on photographs. *Cambodian Journal of Natural History*, **2012,** 150–163.

Kosterin, O.E., Makbun, N. & Dawwrueng, P. (2012b) *Burmagomphus asahinai* sp. nov., a new species from Cambodia and Thailand, with a description of the male of *B. gratiosus* Chao, 1954. *International Journal of Odonatology*, **15,** 275–292.

Lieftinck, M.A. (1940) Descriptions and records of South-East Asiatic Odonata (II). *Treubia,* **17,** 337–390.

Lieftinck, M.A. (1948) Entomological results from the Swedish Expedition 1934 to Burma and British India. *Arkiv för zoologi, Uppsala*, **41A,** 19–21.

Lieftinck, M.A. (1954) Handlist of Malaysian Odonata: a catalogue of the dragonflies of the Malay Peninsula, Sumatra, Java and Borneo, including the adjacent small islands. *Treubia (Supplement)*, **22,** 1–201.

Martin, M. (1909) *Collections Zoologiques du Baron Edm. de Selys Longchamps. Catalogue Systématic et Descriptif. Aeschnines. XX*. Hayez, Brussels, Belgium.

Orr, A. (2003) *A Guide to the Dragonflies of Borneo, their Identification and Biology*. Natural History Publications (Borneo), Kota Kinabalu, Sabah, East Malaysia.

Orr, A. (2008) Eight days in the Peninsular Malaysia—and the benefits of hindsights. *Agrion*, **31,** 24–27.

Ris, F. (1927) Odonaten von Sumatra, gesammelt von Edward Jacobson. *Zoologische Mededeelingen*, **10,** 1–49.

Tsuda S. (2000) *A Distributional List of World Odonata.* Osaka, Japan.

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Short Communication

First record of the rare parachute gecko *Ptychozoon trinotaterra* Brown, 1999 from Cambodia

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The rare parachute gecko *Ptychozoon trinotaterra* Brown, 1999 was first described based on a type series consisting of a single female from Nakhon Ratchasima Province, Thailand, and three males from Gia Lai and Dak Lak provinces, Vietnam (Brown, 1999). In addition to the type series, populations of *P. trinotaterra* have been reported from Ubon Ratchathani Province in eastern Thailand (Kunya *et al.*, 2011) and Dong Nai Province in southern Vietnam (Nguyen *et al.*, 2009) (see Fig. 1). Stuart & Emmett (2006) and Nguyen *et al.* (2009) expected *P. trinotaterra* to occur in northern Cambodia and southern Laos. Here, we confirm their hypothesis and present the first record of *P. trinotaterra* from north-western Cambodia based on photographs taken in Siem Reap Province.

In October 2013, a single unsexed specimen was found resting on a tree trunk, approximately 1.5 m above ground, during voluntary entomological fieldwork by Stéphane De Greef and Anna Bella Betts in old secondary semi-evergreen forests south of the Preah Khan Temple in the Angkor temples complex, Nokor Thom Commune, Siem Reap Province, Cambodia (13.458°N 103.869°E WGS84) (Fig. 2). The specimen was found shortly after midday and a series of detailed photographs was taken (Fig. 3).

Through the combination of the following characters the photo-vouchered individual can be assigned to the species *P. trinotaterra*: three transverse M-shaped dark bands in the axilla-groin region (vs four in *P. lionotum* Annandale, 1905), M-shaped chevrons without two posterior projections (vs distinct posterior projections of chevrons in *P. kaengkrachanense* Sumontha, Pauwels, Kunya, Limlikhitaksorn, Ruksue,

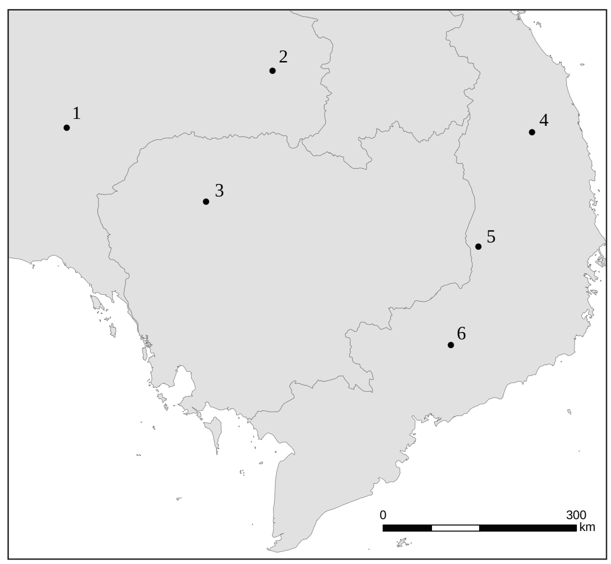

Fig. 1 Map showing the distribution of *Ptychozoon trinotaterra*. THAILAND: (1) Nakhon Ratchasima Province (Type Locality) (Brown, 1999); (2) Ubon Ratchathani Province (Kunya *et al.*, 2011); CAMBODIA: (3) Siem Reap Province; VIETNAM: (4) Gia Lai Province (Brown, 1999); (5) Dak Lak Province (Brown, 1999); (6) Dong Nai Province (Nguyen *et al.*, 2009).

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Fig. 2 Habitat of *Ptychozoon trinotaterra* in Siem Reap Province, Cambodia (© Stéphane De Greef).

Fig. 3 Dorsal views of the live adult *Ptychozoon trinotaterra* from Siem Reap Province, Cambodia (tail tip regenerated) (© Anna Bella Betts).

Taokratok, Ansemet & Chanhome, 2012), and continuation of caudal tubercles distally on to the dorsal surface of tail terminus (vs no caudal tubercles on terminal tail in *P. lionotum*) (Brown, 1999; Sumontha *et al.*, 2012) (see Fig 3.).

While Brown (1999) also stated the presence of a mid-vertebral tubercle row as a diagnostic character of *P. trinotaterra*, our specimen shows no such tubercles. This supports the views of Kunya *et al.* (2011), who postulate this character to be variable and hence not diagnostic.

Besides records of *P. lionotum* from Phnom Sruoch, Kirirom National Park, Kampong Speu Province, south-western Cambodia by Stuart & Emmett (2006) our record of *P. trinotaterra* from north-western Cambodia represents the second documented species of the parachute gecko genus *Ptychozoon* from this country.

References

Brown, R.M. (1999) New species of parachute gecko (Squamata: Gekkonidae: genus *Ptychozoon*) from northeastern Thailand and central Vietnam. *Copeia*, **1999,** 990–1001.

Kunya, K., Pauwels, O.S.G., Sairum, P. & Taokratok, A. (2011) Squamata, Gekkonidae, *Ptychozoon trinotaterra* Brown, 1999: rediscovery in Thailand. *Check List*, **7,** 820–822.

Nguyen V.S., Ho T.C. & Nguyen Q.T. (2009) *Herpetofauna of Vietnam.* Edition Chimaira, Frankfurt am Main, Germany.

Stuart, B.L. & Emmett, D.A. (2006) A collection of amphibians and reptiles from the Cardamom Mountains, southwestern Cambodia. *Fieldiana (Zoology)*, **109,** 1–27.

Sumontha, M., Pauwels, O.S.G., Kunya, K., Limlikhitaksorn, C., Ruksue, S., Taokratok, A., Ansermet, M. & Chanhome, L. (2012) A new species of parachute gecko (Squamata: Gekkonidae: genus *Ptychozoon*) from Kaeng Krachan National Park, western Thailand. *Zootaxa*, **3513,** 68–78.

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Short Communication

A rapid assessment of flying fox (*Pteropus* spp.) colonies in Cambodia

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Flying foxes (Chiroptera: Pteropodidae: *Pteropus*) are among the few wide-ranging frugivores still found in many parts of Southeast Asia and play important seed-dispersion and pollination roles in their ecosystems (Cox *et al.*, 1991; Fujita & Tuttle, 1991; Struebig *et al.*, 2007). Three flying fox species were depicted for Cambodia in the range maps of Francis (2008): large flying fox *Pteropus vampyrus*, Lyle's flying fox *P. lylei* and island flying fox *P. hypomelanus*. These species are currently considered to be globally Near-threatened, Vulnerable and Least Concern by the IUCN (Bates *et al.*, 2008; Bumrungsri *et al.*, 2008; Francis *et al.*, 2008) respectively, and as nationally common (*P. vampyrus* and *P. lylei*) or nationally rare (*P. hypomelanus*) in Cambodian legislation (MAFF, 2007). All three species are included in Appendix II of CITES, but almost nothing is known about their conservation status in Cambodia. Although likely present, the occurrence of *P. vampyrus* remains unconfirmed, having yet to be validated by the unequivocal documentation of a live animal or museum specimen to our knowledge. As colony surveys are central to determining conservation priorities for flying foxes (Mickleburgh *et al.*, 1992), we provide here the findings of a rapid assessment of pteropodid colonies in Cambodia.

Using an unpublished list of roost sites provided by the Wildlife Conservation Society, supplemented by additional sites reported by local field workers, we conducted field surveys between June 2013 and February 2014 to assess all of the known or suspected *Pteropus* colonies in Cambodia. At every site, the location and basic setting of the roost environment was recorded and standardized estimates of roost populations made using direct census methods, and, where possible, nightly dispersal counts (Kunz *et al.*, 1996). Efforts were also made to identify the species present at each site, but because these necessarily relied upon impressions of relative size (Francis, 2008) using binoculars, species identifications were uncertain and so no attempts were made to estimate total population sizes for each species. As *P. hypomelanus* primarily occurs in coastal areas and on marine islands, however (Francis, 2008), we assumed that the species present at all inland sites surveyed were *P. lylei* and/or *P. vampyrus* (Fig. 1).

Direct censuses were undertaken by visually counting the bats during the day at each site with the aid of 8 x 42 binoculars and manual hand-counters, whereas nightly dispersal counts began at dusk when the bats emerged to forage until all had left the roost site (typically from 1830 h to 1910 h). The latter was

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Fig. 1 Flying foxes on Koh Trong Island on the Mekong River (© Gordon Congdon, left) and Koh Bong Island off the coast of Cambodia (© Jeremy Holden, right). The species on the left is thought to be *P. lylei* and the species on the right *P. hypomelanus.*

confirmed by checking roost trees with a spotlight after the dispersal count at each site. Due to the density of bats and brevity of the evening dispersal, in some instances bats were counted in groups of 10 as they dispersed. The higher count from the two methods was rounded down to the nearest hundred and accepted as the estimated population size for a given site. Interviews were also undertaken by the first author with local authorities and residents at roost sites to determine: (i) the status of the colony (permanent or seasonal); (ii) annual breeding periods (defined as birth periods); (iii) whether the colony receives any protection; (iv) conservation threats at each site; and (v) local perceptions concerning the flying fox colony.

Over the course of the rapid field survey, 12 roost sites were located and assessed (Table 1, Fig. 2). Based on our experience and discussions with site-based conservationists around the country, it appears likely these comprise most of the flying fox colonies in Cambodia. (The possibility that other colonies might be discovered in the future cannot be excluded, however, particularly in poorly surveyed coastal regions and areas surrounding the Tonle Sap Lake). At least one interview was completed at each site. According to local informants, all of the colonies assessed were present year-round. Offspring were largely reported by respondents as appearing in April each year, and this is supported by monthly observations at the Wat Pi Chey Sa Kor (Kandal Province) and Wat Bay Dam Ram (Battambang Province) colonies where mating takes place in November and parturition primarily occurs in April (Hul, 2013; J. Cappelle, unpublished data).

Most of the roost sites were situated inside the grounds or within the vicinity of a religious or govern-

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Table 1 Summary characteristics of 12 flying fox colonies in Cambodia. Key: * Site where hunting of bats was reported or observed; [1] DC = Direct Census, ND = Night Dispersal, n/a = not applicable; [2] Value given is the highest figure from the count methods, rounded down to the nearest hundred.

#	Site Name (Province)	Latitude, Longitude	Census Date	Roost Environment	Census Methods[1]	Population Estimate[2]
1	Ang Trapeang Thmor (Banteay Meanchey)	13.804 N, 103.261 E.	14 Aug 2013	One roost tree on small island in reservoir.	DC	≈200
2	Wat Bay Dam Ram (Battambang)	12.993 N, 103.161 E.	23 Jun 2013	Pagoda. Three roost trees in site vicinity.	DC / ND	≈1,400
3	Royal Gardens * (Siem Reap)	13.363 N, 103.859 E.	10 Aug 2013	Official site. 14 roost trees in urban park.	DC / ND	≈5,000
4	Kampong Thom * (Kampong Thom)	12.714 N, 104.883 E.	8 Aug 2013	Official site. Three roost trees along roadside.	DC / ND	≈6,000
5	Koh Trong Island (Kratie)	12.507 N, 105.993 E.	26 Aug 2013	Pagoda. Two roost trees on site perimeter.	DC	≈200
6	Koh Chreng Island * (Kratie)	12.361 N, 106.044 E.	27 Aug 2013	Pagoda. 17 roost trees on site perimeter.	DC	≈900
7	Wat Srey Santaor * (Kampong Cham)	11.915 N, 105.183 E.	8 Aug 2013	Pagoda. Small forest on site perimeter.	n/a	Extirpated
8	Council for Development of Cambodia (Phnom Penh)	11.577 N, 104.924 E.	18 Oct 2013	Official site. One roost tree on site perimeter.	DC / ND	≈1,800
9	Wat Prek Chey Lech * (Kandal)	11.465 N, 105.235 E.	1 Aug 2013	Pagoda. Five roost trees on site perimeter.	DC / ND	≈500
10	Wat Pi Chey Sa Kor * (Kandal)	11.200 N, 105.058 E.	15 Jan 2014	Pagoda. 21 roost trees on site perimeter.	DC / ND	≈4,000
11	Wat Veal Lbang (Prey Veng)	11.173 N, 105.310 E.	17 Jan 2014	Pagoda. 12 roost trees in site vicinity.	DC	≈700
12	Koh Bong Island (Sihanoukville)	10.759 N, 103.265 E.	1 Feb 2014	Three roost trees in forest on small private island.	DC	≈200

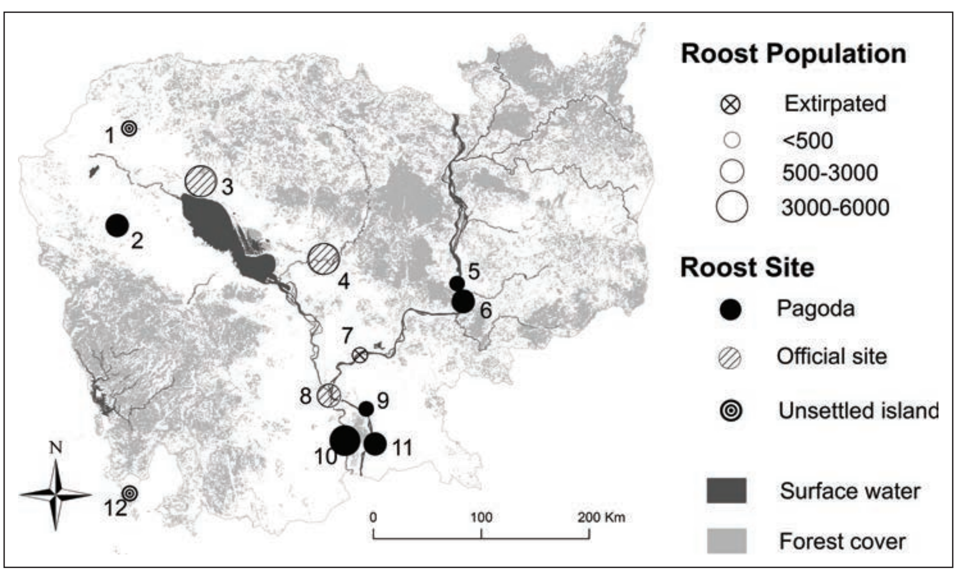

Fig. 2 Locations and relative sizes of 12 flying fox colonies in Cambodia.

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ment building, which apparently afforded them some protection from hunting (seven roosts were near a pagoda and three were near a government building). Only two roosts were protected by a natural barrier: the very small uninhabited islands of Ang Trapaeng Thmor and Koh Bong in the country's Northwest and Southwest respectively (Table 1, Fig. 2). This situation is similar to Thailand—another predominantly Buddhist country—where many flying fox colonies are near pagodas (Wacharapluesadee *et al.*, 2010), but differs from the Philippines—a largely Christian and Muslim country—where most colonies are in forest areas (Mildenstein, 2012). Religion may therefore play an important role in flying fox conservation in Cambodia, and a better understanding of local perceptions of bats could aid the design of more effective conservation initiatives.

Despite the potential influence of religious views however, hunting of bats for bushmeat, trade and/or medicinal use was reported at half of the 12 sites in Table 1. In fact, one colony in Srey Santaor (Kampong Cham Province) was recently extirpated by large-scale hunting, despite protests from local monks (Prak Bali, pers. comm.), and colonies at other sites could well be declining. Even though most of the remnant flying fox colonies in Cambodia now appear to be confined to sites which afford some measure of protection, the bats are still actively hunted while foraging or occur in non-protected areas (Timmins, 2008; present study). Thus, while there is a clear need for further surveys—preferably entailing synchronized counts employing standard methods at all known colonies to establish seasonal variation and population trends—our data nonetheless suggest that flying fox colonies in mainland Cambodia are heavily threatened and by no means nationally common.

This poses an obvious concern, not least because flying foxes can cease to be effective seed dispersers long before they become rare (McConkey & Drake, 2006). Besides their ecological services to humans, flying foxes may also play a role as reservoir of pathogens of public health importance in Cambodia. Evidence of Nipah virus circulation was reported in national flying fox populations some years ago (Reynes *et al.*, 2005), but very little information is available on the risk of transmission to domestic animals and humans in the country. Further research on the status and ecology of Cambodian *Pteropus* is therefore central to overcoming current challenges to reliable field identification and designing conservation plans and public health risk mitigation strategies. Campaigns to raise awareness are also required in colony areas to eliminate misconceptions regarding their medicinal values and to generate local support for their protection. To this end, a website (www.facebook.com/CFFCPH) has been developed to gain public information about flying fox colonies in Cambodia, which we hope will help to stimulate greater conservation interest in these charismatic and inherently vulnerable animals.

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References

Bates, P., Francis, C., Gumal, M., Bumrungsri, S., Walston, J., Heaney, L. & Mildenstein, T. (2008) *Pteropus vampyrus*. In *IUCN Red List of Threatened Species*. Http://www.iucnredlist.org/details/18766/0> [accessed 2 July 2014].

Bumrungsri, S., Suyanto, A. & Francis, C. (2008) *Pteropus lylei*. In *IUCN Red List of Threatened Species*. Http://www.iucnredlist.org/details/18734/0> [accessed 2 July 2014].

Cox, P.A., Elmqvist, T., Pierson, E.D. & Rainey, W.A. (1991) Flying foxes as strong interactors in South Pacific island ecosystems: a conservation hypothesis. *Conservation Biology*, **5**, 448–454.

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

Francis, C., Rosell-Ambal, G., Bonaccorso, F.A., Heaney, L., Molur, S. & Srinivasulu, C. (2008) *Pteropus hypomelanus*. In *IUCN Red List of Threatened Species*. Http://www.iucnredlist.org/details/18729/0> [accessed 2 July 2014].

Fujita, M.S. & Tuttle, M.D. (1991) Flying foxes (Chiroptera: Pteropodidae): threatened animals of key ecological and economic importance. *Conservation Biology*, **5**, 455–463.

Hul V. (2013) *Ecology of flying fox (*Pteropus *species) and assessment of the risk of emergence of Nipah virus in Battambang and Kandal Provinces, Cambodia*. MSc thesis, Royal University of Phnom Penh, Cambodia.

Kunz, T.H., Thomas, D.W., Richards, G.C., Tidemann, C.R., Pierson, E.D. & Racey, P.A. (1996) Observational techniques for bats. In *Measuring and Monitoring Biological Diversity: Standard Methods for Mammals* (eds D.E. Wilson, F.R. Cole, J.D. Nichols, R. Rudran & M.S. Foster), pp. 105–114, Smithsonian Institution Press, Washington D.C., USA.

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MAFF—Ministry of Agriculture, Forestry & Fisheries (2007) *Prakas on Classification and List of Wildlife Species. Ministry of Agriculture, Forestry and Fisheries, No. 020 PR*. Ministry of Agriculture, Forestry & Fisheries, Phnom Penh, Cambodia.

McConkey, K.R. & Drake, D.R. (2006) Flying foxes cease to function as seed dispersers long before they become rare. *Ecology*, **87,** 271–276.

Mickleburgh, S.P., Hutson, A.M. & Racey, P.A. (1992) *Old World Fruit Bats: an Action Plan for their Conservation*. IUCN, Gland, Switzerland.

Mildenstein, T.L. (2012) *Conservation of endangered flying foxes in the Philippines: effects of anthropogenic disturbance and methods for monitoring*. PhD thesis, University of Montana, USA.

Reynes, J.M., Counor, D., Ong, S. & Faure, C. (2005) Nipah virus in Lyle's flying foxes, Cambodia. *Emerging Infectious Diseases*, **11,** 1042–1047.

Struebig, M.J., Harrison, M.E., Cheyne, S.M., Limin, S.H. (2007) Intensive hunting of large flying foxes *Pteropus vampyrus natunae* in Central Kalimantan, Indonesian Borneo. *Oryx*, **41**, 390–393.

Timmins, R. (2008) Large mammals. In *Biological Surveys of the Mekong River between Kratie and Stung Treng Towns, Northeast Cambodia, 2006–2007* (eds M.R. Bezuijen, R. Timmins & Seng T.), pp. 82–89. WWF Cambodia Country Programme, Cambodian Fisheries Administration & Cambodian Forestry Administration, Phnom Penh, Cambodia.

Wacharapluesadee, S., Boongird, K., Wanghongsa, S., Ratanasetyuth, N., Supavonwong, P., Saengsen, D., Gongal, G.N. & Hemachudha, T. (2010) A longitudinal study of Nipah virus in *Pteropus* lylei bats in Thailand: evidence for seasonal preference in disease transmission. *Vector-borne and Zoonotic Diseases*, **10,** 183–190.

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Short Communication

A small terrestrial mammal survey and analysis of bait consumption at Bokor National Park, Cambodia

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Cambodia boasts a rich array of species and the Greater Cardamom Mountains in the country's Southwest are recognised as part of a global biodiversity hotspot (Myers *et al.*, 2000) and one of the planet's 200 Global Ecoregions (Olson *et al.*, 2000). Survey effort in this region has recently intensified and uncovered new species of plants (Mey, 2009), amphibians and reptiles (e.g. Daltry & Wuster, 2002; Grismer *et al.*, 2008; Neang *et al.*, 2012). Medium-sized to large mammals have also been a research focus in Cambodia, with several papers describing their distribution, populations and threats (e.g. Emmett & Olssen, 2005; Royan, 2010; Edwards *et al.*, 2012; Gray *et al.*, 2012). In contrast, little work has been conducted on the small terrestrial mammals of Cambodia. Bats (order Chiroptera) have been the most intensively researched small mammals in Cambodia, with 70 species presently known (Chheang *et al.*, 2013), including taxa new to science (Csorba, 2011; Csorba *et al.*, 2011). However, a recent study identified a new species of shrew (Jenkins *et al.*, 2010).

Within the Cardamom Mountains, only two systematic surveys of small terrestrial mammals have been reported. The first used aluminium box traps and pitfall traps and caught mostly rodents (Muridae) except for a single capture of the insectivore *Hylomys suillus* (Swan & Kry, 2000). The second study employed box, pitfall and mesh traps and encountered two species of shrew (*Crocidura* spp.), two species of tree shrews and eight rats (Emmett & Olssen, 2005).

Capture rates for small terrestrial mammals in forested ecosystems in Cambodia tend to be low. For instance, Swan & Kry (2000) recorded a mean capture rate of 1.3% and 0.9% for small terrestrial mammals in the Phnom Samkos Wildlife Sanctuary, while Emmett & Olssen (2005) achieved a capture rate of 2.6% for small and medium-sized mammals using traps in the Central Cardamoms Protected Forest. These are similar to the capture rates of 0.04–2.6% in northern Cambodia (Edwards *et al.*, 2012), but lower than a study of rodents across four habitat types in eastern and southern Cambodia, including settlements and agricultural areas (mean 13.5%: Ivanova *et al.*, 2012).

The type of bait used to attract mammals can significantly affect the species and number of individuals trapped (Patric, 1970; Kok *et al.*, 2013). Most studies in Cambodia have used vegetable matter, including sticky rice, peanuts, bananas and/or cassava as bait (Kemper & Bell, 1985; Swan & Kry, 2000; Emmett & Olssen, 2005; Blasdell *et al.*, 2011; Edwards *et al.*, 2012; Starr *et al.*, 2012), but two studies used dried fish or shrimp (Swan & Kry, 2000; Conservation International, 2007), one used dried beef (Conservation International, 2007) and one used chicken or egg (Starr *et al.*, 2012). Shrews may be particularly attracted to meat lures, but little is known of these

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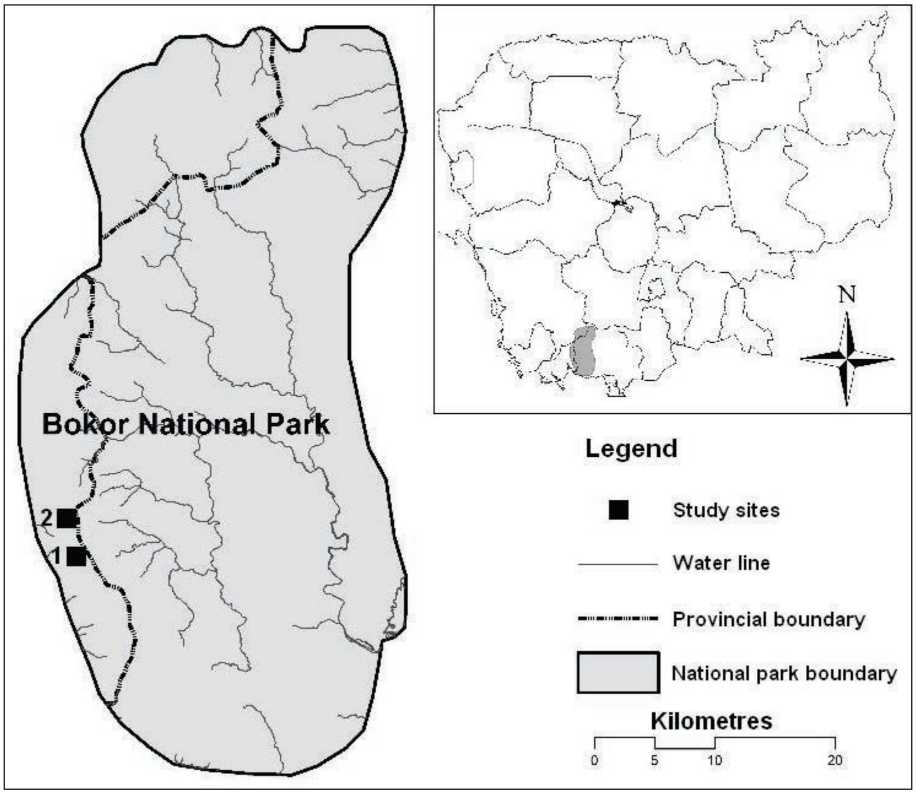

Fig. 1 Location of study sites in Bokor National Park, Cambodia. Site 1 was at 10°43.826′N, 103°55.601′E, at an elevation of 408 metres above sea level (asl), and consisted of wet dipterocarp forest with bananas and sugar palms. Canopy cover was estimated at >80% and there was extensive ground cover with many fallen logs. Site 2 was at 10°45.542′N, 103°55.154′E, at an elevation of 416 m asl, and consisted of drier dipterocarp forest with none of large-leafed plants that occurred in Site 1. Canopy cover was estimated at >60% and there was less ground cover than in Site 1.

species in Cambodia (Emmett & Olssen, 2005; Jenkins *et al.*, 2010). As species composition is likely to vary markedly across Cambodia and different bait types may affect the numbers of species attracted to traps, this paper reports the results of a pilot investigation of small mammal assemblages and their bait consumption in two sites in Bokor National Park.

Bokor National Park (Fig. 1) covers an area of >1,400 km^2 and is in the Elephant Mountains of Cambodia (Seng *et al.*, 2003), a southern offshoot of the Cardamom Mountains. The small mammal study was undertaken at two sites in the southern portion of the park from 11–24 February 2013 as part of a broader biodiversity study investigating amphibians, reptiles, birds, bats, large mammals and gibbons from October 2012 to May 2013.

In Site 1 (Fig. 1), Elliott small live mammal traps (9 cm × 10 cm × 33 cm) were set along a transect at approximately 15–20 m intervals for a total of 60 trap-nights. In Site 2 (Fig. 1), Elliott traps were set for a total of 50 trap-nights along four transects with approximately 15–20 m intervals between traps. The four transects were along a dry creek bed (15 trap-nights), off a steep path (21 trap-nights), on a sloped path (six trap-nights) and along a stream (eight trap-nights). Where necessary, traps were moved within their chosen locations to protect trapped animals from ants and to reduce the amount of bait consumed by non-target species.

Traps were placed in areas likely to be used by mammals including alongside fallen logs, under boulders, and near runways, holes and observed scats. All traps were checked at dawn (≈0630 h), midday (≈1300 h) and dusk (≈1730 h). Every trap was covered with thick plastic to protect animals from wind and rain and was filled with cotton wadding and tissue paper to provide nesting material. As animal preferences for bait were unknown, every trap was baited simultaneously with ≈5 g of locally produced

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lap cheong (fatty pork salami), uncooked rice, dried papaya, dried cranberries, liver dog treats and a mixed ball of peanut butter, rolled oats and honey. Following every capture, the remaining bait was collected and the amount consumed was assigned to the following classes: 100%, 75–99%, 50–74%, 25–49% and <25%.

Upon capture, every animal was weighed using a Pesola™ 60 g or 600 g spring balance and measured using vernier callipers. Reproductive status and age class were also recorded (Aplin *et al.*, 2003). On their first capture, animals were individually marked with a unique set of ear clips and the removed tissue was stored in 90% ethanol for genetic analyses. Animals were generally handled in cloth bags, but the *Maxomys* sp. was measured briefly in a large clear plastic bag because the animals appeared calmer and handling of their delicate tail skin was avoided (Francis, 2008). Genetic samples were deposited and stored at -20°C at the Royal University of Phnom Penh Centre for Biodiversity Conservation (they will be analysed at the Museum Victoria, Australia). Following measurement, all animals were released at their point of capture.

All captures occurred overnight with no animals trapped during daylight hours. There were 29 successful captures from 110 trap-nights giving an overall capture rate of 26%.

From the total of 60 trap-nights in Site 1, four specimens were trapped, giving a capture rate of 7%. They included a 160 g female rat with silver upperparts, white underparts and feet, and a mottled grey tail (Fig. 2), which was identified as *Berylmys berdmorei*, albeit smaller than published measurements for this species (Aplin *et al.*, 2003). Two female shrews were trapped, which were dark grey with a tail shorter than their head-body length and had sparse hairs near the base of the tail (Fig. 3). They weighed 7.3 and 7.5 g (mean 7.4 g) and had a distinctive musky odour. These animals were likely in the genus *Crocidura*, but their measurements did not match any species presently known in Cambodia or Southeast Asia. A palm civet *Paradoxurus hermaphrodites* was also trapped, but after consuming the bait it broke out of the trap and was subsequently identified from its hair and scats.

A total of 50 trap-nights were conducted in Site 2 with 15 rats (seven females, eight males) trapped on 25 occasions (including 10 recaptures), giving a capture rate of 50%. The rats' upperparts were a distinctive reddish-orange colour with a darker midline and numerous stiff dark spines throughout the fur (Fig. 4). Underparts were white with small stiff spines and

Fig. 2 Rat resembling *Berylmys berdmorei* trapped in Site 1.

Fig. 3 *Crocidura* sp. trapped in Site 1.

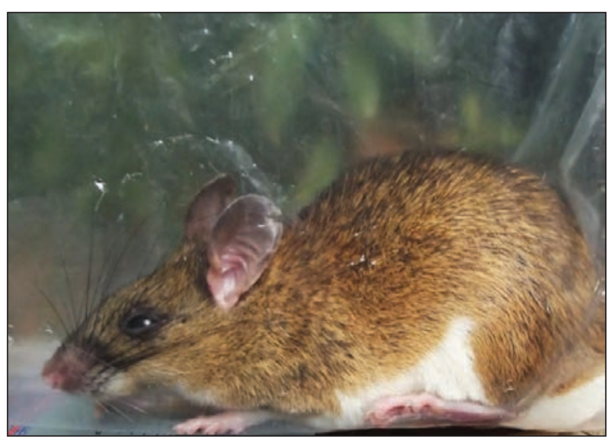

Fig. 4 *Maxomys* sp. trapped in Site 2 (being briefly held in plastic bag).

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were sharply demarcated from upperparts. The tail was bicoloured, being dark grey above and white underneath, with a white tip comprising one-third of the tail length. Feet were white and ears were dark grey. Mean mass was 170.27 ± 22.38 g (males 173.6 ± 21.6 g; females 166.4 ± 24.3 g) and ranged from 130–209 g. This species appeared most similar to *Maxomys surifer* (Aplin *et al.*, 2003), but had a number of differences, including consistently shorter ears. The rats were all adults in breeding condition with enlarged testes in the males and signs of early-mid pregnancy in three of the seven females.

Rates of bait consumption by the rodents were: lap *cheong* 100%, dog treats 50–74%, bait ball 50–74%, dried papaya 25–49%, dried cranberries 25–49% and rice <25%. The shrews consumed *lap cheong* only. The *Maxomys* rats trapped on consecutive nights gained between 2–13 g (mean 5.14 ± 1.64 g), the equivalent of up to 8% of their body mass, indicating that large amounts of bait had been consumed.

This is the first study of small terrestrial mammals at Bokor National Park, and insectivores, carnivores and rodents were trapped. To the best of our knowledge, the trap success rate achieved at Site 2 (50%) is the highest recorded for small terrestrial mammals in Cambodia to date. This may be attributed to the rats occurring at high population densities, becoming "trap happy" (whereby individuals that are trapped have a positive experience and are more inclined to enter traps again), and/or the use of more attractive baits.

The pork-based *lap cheong* was entirely consumed by all species caught, and shrews consumed this bait alone. This is likely due to their small size (≈7.4 g) and inability to eat any further items during their brief period in the traps. Rodents also consumed greater amounts of liver dog treats and bait ball mixture than dried fruits. Little to no rice was consumed. This mirrors studies in South Africa where peanut butter and oat mixes were the most successful bait, achieving more captures than fruit or meat lures (Kok *et al.*, 2013). Similarly, peanut butter mixes are the most effective lure in the USA, although meat lures are effective at attracting carnivores (Patric, 1970). However, a study of arboreal species in Cambodia found banana to be a more effective lure than chicken for small and medium-sized mammals, including carnivores (Starr *et al.*, 2012). Small mammal surveys in Cambodia have commonly used fruit or sticky rice as bait (Kemper & Bell, 1985; Swan & Kry, 2000; Blasdell *et al.*, 2011), although two studies also used dried fish, shrimp and beef (Swan & Kry, 2000; Conservation International, 2007). We recommend the use of multiple food types, including meat lures and peanut butter mixes, to increase capture success in Cambodia.

This short study may have uncovered new species of rat and shrew, but further genetic and morphological work is required and will be conducted shortly. Further studies on shrews are likely to uncover new records for Cambodia and potentially species new to science. In 2004, Emmett & Olssen (2005) collected two unidentified species of shrew. Two further unidentified species were found in Virachey National Park in 2007 (Conservation International, 2007), and a new species of *Crocidura* was recently described from Northeast Cambodia (Jenkins *et al.*, 2010). Among the rodents, the genus *Maxomys* in particular has highly divergent populations within and between island regions (Achmadi *et al.*, 2013) and new *Maxomys* species continue to be described (e.g. Achmadi *et al.*, 2012). Emmett & Olssen (2005) also discovered *Maxomys* and *Niviventer* species in the Cardamom Mountains which appear to differ externally from previously recorded species. With so little research on small terrestrial mammals in Cambodia, new records and possibly new species likely await discovery.

Further research and allied conservation initiatives are vital to protect biodiversity in Bokor National Park. Several areas within the park are likely to support high numbers of small mammal species and need protection from inappropriate land-use. More intensive small mammal surveys, using a variety of traps and baits over a longer time period in different regions of Bokor National Park, and Cambodia as a whole, are required to elucidate species diversity and conservation requirements for future management.

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References

Achmadi, A.S., Maryanto, I. & Maharadatunkamsi (2012) Systematic and descriptions of new species within genus *Maxomys* from East Kalimantan, Borneo Island. *Treubia*, **39,** 1–28.

Achmadi, A.S., Esselstyn, J.A., Rowe, K.C., Maryanto, I. & Abdullah, M.T. (2013) Phylogeny, diversity, and biogeography of Southeast Asian spiny rats (*Maxomys*). *Journal of Mammalogy*, **94,** 1412–1423.

Aplin, K.P., Brown, P.R., Jacob, J., Krebs, C.J. & Singleton, G.R. (2003) *Field Methods for Rodent Studies in Asia and the Indo-Pacific*. ACIAR Monograph No 100. Australian Centre for International Agricultural Research, Canberra, Australia.

Blasdell, K., Cosson, J.K., Chaval, Y., Herbreteau, V., Douangboupha, B., Jittapalapong, S., Lundqvist, A., Hugot, J., Morand, S. & Buchy, P. (2011) Rodent–borne hantaviruses in Cambodia, Lao PDR, and Thailand. *EcoHealth*, **8,** 432–443.

Chheang S., Bates, P.J.J., Boughey, K., Csorba, G., Hayes, B., Ith S., Mould, A., Phauk S. & Furey, N.M. (2013) Further new country records of four bat species (Chiroptera) from Cambodia and a call for information. *Cambodian Journal of Natural History*, **2013,** 73–82.

Conservation International (2007) *Preliminary Report: Virachey National Park RAP 2007 Cambodia*. Rapid Assessment Program, Conservation International, Phnom Penh, Cambodia.

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

Csorba, G., Son N.T., Ith S. & Furey, N. (2011) Revealing cryptic bat diversity: three new *Murina* and redescription of *M. tubinaris* from Southeast Asia. *Journal of Mammalogy*, **92,** 891–904.

Daltry, J.C. & Wüster, W. (2002) A new species of wolf snake (Serpentes: Colubridae: *Lycodon*) from the Cardamom Mountains, southwestern Cambodia. *Herpetologica*, **58,** 498–504.

Edwards, S., Allison, J. & Cheetham, S. (2012) Recent mammal records from the Oddar Meanchey portion of the Kulen–Promtep Wildlife Sanctuary, Northern Cambodia. *Cambodian Journal of Natural History*, **2012,** 8–12.

Emmett, D.A. & Olsson, A. (2005) *Biological Surveys in the Central Cardamom Mountains*. Conservation International Cambodia Program and Forestry Administration, Phnom Penh, Cambodia.

Francis, C.M. (2008) *A Field Guide to the Mammals of Thailand and Southeast Asia*. Asia Books, Bangkok, Thailand.

Gray, T.N.E., Ou R., Huy K, Pin C. & Maxwell, A.L. (2012) The status of large mammals in eastern Cambodia: a review of camera trapping data 1999–2007. *Cambodian Journal of Natural History*, **2012,** 42–55.

Grismer, L.L., Neang T., Chav, T., Wood, P.L., Oaks, J.R., Holden, J., Grismer, J.L., Szutz, T.R. & Youmans, T.M. (2008) Additional amphibians and reptiles from the Phnom Samkos Wildlife Sanctuary in northwestern Cardamom Mountains, Cambodia, with comments on their taxonomy and the discovery of three new species. *Raffles Bulletin of Zoology*, **56,** 161–175.

Ivanova, S., Herbreteau, V., Blasdell, K., Chaval, Y., Buchy, P., Guillard, B. & Morand, S. (2012) Leptospira and rodents in Cambodia: environmental determinants of infection. *American Journal of Tropical Medicine and Hygiene*, **86,** 1032–1038.

Jenkins, P.D., Abramov, A.V., Rozhnov, V.V. & Olsson, A. (2010) A new species of *Crocidura* (Soricomorpha: Soricidae) from southern Vietnam and north-eastern Cambodia. *Zootaxa*, **2345,** 60–68.

Kemper, C, & Bell, D.T. (1985) Small mammals and habitat structure in lowland rain forest of Peninsular Malaysia. *Journal of Tropical Ecology*, **1,** 5–22.

Kok, A.D., Parker, D.M. & Barker, N.P. (2013) Rules of attraction: the role of bait in small mammal sampling at high altitude in South Africa. *African Zoology*, **48,** 84–95.

Mey, F.S. (2009) *Nepenthes bokorensis*, a new species of Nepenthaceae from Cambodia. *Carniflora Australis*, **7,** 6–15.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. & Kent, J. (2000) Biodiversity hotspots for conservation priorities. *Nature*, **403,** 853–85.

Neang T., Grismer, L.L & Daltry, J.C. (2012) A new species of kukri snake (Colubridae: *Oligodon* Fitzinger, 1826) from the Phnom Samkos Wildlife Sanctuary, Cardamom Mountains, Southwest Cambodia. *Zootaxa*, **3388,** 41–55.

Olson, D.M., Dinerstein, E., Abell, R., Allnutt, T., Carpenter, C., McClenachan, L., D'Amico, J., Hurley, P., Kassem, K., Strand, H., Taye, M. & Thieme, M. (2000) *The Global 200: A Representation Approach to Conserving the Earth's Distinctive Ecoregions*. Conservation Science Program, World Wildlife Fund–US, Washington, DC, USA.

Patric, E.F. (1970) Bait preference of small mammals. *Journal of Mammalogy*, **51,** 179–182.

Royan, A. (2010) Significant mammal records from Botum–Sakor National Park, Southwest Cambodia. *Cambodian Journal of Natural History*, **2010,** 22–26.

Seng K.H., Pech B., Poole C., Tordoff, A., Davidson, P. & Delattre, E. (2003) *Directory of Important Bird Areas in Cambodia: Key Sites for Conservation*. Department of Forestry and Wildlife, Department of Nature Conservation and Protection, Cambodia, BirdLife International in Indochina and the Wildlife Conservation Society Cambodia Program, Phnom Penh, Cambodia.

Starr, C., Nekaris, K.A.I. & Leung, L.K.P (2012) A comparison of three survey methods for detecting the elusive pygmy slow loris *Nycticebus pygmaeus* in Eastern Cambodia. *Cambodian Journal of Natural History*, **2012,** 123–130.

Swan, S.R. & Kry M. (2000) Small mammals. In *Cardamom Mountains Biodiversity Survey 2000* (eds J.C. Daltry & F. Momberg), pp. 69–78. Fauna & Flora International, Cambridge, UK.

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Notes on a collection of stomatopod and decapod crustaceans from Cambodia

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មូលន័យសង្ខេប

មានការយល់ដឹងតិចតួចពីពពួកសត្វគ្រុស្តាសេនៅកម្ពុជា។ ការសិក្សានាពេលបច្ចុប្បន្នបានកត់ត្រាគ្រុស្តាសេមាឌធំ (Malacostraca) ចំនួន២១ប្រភេទ ដែលបានមកពីអ្នកនេសាទចាប់បាននៅខេត្តកំពត ក្នុងនោះមានព្រោនstomatopodsបីប្រភេទ បង្កងសមុទ្រ scyllarid lobster ១ប្រភេទ និងក្តាមសមុទ្រ brachyuran crabs ១៧ប្រភេទ។ គ្រុស្តាសេ១២ប្រភេទក្នុងចំណោម២១ ប្រភេទនោះជាកំណត់ត្រាថ្មីសម្រាប់ប្រទេសកម្ពុជា។ រូបថតនិងការពន្យល់ដោយមានរូបភាពបង្ហាញក៏ដូចជាកំណត់សំគាល់លក្ខណៈ ចំណែកថ្នាក់និងកំណត់សំគាល់អេកូឡូស៊ីត្រូវបានផ្តល់ជូនសម្រាប់ប្រភេទនីមួយៗ។

Abstract

The crustacean fauna of Cambodia is poorly known. The present study records 21 species of Malacostraca (three stomatopods, one scyllarid lobster and 17 brachyuran crabs) from the by-catch of fishermen in Kampot City, Kampot Province, Cambodia. Twelve species are new records for this country. Photographs and illustrations as well as taxonomic and ecological notes are provided for every species.

Keywords

Marine biodiversity, crustaceans, faunal survey, by-catch, Gulf of Thailand.

Introduction

Cambodia has a coastline of 435 km in length, covering an area estimated at between 17,791 km² and 18,477 km², including mangroves (728 km²), seagrass beds (301–325 km²), and coral reefs (approximately 10 times smaller than area covered by seagrass) (Spalding *et al.*, 2010; Rizvi & Singer, 2011). So far, only about 50 species of crustaceans have been listed for Cambodia (UNEP, 2007). Considering that more than 600 crustacean species have been recorded from the Gulf of Thailand ports in neighbouring Thailand (Naiyanetr, 2007), the marine and coastal biodiversity of Cambodia is clearly understudied.

In December 2010, the first and second authors had an opportunity to make a brief visit to a local fishing port in Kampot City, Kampot Province, and found many crustacean species among the by-catch of

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trash fish that were being sold to a fishmeal factory. Such by-catch can be a very useful source of material for faunal studies, including rare or unusual species (Jensen *et al.*, 2011). The present paper reports some of the crustaceans sampled (21 species in total). Photographs as well as taxonomic and ecological notes are provided for the species.

The material examined was deposited in the Ryukyu University Museum, Fujukan (RUMF), University of the Ryukyus, Okinawa, Japan; the Zoological Reference Collection (ZRC) of the Lee Kong Chian Natural History Museum (formerly known as Raffles Museum for Biodiversity Research) of the National University of Singapore; and the National Museum of the Philippines in Manila (NMCR). All specimens from Cambodia were collected from the Kampong Kandal Fishery Port (10°34′7.01″N, 104°14′33.21″E), Kampot City, Kampot Province, on 27 December 2010 by T. Naruse, D.C.J. Yeo, L. Sarorn and E.C.K. Khoo.

In the following accounts, the body sizes of stomatopods and scyllarid lobsters are presented as carapace length (CL) / total length (TL), while those of the brachyurans are presented as carapace length (CL) × carapace width (CW). All measurements are in millimetres.

Species accounts

Order STOMATOPODA Latreille, 1817

Family SQUILLIDAE Latreille, 1802

***Carinosquilla multicarinata* (White, 1849)** (Fig. 1a)

Material examined: RUMF-ZC-1539, two males, 17.0 / 73.6 mm, 18.2 / 78.3 mm, two females, 20.2 / 86.7 mm, 17.3 / 72.4 mm.

Distribution: Southern India to Indonesia, Thailand (Andaman Sea and Gulf of Thailand), Cambodia, Vietnam, the Philippines, China, Taiwan and Japan (Naiyanetr, 2007; Ahyong *et al.*, 2008; present study).

Remarks: The present specimens agree well with recent descriptions of *C. multicarinata* (e.g. Ahyong & Moosa 2004; Ahyong *et al.*, 2008). As discussed by Ahyong (2001) and Ahyong *et al.* (2008), *C. multicarinata* closely

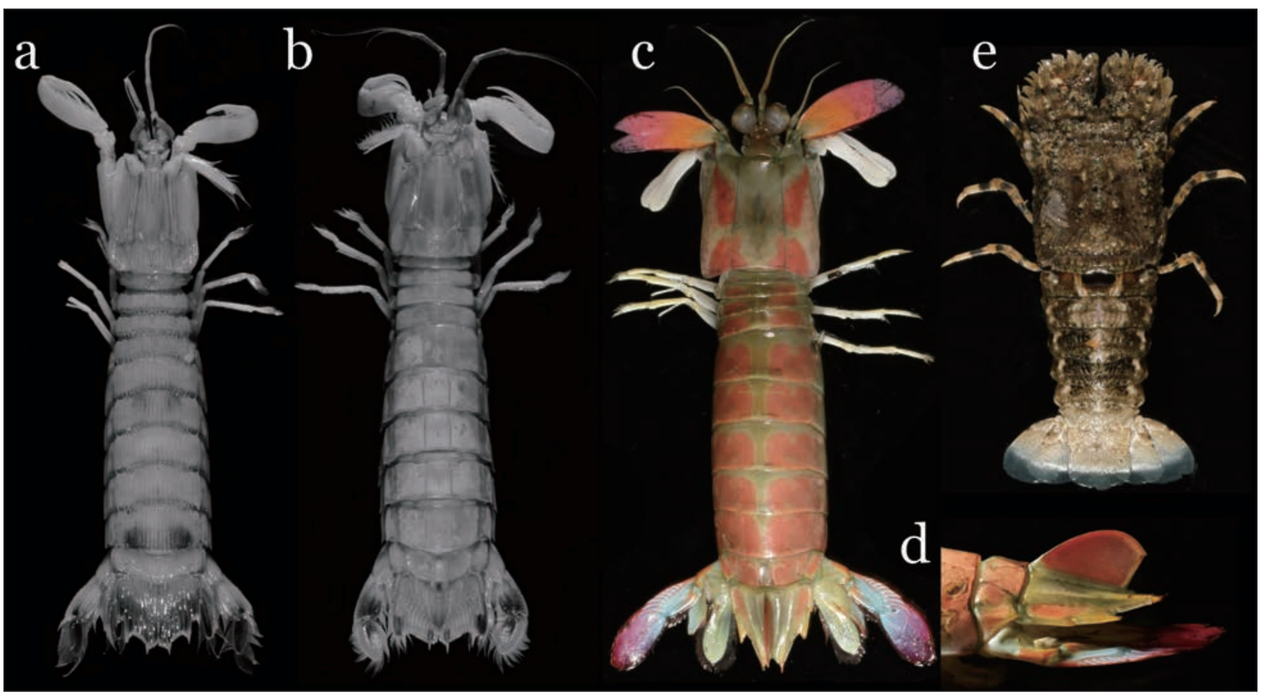

Fig. 1 Stomatopod and scyllarid species collected from Kampong Kandal Fishery Port: a, *Carinosquilla multicarinata* (White, 1849) (RUMF-ZC-1539, male, 17.0 / 73.6 mm); b, *Erugosquilla woodmasoni* (Kemp, 1911) (RUMF-ZC-1541, male, 31.1 / 138.3 mm); c, d, *Odontodactylus cultrifer* (White, 1851) (RUMF-ZC-1540, male, 23.3 / 93.4 mm, in live colouration); e, *Biarctus sordidus* (Stimpson, 1860) (RUMF-ZC-1328, male, 16.5 / 42.5 mm, in live colouration). a, b, c, e, habitus, dorsal view; d, telson and uropods, lateral view.

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resembles *C. carita* Ahyong, 2001, known only from Australia, but differs from the latter in the presence of the mandibular palp and the prelateral lobe of the telson with a spinular instead of blunt apex.

***Erugosquilla woodmasoni* (Kemp, 1911)** (Fig. 1b)

Material examined: RUMF-ZC-1541, two males, 31.1 / 138.3 mm, 21.0 / 81.6 mm.

Distribution: Western Indian Ocean to Indonesia; Thailand (Gulf of Thailand), Cambodia, Vietnam, the Philippines, Taiwan, Japan and Australia (Naiyanetr, 2007; Ahyong *et al.*, 2008; present study).

Remarks: The present material agrees well with recent descriptions of *E. woodmasoni* (e.g. Ahyong, 2001; Ahyong *et al.*, 2008). This species is readily distinguished from its congeners by the merus of the raptorial claw possessing an outer inferodistal spine (versus no spine in the other species).

Family ODONTODACTYLIDAE Manning, 1980

***Odontodactylus cultrifer* (White, 1851)** (Figs 1c, d)

Material examined: RUMF-ZC-1540, one male, 23.3 / 93.4 mm.

Distribution: Thailand (Andaman Sea and Gulf of Thailand), Cambodia, South China Sea, Indonesia, Taiwan, Australia and New Caledonia (Naiyanetr, 2007; Ahyong *et al.*, 2008; present study).

Remarks: The present specimen agrees well with recent descriptions of *O. cultrifer* (e.g. Ahyong, 2001; Ahyong *et al.*, 2008). This species is immediately distinguished from its congeners by the high, thin median crest on the telson (Fig. 1d) (versus no such crest in the others).

Order DECAPODA Latreille, 1802

Infraorder ACHELATA Scholtz & Richter, 1995

Family SCYLLARIDAE Latreille, 1825

***Biarctus sordidus* (Stimpson, 1860)** (Fig. 1e)

Material examined: RUMF-ZC-01328, one male, 16.5 / 42.5 mm.

Distribution: Persian Gulf to Australia, the Gulf of Thailand, Cambodia, southern China (Holthuis, 2002; Naiyanetr, 2007; present study).

Remarks: The present specimen agrees well with the redescription of *Biarctus sordidus* by Holthuis (2002). Yang *et al.* (2012) performed phylogenetic analyses of species of the family Scyllaridae and pointed out the need for a generic re-arrangement of Scyllarinae.

Infraorder BRACHYURA Latreille, 1802

Family DROMIIDAE De Haan, 1833

***Conchoecetes artificiosus* (Fabricius, 1798)** (Fig. 2a)

Material examined: RUMF-ZC-1907, one male, 23.1 × 24.7 mm.

Distribution: Western Indian Ocean to Australia; Thailand (Gulf of Thailand); China; Taiwan; Japan (Naiyanetr, 2007; Ahyong *et al.*, 2009) and now Cambodia (present study).

Remarks: Dromiid crabs usually carry a piece of sponge, an ascidian, or a bivalve shell to cover the dorsal surface of the cephalothorax using the last two pairs of pereopods (except for *Conchoecetes* species that use the fourth pereopods only), which are subchelate (McLay, 1993). Species of *Conchoecetes, Hypoconcha* and *Desmodromia* have been known to carry bivalve shells as camouflage (Wicksten, 1986; Guinot *et al.*, 1995; Guinot & Tavares, 2000; McLay & Hosie, 2012). *Conchoecetes artificiosus* is unique within the genus because of the presence of two distinct anterolateral teeth on the carapace (McLay, 1993). It may carry bivalve shells for camouflage (Ahyong *et al.*, 2009).

***Dromidiopsis indica* (Gray, 1831)** (Fig. 2b)

Material examined: RUMF-ZC-1903, one male, 43.6 × 43.9 mm, one female, 53.9 × 56.5 mm.

Distribution: Thailand (Phuket, Andaman Sea), Singapore (McLay *et al.*, 2001; Naiyanetr, 2007), and now Cambodia (present study).

Remarks: Dromidiopsis indica is diagnosed by the presence of three anterolateral teeth, which are close to each other (present study).

Family DORIPPIDAE MacLeay, 1838

***Dorippe quadridens* (Fabricius, 1793)** (Fig. 2c)

Material examined: RUMF-ZC-2318, one male, 31.0 × 30.1 mm, one ovigerous female, 43.0 × 42.8 mm.

Distribution: Widely distributed in the Indo-West Pacific from the Suez Canal, the Red Sea and south-eastern Africa to Hong Kong, the Philippines, Indonesia, Australia, Thailand (Andaman Sea and Gulf of Thailand) (Holthuis & Manning, 1990; Naiyanetr, 2007), and now Cambodia (present study).

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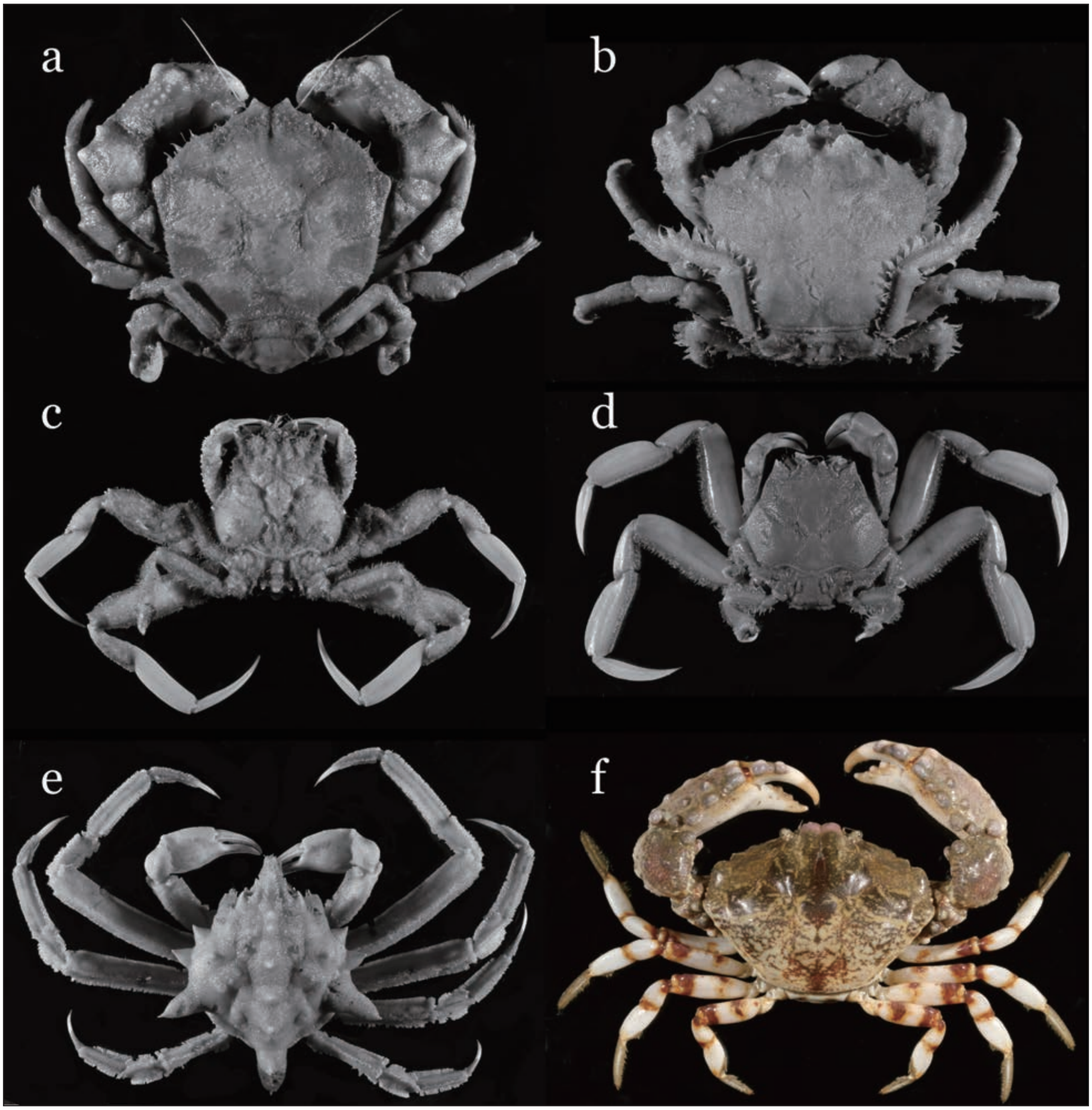

Fig. 2 Brachyuran species collected from Kampong Kandal Fishery Port: a, *Conchoecetes artificiosus* (Fabricius, 1798) (RUMF-ZC-1907, male, 23.1 × 24.7 mm); b, *Dromidiopsis indica* (Gray, 1831) (RUMF-ZC-1903, male, 43.6 × 43.9 mm); c, *Dorippe quadridens* (Fabricius, 1793) (RUMF-ZC-2318, male, 31.0 × 30.1 mm); d, *Dorippoides facchino* (Herbst, 1785) (RUMF-ZC-2319, male, 19.6 × 23.7 mm); e, *Doclea armata* De Haan, 1839 (RUMF-ZC-2320, male, 59.4 × 52.1 mm); f, *Halimede ochtodes* (Herbst, 1783) (RUMF-ZC-1917, male, 28.2 × 37.9 mm, in live colouration).

Remarks: Dorippe quadridens has been recorded to carry various types of material for camouflage (e.g. sponge, pieces of shell or other debris): see Guinot *et al.* (1995).

***Dorippoides facchino* (Herbst, 1785)** (Fig. 2d)

Material examined: RUMF-ZC-2319, one male, 19.6 × 23.7 mm, one ovigerous female, 19.9 × 25.1 mm.

Distribution: This species is known from Sri Lanka, southern India, Thailand (Gulf of Thailand), southern China, Vietnam, Thailand, Malaysia, Indonesia (Holthuis & Manning, 1990), and now Cambodia

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(present study).

Remarks: Dorippoides facchino often carries a shell with a sea anemone attached (see Guinot *et al*., 1995).

Family EPIALTIDAE MacLeay, 1838

Doclea armata De Haan, 1839 (Fig. 2e)

Material examined: RUMF-ZC-2320, one male, 59.4 × 52.1 mm, one female, 57.6 × 49.3 mm.

Comparative material: Doclea armata: four males, 45.0 × *ca.* 34.4–53.4 × 42.2 mm, three females, 30.1 × 23.3 to 46.8 × 43.0 mm, three ovigerous females, 45.3 × 38.4 to *ca.* 49.3 × 47.2 mm, ZRC 1998.1054, Angsila fishing port, Chonburi, Thailand (Gulf of Thailand), collected by P.K.L. Ng, 29 September 1998; six males, 46.5 × 41.2 to 56.1 × 54.2 mm, one ovigerous female, 49.5 × 46.3, ZRC 2002.0071, Pichai fishing port, Phuket, Thailand (Andaman Sea), collected by J.C.Y. Lai, 22–25 August 2002.

Distribution: This species is known from Sri Lanka, India, Myanmar, Singapore, Malaysia, Thailand (Gulf of Thailand and Andaman Sea), Vietnam, Hong Kong, the Philippines (Wagner, 1986; Naiyanetr, 2007), and now Cambodia (present study).

Remarks: This species can be distinguished from congeners by the absence of a spine on the supraorbital margin, the comparatively long rostrum, and the presence of four longitudinal rows of dense and rather long setae on the ambulatory legs (Wagner, 1986; Chen & Ng, 2004).

Family GALENIDAE Alcock, 1898

Halimede ochtodes (Herbst, 1783) (Fig. 2f)

Material examined: RUMF-ZC-1917, one male, 28.2 × 37.9 mm.

Comparative material: Halimede ochtodes (Herbst, 1783): two males, 33.2 × 46.6, 35.5 × 50.5 mm, ZRC 1998.1053,

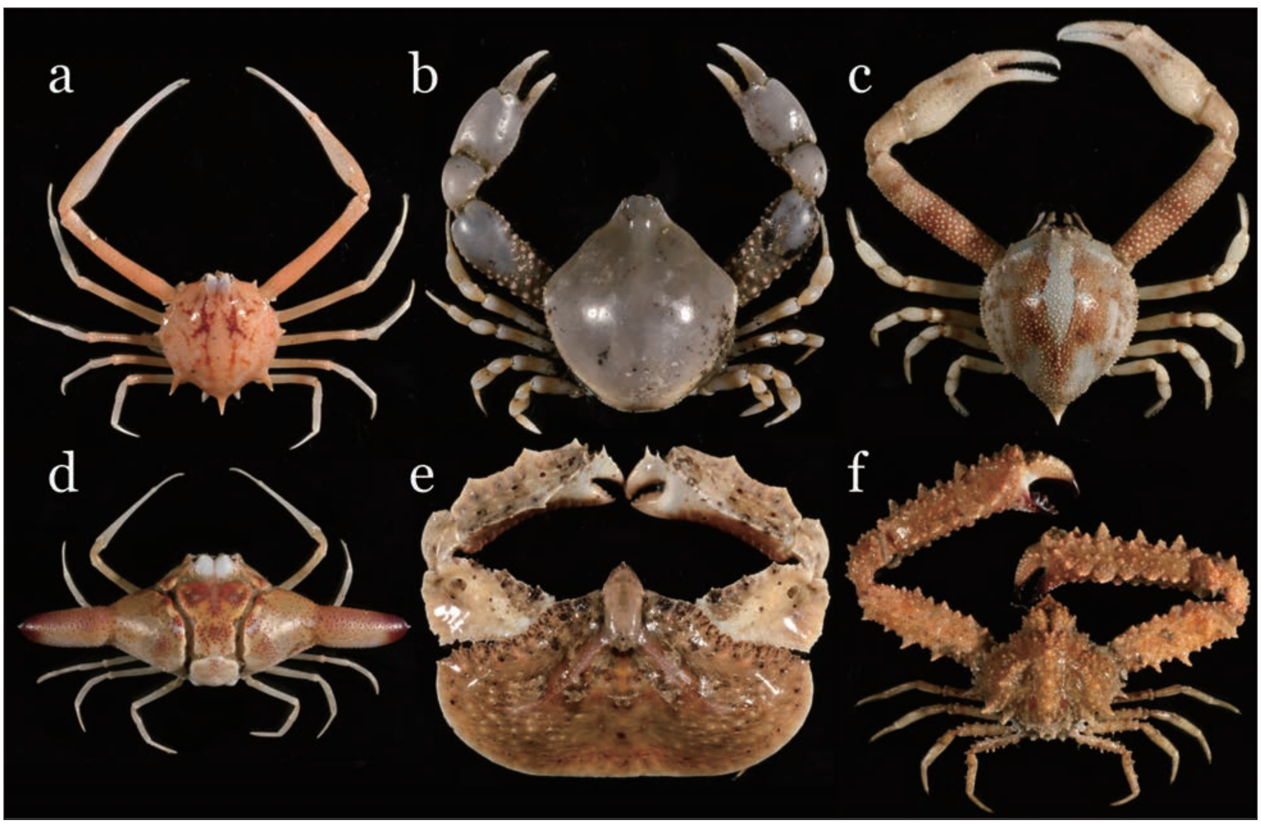

Fig. 3 Brachyuran species collected from Kampong Kandal Fishery Port. a, *Arcania novemspinosa* (Lichtenstein, 1816) (RUMF-ZC-1910, male, 25.9 × 22.9 mm); b, *Leucosia formosensis* Sakai, 1937 (RUMF-ZC-1911, male, 23.6 × 20.9 mm); c, *Myra affinis* Bell, 1855 (RUMF-ZC-1909, male, 39.0 × 31.0 mm); d, *Ixa cylindrus* (Fabricius, 1777) (RUMF-ZC-1908, male, 19.5 × 56.1 mm); e, *Cryptopodia fornicata* (Fabricius, 1787) (RUMF-ZC-1574, male, 35.8 × 59.8 mm); f, *Rhinolambrus longispinus* (Miers, 1879) (RUMF-ZC-1912, male, 34.3 × 36.8 mm).

Angsila fishing port, Chonburi, Thailand (Gulf of Thailand), collected by P.K.L. Ng, 29 September 1998; one male, 23.9 × 31.8 mm, 27.2 × 36.7 mm, ZRC 2012.0148, Changi Coast, Singapore, low tide, sand flat and sea grasses, collected by S.Y. Chan & L. Nguang, 7 May 2012.

Distribution: Northern half of Australia, Pakistan, India, Thailand (Gulf of Thailand), Singapore, China (Guangxi, Hainan, Hong Kong), the Philippines, Indonesia (Dai & Yang, 1991; Davie, 2002; Naiyanetr, 2007), and now Cambodia (present study).

Remarks: Halimede currently includes four species (Ng *et al.*, 2008). *Halimede ochtodes* can be distinguished from its congeners by the ill-defined regions of the carapace (versus well-defined) (see Miers, 1884; Galil, 2000).

Family LEUCOSIIDAE Samouelle, 1819

Arcania novemspinosa (Lichtenstein, 1816) (Figs 3a, 4a, b)

Material examined: RUMF-ZC-1910, two males, 23.6 × 21.0, 25.9 × 22.9 mm.

Comparative material: Arcania novemspinosa (Lichtenstein, 1816): One male, 18.5 × 17.0 mm, RUMF-ZC-2122, Oura Bay, Okinawa Island, Japan, -15 m, collected by T. Fujii, 20 August 2011; three juveniles, 6.7 × 5.8 to 8.5 × 7.9 mm, RUMF-ZC-2123, Oura Bay, Okinawa Island, -19.6 m, collected by T. Fujii, T. Naruse, D. Uyeno & S. Nishihira, 13 November 2012; six males, 13.5 × 12.3 to 22.1 × 21.5 mm, 13 females, 13.9 × 13.2 to 27.2 × 25.2 mm, ZRC 2008.1321, Ang Sila fishing port, Chonburi, Thailand (Gulf of Thailand), collected by Z. Jaafar *et al.* 12 August 2003; one male, 21.3 × 18.2 mm, one female, 22.2 × 20.0 mm, ZRC 2005.0065, Aer Prang, Lembeh Straits, Bitung, North Sulawesi, Indonesia, collected by Tan Heok Hui, 17 July 2003.

Distribution: Andaman Sea, Malaysia, Singapore, Thailand (Gulf of Thailand), Taiwan Strait, Okinawa Island, Indonesia, the Philippines, Australia (Galil, 2001a; Naiyanetr, 2007; Fujii & Naruse, 2013), and now Cambodia (present study).

Remarks: Arcania novemspinosa (Lichtenstein, 1816) has been misidentified as, or regarded as possibly being conspecific with, *A. undecimspinosa* De Haan, 1841 (Alcock, 1896; Hill, 1982; Tan, 1996), but they are clearly two different species. *Arcania novemspinosa* can be distinguished from *A. undecimspinosa* by the very long posterolateral spines of the carapace (posterolateral spines distinctly longer than lateral spines versus posterolateral spines as long as lateral spines) (Fujii & Naruse, 2013: Fig. 3). Galil (2001a) identified what Campbell & Stephenson (1970) recorded as "*A. novemspinosa*" from Moreton Bay as *A. undecimspinosa*, but Naruse (2014) raised doubts as to whether it is either species. Careful reexamination of previous records is necessary to draw conclusions regarding the true distribution of *A. novemspinosa*.

Leucosia formosensis Sakai, 1937 (Figs 3b, 4c–e)

Material examined: RUMF-ZC-1911, one male, 23.6 × 20.9 mm,

Comparative material: Leucosia formosensis: ZRC 1984.6327–6329, one male, 22.5 × 19.0 mm, one female, 22.0 × 19.4 mm, about 30 miles from Horsburgh Lighthouse, South China Sea, collected by Hee Huat, 10 September 1983.

Distribution: Singapore, Gulf of Tongking, Taiwan, China (Guangdong and Fujian), the Philippines (Tan, 1996; Sakai, 2004; present study), and now Cambodia (present study).

Remarks: This species is diagnosed by the G1 possessing a screw-like, longitudinally coiled shaft with setose and swollen distal end bearing a long slender process. Dai *et al.* (1986), Dai & Yan (1991), and Tan (1996) recorded *L. formosensis* from the Philippines. Tan (1996) noted that her record was based on specimens deposited in the National Museum of Natural History (Smithsonian Institution), but did not provide detailed information.

Myra affinis Bell, 1855 (Figs 3c, 4f, g)

Material examined: RUMF-ZC-1909, one male, 39.0 × 31.0 mm, one female, 30.9 × 26.3 mm; ZRC 2014.0338, one male, 37.9 × 29.8 mm, one female, 28.6 × 24.3 mm.

Distribution: Sri Lanka, Indonesia, Thailand (Gulf of Thailand), the Philippines (Galil, 2001b; Naiyanetr, 2007), and now Cambodia (present study).

Remarks: Myra affinis is characterised by a prominently granulate carapace, acuminate posteromedian carapace denticle, presence of a horizontal granulate band on the male third thoracic sternite, cheliped dactylus about three-quarters as long as the upper margin of the palm, and male cheliped merus being shorter than the carapace length (Galil, 2001b).

***Ixa cylindrus* (Fabricius, 1777)** (Figs 3d, 4h, i)

Material examined: RUMF-ZC-1908, two males, 12.7 × 32.8, 19.5 × 56.1 mm, one female, 19.3 × 52.7 mm; ZRC 2014.0339, one male, 18.7 × 52.5 mm, one female, *ca.* 19 × *ca.* 60 mm.

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Distribution: Widely distributed. Known from East Africa, Mauritius, India, Sri Lanka, Singapore, Thailand (Gulf of Thailand), Cambodia, Malaysia (Borneo), China, the Philippines, Taiwan, Australia (Komatsu *et al.*, 2004; Naiyanetr, 2007; Takeda & Nagai, 2009; UNEP, 2007).

Remarks: Among the nine known species of *Ixa* Leach, 1816 (Ng *et al.*, 2008; also see Komatsu *et al.*, 2004, Takeda & Nagai 2009), *I. cylindrus* can be easily distinguished by the presence of a pair of sharp-edged narrow and deep grooves that run longitudinally along the sides of the gastric and cardiac regions to the intestinal regions. Komatsu *et al.* (2004) indicated that there is considerable variation in the condition of the lateral process of the carapace. Takeda & Nagai (2009) noted that the geographical ranges of *I. cylindrus* and *I. edwardsii* Lucas, 1858, reach Mersin Bay, southeastern Turkey, in the Mediterranean Sea. This information appears to be cited from Holthuis & Gottlieb (1956). However, the only *Ixa* species recorded from the Mediterranean Sea by Holthuis & Gottlieb (1956) was their new species, *I. monodi*. Since Takeda & Nagai (2009) regarded *I. monodi* as a valid species, it is likely they cited Holthuis & Gottlieb (1956) in error.

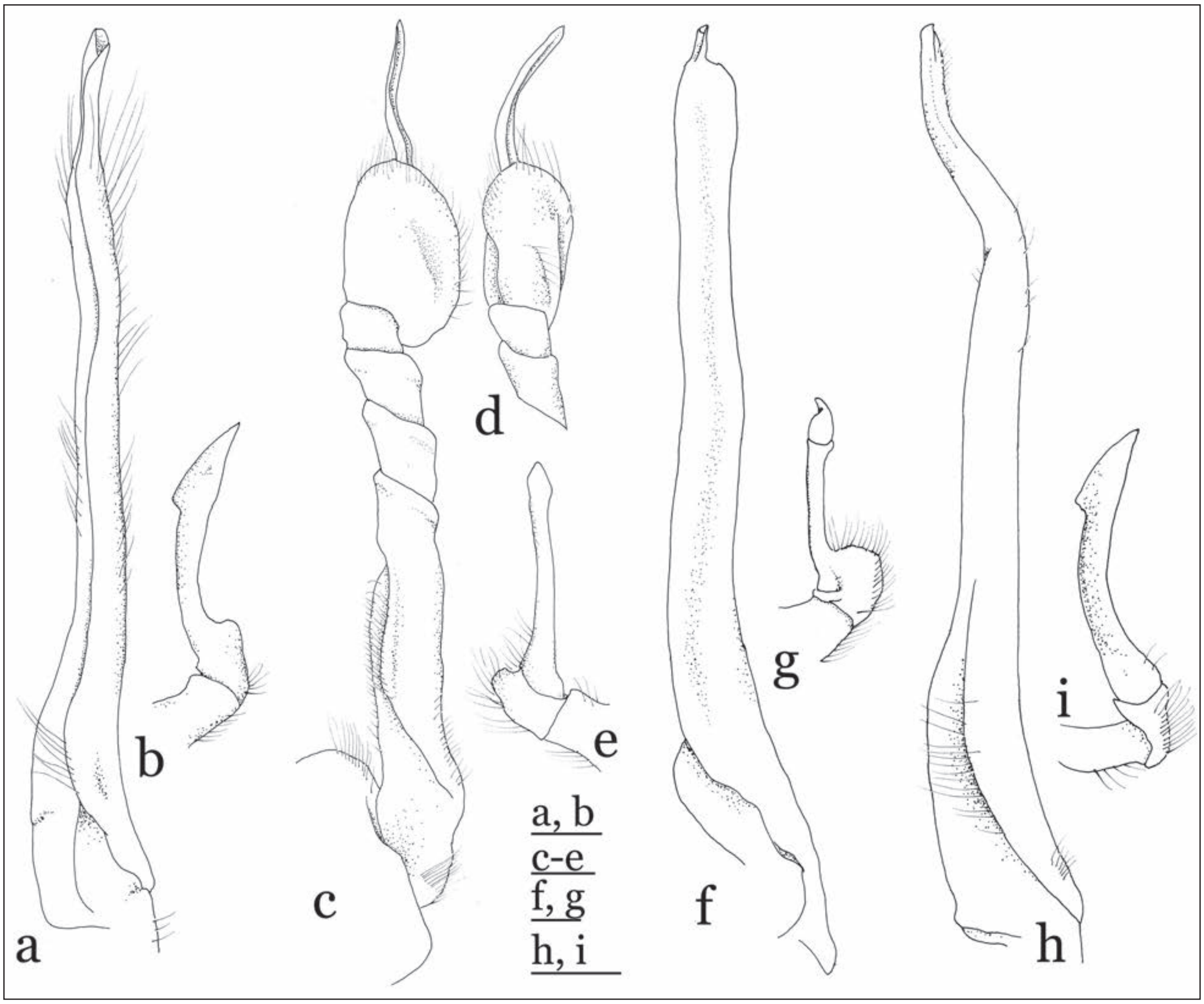

Fig. 4 Male first and second gonopods of leucosiid species collected from Kampong Kandal Fishery Port: a, b, *Arcania novemspinosa* (Lichtenstein, 1816) (RUMF-ZC-1910, 25.9 × 22.9 mm) (a, left G1, ventral view; b, left G2, ventral view); c–e, *Leucosia formosensis* Sakai, 1937 (RUMF-ZC-1911, 23.6 × 20.9 mm) (c, left G1, ventral view; d, distal part of left G1, mesial view; e, right G2, ventral view); f, g, *Myra affinis* Bell, 1855 (RUMF-ZC-1909, 39.0 × 31.0 mm) (f, left G1, ventral view; g, left G2, ventral view); h, i, *Ixa cylindrus* (Fabricius, 1777) (RUMF-ZC-1908, 19.5 × 56.1 mm) (h, left G1, ventral view; i, left G2, ventral view). Scales = 1 mm.

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Family PARTHENOPIDAE MacLeay, 1838

***Cryptopodia fornicata* (Fabricius, 1787)** (Figs 3e, 5a, b)

Material examined: RUMF-ZC-1574, one male, 35.8 × 59.8 mm.

Distribution: Central Indian Ocean, Thailand (Gulf of Thailand), Cambodia, South China Sea, Japan (Chiong & Ng, 1998; Naiyanetr, 2007; UNEP, 2007).

Remarks: Cryptopodia fornicata can be distinguished from all congeners by the following combination of morphological characters: entire posterior to postero-lateral margins of the carapace; rostrum being broader than long, with convex lateral margins; and smooth pterygostomial region and outer surface of third maxilliped (Chiong & Ng, 1998).

***Rhinolambrus longispinus* (Miers, 1879)** (Figs 3f, 5c, d)

Material examined: RUMF-ZC-1912, one male, 34.3 × 36.8 mm.

Comparative material: Rhinolambrus longispinus: one male, 38.3 × 38.8 mm, ZRC 1984.6380, about 30

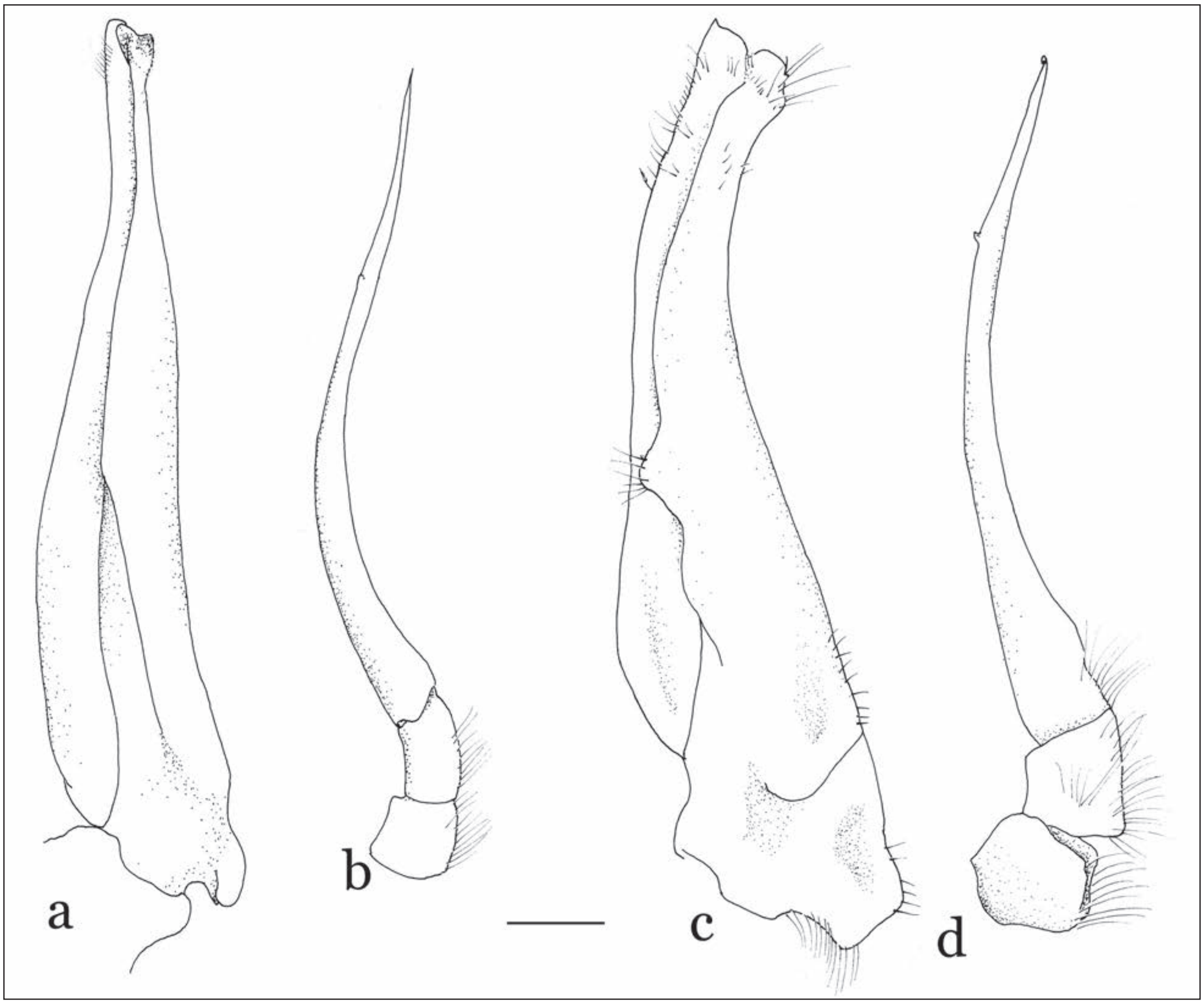

Fig. 5 Male first and second gonopods of parthenopid species collected from Kampong Kandal Fishery Port: a, b, *Cryptopodia fornicata* (Fabricius, 1787) (RUMF-ZC-1574, 35.8 × 59.8 mm) (a, left G1, ventral view; b, left G2, ventral view); c, d, R*hinolambrus longispinus* (Miers, 1879) (RUMF-ZC-1912, 34.3 × 36.8 mm) (c, left G1, ventral view; d, left G2, ventral view). Scale = 1 mm.

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miles from Horsburgh Lighthouse, South China Sea, collected by Hee Huat, 10 September 1983; one male, 39.5 × 40.7, ZRC 1984.6068, Singapore. *Rhinolambrus contrarius* (Herbst, 1804): one male, 45.3 × 42.6 mm, ZRC 1999.0058, Kii Peninsula, Japan, collected by NSMT, 27 Feb. 1999.

Distribution: Amirante Islands, Seychelles, Arrakanküste, Maldives, Sri Lanka, Cambodia, Singapore, Thailand (Gulf of Thailand), China (Shanghai), Sabira, Kepulauan Seribu, Sulawesi, and Torres Strait, Australia (Flipse, 1930; Naiyanetr, 2007; UNEP, 2007).

Remarks: The present specimen agrees well with the original description of the species (Miers, 1879). Shen *et al.* (1982) recorded *R. longispinus* [as *Parthenope (Rhinolambrus) longispinus*] from Hainan Island, China. However, their photographed specimen (Shen *et al.*, 1982: pl. 1–4) had a relatively long and sharp rostrum, and long cheliped and carapace spines. These Chinese specimens most probably belong to a different species.

Family PORTUNIDAE Rafinesque, 1815

***Podophthalmus vigil* (Fabricius, 1798)** (Fig. 6a)

Material examined: RUMF-ZC-1914, one male, 26.4 × *ca.* 57.3 mm.

Distribution: Western Indian Ocean including the Red Sea to Malaysia, Cambodia, China (Guangxi, Hainan), Taiwan, Japan, Australia, Hawaii, Samoa and Tahiti (Dai & Yang, 1991; Naiyanetr, 2007; UNEP, 2007).

Remarks: The genus *Podophthalmus* Lamarck, 1801, contains three species. *Podophthalmus vigil* differs from its two congeners in the following combination of characters: eyestalk entire (without pterygoid expansion) and carapace broad (width *ca.* 2.5 times carapace length) (Stephenson, 1972).

***Charybdis (Charybdis) anisodon* (De Haan, 1850)** (Fig. 6b)

Material examined: RUMF-ZC-1915, one male, 31.2 × 53.7 mm.

Distribution: Madagascar, Red Sea, Thailand (Andaman Sea and Gulf of Thailand), Cambodia, Malaysia, Singapore, Indonesia (Sulawesi), China, Taiwan, Japan, the Philippines, Australia and New Caledonia (Wee & Ng, 1995; Naiyanetr 2007; UNEP, 2007).

Remarks: Charybdis anisodon is characterized by the olive-coloured dorsal surface of the carapace. Identification keys to species of *Charybdis* were provided by Stephenson (1972), Wee & Ng (1995) and Apel & Spiridonov (1998).

Family EURYPLACIDAE Stimpson, 1871

***Eucrate alcocki* Serène, in Serène & Lohavanijaya, 1973** (Fig. 6c)

Material examined: RUMF-ZC-1913, one male, *ca.* 22 × *ca.* 25 mm, one female, 16.7 × 19.5 mm.

Distribution: Southern China, Hong Kong, the Philippines, Vietnam, Thailand (Gulf of Thailand), eastern Peninsular Malaysia, Singapore (Naiyanetr, 2007; Castro & Ng, 2010), and now Cambodia (present study).

Remarks: The genus *Eucrate* De Haan, 1835, contains eight species. A key to the species of *Eucrate* is provided by Castro & Ng (2010).

Family SCALOPIDIIDAE Števčić, 2005

***Scalopidia spinosipes* Stimpson, 1858** (Fig. 6d)

Material examined: RUMF-ZC-1858, one female, 11.2 × 15.6 mm.

Distribution: India (Calcutta), Thailand (Andaman Sea and Gulf of Thailand), Singapore, Vietnam, South China Sea, Hong Kong, Taiwan, the Philippines, Indonesia (Lonbok, Macassar) (Tesch, 1918; Ng *et al.*, 2001; Naiyanetr, 2007; Guinot *et al.*, 2013; Ng & Castro, 2013), and now Cambodia (present study).

Remarks: The genus *Scalopidia* Stimpson, 1858, contains three species. Diagnostic characters of *S. spinosipes* are indicated and illustrated in detail by Ng & Castro (2013).

Family MACROPHTHALMIDAE Dana, 1851

***Macrophthalmus vietnamensis* Serène, 1971** (Fig. 7a, b)

Material examined: RUMF-ZC-1918, one male, 16.9 × 22.4 mm,

Comparative material: Macrophthalmus vietnamensis: Holotype, ZRC 1969.12.5.7, male, 13.5 x 17.5 mm, South China Sea, collected by Fisheries Vietnam/ UNDP, 28 November 1969; Paratype, ZRC 1971.3.11.1, one female, 14.1 x 18.4 mm, South China Sea, collected by Fisheries Vietnam / UNDP, 28 November 1969. *Macrophthalmus latreillei* (Desmarest, 1822): RUMF-ZC-2867, one male, 37.6 × 54.4 mm, Siargao, Surigao, the Philippines, collected in a tangle net, 2014; NMCR 8558, four males, 18.5 × 24.1 – 43.0 × 62.2 mm, two

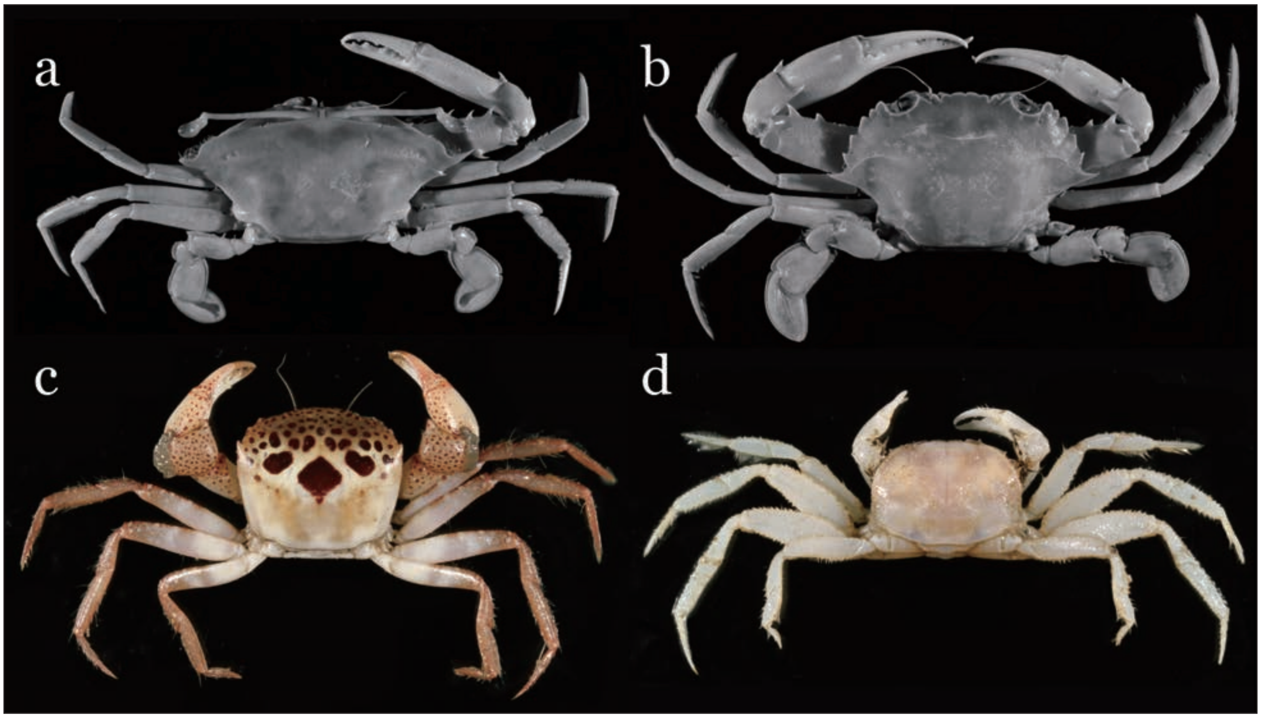

Fig. 6 Brachyuran species collected from Kampong Kandal Fishery Port: a, *Podophthalmus vigil* (Fabricius, 1798) (RUMF-ZC-1914, male, 26.4 × ca. 57.3 mm); b, *Charybdis (Charybdis) anisodon* (De Haan, 1850) (RUMF-ZC-1915, male, 31.2 × 53.7 mm); c, *Eucrate alcocki* Serène, in Serène & Lohavanijaya, 1973 (RUMF-ZC-1913, female, 16.7 × 19.5 mm); d, *Scalopidia spinosipes* Stimpson, 1858 (RUMF-ZC-1858, female, 11.2 × 15.6 mm).

females, 18.0 × 23.3, 28.4 × 36.9 mm, Calubcub II, San Juan, Batangas, mud flat, collected by J. Cabrera, 2 August 1982.

Distribution: Thailand (Gulf of Thailand), Vietnam (Serène, 1971; Naiyanetr, 2007), and now Cambodia (present study).

Remarks: Macrophthalmus vietnamensis was described based on specimens collected from the South China Sea, off the tip of Camau (= Cà Mau?). The present Cambodian specimen (Fig. 7a), which was collected from about 230 km northwest of Cà Mau, agrees very well with the holotype of *M. vietnamensis* (Fig. 7b). Barnes (1977) synonymized *M. vietnamensis* under *M. latreillei* (Desmarest, 1822). Subsequently, Ng *et al.* (2008) resurrected *M. vietnamensis* without any comment (also see Mendoza & Ng, 2007), but Barnes (2010) again treated the two as conspecific. *Macrophthalmus latreillei* was described based on fossil specimens from the "Indes orientales" (South to Southeast Asia) (Desmarest, 1822: 99). Davie (2002) checked the data of the syntypes and indicated that the type locality of the species is "East India and Luzon" (Davie, 2002: 354). Recently, Davie (2012) indicated that *M. latreillei* exhibits marked allometric growth changes in morphology, especially in the carapace contour and the size and position of anterolateral teeth of the carapace (Davie, 2012: Fig. 37). Our examination of a series of *M. latreillei* specimens from Batangas, Luzon, the Philippines, also confirmed its wide range of growth changes in the carapace, chelipeds and ambulatory legs. However, when similar-sized specimens of *M. vietnamensis* and *M. latreillei* are compared, differences between the two species are remarkable, especially in the length/ width ratio of the carapace (shorter in *M. vietnamensis*), the robustness of the chela (weaker in *M. vietnamensis*), eye length (proportionally longer in *M. vietnamensis*), and the size of subdistal tooth of the anterior margin of the merus of ambulatory legs (stronger in *M. vietnamensis*) (Fig. 7a, d). Considering these morphological differences, *M. vietnamensis* is treated as a distinct species.

Discussion

The present paper reports 21 crustacean species (three stomatopods, one scyllarid lobster and 17

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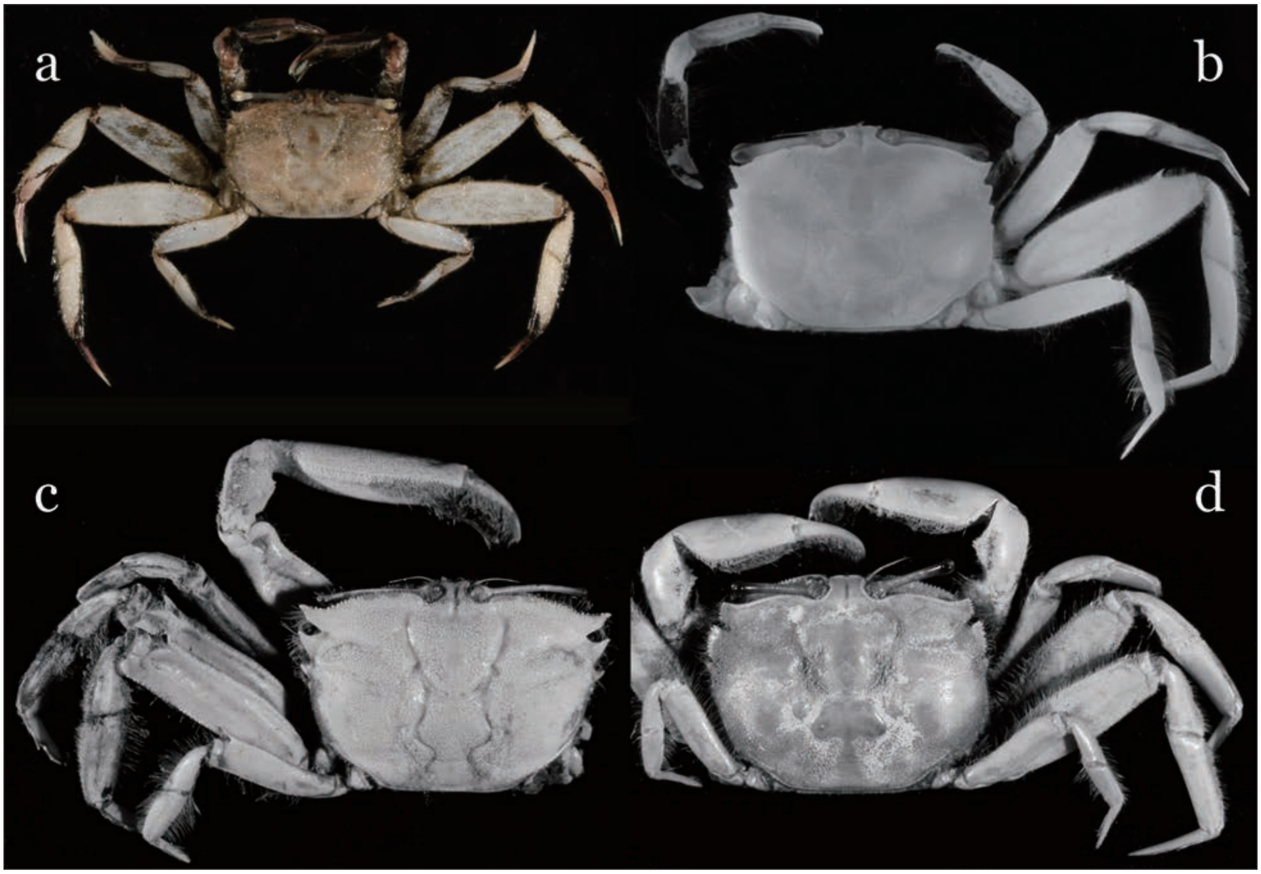

Fig. 7 *Macrophthalmus vietnamensis* Serène, 1971 and *Macrophthalmus latreillei* (Desmarest, 1822): a, *M. vietnamensis* (RUMF-ZC-1918, male, 16.9 × 22.4 mm); b, holotype of *M. vietnamensis* (ZRC 1969.12.5.7, male, 13.5 × 17.5 mm); c, *M. latreillei* (NMCR 8558, male, 43.0 × 62.2 mm); d, *M. latreillei* (NMCR 8558, male, 18.5 × 24.1 mm).

brachyuran crabs) from a brief visit at a local fishing port. This number, however, falls short of reflecting the true diversity of actual catch, as our quick and rather selective sampling led to us picking up species that appeared at a glance to be more unusual or outstanding. Many penaeid, caridean, and anomuran species were observed among the by-catch but not collected due to space and time limitations. Jensen *et al.* (2011) recorded a rare porcellanid, *Pseudoporcellanella manoliensis* Sankarankutty, 1962, based on material from baskets of "trash fish" in two fishing ports in Cambodia. Among the 20 marine crabs species recorded by UNEP (2007), only five species are reported here.

Further detailed studies will therefore certainly increase the number of Cambodian species, and serve as baseline for future faunal lists and conservation policy-making.

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References

Ahyong, S.T. (2001) Revision of the Australian stomatopod Crustacea. *Records of the Australian Museum*, **26,** 1–326.

Ahyong, S.T. & Moosa, M.K. (2004) Stomatopod Crustacea from Anambas and Natuna islands, South China Sea, Indonesia. *Raffles Bulletin of Zoology, Supplement 11*, 61–66.

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Ahyong, S.T., Chan, T.-Y. & Liao, Y.-C. (2008) *A Catalog of the Mantis Shrimps (Stomatopoda) of Taiwan*. National Taiwan Ocean University, Keelung, Taiwan.

Ahyong, S.T., Naruse, T., Tan, S.H. & Ng P.K.L. (2009) Part II. Infraorder Brachyura: Sections Dromiacea, Raninoida, Cyclodorippoida. In *The Crustacean Fauna of Taiwan: Brachyuran Crabs, Volume 1—Carcinology in Taiwan and Dromiacea, Raninoida, Cyclodrippoida* (eds P.K.L. Ng, T.-Y. Chan, S.T. Ahyong & S.H. Tan), pp. 27–198. National Taiwan Ocean University, Keelung, Taiwan.

Alcock, A. (1896) Materials for a carcinological fauna of India: No. 2, the Brachyura Oxystomata. *Journal of the Asiatic Society of Bengal*, **65,** 134–296, pls. 6–8.

Apel, M. & Spiridonov, V.A. (1998) Taxonomy and zoogeography of the portunid crabs (Crustacea: Decapoda: Brachyura: Portunidae) of the Arabian Gulf and adjacent waters. *Fauna of Arabia*, **17,** 159–331.

Barnes, R.S.K. (1977) Concluding contribution towards a revision of, and a key to, the genus *Macrophthalmus* (Crustacea: Brachyura). *Journal of Zoology, London*, **182,** 267–280.

Barnes, R.S.K. (2010) A review of the sentinel and allied crabs (Crustacea: Brachyura: Macrophthalmidae), with particular reference to the genus *Macrophthalmus. Raffles Bulletin of Zoology*, **58,** 31–49.

Campbell, B.M. & Stephenson, W. (1970) The sublittoral Brachyura (Crustacea: Decapoda) of Moreton Bay. *Memoirs of the Queensland Museum*, **15,** 235–302, pl. 22.

Castro, P. & Ng P.K.L. (2010) Revision of the family Euryplacidae Stimpson, 1871 (Crustacea: Decapoda: Brachyura: Goneplacoidea). *Zootaxa*, **2375,** 1–130.

Chen, H.-L. & Ng P.K.L. (2004) On two species of spider crabs of the genus *Doclea* (Crustacea: Decapoda: Brachyura: Majidae: Pisinae) from China, one of which is new. *Raffles Bulletin of Zoology*, **52,** 201–208.

Chiong, W.L. & Ng P.K.L. (1998) A revision of the buckler crabs of the genus *Cryptopodia* H. Milne Edwards, 1834 (Crustacea: Decapoda: Brachyura: Parthenopidae). *Raffles Bulletin of Zoology*, **46,** 157–216.

Dai, A. & Yang, S. (1991) *Crabs of the China Sea.* China Ocean Press, Beijing and Springer-Verlag, Berlin, Heidelberg, New York, Tokyo, Japan.

Dai, A.-Y., Yang, S.-L., Song, Y.-Z. & Chen, G.-X. (1986) *Crabs of Chinese Seas*. China Ocean Press, Beijing, China. [*In Chinese*].

Davie, P.J.F. (2002) Crustacea: Malacostraca: Eucarida (Part 2): Decapoda—Anomura, Brachyura. In *Zoological Catalogue of Australia, Vol. 19.3B* (eds A. Wells & W.W.K. Houston). CSIRO Publishing, Melbourne, Australia.

Davie, P.J.F. (2012) A review of *Macrophthalmus sensu lato* (Crustacea: Decapoda: Macrophthalmidae) from Australia, including two new species and new records. *Memoirs of the Queensland Museum – Nature*, **56,** 149–219.

Desmarest, A.-G. (1822) Les crustacés proprement dits. In *Histoire Naturelle des Crustacés Fossiles, Sous les Rapports Zoologique et Géologiques* (eds A. Brongniart & A.G. Desmarest), pp. 138–425. F.G. Levrault, Paris, France.

Flipse, H.J. (1930) Decapoda F. (Decapoda Brachyura continued) Oxyrhyncha: Parthenopidae. *Siboga Expéditie Monographie*, **39c,** 1–96.

Fujii, T. & Naruse, T. (2013) First record of *Arcania novemspinosa* (Crastacea: Decapoda: Leucosiidae) from Okinawa Island, Japan. *Fauna Ryukyuana*, **3,** 1–6. [*In Japanese*].

Galil, B.S. (2000) *Halimede tyche* (Herbst, 1801) (Decapoda; Xanthidae; Halimedinae) from the Mediterranean coast of Israel, with a review of the genus. *Journal of Crustacean Biology*, **20,** 325–331.

Galil, B.S. (2001a) A revision of the genus *Arcania* Leach, 1817 (Crustacea: Decapoda: Leucosioidea). *Zoologische Mededelingen*, **75,** 169–205.

Galil, B.S. (2001b) A revision of *Myra* Leach, 1817 (Crustacea: Decapoda: Leucosioidea). *Zoologische Mededelingen*, **75,** 409–446.

Guinot, D. & Tavares, M.S. (2000) *Conchoeodromia alcocki* Chopra, 1934: megalopa of *Conchoecetes artificiosus* (Fabricius, 1798) (Decapoda, Brachyura, Dromiidae). *Journal of Crustacean Biology*, **20,** 301–309.

Guinot, D., Doumenc, D. & Chintiroglou, C.C. (1995) A review of the carrying behaviour in brachyuran crabs, with additional information on the symbioses with sea anemones. *Raffles Bulletin of Zoology*, **43,** 377–416.

Guinot, D., Tavares, M. & Castro, P. (2013) Significance of the sexual openings and supplementary structures on the phylogeny of brachyuran crabs (Crustacea, Decapoda, Brachyura), with new nomina for higher-ranked podotreme taxa. *Zootaxa*, **3665,** 1–414.

Hill, D.S. (1982) The Leucosiidae (Crustacea: Decapoda) of Hong Kong. In *Proceedings of the First International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China* (eds B. Morton & C.K. Tseng), pp. 195–205. Hong Kong University Press, Hong Kong.

Holthuis, L.B. (2002) The Indo-Pacific scyllarine lobsters (Crustacea, Decapoda, Scyllaridae). *Zoosystema*, **24,** 499–683.

Holthuis, L.B. & Gottlieb, E. (1956) Two interesting crabs (Crustacea Decapoda, Brachyura) from Mersin Bay, S.E. Turkey. *Zoologische Mededelingen*, **34,** 287–299, pls. 4, 5.

Holthuis, L.B. & Manning, R.B. (1990) Crabs of the subfamily Dorippinae MacLeay, 1838, from the Indo-West Pacific Region (Crustacea: Decapoda: Dorippidae). *Researches on Crustacea, Special Number 3*, 1–151.

Jensen, K.R., Ing T. & Va L. (2011) First record of the rare porcellanid crab *Pseudoporcellanella manoliensis* Sankarankutty, 1961 (Crustacea: Anomura) in the coastal waters of Cambodia. *Cambodian Journal of Natural History*, **2011,** 81–85.

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Komatsu, H., Manuel M.R. & Takeda, M. (2004) Some rare leucosiid crabs (Crustacea, Decapoda, Brachyura) from the Philippines, with description of a new species of the genus *Arcania*. *Biogeography*, **6,** 75–86.

Leach, W.E. (1817) *The Zoological Miscellany; Being Descriptions of New, or Interesting Animals: Volume 3*. E. Nodder and Son, Covent Garden, London, UK.

McLay, C.L. (1993) Crustacea Decapoda: the sponge crabs (Dromiidae) of New Caledonia and the Philippines with a review of the genera. In *Résultats des Campagnes MUSORSTOM, Volume 10* (ed. A. Crosnier). *Mémoires du Muséum national d'Histoire naturelle*, **156,** 111–251.

McLay, C.L. & Hosie, A. (2012) Another shell-carrying dromiid crab, *Desmodromia tranterae* McLay, 2001, from the Dampier Archipelago, Western Australia and observations of shell-acquisition behaviour of *Conchoecetes artificiosus* (Fabricius, 1798) (Decapoda, Brachyura, Dromiidae). In *Studies on Eumalacostraca: a homage to Masatsune Takeda, Vol. 17* (eds H. Komatsu, J. Okuno & K. Fukuoka), pp. 183–196. Brill, Leiden, the Netherlands.

McLay, C.L., Lim, S.S.L. & Ng P.K.L. (2001) On the first zoea of *Lauridromia indica* (Gray, 1831), with an appraisal of the generic classification of the Dromiidae (Decapoda: Brachyura) using larval characters. *Journal of Crustacean Biology*, **21,** 733–747.

Mendoza, J.C.E. & Ng P.K.L. (2007) *Macrophthalmus (Euplax)* H. Milne Edwards, 1852, a valid subgenus of ocypodid crab (Decapoda: Brachyura: Macrophthalmidae), with description of a new species from the Philippines. *Journal of Crustacean Biology*, **27,** 670–680.

Miers, E.J. (1884) *Crustacea. Report of the Zoological Collections Made in the Indo-Pacific Ocean During the Voyage of HMS 'Alert', 1881–1882*, 178–331, part 2, 513–575, pls, XVIII-XXXIV, part 2, XLVI-LII.

Naiyanetr, P. (2007) *Checklist of Crustacean Fauna in Thailand (Decapoda, Stomatopoda, Anostraca, Myodocopa and Isopoda).* Office of Natural Resources and Environmental Policy and Planning, Bangkok, Thailand.

Naruse, T. (2014) Description of two new species of *Arcania* Leach, 1817, from the western Pacific Ocean and redescriptions of *A. undecimspinosa* De Haan, 1841, and *A. elongata* Yokoya, 1933 (Crustacea: Brachyura: Leucosiidae). *Zootaxa*, **3814,** 301–332.

Ng P.K.L. & Castro, P. (2013) On the genus *Scalopidia* Stimpson, 1858 (Crustacea: Brachyura: Goneplacoidea: Scalopidiidae), with the description of one new genus and three new species. *Zootaxa*, **3731,** 58–76.

Ng P.K.L., Wang, C.-H., Ho, P.-H. & Shih, H.-T. (2001) An annotated list of brachyuran crabs from Taiwan (Crustacea, Decapoda). *National Taiwan Museum Special Publication Series*, **11,** 1–86.

Ng P.K.L., Guinot, D. & Davie, P.J.F. (2008) Systema Brachyurorum: Part I. An annotated checklist of extant brachyuran crabs of the world. *Raffles Bulletin of Zoology, Supplement 17*, 1–286.

Rizvi, A.R. & Singer, U. (2011) *Cambodia Coastal Situation Analysis.* IUCN, Gland, Switzerland.

Sakai, K. (2004) *Crabs of Japan.* World Biodiversity Database CD-ROM Series, Expert Center for Taxonomic Identification (ETI), Amsterdam, the Netherlands. [*CD-ROM*].

Shen, C.-J., Dai, A.-Y. & Chen, H.-L. (1982) New and rare species of Parthenopidae (Crustacea: Brachyura) from China Seas. *Acta Zootaxonomica Sinica*, **7,** 139–149, 2 pls. [*In Chinese with English summary*].

Spalding, M., Kainuma, M. & Collins, L. (2010) *World Atlas of Mangroves.* Earthscan, London, UK.

Stephenson, W. (1972) An annotated check list and key to the Indo-West-Pacific swimming crabs (Crustacea: Decapoda: Portunidae). *Bulletin of the Royal Society of New Zealand*, **10,** 1–64.

Takeda, M. & Nagai, S. (2009) New material of two rare species of the leucosiid crab genus *Ixa* Leach (Crustacea: Decapoda: Brachyura) from the West Pacific. *Journal of Teikyo Heisei University*, **20,** 203–207.

Tan, C.G.S. (1996) Leucosiidae of the Albatross expedition to the Philippines, 1907–1910 (Crustacea: Brachyura: Decapoda). *Journal of Natural History*, **30,** 1021–1058.

UNEP—United Nations Environment Programme (2007) *National Reports on the Fish Stocks and Habitats of Regional, Global, and Transboundary Significance in the South China Sea*. UNEP/GEF/SCS Technical Publication No. 15. United Nations Environment Programme, Bangkok, Thailand.

Wagner, H.P. (1986) A revision of the genus *Doclea* Leach, 1815 (Crustacea, Brachyura, Majidae). *Bulletin du Muséum national d'histoire naturelle, Paris, 4e Série*, **8,** 893–953.

Wee, D.P.C. & Ng P.K.L. (1995) Swimming crabs of the genera *Charybdis* De Haan, 1833, and *Thalamita* Latreille, 1829 (Crustacea: Decapoda: Brachyura: Portunidae) from Peninsular Malaysia and Singapore. *Raffles Bulletin of Zoology, Supplement 1*, 1–128.

Wicksten, M.K. (1986) Carrying behavior in brachyuran crabs. *Journal of Crustacean Biology*, **6,** 364–369.

Yang, C.-H., Bracken-Grissom, H., Kim, D., Crandall, K.A & Chan, T.-Y (2012) Phylogenetic relationships, character evolution, and taxonomic implications within the slipper lobsters (Crustacea: Decapoda: Scyllaridae). *Molecular Phylogenetics and Evolution*, **62,** 237–250.

Seagrass diversity and distribution in the Koh Rong Archipelago, Preah Sihanouk Province, Cambodia

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ស្មៅសមុទ្រនៅជុំវិញកោះនានាក្នុងសមុទ្រប្រទេសកម្ពុជាត្រូវបានសិក្សាតិចតួច និងកំពុងស្ថិតក្រោមការគម្រាមកំហែងពីកត្តាផ្សេងៗដែលបង្កដោយមនុស្សជាពិសេសកត្តាដែលទាក់ទងនឹងការបំផ្លាញនៃបច្ចេកទេសនេសាទ។ ការចុះសិក្សាស្រាវជ្រាវត្រូវបានដំណើរការនារដូវប្រាំងក្នុងឆ្នាំ២០១៣ និងឆ្នាំ២០១៤ នៅជុំវិញកោះពីរ ដែលស្ថិតនៅក្នុងតំបន់គ្រប់គ្រងជលផលសមុទ្រស្នើឡើងដំបូងគេរបស់កម្ពុជា គឺកោះរុង និងកោះរុងសន្លឹម។ ការសិក្សានេះមានគោលបំណងវាយតម្លៃរបាយនានាភាព និងភាពសម្បូរបែបរបស់ស្មៅសមុទ្រនៅជុំវិញកោះទាំងពីរ។ វិធីសាស្ត្របង្កើតទីតាំងកាត់ទទឹង(transect)និងវាយជាក្រឡាចត្រង្គ (quadrat) ត្រូវបានប្រើក្នុងការប្រមូលយកសំណាកប្រភេទស្មៅសមុទ្រដើម្បីរកភាពសំបូរបែបនិងគម្របជាភាគរយរបស់វា។ ការសិក្សាបានបង្ហាញថាតំបន់គ្រប់គ្រងជលផលសមុទ្រស្នើឡើងនេះមានជម្រកស្មៅសមុទ្រប្រមាណ១៨ហិចតា។ ស្មៅសមុទ្របួនប្រភេទត្រូវបានរកឃើញគឺ*Halodule pinifolia, Thalassia hemprichii, Enhalus acoroides* និង*Halophila minor*។ ប្រភេទដែលសំបូរជាងគេគឺ *Halodule pinifolia*។ គម្របស្មៅសមុទ្រដែលមានភាគរយច្រើនជាងគេត្រូវបានរកឃើញនៅតំបន់ដែលបាតសមុទ្រធ្លាប់មានខ្សាច់ច្រើន។ ការសិក្សានេះតំណាងអោយការវាយតម្លៃទូលំទូលាយដំបូងពីសមាសភាពប្រភេទស្មៅសមុទ្រនៅប្រជុំកោះរុង និងផ្តល់នូវមូលដ្ឋានសម្រាប់ការពិនិត្យតាមដានទៅអនាគត។

Abstract

Seagrass habitats around Cambodia's offshore islands have been little studied and are under threat from various anthropogenic factors, especially those related to destructive fishing techniques. Field surveys were conducted in 2013 and 2014 during the dry season around both islands within Cambodia's first proposed Marine Fisheries Management Area: Koh Rong and Koh Rong Sanloem. The surveys aimed to evaluate seagrass distribution, abundance and diversity around the islands, and employed transect and quadrat methods to sample seagrass species richness and percentage cover. The area was found to contain an estimated 18 hectares of seagrass habitat. Four species of seagrass were recorded: *Halodule pinifolia, Thalassia hemprichii, Enhalus acoroides* and *Halophila minor*. The commonest species was *Halodule pinifolia*. The highest percentage cover of seagrass was found in areas where the benthos was course sand. This study represents the first comprehensive assessment of seagrass species composition in the Koh Rong Archipelago and provides a baseline for future monitoring.

Keywords

Fisheries, Marine Fisheries Management Area, MPA, percentage cover.

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Introduction

Seagrasses are aquatic flowering plants located mainly in shallow, sheltered nearshore areas (Carlo & McKenzie, 2011), and are usually found between mangroves and coral reefs in tropical areas (Short *et al.*, 2001, in UNEP, 2008). They are an important food for many species including dugongs *Dugong dugong* and green turtles *Chelonia mydas* (Sereywath & Sokhannaro, 2003; Smyth, 2006). Seagrasses also provide essential nursery habitat and breeding grounds for some important fishes (Unsworth *et al.*, 2006) and invertebrates, and play a role in protecting fringing coral reefs from the impacts of sedimentation (Short *et al*., 2001, in UNEP, 2008). Seagrass beds provide fishing areas for fishermen (Cullen-Unsworth *et al.*, 2013), but the species associated with them are particularly vulnerable to overfishing because such sheltered areas can be targeted even when bad weather restricts access to offshore fishing sites. If seagrass areas become degraded, fish stocks could decline because many fish species utilise seagrass as nursery habitat prior to migrating to coral reefs (Nagelkerken *et al*., 1999).

Cambodia's coastline stretches 440 km along the Gulf of Thailand. Kep Province borders Vietnam to the East, and Koh Kong Province borders Thailand to the West. Cambodia's coastal zone is comprised of the world's largest seagrass areas (Johnson & Munford, 2012). A national report on seagrass in the South China Sea (UNEP, 2008) indicated that seagrasses were found in shallow water throughout most of the country's coastal zone. Seagrass beds in Cambodia cover 33,814 hectares, but relatively little of this area is currently under effective management by the Fisheries Administration (Table 1).

Seagrass habitats in Cambodia can be found in two forms: either in extensive meadows adjacent to the mainland, or in patches of seagrass inter-mixed with corals around islands (Ethirmannasingam,1996 in Nelson, 1999). Kampot Province is the largest seagrass area, but smaller beds are also found around Koh Kong, Kep and Preah Sihanouk provinces (MFF, 2013), including areas bordering the offshore islands of Koh Rong Sanloem and Koh Rong (Ethirmannasingam,1996 in Nelson, 1999). However, there is a lack of information about the environmental factors influencing seagrass distribution and abundance in Cambodia (UNEP, 2008).

Approximately 60 species of seagrass have been observed globally (Short *et al.*, 2007) of which 18 species have been recorded in Southeast Asia (Anonymous, 2014). Previous studies in Cambodia's Kampot Province have reported 12 species (Ouk *et al.*, 2010).

Seagrass areas in Cambodia are threatened by destructive fishing practices, including trawling for shrimp (Adulyanukosol, 2002) and push-netting (Tana, 1995 in UNEP, 2008). In addition, water quality has declined in recent years due to high levels of nutrient input from terrestrial run-off following agricultural use of fertilizers and pesticides and increasing sedimentation following erosion from unsustainable logging practices (UNEP, 2008). Nutrient input and sedimentation increase water turbidity and inhibit seagrass growth by reducing light, which affects the ability of seagrass to photosynthesise (Duarte *et al.*, 1997; Hemmings & Duarte, 2000; UNEP, 2008).

Cambodia's first Marine Fisheries Management Area (MFMA) is currently being established around the islands of Koh Rong and Koh Rong Sanloem by the Government of Cambodia's Fisheries Administration (FiA), with support from Fauna & Flora International (FFI) and several other partners and stakeholders. Environmental attributes favouring the selection of this area for an MFMA include its diversity of habitats, such as mangroves, coral reefs and seagrass areas as well as records of endangered marine species. For example, these areas are known to be inhabited by sea turtles (Leng P., pers. obs; FFI, 2013) and seahorses (MCC, 2011a). However, the species distribution, abundance and composition of seagrass beds in Koh Rong and Koh Rong Sanloem are largely unknown. These data are required to inform the design of a zoning scheme for the MFMA.

After obtaining permission from FiA in April 2013 (letter 2948), field surveys were conducted to evaluate seagrass distribution, abundance and diversity during both the 2013 and 2014 dry seasons. Surveys were conducted collaboratively with and by local stakeholders, including the Department of Fisheries, FFI, local authorities from Koh Rong and Koh Rong Sanloem and Community Fisheries (CFi) members from four villages.

Methods

Study site

This study was conducted around Koh Rong and Koh Rong Sanloem in Preah Sihanouk Province. These islands lie within the proposed MFMA. Four villages were selected for this study: three villages on Koh

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Rong (Koh Touch, Daem Thkov and Prek Svay) and one village on Koh Rong Sanloem (Koh Rong Sanloem village, also known as M'Pai Bai) (Fig. 1), all of which lie within CFi areas and receive support from local and international NGOs. Small-scale fishing takes place in these seagrass areas.

Field Methods

Surveys were conducted by staff from FiA and FFI as well as representatives from the Community Fisheries Committee and local villages. For the first field season (2013), seagrass sites were selected through examination of existing habitat maps produced by other organisations and researchers working in the area (Skopal-Papin, 2011) and national natural resources maps (e.g. SCW, 2006), as well as consultation with the community fisheries and villagers. For the second field season in 2014, we revisited the sites that had been surveyed in 2013.

The first surveys were completed between April and May 2013 by snorkelling. During this survey, six sites were sampled and a total of 30 transects were conducted across these sites (Fig. 2). Prior to the transects being laid, the field observers snorkelled around the sites to identify areas with the highest seagrass coverage, and transects were located on these areas. The second survey was completed in March 2014 using snorkelling and SCUBA. In this survey, nine sites were sampled and a total of 45 transects were completed. Where possible, the 2014 transects were placed in the same locations as the 2013 transects by using their GPS coordinates. The survey method was adapted from Ouk *et al.* (2010), whereby 10-m transects were laid perpendicular to the shoreline, and 50 cm x 50 cm quadrats were laid along each transect at 5-m intervals. These quadrats were divided into 25 sectors, each measuring 10 cm x 10 cm, to increase ease of sampling and reduce error in visual cover estimates (English *et al.*, 1997). For each quadrat, all species present were identified in situ using a laminated seagrass identification sheet for reference (Short *et al.*, 2001). The percentage cover of each species, and total seagrass coverage for each quadrat, were estimated using a seagrass percentage cover guide sheet (Ouk *et al.*, 2010).

In addition to these measurements, a dive computer was used to record water depth during the 2014 surveys, and a metric rule was used to measure the height of the seagrass.

Table 1 Overview of seagrass extent in Cambodia and current state of management (MFF, 2013). *In a conservation site managed by FiA or CFi.

Province	Known seagrass extent	Seagrass area under management*	Percentage under management
Kep	3,905 ha	731 ha	19%
Kampot	25,240 ha	1,500 ha	6%
Koh Kong	3,993 ha	1,000 ha	25%
Preah Sihanouk	1,468 ha	600 ha	41%

Table 2 Seagrass species with their range of water depths and foliage dimensions.

Species	Water depth (m)	Species foliage dimensions
Enhalus acoroides	0.5–0.7	Length 12–46 cm Width 1.5–1.5 cm
Halodule pinifolia	0.4–1.5	Length 4–12 cm Width 0.25–0.7 cm
Thalassia hemprichii	0.4–1.9	Length 0.9–1.4 cm Width 0.7–1.0 cm
Halophila minor	0.4–1.5	Length 0.3–1.0 cm Width 0.4–0.7 cm

Results

Four species of seagrass were recorded during this study around Koh Rong and Koh Rong Sanloem; *Halodule pinifolia*, *Enhalus acoroides*, *Halophila minor* and *Thalassia hemprichii*. Mean seagrass percentage cover was higher in the Deam Thkov sites than Koh Touch, Koh Rong Sanloem and Prek Svay (Fig. 3). The Daem Thkov sites were dominated by *Halodule pinifolia*, whereas *T. hemprichii* was the commonest species observed around both Koh Rong Sanloem and Koh Touch. All four species of seagrass were recorded near Daem Thkov village, whereas only *H. pinifolia* and *T. hemprichii* were documented at Koh Touch and only one species was recorded at both Koh Rong Sanloem (*T. hemprichii*) and Prek Svay (*Halodule pinifolia*) (Fig. 3). The percentage cover of *Enhalus acoroides* and *Halophila minor* was low, but both species were observed fairly regularly throughout the sites. Seagrass surveys were conducted at water depths of between 0.4 and 1.9 m, and there was considerable

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variation in the range of foliage dimensions within and between species (Table 2). Based on the 2013 survey, we estimate the total area of seagrass in the Koh Rong Archipelago to be 18 hectares.

Site specific results

Koh Rong Sanloem

The seagrass bed by Koh Rong Sanloem is located seaward of an area of fringing mangrove. Inter-annual variation in overall seagrass percentage cover between the two surveys on Koh Rong Sanloem was low (44% in 2013 and 41% in 2014). However, in 2013 only one seagrass species was recorded, whereas in 2014 both *T. hemprichii* and *Halodule pinifolia* were observed (although *H. pinifolia* was not recorded within the sampling quadrats). We inferred that *H. pinifolia* was present in low abundance, possibly representing a 5% share of coverage overall, while *T. hemprichii* was dominant. The substrate was sand, with some seaweed and bivalves (bicolour pen shell *Pinna bicolor* and common geloina *Polymesoda [Geloina] erosa*). Other species recorded during the surveys included sea stars, collector sea urchins, several schools of small fish, and one unidentified species of seahorse. The seagrass bed covered approximately 150 m x 150 m.

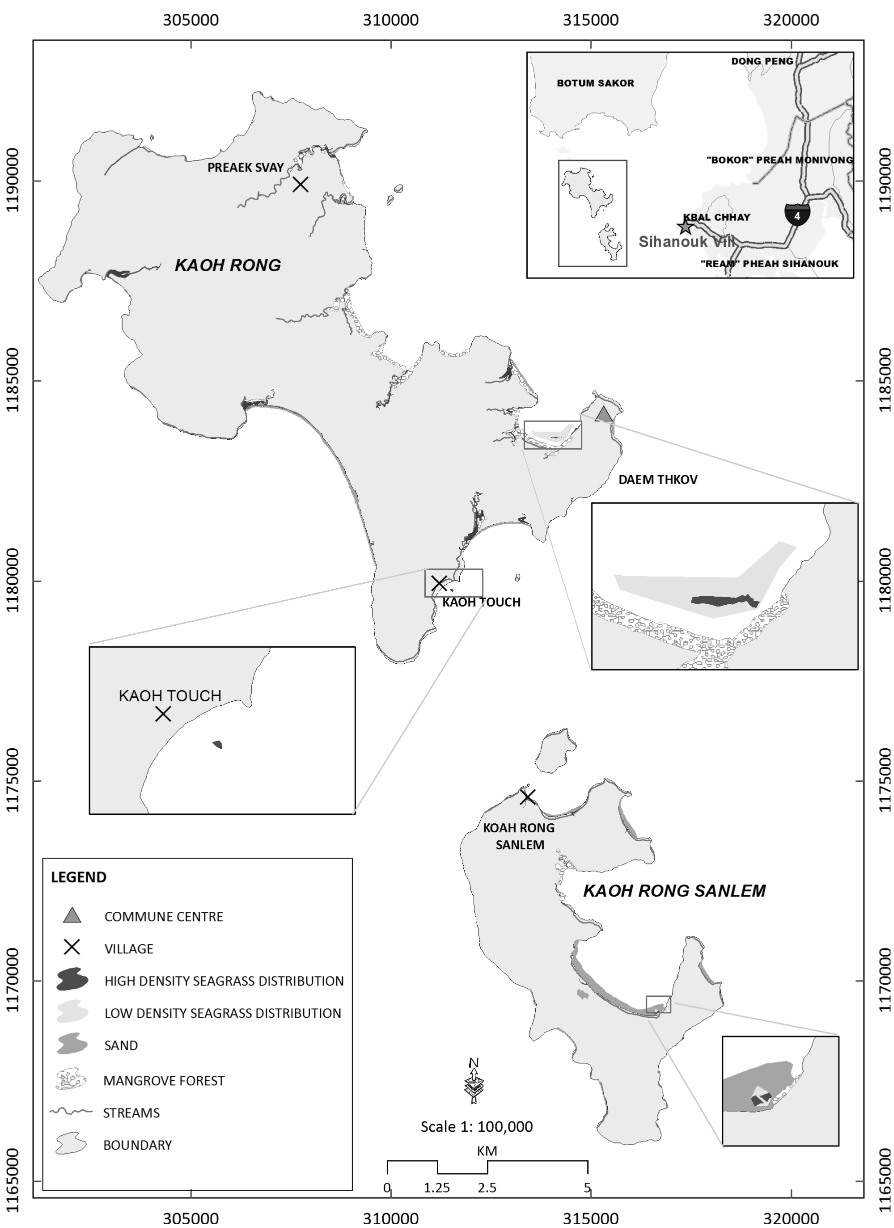

Fig. 1 Map of the study site showing villages and estimated extent of seagrass beds.

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Daem Thkov

Similar to Koh Rong Sanloem, the seagrass areas of Daem Thkov were directly adjacent to mangroves. Daem Thkov was the most species-rich site, with four species of seagrass recorded in 2013. However, we observed a decrease in the number of species between the two field seasons, as *T. hemprichii* was not recorded in 2014 (Fig. 4). This site was dominated by *H. pinifolia* (73%) and relatively small numbers of the other three species in 2013 (*Halophila minor* 9%, *T. hemprichii* 3.33% and *Enhalus acoroides* 6%). The benthos was composed of course sand, and many invertebrate species were sighted, including sea stars, crabs, octopuses, collector sea urchins and bivalves (e.g. bicolour pen shell and mud creeper *Terebralia* sp.) as well as small schools of fish. Seahorses were not sighted in 2013, but during the 2014 surveys we recorded 14 individuals representing three different species. The seagrasses of Daem Thkov covered around 10 ha, but the area of high seagrass species diversity was limited to 2 ha (Fig. 1).

Prek Svay

In 2013, no seagrasses were recorded around Prek Svay, but after consulting local fishers in 2014, an

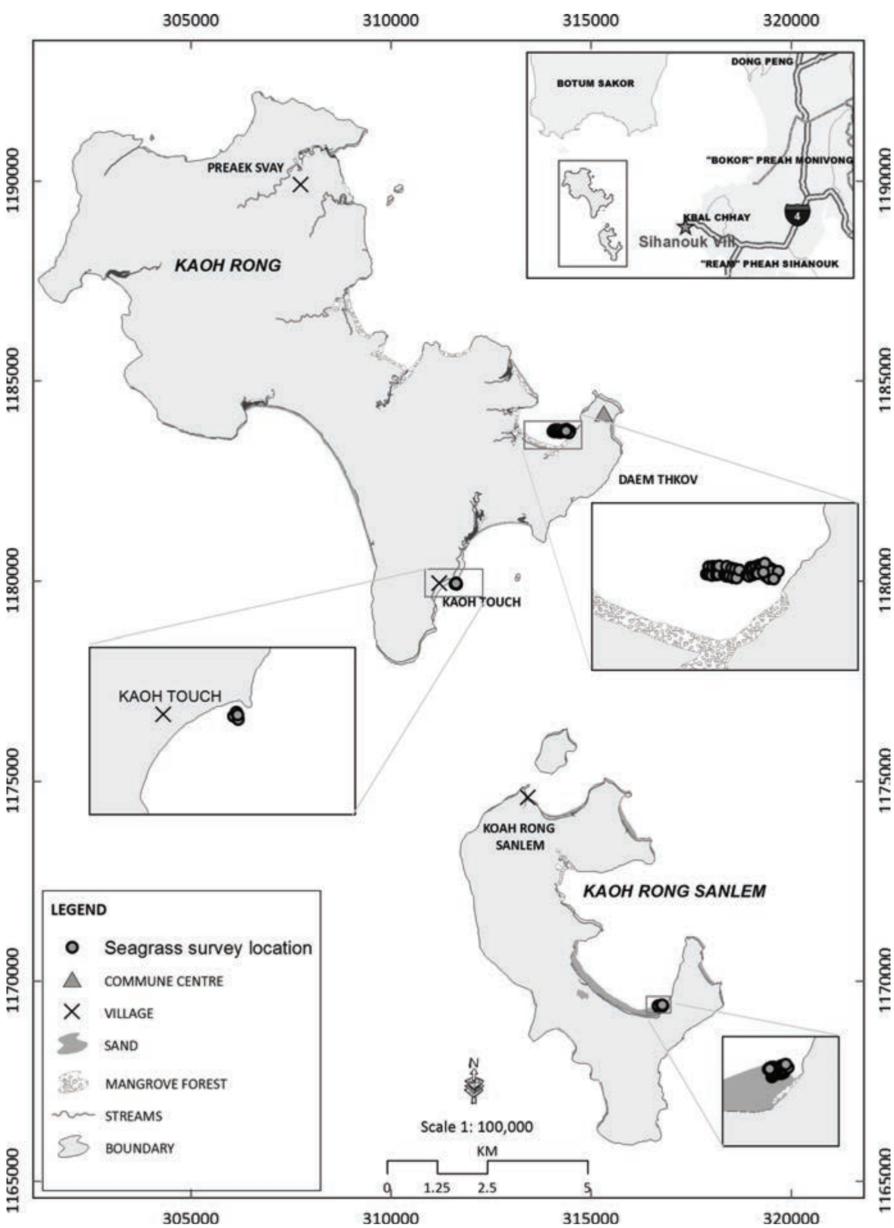

Fig. 2 Approximate survey locations in 2013 and 2014.

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area of seagrass was observed at Av Thean in front of fringing mangrove. Two species of seagrass were recorded here: *Halodule pinifolia* (3.5%) and *Halophila minor*, although *H. minor* was not recorded within the survey quadrats. The substrate was mainly sand and fine sand, and some species, such as anemone fish, collector sea urchins, sea stars and schools of small fish, were observed. The total area of the seagrass bed covered 100 m x 100 m and included small patches on the boundary with small seagrass shoots that we were unable to identify to species level.

Koh Touch

The extent of seagrass at Koh Touch was small, covering an area of only 20 m x 20 m, so observations were made by snorkelling. No transects were conducted here because the seagrass bed was too small. Overall species coverage decreased between the 2013 and 2014 surveys: *Thalassia hemprichii* coverage decreased from 85% to 25% and *Halodule pinifolia* decreased from 15% to 5%. The substrate of this site was sand with seaweed and some invertebrate species, such as collector sea urchins and bivalves (bicolour pen shell, common geloina), and groups of small fish.

Table 3 Description of all seagrass survey sites.

Year	Site	Local Site Name	Nearest village	Species richness	Dominant species?	Substrate	Geophysical description
2013	1	Av Lich	Daem Thkov	3	*Halodule pinifolia*	Coarse sand and sand	In front of the mangrove
	2	Av Lich	Daem Thkov	3	*Halodule pinifolia*	Coarse sand and sand	In front of the mangrove
	3	Av Lich	Daem Thkov	3	*Halodule pinifolia*	Coarse sand and sand	In front of the mangrove
	4	Av Lich	Daem Thkov	4	*Halodule pinifolia*	Coarse sand and sand	In front of the mangrove
	1	Av Yiy	Koh Rong Sanloem	1	*Thalassia hemprichii*	Sand	In front of the mangrove
	2	Av Yiy	Koh Rong Sanloem	1	No	Sand	In front of the mangrove
	1	In front of village	Koh Touch	2	*Thalassia hemprichii*	Sand	In front of the forest
2014	1	Av Lich	Daem Thkov	2	*Halodule pinifolia*	Coarse sand	In front of the mangrove
	2	Av Lich	Daem Thkov	2	*Halodule pinifolia*	Coarse sand	In front of the mangrove
	3	Av Lich	Daem Thkov	1	*Halodule pinifolia*	Coarse sand	In front of the mangrove
	4	Av Lich	Daem Thkov	1	*Halodule pinifolia*	Coarse sand	In front of the mangrove
	5	Av Lich	Daem Thkov	1	*Halodule pinifolia*	Coarse sand	In front of the mangrove
	6	Av Lich	Daem Thkov	2	*Halodule pinifolia*	Coarse sand and sand	In front of the mangrove
	1	Av Yiy	Koh Rong Sanloem	2	*Thalassia hemprichii*	Sand	In front of the mangrove
	2	Av Yiy	Koh Rong Sanloem	2	No	Sand	In front of the mangrove
	1	Av Thean Koh Dong	Prek Svay	2	No	Sand	In front of the mangrove
	1	In front of village	Koh Touch	2	*Thalassia hemprichii*	Sand	In front of the forest

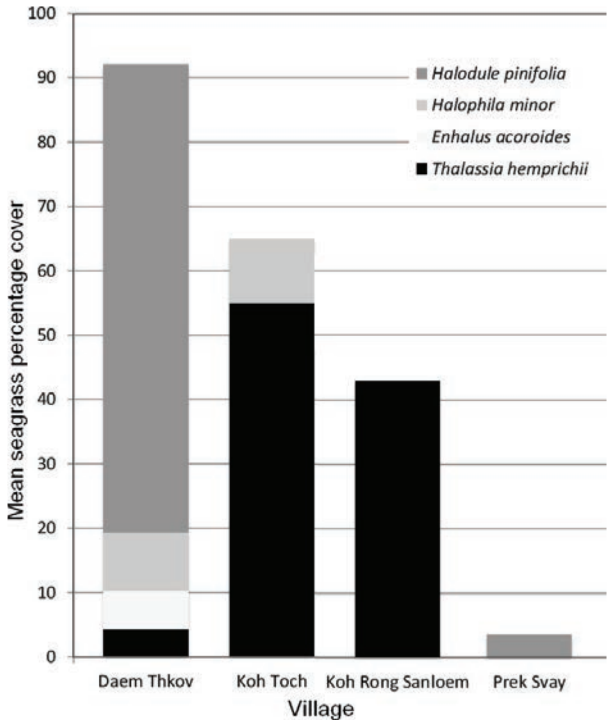

Fig. 3 Mean overall percentage cover of seagrass species per quadrat (2013 and 2014 data combined).

Discussion

Four species of seagrass were recorded across the survey sites over the study period. Our data appear to show that percentage cover of the seagrass species varied both between sites and between years. *Halodule pinifolia* was the commonest species in all sites, and Daem Thkov Village had the highest percentage cover of seagrass overall and seemed to present the most suitable environment for seagrass growth. The loss of some species seen between the two years of the field surveys is problematic and may be the result of increasing human impacts on the area or sampling error. Increased fishing effort in seagrass areas, particularly using techniques which physically impact on the seabed, may be reducing seagrass coverage (as reported by fishermen in Daem Thkov and Koh Rong Sanloem during the 2014 seagrass survey). We note that the seagrass area of Daem Thkov is a popular fishing site (Daem Thkov CFi chief Mr Ban, pers. comm.), particularly using crab gill-nets, which supports our theory that fishing activities may be negatively affecting seagrass.

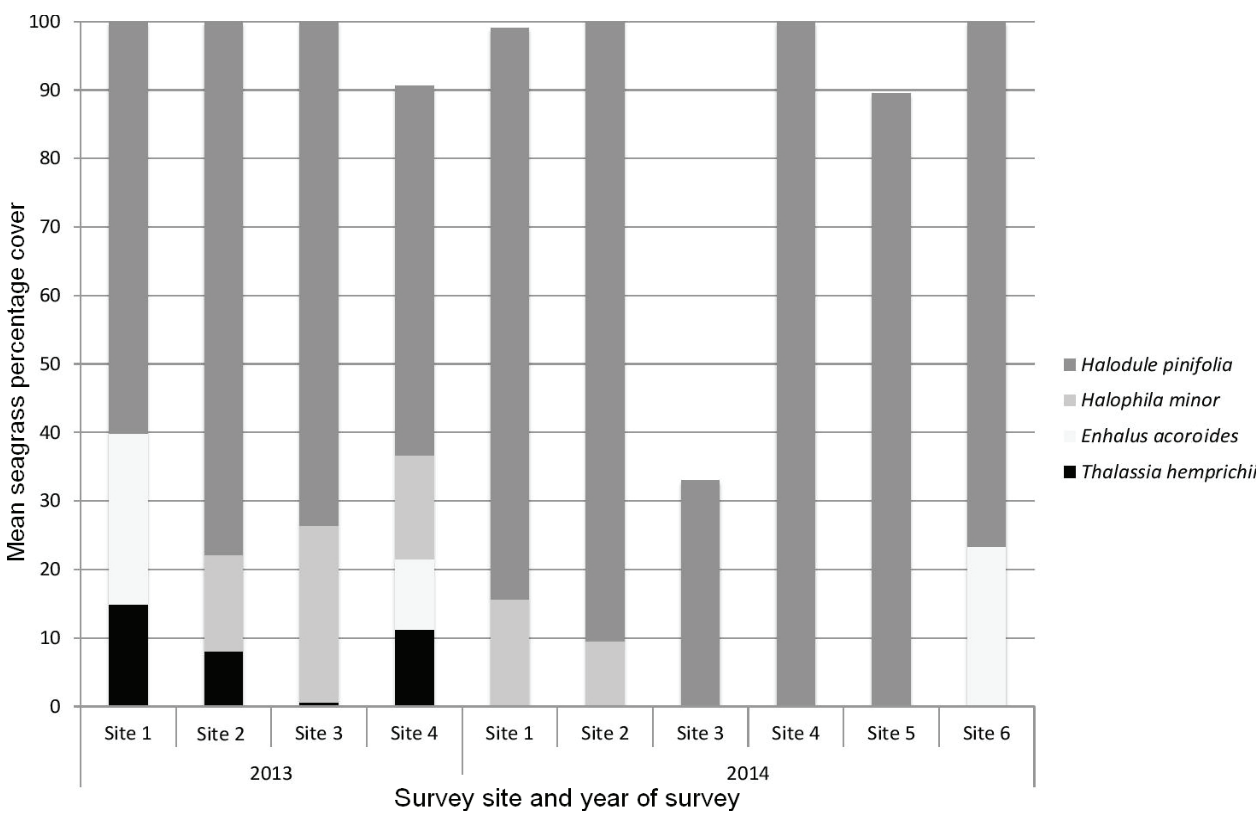

Fig. 4 Seagrass cover by species near Daem Thkov Village.

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According to our observations, the patch of seagrass at Koh Touch was small and decreased in size. The perceptions of the local village chief in 2014 also support the idea that the seagrass area is shrinking, reportedly as a result of damage by strong winds and waves. Koh Touch is also rapidly becoming a popular tourist site, and during the peak season more than 100 tourists per day may pass through the area (Koh Rong Sanloem CFi, unpublished data), hiring local boats for sea cruises that anchor in seagrass areas and cause further damage. No data are available from this busy village to determine whether changes in water quality may have affected the nearby seagrass bed.

Koh Rong Sanloem is a good place for seagrass, but it is a popular fishing site. We propose that the MFMA zoning plan allows measures to reduce fishing impacts on this ecologically important area. During this study, we observed *T. hemprichii* and *H. pinifolia* by Koh Rong Sanloem. Earlier observations by MCC (2011b) found a further two species—*Cymodocea serrulata* and *Halophila ovalis*—in the Koh Rong Sanloem CFi that were not observed during our study. Their precise locations were unclear from the report, however, so there might not necessarily have been a real change in species composition.

Seagrasses provide an important marine habitat for a number of species and form an important part of the coastal ecosystem linking mangroves to coral reefs (Unsworth *et al.*, 2006). Seagrass areas in the Koh Rong Archipelago were predominantly associated with fringing mangroves, of which there are 128 hectares in the archipelago (FFI, unpublished data). Large numbers of invertebrate species recorded at several sites around Koh Rong Sanloem and Daem Thkov Village provide further evidence of the importance of seagrass beds for a number of species. Three species of seahorses were observed near Daem Thkov Village and at least one, identified as *Hippocampus spinosissimus*, is listed as Vulnerable on the IUCN Red List (Wiswedel, 2012). In addition, octopuses and crabs were observed in seagrass sites—both commercially important taxa for local fishers. Interviews with fishers suggest the crab fishery has declined in this area (Leng, 2013) and underline the importance of protecting the remaining intact habitats.

There is evidence of general decline in the extent of seagrass coverage over time in the Koh Rong Archipelago. Previous surveys recorded seven seagrass areas around Koh Rong (Skopal-Papin, 2011), but our study identified only three sites suitable for surveys. Similarly, three suitable survey sites were previously identified around Koh Rong Sanloem (Skopal-Papin, 2011), but our study located only one. Anecdotal reports suggest that one area northeast of Koh Rong Sanloem used to have a small seagrass bed (included on maps in Skopal-Papin, 2011), but that area was impacted by spillage and pollution from a nearby fuel trading depot, and the seagrass has gone. Conversely, the current study suggests the sites surveyed around Daem Thkov support the largest and most species-rich area of seagrass, the extent of which is greater than that reported by Skopal-Papin (2011). In addition, seagrass sites around Prek Svay identified by Skopal-Papin (2011) were not located, although re-growth was evident at a small, previously unrecorded seagrass bed north of Koh Rong, near Koh Dong.

Human impacts appear to be widespread in the remaining seagrass habitats in the archipelago, including effects from fishing and, potentially, land-based pollution in some sites. Trawling and push-netting are the most damaging fishing activities for the seagrass beds in Cambodia (UNEP, 2008). Specific examples have been gathered through local interviews of trawlers damaging seagrass beds historically (e.g., near Koh Touch), as well as the perception that illegal fast trawls are a significant threat to local livelihoods and marine resources (Leng, 2013).

It is important to note that our analysis did not include all seagrass beds in the archipelago. National natural resources maps (SCW, 2006) estimate there are as many as 92 hectares of seagrass in the study site, and Skopal-Papin (2011) reported approximately 47 hectares in the Koh Rong Archipelago: considerably more than the 18 hectares estimated from this study using 2013 data. It is important to recognise these figures do not necessarily indicate the actual rate of seagrass decline due to the difficulties in directly comparing data produced using different methods across differing spatial scales, and the limited historical data sources. During our study, some areas were reported but not verified during the first site visits in 2013; for example, an area of seagrass to the east of Koh Rong (Barnaby Olsen, pers. comm.). In contrast to the intensive field work undertaken here, the available historical extent estimates from SCW used coarse-resolution spatial data for the entire Cambodian coast. Seasonal variations in extent are also possible (Govindasamy *et al.*, 2013), and the timings of previous surveys of seagrass are unknown. While providing the most detailed information available to date, the seagrass distribution maps in Skopal-Papin (2011) were not based on comprehensive archipelago-wide surveys targeting seagrasses, and included rough estimates of seagrass extent based on visual observations by divers (M. Skopal-Papin, pers. comm.).

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Despite such uncertainties among these various data sets, an overall downward trend of seagrass habitats is supported by anecdotal reports from local people concerning human impacts on the seagrass beds and declines in their extent. The present study provides a more comprehensive baseline against which future trends, and the effectiveness of management activities, can be measured. This study also highlights the challenges in tracking the various national area-based targets for marine habitats. For example, within the *Strategic Planning Framework for Fisheries,* the government aims to secure at least 7,000 ha of seagrass under an appropriate form of sustainable management by the end of 2019 (FiA, 2011).

Conclusions

Seagrasses provide important habitats for commercially valuable fish and invertebrate species. Our study has found evidence of some declines in seagrass coverage and species richness in the Koh Rong Archipelago. This highlights the need for including seagrass beds—in particular those around the village of Daem Thkov—into conservation zones during the MFMA zoning consultation, to ensure the long-term sustainability of the MFMA and to meet national level targets for marine habitat protection. Recent efforts by the CFi in Daem Thkov to reduce fishing pressure within seagrass habitats suggest that CFi members can play a key role in preserving this crucial marine habitat.

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References

Adulyanukosol, K. (2002) *Report of Dugong and Seagrass Survey in Vietnam and Cambodia*. Phuket Marine Biological Center, Phuket, Thailand.

Anonymous (2014) *Seagrasses: the Least Understood of the Coastal Canaries.* Biodiversity Information Sharing Service (ASEAN Clearing House mechanism). Http://chm.asean-biodiversity.org/index.php?option=com_content&view=article&id=169&Itemid=169 [accessed 1 May 2014].

Carlo, G. D. & McKenzie, L. (2011) *Seagrass Syllabus: a Training Manual for Resource Managers*. Conservation International, Arlington, USA.

Cullen-Unsworth. L.C., Nordlund. L.M., Paddock. J., Baker. S., McKenzie, L.J. & Unsworth, R.K.F. (2014) Seagrass meadows globally as a coupled social-ecological system: implication for human wellbeing. *Marine Pollution Bulletin,* **83,** 387–397.

Duarte, C., Terrados, J., Agawin, N.S.R., Fortes, M.D., Bach, S. & Kenworthy, W.J. (1997) Response of a mixed Philippine seagrass meadow to experimental burial. *Marine Ecology Progress Series,* **147,** 285–294.

English, S., Wilkinson, C. & Baker, V. (eds) (1997) *Survey Manual for Tropical Marine Resources, Second Edition*. Australian Institute of Marine Science, Townsville, Australia.

Ethirmannasingam, S. (1996) *Preliminary survey for Cambodian seagrass resources*. Unpublished report to Wetlands International, Phnom Penh, Cambodia.

FFI—Fauna & Flora International (2013) *Protection and management of marine turtle habitat in Cambodia's first marine protected area.* Unpublished final report to the USFWS Marine Turtle Conservation Fund. Fauna & Flora International—Cambodia Programme, Phnom Penh, Cambodia.

FiA—Fisheries Administration (2011) *The Strategic Planning Framework for Fisheries: 2010–2019 Cambodia.* Fisheries Administration of the Ministry of Agriculture, Forestry and Fisheries, Phnom Penh, Cambodia.

Govindasamy, G., Arulpriya, M., Anantharaj, K., Ruban, P. &R Srinivasan, R. (2013) Seasonal variations in seagrass biomass and productivity in Palk Bay, Bay of Bengal, India. *International Journal of Biodiversity and Conservation,* **5,** 408–417.

Hemmings, M.A. & Duarte, C.M. (2000) *Seagrass Ecology: An Introduction.* Cambridge University Press, Cambridge, UK.

Johnsen, S. & Munford, G. (2012) *Country Environment Profile: Royal Kingdom of Cambodia*. Report by Euronet Consulting for the European Union, Brussels, Belgium.

Leng P. (2013) Assessment of fishing practices in marine fisheries management areas around Koh Rong and Koh Rong Sanleom, Cambodia. *Cambodian Journal of Natural History*, **2013,** 113–114.

MFF—Mangroves for the Future (2013) *Cambodia National Strategy and Action Plan 2014–2016.* Ministry of Environment and Mangroves for the Future, Phnom Penh,

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Cambodia.

MCC—Marine Conservation Cambodia (2011a) *Koh Rong Samloem and Koh Kon Marine Environmental Assessment: Report on Marine Resources and Habitats.* Report to the Fisheries Administration from Marine Conservation Cambodia, Koh Rong Samloem, Cambodia.

MCC—Marine Conservation Cambodia (2011b) *Koh Rong Samloem Community Fishery Socio-demographic Survey: April 2011 Update.* Report to the Fisheries Administration from Marine Conservation Cambodia, Koh Rong Samloem, Cambodia.

Nagelkerken, I., van der Velde, G., Gorissen, M.W., Meijer, G.J., van't Hof, T. & den Hartog, C. (1999) Importance of mangroves, seagrass beds and the shallow coral reef as a nursery for important coral reef fishes, using a visual census technique. *Estuarine, Coastal and Shelf Science*, **51,** 31–44.

Nelson, V. (1999) *Draft Coastal Profile: Volume I, II : The Coastal Zone of Cambodia: Current status and Threats.* Ministry of Environment/DANIDA Coastal Zone Management Project, Phnom Penh, Cambodia.

Ouk V., So N. & Lim P. (2010) Seagrass diversity and distribution in coastal area of Kampot Province, Cambodia. *IJERD—International Journal of Environmental and Rural Development,* **2010,** 112–117.

Sereywath P. & Sokhannaro H. (2003) Seagrass meadow and green turtle in Cambodia. In *Proceedings on the 4th SEASTAR2000 Workshop, December 11-13, 2003, Bangkok, Thailand* (ed. N. Arai), pp. 36–39. Graduate School of Informatics, Kyoto University, Japan.

SCW—Save Cambodia's Wildlife (2006) *Atlas of Cambodia: National Poverty and Environment Maps*. Save Cambodia's Wildlife, Phnom Penh, Cambodia.

Short, F.T., McKenzie, L.S., Coles, R.G. & Vidler, K.P. (2001) *SeagrassNet Manual for Scientific Monitoring of Seagrass Habitat.* Department of Primary Industries, Queensland Government and Marine Plant Ecology Group, Cairns, Australia.

Short, F., Carruthers, T., Dennison, W. & Waycott, M. (2007) Global seagrass distribution and diversity: a bioregional model. *Journal of Experimental Marine Biology & Ecology,* **350,** 3–20.

Skopal-Papin, M. (2011) *Koh Rong, Koh Rong Samloem and Koh Koun Marine Fisheries Management Area: 3rd Draft for Zoning Proposal.* Report to the Fisheries Administration, Department of Fisheries Conservation, Phnom Penh, Cambodia.

Smyth, D. (2006) *Dugong and Marine Turtle Knowledge Handbook: Indigenous and Scientific Knowledge of Dugong and Marine Turtles in Northern Australia*. North Australian Indigenous Land & Sea Management Alliance, Darwin, Northern Territory, Australia.

Tana T.S. (1995) Status of marine biodiversity management in Cambodia and possible measures for effective conservation. *Paper prepared for the Global Biodiversity Forum, 4-5 November 1995, Jakarta, Indonesia*.

UNEP—United Nations Environment Programme (2008) *National Reports on Seagrass in the South China Sea, Cambodia.* UNEP/GEF/SCS Technical Publication No. 12. United Nations Environment Programme, Bangkok, Thailand.

Unsworth, R.K.F., Bell, J.J. & Smith, D.J. (2006) Tidal fish connectivity of reef and seagrass habitats in the Indo-Pacific. *Journal of the Marine Biological Association of the United Kingdom*, **2007,** 1287–1296.

Wiswedel, S. (2012) *Hippocampus spinosissimus*. In *IUCN Red List of Threatened Species. Version 2012.2*. Http://www.iucnredlist.org/details/10084/0 [accessed 14 May 2013].

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A current status assessment of the coral reefs in the Koh Sdach Archipelago, Cambodia

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មូលន័យសង្ខេប

កម្ពុជាកំពុងបោះជំហានឆ្ពោះទៅអភិវឌ្ឍន៍ជាបន្តបន្ទាប់នូវតំបន់ការពារសមុទ្រដើម្បីប្រឆាំងនឹងការរិចរិលបរិស្ថាន។ ប្រជុំកោះស្តេចត្រូវបានរៀបចំអោយក្លាយជាតំបន់ការពារសមុទ្រធំលំដាប់ទីពីររបស់ប្រទេសកម្ពុជា។ចំណែកឯផែនការគ្រប់គ្រងក៏កំពុងតែត្រូវបាអភិវឌ្ឍ ដោយមានកិច្ចសហការរវាងសហគមន៍មូលដ្ឋាន និងអង្គការអភិរក្សជាតិនិងអន្តរជាតិ។ យ៉ាងណាក៏ដោយមុនពេលអនុវត្តកម្មវិធីគ្រប់គ្រងណាមួយការវិភាគទូលំទូលាយពីបច្ចុប្បន្នភាពនៃស្ថានភាពបរិស្ថានក្នុងតំបន់ពិតជាមានប្រយោជន៍ និងអាចអនុញ្ញាតឱ្យមានការអភិវឌ្ឍយុទ្ធសាស្ត្រគ្រប់គ្រងជាក់ស្តែងសមស្រប។ ការសិក្សានេះបានប្រើប្រាស់ទំរង់កែច្នៃពីពិធីសារស្ទង់មតិពីការពិនិត្យមើលថ្មប៉ប្រាសទឹក(Reef Check)។ លទ្ធផលបានបង្ហាញថាផ្កាថ្មប៉ប្រាស់ទឹកដែលប្រទះឃើញនៅជុំវិញប្រជុំកោះស្តេចកំពុងស្ថិតក្នុងស្ថានភាពល្អនៅឡើយប៉ុន្តែក៏មានភស្តុតាងខ្លះនៃការរិចរិលអេកូឡូស៊ីដែរ។កិច្ចខិតខំប្រឹងប្រែងអភិរក្សត្រូវបានផ្តល់ជាអនុសាសន៍សម្រាប់ជាមធ្យោបាយទប់ស្កាត់ការរិចរិលនៅអនាគតកាល និងលើកទឹកចិត្តធ្វើអោយមានស្ថិរភាពយូរអង្វែងក្នុងឋានប្រព័ន្ធនេះ។

Abstract

Cambodia is taking steps towards developing a series of marine protected areas to combat increased environmental degradation. The Koh Sdach Archipelago has been highlighted to become the country's second large marine protected area, and management plans are being developed through collaborations between local communities and national and international conservation organisations. Prior to the implementation of any management programme, however, an up-to-date baseline analysis of the environmental status of the area is helpful, and will allow the development of appropriate site-specific management strategies. This study used a modified form of the Reef Check survey protocol. Results indicated that the coral reefs found throughout the Koh Sdach Archipelago are in good condition, but with some evidence of ecological degradation. Conservation efforts are recommended as a means of preventing future degradation, and encouraging long-term stability within the ecosystem.

Keywords

Koh Sdach Archipelago, community-based marine management, coral reef ecology, status assessment.

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Introduction

In many parts of the world, anthropogenic stresses and climatic changes have resulted in dramatic changes to coral reefs (Hughes *et al.*, 2005). Coral reefs provide ecosystem goods and services to millions of people around the world (Mascia, 2003). Estimated to provide roughly $40 billion in net goods and benefits to the world's economies, including tourism, fisheries and coastal protection (Cesar *et al.*, 2003), coral reefs also support subsistence and local economy needs in developing countries (Medley *et al.*, 1993). The long-term sustainability of these benefits is threatened, however, by direct over-exploitation of coral reef resources, destructive fishing practices, air and water pollution and climate change (Wilkinson, 2000). From an ecological perspective, effective coral reef management can be viewed as increasing or maintaining key ecosystem parameters, such as fish biomass or coral cover, maintaining ecosystem processes and function, and, increasingly, promoting resilience to disturbance and fluctuations (Hughes *et al.*, 2003).

Cambodia is a post-conflict country currently undergoing a phase of recovery and development. Cambodia's coastline extends 435 km between the borders of Thailand and Vietnam, with 69 islands and territorial waters covering 55,600 km^2 (Nelson, 1999; Savage *et al.*, 2013). Cambodia's coral reefs are mostly fringing reefs surrounding the coastal islands (Chou & Tun, 2003). Fishing in Cambodia is important for both food and economic security, and marine protected areas (MPAs) are currently seen as the best way to protect coral reefs from damage and encourage recovery (Bellwood *et al.*, 2004; Mumby, 2006).

Cambodia's marine protection efforts are currently limited to several small community fisheries throughout the coastal zone, in addition to a small privately owned and managed no-take zone in the northern Koh Rong Archipelago (Savage *et al.*, 2013). Currently, plans are in place to establish the country's first large-scale MPA around the Koh Rong Archipelago. Plans for a second large-scale MPA are also being developed, and will surround the Koh Sdach Archipelago. The local communities within the Koh Sdach Archipelago are actively involved in the design of these management plans.

The Koh Sdach Archipelago (Fig. 1) is located approximately 60 km east of Cambodia's border with Thailand (10°55'N, 103°5'E), in the Kiri Sakor District of Koh Kong Province. There are seven islands in the archipelago: Koh Ampul, Koh Andech, Koh Chan, Koh Damloung, Koh Sdach, Koh Smach and Koh Totang. Koh Smach is the largest of the islands (~30 ha), and Koh Andech the smallest (~4 ha). The islands are covered in primary rainforest, with rocky coastlines descending into fringing reefs. Koh Sdach is home to most of the local population, with approximately five households living on the islands of Koh Ampul, Koh Smach and Koh Totang. The remaining islands are uninhabited except for occasional visits by passing fishermen seeking shelter during bad weather.

Fig. 1 Map of the Koh Sdach Archipelago, Cambodia, showing the location of baseline survey sites (circles).

Koh Sdach Village is home to *ca.* 670 households giving a total population of around 4,000, and fishing is the primary business, with the majority of people economically dependent on the fishing industry, directly or indirectly. Koh Sdach is also the centre of both Kiri Sakor District and the Koh Sdach Commune, home to several governmental offices and a strong military presence. The island provides a very important shipping port on the trade route between

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Thailand, Cambodia and Vietnam, allowing reliable import and export opportunities. Consequently, the Koh Sdach community is much more affluent than most small villages in coastal Cambodia, with facilities such as a medical clinic, primary and secondary schools, a market, and an array of household-operated shops, bars and restaurants.

Management plans for a community-based MPA are currently under development by the Koh Sdach residents with the assistance of the international marine conservation organisation Shallow Waters. While not a prerequisite for the development of marine management plans, having baseline data on the 'pre-implementation' status of an area can facilitate the detection of change and guide the evolution of the management plans, ensuring their long-term applicability in a changing environment. The most recent marine assessment of the Koh Sdach Archipelago was completed in 2003 (Chou *et al.*, 2002; Chou & Tun, 2003). Due to the elapsed time since the last assessment of the archipelago, the present survey was conducted to provide up-to-date knowledge on the health of the coral reef systems.

The aim of this baseline assessment was to determine the general distribution of reefs throughout the archipelago. Quantitative data on the abundance and diversity of fish, invertebrate and substrate communities were collected, facilitating the development of a comprehensive and up-to-date baseline data set for the region. This will be used in collaboration with future monitoring programmes to inform future management plans and decisions.

Methods

Baseline data were collected using underwater visual census techniques, utilizing SCUBA and snorkelling. Preliminary scoping surveys were conducted around the archipelago to determine the extent of the coral reefs, and the archipelago was separated into seven survey zones. Zones were designated around each island (or groups of islands in the case of Koh Sdach and Koh Ampul, which have two and three islands respectively). Thirty 100-metre Reef Check surveys were conducted across the archipelago (see Hodgson, 1999, for detailed methodology), with the 30 surveys distributed between the survey zones based on the geographical size of the landmass, and the extensiveness of the reefs. The four largest zones were allocated five surveys each, the sixth and seventh allocated four surveys, and the smallest survey zone was allocated two surveys. Surveys were arranged in this way to allow the development of a zonation-based management plan, with different levels of protection for different areas in the archipelago. Sites adjacent to the mainland were not included due to the lack of a developed reef system, and also because of construction work and developments on the mainland, rendering the area unsafe for SCUBA diving.

Due to the duration of a 100-m survey (approximately 90 minutes), each survey was completed in two dives, with the first dive assessing the first 50 m and the second dive assessing the last 50 m. Where possible, these surveys were completed consecutively, but in some cases weather conditions did not allow this: in these instances the second dive was completed as soon as possible. Transect locations were determined using depth, distance from starting marker and suitability of substrate for attaching a transect line. Where possible, all surveys were conducted at a depth of 5 ± 1 m. In shallower reef areas, transects were laid at the deepest, consistent depth. All transect lines began within 5 metres of the starting marker buoy (recorded using GPS), and were tied so as not to damage any living reef fauna or flora.

Occurrence data were collected using a predetermined target list of species. In addition, certain species of key economic or ecological importance were also categorised by size (in 10-cm interval categories) to allow for more detailed investigation on the impacts of fishing on their population dynamics. These species included: groupers (Epinephilinae), parrotfish (Scarinae) and giant clams (*Tridacna* sp. or spp.). Substrate community composition was assessed using primary and secondary data. Primary data included information on the type of substrate in the following categories: hard corals, soft corals, other living substrates, nutrient indicator algae, recently killed coral and abiotic substrates. Secondary data included species-specific data, using a predetermined list.

Adjustments were made to the basic Reef Check survey methodology to make it more suitable for the area, and to meet the needs of the investigation. The Reef Check programme utilises a series of 100-m transects assessing fish, invertebrate and substrate communities. The standard Reef Check methodology breaks down this transect into a series of four 20-m segments, each separated by a 5-m section of unsurveyed reef, with each 20-m section considered a replicate. However, owing to the risks of scientific inaccuracy related to pseudoreplication (Hurlbert, 1984), for the purpose of this investigation, the results of each 20 m segment were combined into a single survey to give a total length of 80 m. This allowed

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comparison of these data with similar projects in the Cambodian coastal zone, while still maintaining scientific integrity. For this investigation, each 80 m survey was considered a replicate in each of the survey zones.

Fish and invertebrate populations were analysed using standard community descriptors: species richness (*S*), abundance (calculated using species counts) (Magurran, 2004) and Simpson's indices for diversity (1-*D*) and equitability (1-*E*) (Simpson, 1949).

Results

Fish

The lowest Simpson's Diversity score for fish species was detected by Koh Andech (Table 1). Owing to the relatively high number of fusiliers (Caesionidae), the Simpson's Diversity (1-*D*) was re-calculated with the fusiliers excluded (1-*D* = 0.7539).

The abundance of commercially important species was low across all sites. Counts of snappers (Lutjanidae) were high in certain sites where large schools of individuals were recorded, but these schools were primarily comprised of species of lower commercial value. The more valuable red snapper *Lutjanus campechanus* was not sighted at all during survey dives, although a very low number of small individuals was spotted on species inventory and training dives.

Size assessments of groupers indicated that the mean size class for groupers in the Koh Sdach Archipelago was 11–20 cm. No groupers were detected over 31 cm in total body length. The chocolate grouper *Cephalopholis boenak* was the most abundant of all the target grouper species, and was the only species found within all survey zones. Koh Totang was the only survey zone where all species of groupers were detected. The mean size of parrotfish detected across the archipelago was 11–20 cm. Only one individual greater than 50 cm was recorded, by the island of Koh Smach. The highest number of individuals was found at Koh Sdach, which supported approximately three times the density of any other island, again with the commonest size category being 11–20 cm.

Invertebrates

Invertebrate diversity was lower than fish and substrate diversity in all sites except Koh Sdach, where fish and invertebrate diversity were almost the same (Tables 1 and 2). Koh Totang supported the highest number of invertebrate species, while Koh Chan had the highest mean number of invertebrates (Table 2). *Diadema* sp. or spp. were the most abundant invertebrates, found across all survey zones, with the highest numbers seen in Koh Chan and Koh Andech.

Coral-associated worms (boring polychaete worms) were found in all survey sites, with a particularly high abundance around Koh Andech and Koh Chan. Only one cephalopod was recorded during the surveys: a cuttlefish found by Koh Totang. Other cephalopod sightings, including octopus and squid, occurred on species inventory and training dives.

Table 1 Mean fish community composition per hectare around islands in the Koh Sdach Archipelago.

Island	No. spp.	No. indiv.	Simpson's Diversity (1-*D*)	Simpson's Equitability (1-*E*)
Koh Ampul	16.0	763	0.7206	0.9486
Koh Andech	18.5	3,765	0.4284	0.9659
Koh Chan	19.8	1,685	0.6935	0.9843
Koh Damloung	18.0	491	0.7511	0.8066
Koh Sdach	18.8	1,793	0.6019	0.9791
Koh Smach	21.6	1,045	0.7310	0.9867
Koh Totang	15.0	932	0.7600	0.9856

Table 2 Mean invertebrate community composition per hectare around islands in the Koh Sdach Archipelago.

Island	No. spp.	No. indiv.	Simpson's Diversity (1-*D*)	Simpson's Equitability (1-*E*)
Koh Ampul	7.50	366	0.7109	0.8990
Koh Andech	7.75	1,417	0.6358	0.9530
Koh Chan	8.00	1,606	0.5763	0.9430
Koh Damloung	6.00	254	0.5733	0.9228
Koh Sdach	7.00	544	0.6145	0.9514
Koh Smach	8.00	504	0.6182	0.9627
Koh Totang	9.60	541	0.6726	0.9656

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Fig. 2 Percentage cover of substrate categories detected in the Koh Sdach Archipelago.

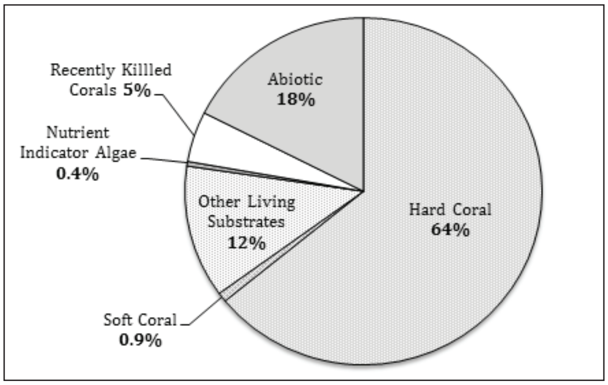
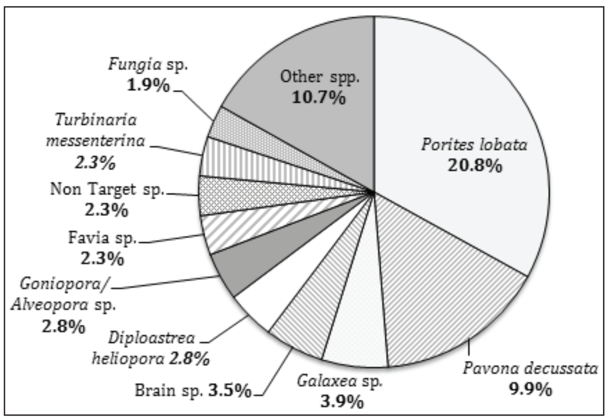


Fig. 3 Percentage cover of the 10 most abundant hard coral species in the Koh Sdach Archipelago.



Substrate

Substrates detected across the archipelago included hard corals, abiotic substrates (including rock, sand, rubble and silt), and certain other living substrates (such as anemones, coralline algae, corallimorphs, sponges, turf algae, tunicates and zooanthids) (Fig. 2). The percentage cover of hard corals varied across sites from 31% at one site by Koh Sdach to 88% at one of the sites within the Koh Ampul survey zone. Massive colonies of *Porites lobata* (where 'massive' refers to the structure of the colony, not its size) were the most abundant hard corals detected: this was the only species found at every survey site during the baseline investigation. The abundance of soft corals was low in all sites, with no survey sites having above 4% cover. Mean coverage across the archipelago was 0.85%. Coverage of nutrient indicator algae was low across all sites, as was recently killed coral. Nutrient indicator algae were detected at four out of seven survey zones, with the highest percentage cover not exceeding 2%. The highest and lowest levels of nutrient indicator algae were by Koh Chan and Koh Totang respectively.

Percentage cover of abiotic substrates was low across all survey zones, with the highest percentage cover seen on Koh Totang, where the percentage predominantly comprised recently killed corals and rock. Koh Totang had the highest level of recently killed corals, while the lowest levels were found in Koh Ampul and Koh Smach.

Discussion

The results of the baseline analysis of the Koh Sdach archipelago highlight some interesting patterns and suggest that the area is in relatively good condition.

Fish

The analysis of fish populations incurred issues with large numbers of fusiliers skewing the results at certain sites. Because fusiliers are a schooling species, they were often found in very large numbers, with mean sightings ranging between 10.75 individuals on transects in Koh Ampul, to 1,122.75 in Koh Andech. Clearly, this demonstrates that large variations in counts are possible, probably because fusilier schools can travel relatively large distances. Therefore, discerning their true population density is very difficult. However, the presence of these large schools of fusiliers is encouraging, as local subsistence fishers often target these species (pers. obs.).

Parrotfish and groupers are extremely important in coral reef ecosystems. These fish can have a relatively long life-span, with some species living upwards of 40 years. However, this means that many species exhibit late sexual maturity (5–10 years). This characteristic, along with a tendency towards aggregated spawning, makes groupers and parrotfish extremely vulnerable to heavy fishing (Sadovy de Mitcheson *et al.*, 2013).

As human populations increase, so do fishing effort and technologies to meet their rising needs. Both parrotfish and groupers are also important species for the fishing industry, and care needs to be taken to ensure that there is a healthy supply of such reef fish for the future. With this understanding, our data concerning the sizes of parrotfish and groupers indicate a disproportionately greater abundance of smaller individuals, suggesting that the larger individuals have been lost, most likely through fishing. This could result in a distinct lack of the sexually mature

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Table 3 Mean hard coral community composition per hectare around islands in the Koh Sdach Archipelago.

Island	No. spp.	No. indiv.	Simpson's Diversity (1-*D*)	Simpson's Equitability (1-*E*)
Koh Ampul	13.0	63	0.8022	0.9349
Koh Andech	16.5	77	0.7410	0.9847
Koh Chan	11.6	64	0.5472	0.9446
Koh Damloung	13.5	64	0.7810	0.9817
Koh Sdach	12.4	55	0.7620	0.9818
Koh Smach	15.2	71	0.8480	0.5993
Koh Totang	11.6	52	0.7860	0.9776

Table 4 Mean percentage cover of three common reef health indicators from the Koh Rong and Koh Sdach archipelagos. Data for the Koh Rong Archipelago were taken from Savage *et al.* (2013).

Island	Koh Sdach Archipelago	Koh Rong Archipelago
Live coral cover	63.70%	26.76%
Nutrient indicator algae	0.40%	15.13%
Recently killed coral	5.00%	5.73%

males needed for reproduction, increasing the risk of population collapse, and subsequent impacts on the local fishing communities. Effective conservation is therefore required to ensure the continuation of the fishery.

Our survey assessed the sizes of groupers to provide a broad understanding of their current status. Further analyses need to be conducted to determine whether there is variation between species in the mean sizes of individuals. Each species may respond in different ways to fishing pressure and environmental changes in accordance with its biology and ecology. More consideration needs to be given to the individual needs of species when designing and implementing conservation actions.

Similar patterns were seen in the snapper populations, where certain species were recorded as individuals and others were in schools. Considering data gathered during our surveys, and observations made on other dives, it would appear that the more commercially popular snappers reside individually, while schooling snappers appeared to be less sought after. This could be an important point for consideration in future work with local fishers. Determining the commercial desirability of each species and its ecology will help to inform management plans and monitoring techniques. The low abundance of many of the commercially important species, such as groupers, parrotfish, snapper and wrasse (Labridae), suggests that there has been an effect from fishing.

One major issue with the visual censuses of fish populations is that it is practically impossible to conduct an accurate assessment, particularly when using inexperienced volunteers (Foster-Smith & Evans, 2003). A single visual survey of the fishes at a site seldom records every individual present: cryptic species are not seen and abundant species are often inaccurately counted (Sale & Douglas, 2006). However, bearing in mind the usual financial and logistical constraints, a reasonable alternative has yet to be developed. For the present study, all surveyors underwent extensive species identification training, conducted numerous practice surveys and underwent in-water examinations with experienced surveyors prior to conducting surveys.

Invertebrates

Among the invertebrate populations, the most interesting results were seen in the coral-associated species i.e. feather duster worms (*Sabellastarte* sp.), Christmas tree worms *Spirobranchus giganteus*, long-spine sea urchins (*Diadema* sp.) and giant clams. Invertebrate diversity was lower than fish and substrate diversity across all sites (with the exception of Koh Andech, before the fusilier recalculation). Populations were typically dominated by echinoderms and worms—the most abundant being long-spine sea urchins, feather duster worms and Christmas tree worms—although as with other groups, there was a wide amount of variation both across and within sites. This suggests that a more in-depth assessment is required.

Reported increases in urchin abundance in overfished reefs (McClanahan, 1994; McClanahan & Mutere, 1994; McClanahan & Obura, 1997) are a cause for concern. Although their numbers in most survey zones were not very large, the populations of long-spine sea urchins need to be carefully monitored as an indicator of stress and instability within the system.

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Substrates

The high percentage cover of hard corals gives encouraging information about the health and quality of the reefs surrounding the Koh Sdach Archipelago (Fig. 2). The relatively high diversity of hard corals (Table 3), combined with the low percentage cover of nutrient indicator algae, suggest the reefs are relatively healthy. Again, this is another factor that requires careful future monitoring.

A universal symptom of coral reef degradation is mass coral mortality, followed by an invasion of algae onto coral skeletons, known as a "phase shift" (Done *et al.* 1992). Phase shifts generally require both over-harvesting of grazers and the input of excess nutrients into a system (McCook, 1999). Once a phase shift has occurred, it becomes increasingly difficult for the system to revert back to a coral-dominated state (McManus & Polsenberg, 2004). Areas experiencing a possible phase shift to an algal-dominated system were detected in both Koh Damloung and Koh Totang, characterized by higher levels of recently killed coral and nutrient indicator algae. This may be due to parrotfish and other grazers being removed through fishing, coupled with the potential increase in nutrient input as a result of development in this area. Management plans should therefore consider managing the risk factors associated with phase shifts, and use monitoring as an early detection mechanism.

There was a low abundance of soft corals across the archipelago. Observations throughout the Cambodian coastal zone suggest that soft corals are not a prevalent group (van Bochove *et al.*, 2011; Savage *et al.*, 2013). However, they are much more abundant on some of the offshore reefs in deeper open water (pers. obs.). This suggests that there may be some underlying factor rendering the inshore reefs less hospitable for soft corals, which requires more investigation.

Assessment of the abiotic substrates found across the archipelago (Figs 2 and 3) suggests that the coral reefs in the area are relatively healthy, although impacted by various fishing activities. The amount of rock available for colonisation by sedentary species is encouraging, particularly when considering the low abundance of nutrient indicator algae. Also encouraging is the low amount of recently killed coral across all sites. Rubble indicates areas where reefs have been damaged, often as a result of fishing-related activities (blast-fishing or trawling) or of boat groundings or anchoring on reefs. Rubble was relatively uncommon across all sites except Koh Damloung, where there was evidence of human-related destruction.

Conclusions

The data collected suggest the Koh Sdach Archipelago is in comparatively better condition than the nearby Koh Rong Archipelago. A recent assessment (Savage *et al.*, 2013) found that the Koh Rong Archipelago had lower levels of live coral cover and higher levels of nutrient indicator algae (Table 4). Interestingly, the levels of recently killed coral were similar for both archipelagos, which may suggest that both sites are subject to similar levels of damage. However, without more detailed data on the causes of such damage in both areas, it is not possible to discern any further patterns. This warrants future investigation.

Marine protection efforts are still limited, particularly in some developing areas of Southeast Asia. There is a distinct need for a better understanding of how to implement MPAs of any kind, particularly in areas where their legal and governance issues will have impacts on human populations nearby. Within the Koh Sdach Archipelago, however, there is evidence that an effective or partially effective traditional marine management system is already in place (Glaser *et al.*, 2010), where protection occurs as a result of traditions, myths or taboos, often without the stated intention of protecting nature, but due to the perceptions of local inhabitants. Koh Samit in the Koh Sdach Archipelago acts as both a natural and traditional refuge because it is well known to the local people as being "un-fishable". This is for two reasons: firstly, due to the extremely shallow reef stretching across the channel between the main island of Koh Sdach and the smaller islet of Koh Samit; secondly, Koh Samit ("Ghost Island") is haunted according to local beliefs. Local fishermen are typically too afraid to fish here. This appears to have had a positive impact on the fish populations, but further investigation is required to determine the effects of these beliefs on reef health. Not only does this highlight Koh Samit as a potentially suitable area for a formalized no-take zone, but demonstrates the importance of integrating local knowledge into the design of marine management strategies. Such cultural beliefs need to be fully understood to judge their potential to contribute to formal marine protected areas (Suriamihardja, 2007).

The data collected in this investigation suggest that the coral reefs around the Koh Sdach Archipelago could benefit greatly from conservation efforts. However, rather than recovery, the focus of management should be on maintaining the system in its current state, while still allowing access to the area by local users. Further socioeconomic investigations are necessary, in addition to collaborative reserve design

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techniques, to incorporate the needs of local resource users while remaining adaptable to future change.

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References

Bellwood, D.R., Hughes, T.P., Folke, C. & Nyström, M. (2004) Confronting the coral reef crisis. *Nature,* **429,** 827–833.

van Bochove, J., Ioannou, N., McVee, M. & Raines, P. (2011) Evaluating the status of Cambodia's coral reefs through baseline surveys and scientific monitoring. *Cambodian Journal of Natural History*, **2011,** 114–121.

Cesar, H., Burke, L. & Pet-soede, L. (2003) *The Economics of Worldwide Coral Reef Degradation.* WWF–Netherlands, Arnham, the Netherlands.

Chou, L.M. & Tun K.P.P. (2003) *Status of Coral Reefs and Socio-economic Evaluation of the Koh Sdach Group of Islands, II, Koh Kong Province, Cambodia.* REST Technical Report, National University of Singapore, Singapore.

Chou, L.M., Tun K.P.P. & Chan, T.C. (2002) *Status of Coral Reefs and Socio-economic Evaluation of the Koh Sdach Group of Islands, Koh Kong Province, Cambodia.* REST Technical Report, National University of Singapore, Singapore.

Done, T.J. (1992) Phase shifts in coral reef communities and their ecological significance. *Hydrobiologica*, **247,** 121-132.

Foster-Smith, J. & Evans, S.M. (2003) The value of marine ecological data collected by volunteers. *Biological Conservation,* **113,** 199–213.

Glaser, M., Baitoningsih, W., Ferse, S.C.A., Neil, M. & Deswandi, R. (2010) Whose sustainability? Top-down participation and emergent rules in marine protected area management in Indonesia. *Marine Policy*, **34,** 1215–1225.

Hodgson, G. (1999) A global assessment of human effects on coral reefs. *Marine Pollution Bulletin,* **38,** 2–8.

Hughes, T.P., Baird, A.H., Bellwood, D.R., Card, M., Connolly, S.R. *et al.* (2003) Climate change, human impacts and the resilience of coral reefs. *Science,* **301,** 929–933.

Hughes, T.P., Bellwood, D.R., Folke, C., Steneck, R.S. & Wilson, J. (2005) New paradigms for supporting the resilience of marine ecosystems. *Trends in Ecology and Evolution* **20,** 380–386.

Hurlbert, S. (1984) Pseudoreplication and the design of ecological field experiments. *Ecological Monographs,* **54,** 187–211.

Magurran, A.E. (2004) *Measuring Biological Diversity.* Blackwell Publishing, Oxford, UK.

Mascia, M.B. (2003) The human dimension of coral reef marine protected areas: recent social science research and its policy implication. *Conservation Biology,* **17,** 630–632.

McClanahan, T.R. (1994) Coral Reefs effects of fishing, substrate complexity, and sea urchins. *Coral Reefs,* **13,** 231–241.

McClanahan, T.R. & Mutere, J.C. (1994) Coral and sea urchin herbivory and competition in Kenyan coral reef lagoons: the role of reef management. *Journal of Experimental Marine Biology and Ecology,* **184,** 237–254.

McClanahan, T.R. & Obura, D. (1997) Sedimentation effects on shallow coral communities in Kenya. *Journal of Experimental Marine Biology and Ecology,* **209,** 103–122.

McCook, L.J. (1999) Macroalgae, nutrients and phase shifts on coral reefs: scientific issues and management consequences for the Great Barrier Reef. *Coral Reefs,* **18,** 357–367.

McManus, J.W. & Polsenberg, J.F. (2004) Coral-algal phase shifts on coral reefs: ecological and environmental aspects. *Progress in Oceanography,* **60,** 263–279.

Medley, P.A., Gaudian, G. & Wells, S. (1993) Coral reef fisheries stock assessment. *Reviews in Fish Biology and Fisheries,* **3,** 242–285.

Mumby, P.J. (2006) The impact of exploiting grazers (Scaridae) on the dynamics of Caribbean coral reefs. *Ecological Applications,* **16,** 747–769.

Nelson, V. (1999) *State of Coral Reefs in Cambodia*. Environmental Coastal Zone Project, Ministry of the Environment, Phnom Penh, Cambodia.

Sadovy de Mitcheson, Y., Craig, M.T., Bertoncini, A.A., Carpenter, K.E., Cheung, W.W.L., Choat, J.H., Sornish, A.S., *et al.* (2013) Fishing groupers towards extinction: a global assessment of threats and extinction risks in a billion dollar fishery. *Fish and Fisheries*, **14,** 119–136.

Sale, P.F. & Douglas, A. (2006) Precision and accuracy of visual census techniques for fish assemblages on coral patch reefs. *Environmental Biology of Fishes,* **6,** 333–339.

Savage, J.M., Osborne, P.E. & Hudson, M.D. (2013) Abundance and diversity of marine flora and fauna of protected and unprotected reefs of the Koh Rong Archipelago, Cambodia. *Cambodian Journal of Natural History,* **2013,** 83–94.

Simpson, E.H. (1949) Measurement of diversity. *Nature,* **163,** 688.

Suriamihardja, D.A. (2007) Re-promoting weakening local values to manage Spermonde marine resources: an insight from compromise to co-existence. In *Final Report of the Project 'Natural Resource Management and Socio-economic Transformations under Decentralization in Indonesia: Toward Sulawesi Area Studies'*, pp. 249–264. Center for Southeast Asian Studies Kyoto University (CSEAS), Kyoto, Japan.

Wilkinson, C. (2000) *Status of Coral Reefs of the World.* Australian Institute of Marine Science, Townsville, Australia.

Zoning Cambodia's first Marine Fisheries Management Area

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មូលន័យសង្ខេប

ការបែងចែកតំបន់ក្នុងដែនការពារសមុទ្រគឺចាំបាច់ ដើម្បីកំណត់តំបន់សម្រាប់គោលបំណងជាក់លាក់ និងដើម្បីដោះស្រាយទំនាស់រវាងសកម្មភាពផ្សេងៗ។ មានវិធីសាស្ត្រជាច្រើនដែលគេអាចប្រើប្រាស់ដើម្បីគាំទ្រដំណើរការនៃការធ្វើសេចក្តីសម្រេចចិត្តក្នុងពេលរៀបចំតំបន់ការពារសមុទ្រ រួមមានការដាក់ពិន្ទុនិងការវិភាគពហុវត្ថុបំណង ដោយប្រើវិធីកំណត់អាទិភាពអភិរក្សតំបន់។ បច្ចុប្បន្ននេះរាជរដ្ឋាភិបាលកម្ពុជាកំពុងធ្វើការងារជាមួយអ្នកពាក់ព័ន្ធក្នុងស្រុក និងអង្គការក្រៅរដ្ឋាភិបាលនានាដើម្បីបង្កើតតំបន់ការពារសមុទ្រសម្រាប់ការប្រើប្រាស់ច្រើនយ៉ាង ដែលត្រូវបានគេស្គាល់ថាជាតំបន់គ្រប់គ្រងជលផលសមុទ្រ ដែលស្ថិតនៅជុំវិញប្រជុំកោះរុង។ ទិន្នន័យផ្កាថ្ម ដែលត្រូវបានប្រមូលដោយអង្គការអភិរក្សផ្កាថ្មពីឆ្នាំ២០១០ដល់ឆ្នាំ២០១២ ត្រូវបានប្រើប្រាស់ដើម្បីគណនាគុណតម្លៃនៃការគ្រប់គ្រងអភិរក្សតាមរយៈវិធីសាស្ត្រដាក់ពិន្ទុជាបឋម។ យ៉ាងណាក៏ដោយ ក៏វិធីសាស្ត្រវិភាគនេះមិនត្រូវបានប្រើក្នុងការកំណត់វិសាលភាពនៃជីវៈចម្រុះជុំវិញកោះ ឬក៏ត្រូវបានពិចារណាសំរាប់ការគម្រាមគំហែងទីជម្រកសមុទ្រនោះទេ។ ការវិភាគបន្ថែមត្រូវបានធ្វើឡើងដោយដំណើរការតាមវិធីវិភាគ Marxan with Zones ដែលប្រើប្រាស់ទិន្នន័យផ្កាថ្ម ព្រៃកោងកាង និងស្មៅសមុទ្រ ក៏ដូចជាស្រទាប់កំទេចកំណនិងផលប៉ះពាល់នៃការនេសាទ។ តំបន់អភិរក្សបានមកពីវិធីវិភាគ Marxan with Zones ត្រូវគ្នាភាគច្រើនជាមួយនឹងតំបន់គ្រប់គ្រងអភិរក្សគុណតម្លៃខ្ពស់ដែលត្រូវបានកំណត់ដោយវិធីដាក់ពិន្ទុ ជាមួយនឹងករណីលើកលែងមួយចំនួន។ យើងរកឃើញថា នៅពេលដែលវិធីវិភាគ Marxan with Zones ផ្តល់នូវដំណោះស្រាយទូលំទូលាយជាងវិធីដាក់ពិន្ទុរហ័សក៏វានៅតែត្រូវការទិន្នន័យបរិមាណច្រើនប្រភេទ ដែលនៅតែជាបញ្ហាប្រឈមចំពោះប្រទេសដែលខ្វះទិន្នន័យដូចជាប្រទេសកម្ពុជា។ យ៉ាងណាក៏ដោយក៏ដំណោះស្រាយទទួលបាននេះគឺជាផែនការកំណត់តំបន់បង្ហាញផ្លូវដែលមានប្រយោជន៍សម្រាប់ពិគ្រោះយោបល់ក្នុងការបែងចែកតំបន់ការពារសមុទ្រដែរ។

Abstract

Zoning of marine protected areas is necessary to spatially designate areas for specific purposes and to resolve conflicts between different activities. A range of methods are available to support decision-making processes during the design of marine protected areas, including scoring and multi-objective analysis using spatial conservation prioritisation tools. The Royal Government of Cambodia is currently working with local stakeholders and NGOs to establish a multiple-use marine protected area, known locally as a Marine Fisheries Management Area,

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around the Koh Rong Archipelago. Coral reef data collected by Coral Cay Conservation in 2010–2012 were used to calculate conservation management values via a preliminary scoring method. However, this analysis did not take into account the full range of biodiversity around the islands nor considered threats to marine habitats. A supplementary analysis was conducted using Marxan with Zones, which used data on coral reefs, mangroves and seagrasses as well as cost layers derived for sedimentation and fishing impacts. The conservation areas derived from the Marxan with Zones analysis corresponded well with the areas of high conservation management value identified through the scoring method, with some notable exceptions. We find that while Marxan with Zones provides more comprehensive solutions than the rapid scoring method, it requires multiple types of quantitative data, which remains a challenge in a data-scarce country like Cambodia. Nonetheless, the resulting solution is an indicative zoning plan that has been useful for zoning consultations.

Keywords

Marine management, Marine Protected Area, spatial planning, Marxan.

Introduction

Marine ecosystems face mounting threats worldwide (Halpern *et al.*, 2008a) and effectively managed Marine Protected Areas (MPAs) are a means of mitigating threats to marine ecosystems (Veitch *et al.*, 2012). With most of the world's oceans characterised by conflicts between and among users, many of which are contrary to conservation objectives, it is necessary to zone marine spaces to designate areas for specific purposes. There may hence be different levels of protection within an MPA, ranging from areas that allow selective extraction of resources to those that are strictly no-take. Zoning plans allows for the determination of trade-offs when resolving conflicts between human resource uses (Halpern *et al.*, 2008b).

Early systematic planning allows for greater effectiveness and cost-efficiency in achieving conservation objectives (Malcolm *et al.*, 2012). A range of methods and tools have been developed to support decision-making processes for MPA design. Multi-criteria decision analysis frameworks were the most commonly used previously (Grantham *et al.*, 2012), where information from several different criteria is combined to form a single index of evaluation for each site. While scoring methods are quick and easy, they do not accommodate several key principles in reserve selection (Grantham *et al.*, 2012). Firstly, scoring methods are mostly ineffective at providing comprehensive solutions in cases where the full range of biodiversity should be included (Klein *et al.*, 2010). Secondly, scoring methods value sites individually rather than collectively and thus fail to take into account complementarity: i.e. relationships between sites are not considered (Wilson *et al.*, 2009).

Spatial conservation prioritisation, on the other hand, considers comprehensiveness and complementarity. This form of assessment aims to identify the spatial location of actions that will be applied across a landscape or seascape (Ferrier & Wintle, 2009). It involves such approaches as defining a minimum size for priority areas and setting biologically relevant conservation targets, as well as incorporating other information such as threats (Wilson *et al.*, 2009). A conservation triage approach can be employed, where prioritisation is conducted with the aim of maximising conservation returns at the lowest possible cost (Bottrill *et al.*, 2008, 2009).

Spatial conservation prioritisation generally involves: 1) Setting overall conservation objectives (e.g. biodiversity conservation, threat management); 2) Determining conservation features, which are the habitat types and/or species to be conserved; 3) Setting targets for each of these conservation features by, for example, following national or international targets; 4) Dividing the planning region into a series of planning units; 5) Calculating the amount of each feature found in each planning unit; 6) Assigning a cost value to each planning unit; and 7) Identifying sets of priority areas for conserving biodiversity that meet the targets, with the constraints of reducing fragmentation of these areas and minimizing planning unit costs (Moilanen *et al.*, 2009a). Cost associated with conservation planning is a metric that summarizes factors to avoid. This may be dollars spent during acquisition, management or transaction, or opportunity costs—the latter is most commonly used (Naidoo & Ricketts, 2006).

Numerical optimization tools such as Marxan and Zonation (Moilanen *et al.*, 2009b) have been developed as decision-making tools for this type of assessment. However, spatial conservation prioritisation has until recently focused only on one type of protected area—

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no-take reserves (Klein *et al.*, 2010). Advances in these tools have allowed for the simultaneous identification of locations for multiple zones with multiple objectives (Watts *et al.*, 2009). Such a multi-objective analysis has thus far been applied to only a few examples in the marine realm (see Klein *et al.*, 2010; Grantham *et al.*, 2012).

Cambodia's 435 km coastline and 69 islands (Touch, 1995) hold a rich diversity of coral reefs, seagrass beds and mangroves (Kim *et al.*, 2004) that are under increasing pressure from unsustainable fishing practices, sedimentation, coastal development and marine-based pollution (Ouk *et al.*, 2012). Ninety percent of the coral reefs in Cambodia, for example, are estimated to be under high level of risk (Tun *et al.*, 2008) and the overall trend is of increasing overexploitation of the coastal zone (Johnsen & Munford, 2012). Research and monitoring of Cambodia's marine ecosystems have historically been limited, due in part to the lack of human resources, infrastructure and finance in the Cambodian Government (Kim *et al.*, 2004). Nonetheless, there has been a shift in political will for improved protection and management of marine resources because there is increasing recognition that improvements in marine fisheries management could increase fish catch, family income, ecosystem health and tourism (Ouk *et al.*, 2012).

The 2006 Cambodian Law on Fisheries afforded additional protection to habitats for marine aquatic animals and plants, including coral reefs, mangroves and seagrass. The *Strategic Planning Framework for Fisheries* set ambitious national targets of at least 70 km^2 of seagrass beds and 8.4 km^2 of coral reefs to be under an appropriate form of sustainable management and 10 km^2 of mangrove to be rehabilitated by 2019. The *National Action Plan for Coral Reef and Seagrass Management in Cambodia 2006–2016* aims to put at least 8.4 km^2 of coral reefs and 90 km^2 of seagrass beds under an appropriate form of sustainable management by 2016 (Ouk *et al.*, 2012). International commitments, including Aichi Target 11 of the Convention on Biological Diversity, also require more of Cambodia's important marine areas to be brought under effective, equitable and ecologically representative management by 2020.

To contribute to these targets, the Fisheries Administration (FiA) of the Ministry of Agriculture, Forestry and Fisheries of the Royal Government of Cambodia is currently working with a range of national stakeholders and international NGOs, including Coral Cay Conservation (CCC) and Fauna & Flora International (FFI), to develop Cambodia's first Marine Fisheries Management Area (MFMA) around the islands of Koh Rong and Koh Rong Sanloem, Preah Sihanouk Province. The waters of the Koh Rong Archipelago are in part to be managed by three Community Fisheries (CFi) covering 18,672 hectares which were formally established in 2008 (Koh Rong Sanloem CFi, Prek Svay CFi) and 2010 (Deom Thkov CFi). There are now 39 recognised CFis in Cambodia's marine waters (FiA, 2013), and ambitious national targets have been set to both strengthen existing CFis and establish new ones. However, the effectiveness of new and existing marine CFis within the four coastal provinces is not generally well understood, and is likely variable. The existing relevant research in the Koh Rong Archipelago has shed light on relatively small areas (e.g. Savage *et al.*, 2013) and found no significant variation in reef fish or invertebrate abundance and composition inside and outside of CFi areas (Thuang, 2013). Additionally, there has been a perceived decline in catches by small-scale fishers across the archipelago (Ouk *et al.*, 2011; Leng, 2013).

The proposed MFMA aims to conserve marine biodiversity and support sustainable fishing and tourism, contributing to poverty alleviation (FiA, *in litt.*). It is expected to support and integrate with the existing CFis and improve management effectiveness to counter ongoing resource declines. Zones to be identified are: 1) *Conservation Areas*, in which any activity that has a negative effect on fishery resources is strictly prohibited except for permitted scientific research; 2) *Protected/Community Fishing Areas*, where subsistence fishing is allowed; and 3) *Multiple Use Areas*, where coastal development is allowed provided it does not destroy reefs (FiA, *in litt.*).

A zoning scheme that considers both the conservation goals and social-economic cost of fisheries is central to the success of the MFMA. Effective conservation prioritization also requires incorporating information on threats (Wilson *et al.*, 2009). Erosion and land runoff due to poor land management have been highlighted as a concern in Cambodia (UNEP, 2008) and riverine run-off has been observed at the site, with high levels of siltation of coral reefs, varying seasonally with the onset of heavy rains (van Bochove *et al.*, 2011). Commercially valuable fish species have also been reported to be decreasing in number (van Bochove *et al.*, 2011; Leng, 2013). It is thus imperative that both sedimentation and fishing pressure are considered in the zoning scheme.

This paper describes a spatial analysis that took place to feed into the consultation on the zoning scheme for Cambodia's first MFMA. A scoring analysis

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was first conducted using only ecological data to give an overview of potential areas of conservation interest for reef and reef-associated species. A more comprehensive Marxan with Zones analysis using ecological (coral, mangroves and seagrass habitats) and threats data, was then conducted to identify the different zones.

Methods

Data Collection

Ecological Data

Reef Check surveys, modified to include an extended species list, were conducted at 156 locations around the islands by CCC between 2010 and 2012 (van Bochove *et al.*, 2011). All potential reef areas were surveyed, with the exception of the southeast area of Koh Rong Sanloem. Seven ecological criteria—namely, target fish species abundance, fish species diversity, food fish abundance, target invertebrate species abundance, invertebrate species diversity, hard coral percentage cover and hard coral species diversity—were analysed and ranked for each site. Fisher's α index was used for all species diversities.

The extent of coral reef habitat was derived by modifying remotely-sensed shallow reef data from the International Coral Reef Research and Monitoring Center (ICRRMC) in Japan (Kakuta *et al.* 2010) with CCC survey data and surveyors' input. Where this data set was incomplete, it was amended with UNEP-WCMC (2010) global coral reef data and with reference to the Marine Conservation Cambodia's reef survey report for 2011 (Krell *et al.*, 2011).

The extent of seagrass habitat was verified through rapid surveys using a transect method in April and May 2013 (Leng *et al.*, in prep.), and mangroves were determined using 5-m resolution RapidEye satellite imagery from January 2013. Potential fish refuge areas were identified by consulting focus groups involving 281 participants across the five villages in the archipelago during April and May 2013, plus ground-truthing visits with participants and the FFI GIS Coordinator.

The distribution of fish and invertebrates was estimated from CCC survey data. These were assumed to be coral-associated species and their ranges were extrapolated from the distribution of coral reefs. Areas of high fish and invertebrate species diversity and abundance were pre-identified by removing areas with less than the 50^{th} percentile of diversity and abundance data, using a buffer of 150 m around every survey site. As the CCC surveys were conducted at two depths, a conservative approach was employed such that sites where only one of the depths had data above the 50^{th} percentile threshold were included in the extent. All calculations were made using R 3.0.1.

Threats data

Sedimentation and fishing pressure were the two threats considered in the multi-objective zoning analysis in Marxan with Zones. Sediment plumes were hand-digitized (following Evans *et al.*, 2012) by interpreting 2013 Google Earth images. Relative values of sedimentation were derived by calculating flow accumulation values from a digital elevation model (GEOSS, 2011) on ArcGIS and weighted by percentage of undisturbed habitat per watershed; forests, grasslands, marshlands and shrublands were considered undisturbed habitat. Land-use types were determined using 5-m resolution RapidEye satellite imagery from January 2013, ground-truthed in June 2013. Artisanal fishing impact was derived from 55 individual fisher interviews and focus groups involving 60 households between March to June 2013 (Leng, 2013) and classified on a relative scale as low = 1,000; medium = 2,000; high = 3,000; and very high = 4,000. No spatial resource-use information was available for seagrass and mangrove habitats. It was assumed that intensities of use were similar to the surrounding reefs and hence these habitats were allocated the fishing cost values of the nearest reef.

Data Analysis

Scoring

Every site surveyed by CCC was allocated a 'Conservation Management Value' (CMV), which was the sum of the number of biological indices that had above-mean values for each index, producing a CMV score between 0 and 7. Areas with high CMV scores, and particularly high individual indices, were then used to delineate areas of reef conservation interest. This followed an approach applied by CCC to identify potential sites for small-scale MPAs in the Philippines (Longhurst *et al*., 2012).

Multi-objective zoning

Analysis was conducted using Marxan with Zones v2.01 and the graphical interface Zonae Cogito, in conjunction with ArcGIS 10.0. Marxan with Zones identifies multiple zones simultaneously based on zone-specific targets while aiming to minimize costs

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Table 1 Conservation targets developed for each zone in the proposed Marine Fisheries Management Area using Marxan with Zones analysis. *Pre-identified areas of >50th percentile.

	Feature	Overall Target	Conservation Area		Community Fishing Areas		Minimum Proportion Met
			Target	Target Met	Target	Target Met	
1	Coral diversity*	80%	60%	yes	40%	yes	1
2	Mangrove forest	70%	60%	no	40%	yes	0.726
3	Seagrass beds	100%	70%	no	30%	no	0.610
4	Fish refuge (proposed)	100%	0%	n/a	100%	no	0.784
5	Overall fish diversity*	90%	70%	yes	30%	yes	1
6	Invertebrate diversity*	90%	70%	yes	30%	yes	1
7	Grouper abundance*	100%	60%	no	40%	no	0.851
8	Parrotfish abundance*	90%	40%	no	60%	yes	0.590

(Watts *et al.*, 2009). The software employs an algorithm called "simulated annealing", which uses iterative improvement while accepting some bad moves in initial iterations to provide near-optimal solutions for zoning configurations (Ball *et al.*, 2009). This algorithm has a randomisation component and therefore generates a different solution for every run. The study site was subdivided into a grid of 2,324 planning units, including all areas that may potentially be selected as part of the zoning design. Each planning unit measured 100 m × 100 m: no smaller than the features mapped and no larger than would be realistic for management decisions. The Marxan analyses involved running the software 100 times, with every run consisting of a million iterations.

There are two major Marxan outputs: the "best solution" and the "summed solution". The "best solution" has the lowest cost across multiple selections of planning units that collectively achieve conservation targets set (costs in this study were opportunity costs using sedimentation and fishing pressure as proxies). The "summed solution" gives the total number of times each planning unit was picked for a zone over all 100 Marxan runs for the scenario.

In this study, conservation targets (Table 1) were set to be much higher than the World Parks Congress global target of 20–30% of marine habitats to be effectively protected by 2012 (IUCN, 2003). This is because the current spatial planning was not conducted on a national scale and this first Marine Fisheries Management Area ought to significantly contribute to Cambodia's aforementioned national targets. The relative percent representation target set for each feature (e.g. coral diversity, fish refuge) was dependent on the extent, importance and/or rarity of the feature, based on its perceived significance to the authors.

Table 2 Zone cost for each zone, given by opportunity costs using sedimentation and fishing pressure as proxies. The higher the zone cost weighting, the less likely the area will be selected for that zone when the particular cost (sedimentation or fishing pressure) is high.

Zone	Sedimentation	Fishing Pressure
Conservation Area	0.05	0.03
Fishing Area	0.03	0.0
Multiple Use Area	0	0.06

Threats were included in the analysis as a cost layer, which typically incorporates factors that may compromise the implementation of a zone to a specific area. To assign zone types to areas with different levels of threats, the two cost types were given different weights for each zone. This was done by setting the zone cost function to reflect the relative influence of sedimentation and fishing pressure for identifying each zone (Table 2).

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Zones can be designated across many small or a few large areas and still meet the same conservation targets set. The level of clumping influences the effectiveness and ease of zone implementation. Too little clumping results in many small areas in each zone which may not meet minimum size requirements for species or habitat protection or to act as a productive fishing ground; too many boundaries may also be confusing and cause management challenges. Creating a few large areas from too much clumping, on the other hand, may cause overlaps and conflicts among resource users. Using Marxan with Zones, a sensitivity analysis of the parameter, zone boundary cost, allows the user to explore different levels of compactness. Calibration was conducted and zone boundary cost was set to 1 across all zones.

Results

The scoring method yielded conservation management values (CMVs) that were highest to the northwest and south of Koh Rong (Fig. 1). Areas of high conservation interest that were estimated from these CMVs were northwest and southwest of Koh Rong (the latter being close to the village of Koh Touch), the southwest of Koh Rong Sanloem, and between Koh Koun and Koh Rong Sanloem, adjacent to the village of M'Pai Bai (Fig. 1).

Artisanal fishing pressure was highest around Koh Ta Team to the north of Koh Rong, northeast and southeast of Koh Rong close to Prek Svay and Doem Thkov respectively, between Koh Koun and Koh Rong

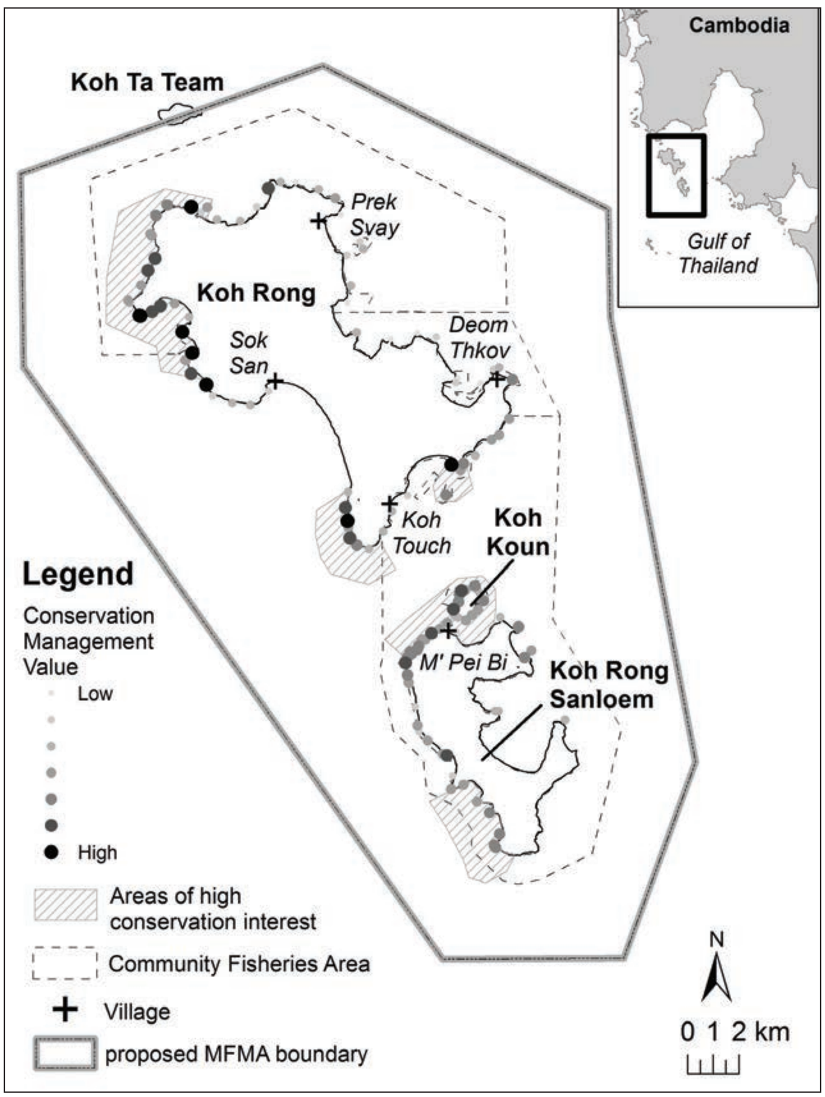

Fig. 1 Conservation management values and areas of high reef conservation interest from the scoring method.

Sanloem around M'Pai Bai, and southeast of Koh Rong Sanloem (Fig. 2a). Sedimentation, on the other hand, was generally higher on the predominantly shallower eastern side of both islands than to the west (Fig. 2b).

The Conservation Areas from the "best solution" identified by the Marxan with Zones analysis largely corroborated with the areas of high conservation interest on Koh Rong and, in addition, highlighted a few smaller potential Conservation Areas on the east coast of the island. For Koh Rong Sanloem, however, areas on the east and the south of the island were selected as Conservation Areas that were not highlighted by the scoring method. Within the area of high conservation interest between Koh Koun and Koh Rong Sanloem for example, only a small patch of habitats were selected as Conservation Areas by Marxan with Zones. Community Fishing Areas in the "best solution" were generally selected to be on the east side of Koh Rong and to the north and southeast of Koh Rong Sanloem (Fig. 3).

It should be noted that not all targets were met for this solution, but six of the eight features included in the analysis met above 70% of their target (Table 1). The exceptions were seagrass and parrotfish abundance.

Discussion

The Conservation Areas identified from the "best solution" from Marxan with Zones largely corresponded to regions of high conservation interest identified from the scoring method, with a few notable exceptions. The lack of areas of high conservation interest on the east coast of Koh Rong was likely due to the island's topography because only a few small areas are suitable for reefs: the east coast is dominated by unconsolidated sediment which may have poor coral larvae survival rates in comparison to the boulders and rocky outcrops on the west coast and Koh Koun (Thorne *et al.*, in prep.). There was also a significantly higher diversity of reef fish on the west than the east coast (Thuang, R., 2013). The "best

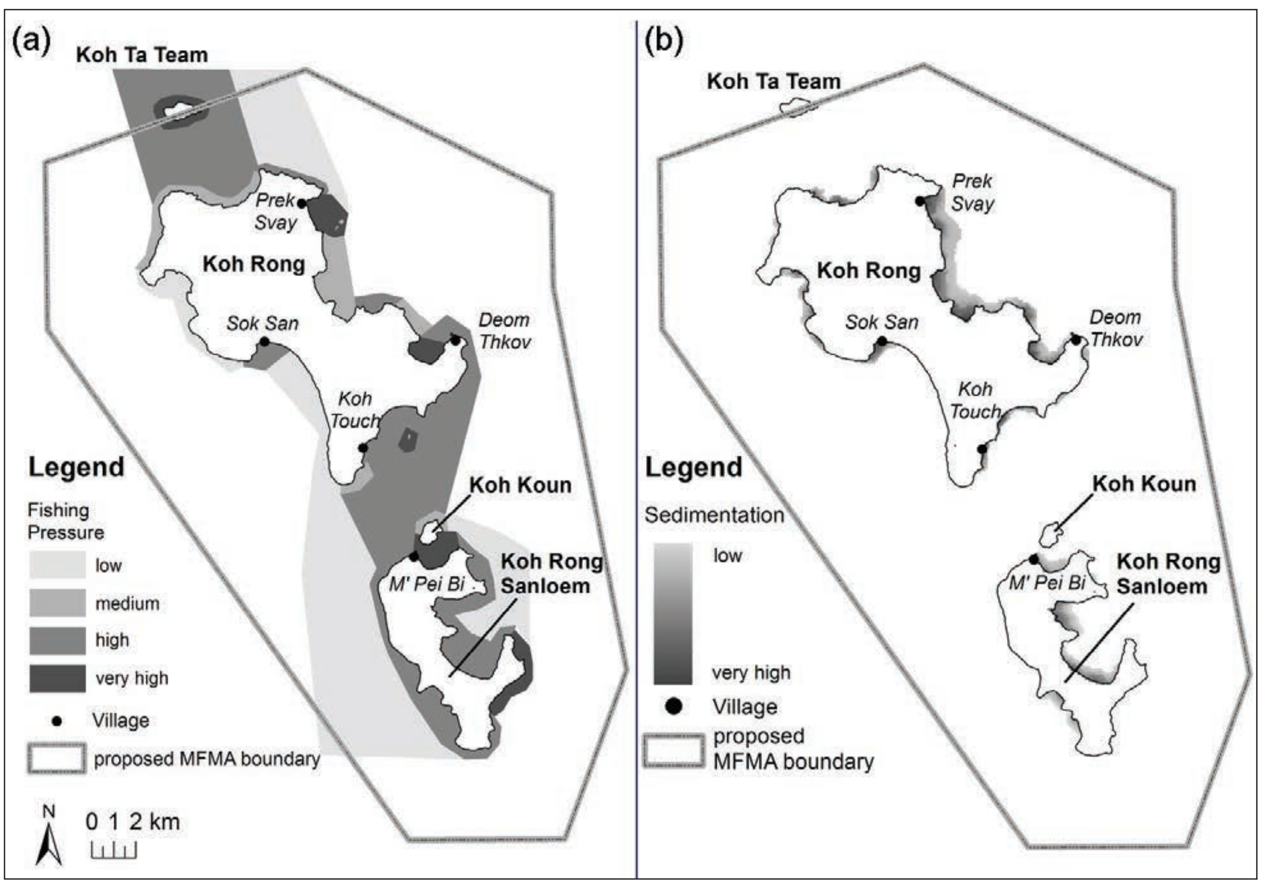

Fig. 2 Marine ecosystem threats: (a) fishing pressure; and (b) sedimentation levels in the Koh Rong Archipelago.

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solution" from Marxan with Zones, on the other hand, highlighted a few Conservation Areas on the east side of the island because despite high sedimentation levels in the east (Fig. 2), the analysis was constrained by the high conservation targets set for mangroves and seagrass, which were not considered in the scoring method and were mostly located on this side of the island. The area between Koh Koun and north of Koh Rong Sanloem recorded high CMVs, yet was identified as a Community Fishing Area in the Marxan with Zones "best solution" (Fig. 3). This was due to the high to very high fishing pressure in that area, which precluded the Conservation Area zone from this site, as dictated by the high zone cost weighting of fishing pressure for the zone (Table 2).

The scoring method is a quick and easy way of informing zoning plans, but is not by itself sufficient to develop a zoning plan, particularly when socioeconomic costs are not considered. Systematic conservation planning methods using tools such as Marxan with Zones provide more comprehensive alternatives and allow the user to explore different scenarios using different values of parameters. For example, the zone boundary cost can be adjusted to encourage further separation of conflicting uses; conservation areas can be placed far from Multiple Use Areas. Zones that share compatible management objectives can also be clustered: Conservation Areas can be located next to forested areas, so as to benefit from their buffering effects against terrestrial runoff.

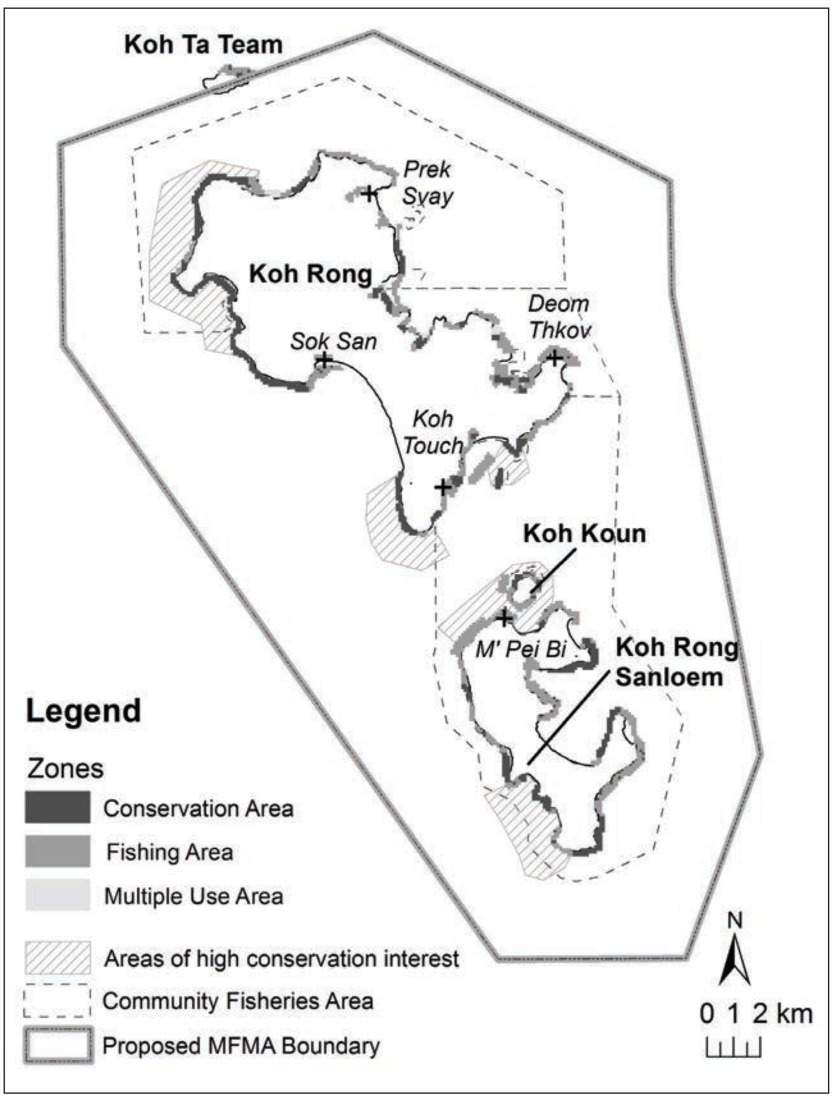

Fig. 3 Initial zonation plan produced from Marxan with Zones in relation to areas of high reef conservation interest.

Like the scoring method, spatial prioritisation software is limited by data to adequately describe ecological, social and economic systems (Grantham & Possingham, 2012). Conservation planners often need to conduct prioritisations with fewer data than they would like and often without direct data on the variables of interest (Game *et al.*, 2013). The zoning of this MFMA is no exception. A number of assumptions had to be made in this study to overcome the data limitations. Pre-identifying areas of higher diversity and abundance comes with the risks of excluding areas with low diversity but more unique species or assemblages (e.g. Kayanne *et al.*, 2012). Nonetheless, the nature of point-form faunal data from Reef Check made it necessary for such pre-identification because these data were extrapolated to the same coral reef polygons. Data on different reef types or species are needed to more adequately represent the range of diversity.

Ground-truthing of reef polygon data and species distribution modelling are also necessary to provide more accurate information of the extent of various biological features. Participatory expert mapping or resource-use surveys can further improve the data sets and add other important data that could be included as features in the analysis: e.g. spawning aggregation sites, recreational dive sites, and important species-specific features, such as turtle nesting beaches or seahorse breeding areas. We also acknowledge that the use of ordinal scales for fishing pressure is not ideal for prioritisation arithmetic (Game *et al.*, 2013). Fish catch data should be used when available, and data collection is currently underway to fine-tune our understanding of spatial patterns of resource use amongst finfish fishers and gleaners harvesting in the intertidal zone. Sedimentation in the site is expected to originate from mainland sources (van Bochove *et al.*, 2011) and illegal inshore trawling around the Koh Rong Archipelago (Krell *et al.*, 2011). These estimates should be validated with total suspended sediment sampling or through expert mapping. Significant trade-offs between data capture and the speed of MPA establishment are required in Cambodia, however, and significant uncertainty exists when leveraging science to make decisions in data-deficient and resource-poor contexts such as this (Mulligan *et al.*, 2013).

Marxan identifies optimal locations based on defined constraints and targets. Thus the development of these constraints and targets represents a key component in the zoning process. In this instance, targets were set through the authors' interpretation of priorities using draft MPA goals. This was determined to be a valid approach given our individual levels of involvement with the zoning process and limitations of data. However, this does highlight a challenge in using such multi-criteria support tools: namely, how to develop targets or manipulate different scenarios in a participatory fashion where government capacity is relatively low. Like many other marine spatial planning tools, Marxan is technically complex (Stelzenmüller *et al.*, 2013) and the in-depth understanding of the issues and processes needed for its use is unlikely to be present within local communities or even among government planners in most contexts. More basic approaches, such as CMVs, offer utility to marine planners who are not scientists or programmers and may be a good 'stepping stone' between broader community and government input and more complex spatial analysis.

In conclusion, numerical optimisation tools, such as Marxan with Zones, allow the development of comprehensive zonation plans that consider an increasing number of variables and more complex interactions. Nonetheless, results from this scientific initial assessment do not represent the final solution and should only be a building block for more in-depth stakeholder consultations (Stelzenmüller *et al.*, 2013). While it is important to reduce the uncertainty of outputs by improving the quality of input data and reducing assumptions, careful consideration must be given to the balance between collecting data and the speed at which an MPA is established. This study has highlighted some of the advantages of using tools such as Marxan with Zones, as well as some limitations. This has demonstrated that simpler, more rapid techniques, such as multi-criteria analysis, though not sufficient alone, may be used to support the initial development of a comprehensive zonation plan. For these tools to be employed successfully, the limitations of all approaches must be clear to all participants in the zoning process.

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References

Ball, I., Possingham, H. & Watts, M.E. (2009) Marxan and relatives: software for spatial conservation prioritization. In *Spatial Conservation Prioritization: Quantitative Methods and Computational Tools* (eds A. Moilanen, K. Wilson & H.P. Possingham), pp. 185–195. Oxford University Press, Oxford, UK.

van Bochove, J., Ioannou, N., McVee, M. & Raines, P. (2011) Evaluating the status of Cambodia's coral reefs through baseline surveys and scientific monitoring. *Cambodian Journal of Natural History*, **2011,** 114–121.

Bottrill, M.C., Joseph, L.N., Carwardine, J., Bode, M., Cook, C., Game, E.T., Grantham, H., Kark, S., Linke, S., McDonald-Madden, E., Pressey, R.L., Walker, S., Wilson, K.A. & Possingham, H.P. (2008) Is conservation triage just smart decision making? *Trends in Ecology & Evolution*, **23,** 649–54.

Bottrill, M.C., Joseph, L.N., Carwardine, J., Bode, M., Cook, C., Game, E.T., Grantham, H., Kark, S., Linke, S., McDonald-Madden, E., Pressey, R.L., Walker, S., Wilson, K.A. & Possingham, H.P. (2009) Finite conservation funds mean triage is unavoidable. *Trends in Ecology & Evolution*, **24,** 183–184.

Evans, R.D., Murray, K.L., Field, S.N., Moore, J.Y., Shedrawi, G., Huntley, B.G., Fearns, P., Broomhall, M., McKinna, L.I.W. & Marrable, D. (2012) Digitise this! A quick and easy remote sensing method to monitor the daily extent of dredge plumes. *PloS one*, 7, e51668.

Ferrier, S. & Wintle, B. (2009) Quantitative approaches to spatial conservation prioritization: matching the solution to the need. In *Spatial Conservation Prioritization: Quantitative Methods and Computational Tools* (eds A. Moilanen, K. WIlson & H.P. Possingham), pp. 1–15. Oxford University Press, Oxford, UK.

FiA—Fisheries Administration (2013) *Inputs for the National Strategic Development Plan Update 2014–2018—Fisheries Sector*. Draft Chapter 2 by Technical Working Group—Fisheries, Fisheries Administration, Phnom Penh, Cambodia.

Game, E.T., Kareiva, P. & Possingham, H.P. (2013) Six common mistakes in conservation priority setting. *Conservation Biology*, **27,** 480–485.

GEOSS (2011) *ASTER GDEM Ver.2*. Http://gdem.ersdac.jspacesystems.or.jp/ [accessed 15 April 2014].

Grantham, H. & Possingham, H. (2012) *Zoning Marine Protected Areas for Biodiversity Conservation and Community Livelihoods: A Case Study from Raja Ampat, West Papua*. University of Queensland, Australia.

Grantham, H.S., Agostini, V.N., Wilson, J., Mangubhai, S., Hidayat, N., Muljadi, A., Rotinsulu, C., Mongdong, M., Beck, M.W. & Possingham, H.P. (2012) A comparison of zoning analyses to inform the planning of a marine protected area network in Raja Ampat, Indonesia. *Marine Policy*, **38,** 184–194.

Halpern, B.S., Walbridge, S., Selkoe, K., Kappel, C.V, Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R., Watson, R. & Agrosa, C.D. (2008a) A global map of human impact on marine ecosystems. *Science*, **319,** 948–52.

Halpern, B.S., McLeod, K.L., Rosenberg, A.A. & Crowder, L.B. (2008b) Managing for Cumulative Impacts in Ecosystem-based Management through Ocean Zoning. *Ocean & Coastal Management*, **51,** 203–211.

IUCN (2003) *Recommendations of the Fifth IUCN World Parks Congress*. IUCN (The World Conservation Union), Gland, Switzerland.

Johnsen, S. & Munford, G. (2012) *Country Environment Profile: Royal Kingdom of Cambodia*. Report by Euronet Consulting to the European Union, Brussels, Belgium.

Leng P. (2013) Assessment of fishing practices in marine fisheries management areas around Koh Rong and Koh Rong Sanleom, Cambodia. *Cambodian Journal of Natural History*, **2013,** 113–114.

Longhurst, K., McVee, M. & Ferguson, A. (2012) *Southern Leyte Coral Reef Conservation Project Summary Report: Results of Community and Scientific Work August 2010—July 2012*. Coral Cay Conservation, Surrey, UK.

Kakuta, S., Hiramatsu, T., Mitani, T., Numata, Y., Yamano, H. & Aramaki, M. (2010) Satellite-based mapping of coral reefs in East Asia, Micronesia and Melanesia Regions. International Archives of Photogrammetry, *Remote Sensing and Spatial Information Science*, **38,** 534–537.

Kayanne, H., Hongo, C., Okaji, K., Ide, Y. & Hayashibara, T. (2012) Low species diversity of hermatypic corals on an isolated reef, Okinotorishima, in the northwestern Pacific. *Galaxea, Journal of Coral Reef Studies*, **14,** 73–95.

Kim S., Chou L.M. & Tun K. (2004) *The coral reefs of Cambodia: present state of information and management capacity: first draft*. Unpublished report to the Ministry of Agriculture, Forestry and Fisheries, Phnom Penh, Cambodia.

Klein, C.J., Steinback, C., Watts, M., Scholz, A.J. & Possingham, H.P. (2010) Spatial marine zoning for fisheries and

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conservation. *Frontiers in Ecology and the Environment*, **8,** 349–353.

Krell, B., Skopal, M. & Ferber, P. (2011) *Koh Rong Samloem and Koh Kon Marine Environmental Assessment.* Marine Conservation Cambodia, Koh Rong Sanloem, Cambodia.

Malcolm, H.A., Foulsham, E., Pressey, R.L., Jordan, A., Davies, P.L., Ingleton, T., Johnstone, N., Hessey, S. & Smith, S.D.A. (2012) Selecting zones in a marine park: Early systematic planning improves cost-efficiency; combining habitat and biotic data improves effectiveness. *Ocean and Coastal Management*, **59,** 1–12.

Moilanen, A., Wilson, K.A. & Possingham, H.P. (2009a) *Spatial Conservation Prioritization*. Oxford University Press, Oxford, UK.

Moilanen, A., Kujala, H. & Leathwick, J. (2009b) The Zonation framework and software for conservation prioritization. In *Spatial Conservation Prioritization* (eds A. Moilanen, K. Wilson & H.P. Possingham), pp. 196–210. Oxford University Press, Oxford, UK.

Mulligan, B., Ouk V. & Longhurst, K. (2013) Balancing the need for speed with appropriate and effective design in Cambodia's first large-scale Marine Protected Area. *Paper presented to the Third International Marine Protected Area Congress, 21–27 October 2013, Marseille, France.*

Naidoo, R. & Ricketts, T.H. (2006) Mapping the economic costs and benefits of conservation. *PLoS biology*, **4,** e360.

Ouk V., Kim S., Leang S. & Skopal-Papin, M. (2011) *Summary Report on Koh Rong and Koh Rong Sanloem Fishing Communities: Socio-demographic report on Koh Rong Sanloem, Koh Toch, Daem Thkov, Prek Svay and Koh Toch communities, Preah Sihanouk*. Fisheries Administration, Phnom Penh, Cambodia.

Ouk V., Prak V. & Rafael, B. (2012) *Coastal Fisheries Management in Cambodia, with Case Study in Prah Sihanouk Province*. Partnerships in Environmental Management for the Seas of East Asia (PEMSEA), Quezon City, the Philippines.

Savage, J.M., Osborne, P.E. & Hudson, M.D. (2013) Abundance and diversity of marine flora and fauna of protected and unprotected reefs of the Koh Rong Archipelago, Cambodia. *Cambodian Journal of Natural History*, **2013,** 83–94.

Stelzenmüller, V., Lee, J., South, A., Foden, J. & Rogers, S.I. (2013) Practical tools to support marine spatial planning: A review and some prototype tools. *Marine Policy*, **38,** 214–227.

Thaung R. (2013) A comparative study of marine fish and invertebrates inhabiting coral reefs surrounding Koh Rong Island, Cambodia. *Cambodian Journal of Natural History*, **2013,** 120.

Thorne, B.V., Mulligan, B., Mag Aoidh, R. & Longhurst, K. Current status of coral reef 'health' around the Koh Rong Archipelago, Cambodia. *In preparation.*

Touch S.T. (1995) *Present Status of Fisheries in Cambodia and the Development Action Plans*. Department of Fisheries, Phnom Penh, Cambodia.

Tun K., Chou, L.M., Yeemin, T., Phongsuwan, N., Affendi, Y.A., Ho, N., Sour K., Van Long N., Nanola, C., Lane, D. & Tuti, Y. (2008) Status of coral reefs in Southeast Asia. In *Status of Coral Reefs of the World: 2008* (ed. C. Wilkinson), pp. 131–144. Global Coral Reef Monitoring Network and Reef and Rainforest Research Center, Townsville, Australia.

UNEP—United Nations Environment Programme (2008) *National Report on Seagrass in the South China Sea*. UNEP/GEF/SCS Technical Publication No. 12, United Nations Environment Programme, Bangkok, Thailand.

UNEP-WCMC—World Conservation Monitoring Centre (2010) *Ocean Data Viewer*. Http://data.unep-wcmc.org/ [accessed 15 April 2014].

Veitch, L., Dulvy, N.K., Koldewey, H., Lieberman, S., Pauly, D., Roberts, C.M., Rogers, A.D. & Baillie, J.E.M. (2012) Avoiding empty ocean commitments at Rio + 20. *Science*, **336,** 1383–1385.

Watts, M.E., Ball, I.R., Stewart, R.S., Klein, C.J., Wilson, K., Steinback, C., Lourival, R., Kircher, L. & Possingham, H.P. (2009) Marxan with Zones: software for optimal conservation based land- and sea-use zoning. *Environmental Modelling & Software*, **24,** 1513–1521.

Wilson, K., Cabeza, M. & Klein, C. (2009) Fundamental concepts of spatial conservation prioritization. In *Spatial Conservation Prioritisation: Quantitative Methods and Computational Tools* (eds A. Moilanen, K. Wilson & H.P. Possingham), Oxford University Press, Oxford, UK.

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

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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.

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

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Books and chapters:

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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.

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Reports:

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

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