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Research priorities for bat conservation in Southeast Asia: a consensus approach

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Abstract Southeast Asia is a critical area for biodiversity conservation; levels of species richness and endemism are among the highest in the world, but rapid land-use changes endanger much of the region's fauna. Bats are a critical component of this diversity, comprising nearly a third of Southeast Asia's mammal species and providing vital ecological and economic services. However, nearly half the species are of conservation concern and as many as 40% of bat species are predicted to be extinct by the end of this century if current deforestation rates persist. Conservation efforts are urgently needed, and the taxonomic continuity of Southeast Asia and the prevalence of major threats throughout suggest that a region-wide initiative could be an effective approach. The Southeast Asian Bat Conservation Research Unit (SEABCRU) was established in 2007 to provide an organizational framework to both accelerate the advancement of bat research, and to coordinate conservation efforts. The SEABCRU is an informal collaboration among institutes, NGOs and individuals and provides a web-based forum for the growing number of researchers and outreach workers to interact and coordinate activities. It was launched at the 1st International Southeast Asian Bat Conference in Thailand (May 2007), during which a forum was held to derive conservation research priorities using a consensus approach. Four priorities were identified by participants: flying fox conservation and monitoring, taxonomy, conservation of cave-dependent bats, and conservation of forest-dependent bats. Here I provide an overview of the rationales behind these priorities and list the specific recommendations for the actions identified.

Keywords Chiroptera · Caves · Conservation priority setting · Deforestation · Hunting · Flying foxes · Southeast Asia · Taxonomy

Introduction

The geopolitical region of Southeast Asia comprises 11 countries (Myanmar, Vietnam, Laos, Thailand, Cambodia, Malaysia, Singapore, Indonesia, Brunei, Philippines and East

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Timor) and is one of the most biologically rich regions in the world, yet rapid land-use changes in recent decades have put much of its biodiversity at risk of extinction (Sodhi et al. 2004). As a consequence, the region encompasses four of the world's biodiversity hotspots (Myers et al. 2000) and seven of the 20 hotspots of latent extinction risk (Cardillo et al. 2006). Bats are a critical component of Southeast Asia's threatened fauna; they constitute approximately 30% of the region's mammal species, and can comprise as many as half of all mammal species in the tropical rainforest ecoregions (Kingston et al. 2006a). Moreover, the region is pivotal for international bat conservation as it supports nearly 30% of world's bat fauna; 320 species are listed by Simmons (2005) and a further ten described since (*Kerivoula kachinensis* (Bates et al. 2004); *K. krauensis* (Francis et al. 2007a); *K. titania* (Bates et al. 2007a); *Murina harrisoni* (Csorba and Bates 2005); *M. tiensa* (Csorba et al. 2007); *Rhinolophus chiewkweeae* (Yoshiyuki and Lim 2005); *Hipposideros khaokhaouayensis* (Guillén-Servent and Francis 2006); *H. boeadii* (Bates et al. 2007b); *Dyacopterus rickarti* (Helgen et al. 2007); and *Styloctenium mindorensis* (Esselstyn 2007). Species diversity is distributed across ten families, and 67 genera (Fig. 1), and of the 330 species identified, 197 are endemic to the region.

Like much of the region's fauna, the conservation status of many Southeast Asian bat species is a major concern. The most recent assessments of IUCN Red List status were conducted by the Southeast Asian Mammal Databank (SAMD) as part of the Global Mammal Assessment. Although yet to be ratified, these provide the most comprehensive evaluation of status to date (Biotani et al. 2006) (Fig. 1). Only 53% of species are currently classified as Least Concern, with the remaining species falling into one of four categories of conservation concern (Near Threatened, Vulnerable, Endangered, and Critically Endangered), considered Data Deficient, or have yet to be evaluated. Nearly 20% of species are Data Deficient, with fewest data available for the Rhinolophidae (14% species), Hipposideridae (24%), Vespertilionidae (27%) and Molossidae (42%) (Fig. 1). The status of the speciose Pteropodidae is better known, with only nine species considered Data Deficient, but 37 of the 96 species are threatened or nearly so (Near Threatened, 8 species; Vulnerable, 19 species; Endangered, 7; Critically Endangered, 3 species) (Fig. 1).

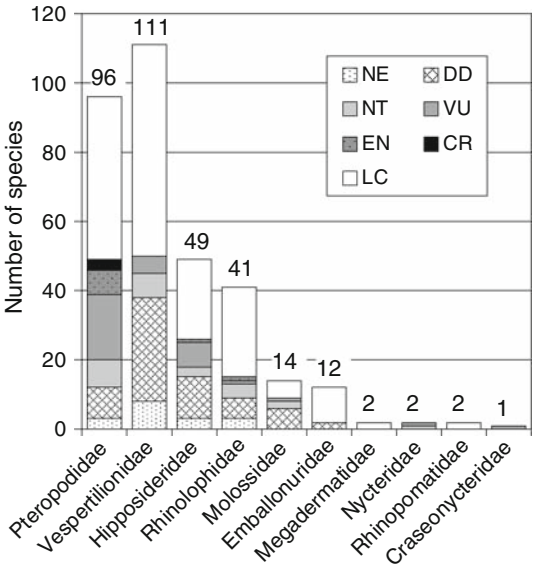

Fig. 1 Distribution of IUCN Red list status among bat families from the eleven countries of Southeast Asia (Myanmar, Vietnam, Laos, Thailand, Cambodia, Malaysia, Singapore, Indonesia, Brunei, Philippines, East Timor). Status from SAMD assessment (Biotani et al. 2006). NE, not evaluated, DD, data deficient, NT, near threatened, VU, vulnerable, EN, endangered, CR, critically endangered, LC, least concern. *Number* at top of *bars* is the total number of species recorded for the family, following Simmons (2005), Biotani et al. (2006) and new discoveries listed in the text

One of the most significant threats to the region's bat diversity is habitat loss. Relative deforestation rates in Southeast Asia are the highest of any tropical region (Achard et al. 2002; Sodhi et al. 2004; Sodhi and Brook 2006) and are expected to lead to extinction of many bat taxa. Upper bound estimates of regional species losses exceed 40% and global extirpation is anticipated for at least 23% of species by 2100 (Lane et al. 2006). Forest-dependent bats are particularly vulnerable (Kingston et al. 2003; Lane et al. 2006), but declines resulting from habitat loss are exacerbated by unregulated hunting of several species, most notably the plant-visiting flying foxes [*Pteropus* and *Acerodon* (Pteropodidae)]. Collection of bats for food and traditional medicine has led to dramatic population declines throughout the region (e.g., Mohd.-Azlan et al. 2001).

Not only does this represent a catastrophic decline in global vertebrate diversity, but the loss of the many ecosystem services that bats provide is likely to lead to an extinction cascade that will have profound ecological and economic impacts. The plant-visiting Pteropodidae provide essential ecosystem services as pollinators (Whittaker and Jones 1994; Corlett 2004; Srithongchuay and Bumrungsri 2007) and seed dispersers (Shilton et al. 1999; Corlett 1998) to more than 300 paleotropical plant species (Marshall 1983; Fujita and Tuttle 1991), and without bats both the regeneration of forest ecosystems (Marshall 1985; Cox et al. 1991; Rainey et al. 1995; Gumal 2001; McConkey and Drake 2006) and the success of bat-dependent fruit crops will be severely compromised. The economic value of these services is substantial. More than 500 products used by people are derived from bat-dependent plants (Fujita and Tuttle 1991); the global durian (*Durio zibethinus*) trade alone is worth in excess of US $1.5 billion per year (Lim 1998) and sales of petai, the beans of *Parkia speciosa*, generate approximately US $2.8 million annually in just the area around Kuala Lumpur (Malaysia) (Chuen et al. 1998). Recent pollination experiments assessing fruit set confirm nectarivorous bats as the most effective pollinators of both petai (Bumrungsri et al. 2007) and durian (S. Bumrungsri, personal communication).

The remaining bat families found in Southeast Asia comprise, with a few carnivorous exceptions, insectivorous species, and are the primary predators of nocturnal insects. Dietary analysis suggests that a single colony of 2.6 million wrinkle-lipped free-tailed bats (*Chaerephon plicata*) in Thailand may consume at least four tons of rice crop pests [white-backed planthoppers (*Sogatella* sp.)] each night (Leelapaibul et al. 2005). Such natural pest control agents help reduce the application of pesticides (Cleveland et al. 2006), and the consequent impacts on local biodiversity that result from their use. Large bat colonies are also a source of guano, which is widely used in Southeast Asia as an organic fertilizer. In Myanmar for example, over 260,000 kg per year are extracted, primarily for domestic use (Khin Maung Lwin 1995), and guano collection from the Khao Chong Pran Cave in Thailand generates an annual income for local villagers of US $135,000 (Leelapaibul et al. 2005). Consequently the conservation of Southeast Asia's bat fauna is a biodiversity priority from perspectives that range from the preservation of global species richness, through ecosystem maintenance to agricultural viability.

Research priorities for the conservation of Southeast Asian bats

Conservation research is urgently needed to reduce the impact of forest loss and hunting on the bat fauna of Southeast Asia, yet for historical, financial and logistical reasons, research in many countries is in its infancy. Nonetheless, there are a growing number of regional scientists and international collaborators dedicated to bat research and conservation in the region. Because of the taxonomic continuity of Southeast Asian bats, researchers share many common objectives and conservation issues yet to date there has been no mechanism

for exchange of ideas and techniques, nor for discussion, synthesis and implementation of region-wide research and conservation objectives. To address this need, the Southeast Asian Bat Conservation Research Unit (SEABCRU) was established in 2007, and launched at the 1st International South East Asian Bat Conference in Thailand, May 2007. The SEABCRU is a collaboration between academic institutions and NGOs intended to provide an organizational framework to coordinate and implement research, capacity building, and outreach to promote the conservation of Southeast Asia's diverse but threatened bat fauna.

One of the first actions of the SEABCRU was to identify priorities for bat research, and to this end an open forum was held during the conference. Over seventy people attended from 20 countries, providing a unique opportunity for a diverse body of conservation stakeholders, ranging from outreach workers and first year students to researchers with 40 years experience, to define and shape bat conservation research for the next decades. Stakeholder involvement is commonly encompassed in applied conservation issues, but research directions are rarely derived from collective bottom-up consensus. The only constraint was that priorities center on activities or issues that are pertinent across the region and which would be best addressed by region-wide collaboration among researchers and conservation biologists. Consensus opinion identified four key areas of that fulfilled these criteria and are detailed below (in no particular order).

Flying fox conservation and monitoring

Based on current deforestation rates, as many as 24% of Southeast Asia's fruit bat (Pteropodidae) species are predicted to have become globally extinct by the end of this century (Lane et al. 2006). Within the Pteropodidae, the flying foxes [defined in this context as members of the genera *Pteropus* (25 species) or *Acerodon* (5 species)] are of particular concern. These large species roost in trees in aggregations of several thousand individuals (and historically in the tens of thousands; Lyon 1911) and are under intense hunting pressure for food and traditional medicine in many parts of Southeast Asia (Mickleburgh et al. 1992, 2002; Wiles and Brooke 2008).

Hunting and habitat loss were identified as major threats to nearly all flying fox species by both the SAMD assessors (Biotani et al. 2006), and participants of a flying fox forum at the 1st International South East Asian Bat Conference. In combination, these threats have led to dramatic, but unquantified, declines in flying fox populations throughout the region. As a consequence, more than half (18/30) of the region's flying fox species were Red Listed (Biotani et al. 2006) by the SAMD and all bar one species is listed by the Convention on International Trade in Endangered Species (CITES) as Appendix II, the exception being the Critically Endangered *Acerodon humilus* from the Taulad Islands in Indonesia which is listed as CITES Appendix I. Of the remaining species, five were considered to be Data Deficient, and only seven species were considered sufficiently secure in their populations to merit Least Concern status. As a family, the Pteropodidae are clearly more vulnerable to extinction than any other bat family, comprising at least 6 of the 14 probable global bat extinctions (Simmons 2005).

Conservation efforts are severely hampered by the lack of regional data on flying fox distributions and populations, and of quantified evaluations of the impact of hunting. Explicit population and hunting data are only available for a few localities, most notably *Pteropus vampyrus* populations in Peninsular Malaysia, which clearly illustrate the regional decline. Mohd.-Azlan et al. (2001) visited 115 sites known historically to have supported *P. vampyrus* colonies. There were no recent sightings at 40% of the sites and all local villagers reported dramatic declines. The authors attributed this to the loss of

mangrove swamps and lowland forest, and the intensification of hunting pressure effected by the use of guns and greater access to remote roost sites. Moreover, although a hunting license is required, and limits the licensee to 50 individuals, the number of licenses issued is not restricted. Based on the number of licenses, harvests have been unsustainable for at least 15 years with 56,000 individuals taken between 1990 and 1996 (Mohd. Azlan et al. 2001) and 87,800 for the period 2002–2005 (Epstein et al. 2007). Similarly, Lee et al. (2005) monitored sales of four species (*P. hypomelanus, P. alecto, Acerodon celebensis, A. humilis*) from monthly surveys of markets in North Sulawesi, and estimated sales of c. 38,000 individuals over a 2 year period from just six markets. Intensive tower netting systems used in Central Kalimantan (Indonesian Borneo) harvested as many as 4,500 *P. vampyrus* from a single location in just a month, each selling for at most US $2.20 (Struebig et al. 2007).

Thus hunting is prevalent across Southeast Asia, but the need for regional cooperation is evinced further by satellite-tracking studies of *P. vampyrus* trans-national migration patterns. Individuals collared in Peninsular Malaysia have been recorded from Sumatra, Singapore and Thailand (Epstein et al. 2007), while those from the Democratic Republic of Timor-Leste cross into Indonesia West Timor (Breed et al. 2007). This not only complicates population assessments and long-term monitoring, but also means that threats must be addressed across migration routes; protection in one locality will not necessarily secure a population if threats persists in other parts of its home range.

As a consequence of the degree of threat and lack of population data, flying fox conservation was identified as key priority action for the SEABCRU. In a few instances, there are data to support immediate conservation action. For example, in those countries where hunting is regulated by the issuance of hunting licenses, there is an opportunity to prevent further population declines by reducing the number of licenses issued, limiting the number of individuals that can be taken per license, or halting the sale of licenses altogether. In countries without such a potential control mechanism, the survival of flying fox populations may ultimately only be secured by legal protection. The success of advocacy for protected status will likely rest on the availability of population data and quantified evaluations of the degree of threat faced. Consequently the research priorities centered on: (1) determining current populations and distributions of *Pteropus* and *Acerodon* species; (2) initiating and coordinating long-term monitoring of populations across the region; (3) assessing the impact of hunting and the bushmeat trade.

It is intended that the research output based on these priorities will identify those species most in need of protection and provide a mechanism to assess the success of conservation intervention.

Taxonomic network

The importance of taxonomy to conservation is increasingly being recognized (Dubois 2003; Golding and Timberlake 2003; Mace 2004). Accurate species identifications are fundamental to biodiversity assessments based on species richness estimates, levels of endemism, and complementarity (e.g., Struebig et al. 2008a, this issue), as well as to evaluations of threat to individual species (e.g., the IUCN Red List), both of which are central concepts guiding priorities for conservation action. Taxonomic studies of Southeast Asian bats began modestly in the mid-eighteenth century, with nine species described by 1800. The nineteenth century witnessed the most dramatic increase in species discoveries, leveling off somewhat during the first half of the twentieth century. Of note is the increase in rate of discovery in the last few decades (Fig. 2), indicating that true species richness may be

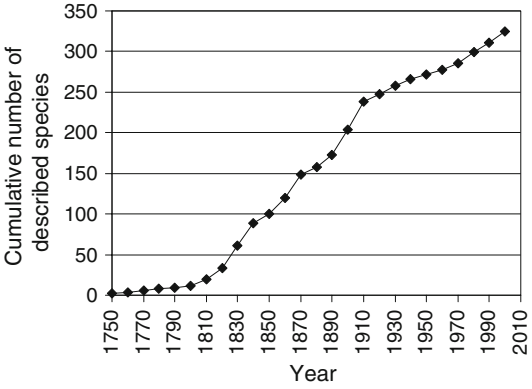

Fig. 2 Species description curve for bats from the eleven countries of Southeast Asia (Myanmar, Vietnam, Laos, Thailand, Cambodia, Malaysia, Singapore, Indonesia, Brunei, Philippines, East Timor). Species included and dates of first description are those currently recognized by Simmons (2005) or described since (as listed in "Introduction")

substantially higher than the currently recognized 330 species. The description of 14 species in the last 7 years reflects renewed survey effort in the region (e.g., Bates et al. 2000; Hendrichsen et al. 2001; Matveev 2005) and multifaceted survey approaches that employ a range of trapping techniques including mist nets, harp traps, tunnel traps (e.g., Sedlock 2001; Kingston et al. 2003). Not only have new species been discovered in areas not previously or recently studied (Bates et al. 2004, 2007b; Matveev and Csorba 2007), but they have also been found in relatively well-known localities as a consequence of greater research intensity (e.g., Francis et al. 2007a). Detailed reviews of museum collections have identified further additions (e.g., Helgen et al. 2007; Bates et al. 2007a), and the increasing use of molecular techniques is proving invaluable in elucidating hitherto hidden species diversity within cryptic species complexes (e.g., Kingston et al. 2001; Francis et al. 2007a, b) and clarifying relationships among them (Campbell et al. 2004; Thabah et al. 2006).

Nonetheless, the taxonomy of many Southeast Asian bat species remains uncertain, and one of the biggest challenges to the advancement of bat taxonomy in the region has been the constraints imposed by political boundaries. Although approximately 126 species are currently thought to be endemic to a single country, the remaining species are distributed across 2–11 countries (Fig. 3). Taxonomic resolution consequently requires mechanisms for multi-national collaboration among researchers that can coordinate taxonomic effort across Southeast Asia. The development of a Taxonomic Network was thus identified as the second SEABCRU research priority, with the specific initial remit to: (1) collate data on collections across the region; (2) establish loan protocols.

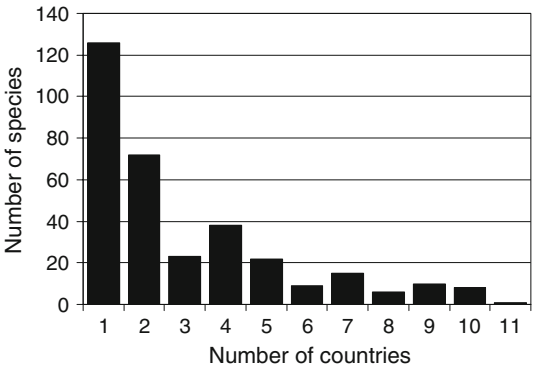

Fig. 3 Frequency of bat species occurring in one or more of the eleven countries of Southeast Asia (Myanmar, Vietnam, Laos, Thailand, Cambodia, Malaysia, Singapore, Indonesia, Brunei, Philippines, East Timor). Country occupancy derived from SAMD database (Biotani et al. 2006) and publications since SAMD assessment

Taxonomic efforts can be further advanced by recording and sharing molecular sequences of vouchered specimens. By contributing sequences to a central, public database (such as GenBank or the DNA Barcoding Initiative) researchers can greatly advance the delineation of taxonomic boundaries and enable ecologists and field workers to verify identifications for bats that are not being collected. The DNA Barcoding Initiative has a public database of sequences for over 165 Southeast Asian bat species, based on a standardized barcode of 655 base-pair segments of the Cytochrome C Oxidase subunit I gene. The barcode provides good discrimination of species and can thus be an effective tool for identifying known species, and for confirming the shared identity of specimens in different collections (Francis et al. 2007b). Small biopsies taken from the wing membrane can be readily obtained from both living and preserved individuals, but provision should be made to build local sequencing capacity to ensure the deposition of standard sequences in the database.

Conservation of cave-roosting bats

Bats spend over half their lives in roosts (Kunz 1982). Roosts provide shelter from the environment and predators, and a secure place to mate, rear young, and interact with other individuals (Kunz 1982). Caves are particularly attractive roost sites for many species because of their size, permanency and the stable microclimates they provide, and many species are highly dependent upon caves for roosting and form large aggregations. Free-tailed bats (Molossidae) roosting in the millions are known from caves around Southeast Asia [e.g., *Chaerephon plicata* in Gomantong Caves (Sabah), Mulu Cave (Sarawak), Khao Chong Pran Cave (Thailand)], but species of Rhinolophidae, Hipposideridae and Miniopterinae (Vespertilionidae) also congregate in numbers exceeding 100,000 individuals (e.g., *Miniopterus* spp., *Hipposideros larvatus*, *Rhinolophus creaghi*; Payne et al. 1985). The Pteropodidae tend to make less use of caves than do other families, presumably because species do not echolocate apart from the tongue-clicking *Rousettus*. However, several species are largely cave-dependent, most notably *Rousettus* spp., *Dobsonia* spp, *Eonycteris spelaea* and *Penthetor lucasi*.

Large complex cave systems provide an array of light and microclimate conditions and consequently harbor a great diversity of species. At least 12 species are known from Gomantong (Sabah), and Deer Cave (Mulu, Sarawak), and 19 from Niah Great Cave (Sarawak) (Abdullah et al. 2007). Although even small caves are likely to support a few bat species, it is the complex limestone karst systems that support the greatest diversity and abundance of bats (Racey 2007). These "Biodiversity Arks" (Clements et al. 2006) cover >400,000 km^2 in Southeast Asia, with particularly extensive systems in Indonesia, Thailand and Vietnam. Surveys in karst areas clearly illustrate their significance to bat diversity, with 35 species in the vicinity of the Sangkulirang karsts of Kalimantan, Indonesian Borneo (Suyanto and Struebig 2007), 33 around Kim Hy, Vietnam (Furey and Racey 2007), and 27 species around the karsts of Bohol, Philippines (Pamaong-Jose et al. 2007).

The threats to cave bats are many-fold. Direct hunting affects several species, most notably large or abundant species such as *Cheiromeles torquatus* in Borneo (Hutson et al. 2001), *Eoyncteris spelaea* in southern Palawan, Philippines (Shively 1997), *Dobsonia chapmani*, Philippines (Heaney and Heideman 1987), and *Chaerephon plicata*, in Lao PDR (Francis et al. 1999) and Cambodia (Yim Saksang, personal communication). More generally, human activities at caves for other purposes disturb bats and, if sustained, can have severe consequences for the long-term viability of the bat populations (Hutson et al. 2001). In Southeast Asia extractive visitations to collect guano or cave

swiftlet (*Collocalia fuciphagus* and *C. maximus*) nests are major causes of disturbance (Suyanto and Struebig 2007; Wiles and Brooke 2008), and in several instances are compounded by visits by tourists (Hutson et al. 2001). Regionally, quarrying of karst areas for limestone and basement minerals probably represents the greatest threats to cave-roosting species. Southeast Asia has the highest annual quarrying rates in the tropics (178 million metric tons per year) and the rate is increasing by 5.7% per year (Clements et al. 2006).

The significance of caves to bat diversity and the multitude of threats to cave populations prompted the SEABCRU forum participants to identify cave bat conservation as the third priority for action. In this instance, it is the similarity of threats across Southeast Asia that supports a regional initiative. Foremost, there is a clear need for greater cave survey effort across Southeast Asia to identify and prioritize caves supporting the highest diversity of bats or populations performing key ecological functions in the local context. The specific resolutions reflect the importance of caves to local economies and are: (1) to develop cave management recommendations that recognize scientific, cultural/religious and economic values of caves AND provide for protection of bats; (2) instigate programs to monitor populations to assess effectiveness of management approaches.

Conservation of forest-dependent bats

Habitat loss is one of the main threats to bats worldwide (Hutson et al. 2001; Racey and Entwistle 2003), and in Southeast Asia, where as much as 74% of forest may be lost by the end of the century (Sodhi et al. 2004), it is a critical issue. A substantial component of the bat fauna appears to be highly dependent on intact stands of forest for foraging and roosting (Lane et al. 2006; Struebig et al. 2008b). Many species, particularly those in the families Hipposideridae, Rhinolophidae and the vespertilionid subfamilies Murininae and Kerivoulinae, combine wing morphologies and echolocation signal designs that confer efficient foraging in densely vegetated habitats, but which are less effective in the more open habitats typical of deforested landscapes (Kingston et al. 2003; Meijaard et al. 2005). The availability of appropriate cavity roosts in both standing and fallen trees is likely to further restrict species to forest habitats (Fletcher 2006). Similarly, although a number of pteropodids are readily captured in villages, secondary habitats, and small agricultural holdings (e.g., *Cynopterus* spp.), others, including over half of the Philippines' pteropodids (Heaney et al. 1998), are found primarily in forests and are highly vulnerable to habitat loss.

The most dramatic illustration of the consequences of forest loss to bat diversity comes from Singapore which has lost 95% of its primary forest since European colonization began in the 1800s (Corlett 1992). Of the 30 species documented for the island, only 20 have been recorded in recent surveys (Pottie et al. 2005), and this is likely a gross underestimate of true species losses because extensive land-use change was already underway before bat inventories began. Estimates of percentage species lost based on the likely presence of species before colonization fall between 67 and 72%, and it is the forest-dependent species that show greatest declines (Lane et al. 2006). The surviving species are generally either insectivorous species that forage in open and edge habitats or plant-visiting species able to forage in agricultural and secondary habitats.

Little is known of the ecological requirements and population dynamics of forest-dependent bats in undisturbed forest, nor the response of forest assemblages to different land-uses. Long-term monitoring of forest-dependent insectivorous bats is being conducted at five large study plots at Krau Wildlife Reserve, Peninsular Malaysia (Kingston et al. 2006a) with studies in the surrounding landscape investigating the persistence of species in forest fragments (Struebig et al. 2008b) and oil palm plantations (T. Wood, unpublished data).

However, there is a general lack of data in dramatic contrast to the growing number of bat assemblage disturbance studies from the Neotropics (reviewed in Kingston 2009). Thus the final SEABCRU resolution identified the need for: (1) a network of long-term study sites to elucidate the dynamics of bat assemblages in undisturbed forest; (2) studies focused on the response of forest-dependent bat species to land-use change. Such data are essential to identify both priority sites for protection and species most adversely affected by anthropogenic disturbance.

Discussion

Currently, bats are among the least-known vertebrates in Southeast Asia, yet their contribution to regional biodiversity and ecosystem functioning is critical, and the threats they face substantial. The adoption of a region-wide approach to conservation research could do much to accelerate the development of in-country programs, and is particularly well-timed. Research programs in many countries are just beginning, and in others transitioning from a few pioneers to a new generation of young researchers specializing in bat biology; a regional perspective can help focus individual efforts, and collaborations enhance their success. The probability that the SEABCRU will attain its objectives is further improved by the current level and rates of development within Southeast Asia. Although internet access in the field is of course limited, most researchers have adequate coverage at their place of work, paving the way for web-based collaborations and interactions through the SEABCRU portal (http://www.seabcru.org). Physical connections among countries are also increasing with development of trans-national highways, railways (e.g., Singapore-China Rail Link) and low-cost airlines. Collaborative efforts are also facilitated by the wide-spread and increasing use of English. As the only official language of ASEAN (Association of Southeast Asian Nations) it has even been adopted as the official second language in nations with a French colonial history (Cambodia, Laos and Vietnam), and initiatives to improve proficiency are common throughout the area.

Conservation resources are limited and it is essential to prioritize activities to maximize return on effort. Typically, conservation priority-setting has fallen into two broad categories. In the first, geographical or political units with high biodiversity value are identified, based on measures that include species richness, levels of endemism (e.g., Stattersfield et al. 1998; Myers et al. 2000), extinction threat (e.g., Ricketts et al. 2005), complementarity (e.g., Struebig et al. 2008a, this issue), and phylogenetic diversity (e.g., Isaac et al. 2007). In the second, individual species are prioritized, and again prioritization can be based on a variety of measures that include degree of threat (IUCN Red Lists), phylogenetic uniqueness (e.g., McGoogan et al. 2007), and the surrogacy role of the taxon as an umbrella, flagship or indicator species.

Although these approaches provide quantitative evaluations of priority that are much-preferred by policy makers, there are a number of limitations of such "top-down" approaches that can confound their application. First, the different biodiversity measures (e.g., species richness, endemism) may not generate congruent hotspots within a taxon (Orme et al. 2005; Ceballos and Ehrlich 2006), cross-taxon congruence may be limited or scale-dependent (Grenyer et al. 2006), and species selected as surrogates may not provide adequate coverage for other biodiversity components (Andelman and Fagan 2000; Roberge and Angelstam 2004). Second, they require substantial datasets that are unavailable for many lesser-known taxa; minimally accurate distribution maps for geographical analyses and some indication of population trends or ecological role for species-centric approaches.

Third, they describe pattern rather than process, and do not typically identify systemic threats. Finally, they are limited in the extent to which they can incorporate local expert knowledge. Researchers and conservation biologists working in situ may be only too aware of the local immediate threats to their taxa, but such "general knowledge" is typically unpublished, or poorly documented, and is difficult to synthesize in meta-analyses.

The bottom-up approach taken by the SEABCRU represents an attempt to synthesize local expert knowledge and identify consensus research priorities that are both relevant across Southeast Asia and best addressed through region-wide collaboration. Expert consensus has been used to identify conservation units and priorities for the jaguar (Sanderson et al. 2002) and American crocodile (Thorbjarnarson et al. 2006) but there are few examples of consensus thematic prioritization. During the SEABCRU forum consensus was relatively easily reached because each priority proposed was generally acknowledged by forum participants to be a major problem, regardless of the specifics of individual systems. None of the suggestions focused on single-species actions nor geographical localities; rather concern centered on systemic threats to bats (hunting) and key habitats (caves, forests), and major knowledge gaps that preclude action (taxonomy of all species and distribution and population data for flying foxes). It is doubtful that conventional priority setting would identify these as key issues, yet the bottom-up consensus reached here clearly indicated that they are central to successful bat conservation in Southeast Asia.

Identifying research priorities is a much-needed first step for bat conservation in Southeast Asia, providing foci for collaborative action and fund raising. To facilitate implementation of the priorities, forum participants requested an interactive website to promote international networking and coordination of efforts, and to enable easier exchange of research and outreach materials. The SEABCRU website (http://www.seabcru.org) was launched in 2008, and provides an interactive platform for all interested parties. Outreach activities are also a critical component in bat conservation (Kingston et al. 2006b), but the cultural and linguistic diversity of Southeast Asia are such that a regional program was not deemed appropriate or practical. Rather, materials developed by individual initiatives from member countries are made available on the SEABCRU website. The similarities among taxa and the key conservation issues across the region are such that outreach workers should have relatively little difficulty adapting materials to their specific locality.

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References

Abdullah MT, Halls LS, Tissen OB et al (2007) The large bat caves of Malaysian Borneo. Bat Res News 48:99–100

Achard F, Eva HD, Stibig H-J et al (2002) Determination of deforestation rates of the world's humid tropical forests. Science 297:999–1002. doi:10.1126/science.1070656

Andelman S, Fagan WF (2000) Umbrellas and flagships: efficient conservation surrogates or expensive mistakes? Proc Natl Acad Sci USA 97:5954–5959. doi:10.1073/pnas.100126797

Bates PJJ, Tin Nwe, Pearch MJ et al (2000) A review of bat research in Myanmar (Burma) and results of a recent survey. Acta Chiropt 2:53–82

Bates PJJ, Struebig MJ, Rossiter SJ et al (2004) A new species of *Kerivoula* (Chiroptera: Vespertilionidae) from Myanmar (Burma). Acta Chiropt 6:219–226

Bates PJJ, Struebig MJ, Hayes BD et al (2007a) A new species of *Kerivoula* (Chiropteridae:Vespertilioinidae) from Southeast Asia. Acta Chiropt 9:323–337. doi:10.3161/1733-5329(2007)9[323:ANSOKC]2.0.CO;2

Bates PJJ, Rossiter SJ, Suyanto A, Kingston T (2007b) A new species of *Hipposideros* (Chiroptera: Hipposideridae) from Sulawesi. Acta Chiropt 9:13–26. doi:10.3161/1733-5329(2007)9[13:ANSOHC]2.0.CO;2

Biotani L, Catullo G, Marzetti I et al. (2006) The Southeast Asian Mammal Databank. A tool for conservation and monitoring of mammal diversity in Southeast Asia. Istituto di Ecologia Applicata, Rome. http://www.ieaitaly.org/samd. Cited 31 March 2008

Breed A, Smith CS, Meers J, Field HE (2007) Transmigrating pteropids: international movements of flying foxes: implications for conservation and introduction of disease. Bat Res News 48:133–134

Bumrungsri S, Harbit A, Benzie C et al (2007) The cave nectar bat (*Eonycteris spelaea*), is the major pollinator of Petai (*Parkia speciosa* Hassk. and *P. timoriana* Merr.) in southern Thailand. Bat Res News 48:113

Campbell P, Schneider CJ, Adnan AM et al (2004) Phylogeny and phylogeography of old world fruit bats in the *Cynopterus brachyotis* complex. Mol Phylogenet Evol 33:764–781. doi:10.1016/j.ympev.2004.06.019

Cardillo M, Mace GM, Gittleman JL, Purvis A (2006) Latent extinction risk and the future battlegrounds of mammal conservation. Proc Natl Acad Sci USA 103:4157–4161. doi:10.1073/pnas.0510541103

Ceballos G, Ehrlich PR (2006) Global mammal distributions, biodiversity hotspots, and conservation. Proc Natl Acad Sci USA 103:19374–19379. doi:10.1073/pnas.0609334103

Chuen WW, Eaton D, Dan YM (1998) Estimation of petai consumption in the Klang Valley in Peninsular Malaysia. In: Lee SS, Dan, YM, Gauld I, Bishop J (eds) Conservation, management and development of forest resources. Proceedings of the Malaysia–UK Programme Workshop 21–24 October 1996. Forest Research Institute Malaysia, Kepong, pp 212–226

Clements R, Sodhi NS, Schilthuizen M, Ng PKL (2006) Limestone karst of Southeast Asia: imperiled arks of biodiversity. Bioscience 56:733–742. doi:10.1641/0006-3568(2006)56[733:LKOSAI]2.0.CO;2

Cleveland CJ, Betke M, Federico P et al (2006) Economic value of the pest control service provided by Brazilian free-tailed bats in south-central Texas. Front Ecol Environ 4:238–243. doi:10.1890/1540-9295(2006)004[0238:EVOTPC]2.0.CO;2

Corlett RT (1992) The ecological transformation of Singapore, 1819–1900. J Biogeogr 19:411–420. doi:10.2307/2845569

Corlett RT (1998) Frugivory and seed dispersal by vertebrates in the oriental (Indomalayan) region. Biol Rev Camb Philos Soc 73:413–448. doi:10.1017/S0006323198005234

Corlett RT (2004) Flower visitors and pollination in the oriental (Indomalayan) region. Biol Rev Camb Philos Soc 79:497–532. doi:10.1017/S1464793103006341

Cox PA, Elmqvist T, Pierson ED, Rainey WR (1991) Flying foxes as strong interactors in south Pacific island ecosystems: a conservation hypothesis. Conserv Biol 5:448–454. doi:10.1111/j.1523-1739.1991.tb00351.x

Csorba G, Bates PJJ (2005) Description of a new species of *Murina* from Cambodia (Chiroptera: Vespertilionidae: Murininae). Acta Chiropt 7:147–163. doi:10.3161/1733-5329(2005)7[1:DOANSO]2.0.CO;2

Csorba G, Thong VD, Bates PJJ, Furey NM (2007) Description of a new species of *Murina* from Vietnam (Chiroptera: Vespertilionidae: Murininae). Museum of Texas Tech University, Occasional Papers No. 268

Dubois A (2003) The relationships between taxonomy and conservation biology in the century of extinctions. C R Biol 326(Suppl 1):S9–S21

Epstein JH, Olival KJ, Smith C et al (2007) Hunting, international movement, and the need for regional conservation of flying foxes (*Pteropus* spp.). Bat Res News 48:104–105

Esselstyn JA (2007) A new species of stripe-faced fruit bat (Chiroptera: Pteropodidae: *Styloctenium*) from the Philippines. J Mammal 88:951–958. doi:10.1644/06-MAMM-A-294R.1

Fletcher CD (2006) Roosting ecology of insectivorous bats in Krau Wildlife Reserve, Pahang, Peninsular Malaysia. Dissertation, Universiti Kebangsaan Malaysia

Francis CM, Guillén A, Robinson MF (comps) (1999) Order Chiroptera: Bats. In: Duckworth JW, Salter RE, Khounboline K (eds) Wildlife in Lao PDR: 1999 Status Report. IUCN, WCS and CPAWM, Vientiane, Lao PDR pp 225–235

Francis CM, Kingston T, Zubaid A (2007a) A new species of *Kerivoula* (Chiroptera: Vespertilionidae) from Peninsular Malaysia. Acta Chiropt 9:1–12. doi:10.3161/1733-5329(2007)9[1:ANSOKC]2.0.CO;2

Francis CM, Guillén-Servent A, Borisekno AV et al (2007b) Use of DNA barcodes to understand Southeast Asian bat diversity. Bat Res News 48:103

Fujita MS, Tuttle MD (1991) Flying foxes (Chiroptera: Pteropodidae): threatened animals of key ecological and economic importance. Conserv Biol 5:455–463. doi:10.1111/j.1523-1739.1991.tb00352.x

Furey NM, Racey PA (2007) Community composition of bat assemblages in a Vietnamese karst protected area. Bat Res News 48:98–99
Golding JS, Timberlake J (2003) How taxonomists can bridge the gap between taxonomy and conservation science. Conserv Biol 17:1177–1178. doi:10.1046/j.1523-1739.2003.02404.x
Grenyer R, Orme DL, Jackson SF et al (2006) Global distribution and conservation of rare and threatened vertebrates. Nature 444:93–96. doi:10.1038/nature05237
Guillén-Servent A, Francis CM (2006) A new species of bat of the *Hipposideros bicolor* group (Chiroptera: Hipposideridae) from Central Laos, with evidence of convergent evolution with Sundaic taxa. Acta Chiropt 8:39–61. doi:10.3161/1733-5329(2006)8[39:ANSOBO]2.0.CO;2
Gumal MT (2001) Ecology and conservation of a fruit bat in Sarawak. Dissertation, University of Cambridge, England
Heaney LR, Heideman PD (1987) Philippine fruit bats: endangered and extinct. Bats 5:3–5
Heaney LR, Balete DS, Dolar ML et al (1998) A synopsis of the mammalian fauna of the Philippine Islands. Fieldiana Zool N Ser 88:1–61
Helgen KM, Kock D, Comez RKSC et al (2007) Taxonomy and natural history of the Southeast Asian fruit bat genus *Dyacopterus*. J Mammal 88:302–318. doi:10.1644/06-MAMM-A-276R.1
Hendrichsen DK, Bates PJJ, Hayes BD, Walston JL (2001) Recent records of bats (Mammalia: Chiroptera) from Vietnam with six species new to the country. Myotis 39:35–122
Hutson AM, Mickleburgh SP, Racey PA (2001) Microchiropteran bats: global status survey and action plan. IUCN/SSC Chiroptera Specialist Group, IUCN, Gland, Switzerland (comps)
Isaac NJB, Turvey ST, Collen B, Waterman C, Baillie JEM (2007) Mammals on the EDGE: conservation priorities based on threat and phylogeny. PLoS ONE 2:e296. doi:10.1371/journal.pone.0000296
Khin Maung Lwin (1995) Non-wood forest products in Myanmar. In: Durst PB, Bishop A (eds) Beyond timber: social, economic and cultural dimensions of nonwood forest products in Asia and the Pacific. Proceedings of the Regional Expert Consultation, Bangkok 28 November to 2 December 1994. FAO, RAP Publication 1995/13, Bangkok. http://www.fao.org/docrep/X5336E/X5336E00.HTM. Cited 31 Mar 2008
Kingston T (2009) Analysis of species diversity of bat assemblages. In: Kunz TH, Parsons S (eds) Behavioral and ecological methods for the study of bats. Smithsonian Institution Press, Washington (in press)
Kingston T, Lara MC, Jones G et al (2001) Acoustic divergence in two cryptic *Hipposideros* species: A role for social selection? Proc R Soc Lond B Biol Sci 268:1381–1386
Kingston T, Francis CM, Zubaid A, Kunz TH (2003) Species richness in an insectivorous bat assemblage from Malaysia. J Trop Ecol 19:67–79
Kingston T, Lim BL, Zubaid A (2006a) Bats of Krau Wildlife Reserve. University Kebangsaan Malaysia, Bangi
Kingston T, Zubaid A, Lim G, Hatta F (2006b) From research to outreach: environmental education materials for the bats of Malaysia. In: Proceedings of the best of both worlds international conference on environmental education for sustainable development 2005. FRIM, Kuala Lumpur
Kunz TH (1982) Roosting ecology. In: Kunz TH (ed) Ecology of bats. Plenum, New York, pp 1–55
Lane DJW, Kingston T, Lee BPY-H (2006) Dramatic decline in bat species richness in Singapore, with implications for Southeast Asia. Biol Conserv 131:584–593. doi:10.1016/j.biocon.2006.03.005
Lee RJ, Gorog AJ, Dwiyahreni A et al (2005) Wildlife trade and implications for law enforcement in Indonesia: a case study from North Sulawesi. Biol Conserv 123:477–488. doi:10.1016/j.biocon.2005.01.009
Leelapaibul W, Bumrungsri S, Pattanawiboon A (2005) Diet of wrinkle-lipped free-tailed bat (*Tadarida plicata* Buchannan, 1800) in central Thailand: insectivorous bats potentially act as biological pest control agents. Acta Chiropt 7:111–119. doi:10.3161/1733-5329(2005)7[111:DOWFBT]2.0.CO;2
Lim TK (1998) Durian. In: Hyde KW (ed) The new rural industries: a handbook for farmers and investors. Rural Industries Research and Development Corporation, Australia, pp 279–285
Lyon MW (1911) Mammals collected by Dr. W. L. Abbott on Borneo. Proc US Nat Mus 40:53–146
Mace GM (2004) The role of taxonomy in species conservation. Philos Trans R Soc Lond B Biol Sci 359:711–719. doi:10.1098/rstb.2003.1454
Marshall AG (1983) Bats, flowers and fruit: evolutionary relationships in the old world. Biol J Linn Soc Lond 20:115–135. doi:10.1111/j.1095-8312.1983.tb01593.x
Marshall AG (1985) Old world phytophagous bats (Megachiroptera) and their food plants: a survey. Zool J Linn Soc 83:351–369. doi:10.1111/j.1096-3642.1985.tb01181.x
Matveev VA (2005) Checklist of Cambodian bats (Chiroptera), with new records and remarks on taxonomy. Russ J Theriol 4:43–62
Matveev VA, Csorba G (2007) Bat fauna of Cambodia. Bat Res News 48:100
Meijaard E, Sheil D, Nasi R et al (2005) Life after logging: reconciling wildlife conservation and production forestry in Indonesian Borneo. Center for International Forestry Research, Bogor
McConkey KR, Drake DR (2006) Flying foxes cease to function as seed dispersers long before they become rare. Ecology 87:271–276. doi:10.1890/05-0386

McGoogan K, Kivell T, Hutchison M et al (2007) Phylogenetic diversity and the conservation biogeography of African primates. J Biogeogr 34:1962–1974. doi:10.1111/j.1365-2699.2007.01759.x
Mohd.-Azlan J, Zubaid A, Kunz TH (2001) The distribution, relative abundance, and conservation status of the large flying fox, *Pteropus vampyrus*, in Peninsular Malaysia: a preliminary assessment. Acta Chiropt 3:149–162
Mickleburgh SP, Hutson AM, Racey PA (1992) Old World Fruit Bats: An Action Plan for their Conservation. International Union for the Conservation of Nature and Natural Resources, Gland
Mickleburgh SP, Hutson AM, Racey PA (2002) A review of the global conservation status of bats. Oryx 36:18–34. doi:10.1017/S0030605302000054
Myers N, Mittermeier RA, Mittermeier CG et al (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858. doi:10.1038/35002501
Orme DL, Davies RG, Burgess M et al (2005) Global hotspots of species richness are not congruent with endemism or threat. Nature 436:1016–1019. doi:10.1038/nature03850
Pamaong-Jose R, Ramayla SP, Granert WG, Cariño AP (2007) Conservation of bats in Karst areas of Bohol Island, Philippines. Bat Res News 48:99
Payne J, Francis CM, Phillipps K (1985) A field guide to the mammals of Borneo. Sabah Society and World Wildlife Fund Malaysia, Kota Kinabalu
Pottie SA, Lane DJW, Kingston T, Lee BPYH (2005) The microchiropteran bat fauna of Singapore. Acta Chiropt 2:237–247. doi:10.3161/1733-5329(2005)7[237:TMBFOS]2.0.CO;2
Racey PA (2007) The role of karst in the conservation of bat biodiversity. Bat Res News 48:98
Racey PA, Entwistle AC (2003) Conservation ecology of bats. In: Kunz TH, Fenton MB (eds) Bat ecology. University of Chicago Press, Chicago, pp 680–743
Rainey WE, Pierson ED, Elmqvist T, Cox P (1995) The role of flying foxes (Pteropodidae) in oceanic island ecosystems of the Pacific. In: Racey PA, Swift S (eds) Ecology, evolution and behaviour of bats. Clarendon Press, Oxford, pp 47–59
Ricketts TH, Dinerstein E, Boucher T et al (2005) Pinpointing and preventing imminent extinctions. Proc Natl Acad Sci USA 102:18497–18501. doi:10.1073/pnas.0509060102
Roberge JM, Angelstam P (2004) Usefulness of the umbrella species concept as a conservation tool. Conserv Biol 18:76–85. doi:10.1111/j.1523-1739.2004.00450.x
Sanderson E, Redford KH, Chetkiewicz C-LB et al (2002) Planning to save a species, the jaguar as a model. Conserv Biol 16:58–72. doi:10.1046/j.1523-1739.2002.00352.x
Sedlock JL (2001) Inventory of insectivorous bats on Mount Makiling, Philippines using echolocation call signatures and a new tunnel trap. Acta Chiropt 3:163–178
Shilton LA, Altringham JD, Compton SG, Whittaker RJ (1999) Old world fruit bats can be long-distance seed dispersers through extended retention of viable seeds in the gut. Proc R Soc Lond B Biol Sci 266:219–223. doi:10.1098/rspb.1999.0625
Shively GE (1997) Poverty, technology, and wildlife hunting in Palawan. Environ Conserv 24:57–63. doi:10.1017/S0376892997000106
Simmons N (2005) Chiroptera. In: Wilson DE, Reeder DM (eds) Mammal species of the World: a taxonomic and geographic reference. John Hopkins University Press, Baltimore, pp 312–529
Sodhi NS, Brook BW (2006) Southeast Asian biodiversity in crisis. Cambridge University Press, Cambridge
Sodhi NS, Koh LP, Brook BW, Ng PKL (2004) Southeast Asian biodiversity: an impending disaster. Trends Ecol Evol 19:654–660. doi:10.1016/j.tree.2004.09.006
Srithongchuay T, Bumrungsri S (2007) Does pollination success of *Oroxylum indicum* Vent. (Bignoniaceae) depend solely on the nectarivorous bat, *Eonycteris spelaea* Dobson (Chiroptera: Pteropodidae)? Bat Res News 48:112–113
Stattersfield AJ, Crosby MJ, Long AJ, Wege DC (1998) Endemic bird areas of the world: priorities for biodiversity conservation. BirdLife International, Cambridge
Struebig MJ, Harrison ME, Cheyne SM, Limin S (2007) Intensive hunting of large flying-foxes *Pteropus vampyrus natunae* in Central Kalimantan, Indonesian Borneo. Oryx 41:390–393. doi:10.1017/S0030605307000310
Struebig MJ, Christy L, Pio D, Meijaard E (2008a) Bats of Borneo: diversity, distributions and representation in protected areas. Biol Conserv (Special Issue) (in review)
Struebig MJ, Kingston T, Zubaid A et al (2008b) Conservation value of forest fragments to palaeotropical bats. Biol Conserv 141:2112–2126. doi:10.1016/j.biocon.2008.06.009
Suyanto A, Struebig MJ (2007) Bats of the Sangkulirang limestone karst formations, East Kalimantan—a priority region for Bornean bat conservation. Acta Chiropt 9:67–95. doi:10.3161/1733-5329(2007)9[67:BOTSLK]2.0.CO;2

Thabah A, Rossiter SJ, Kingston T et al (2006) Genetic divergence and echolocation call frequency in cryptic species of *Hipposideros larvatus sensu lato* (Chiroptera: Hipposideridae) from the Indo-Malayan region. Biol J Linn Soc Lond 88:119–130. doi:10.1111/j.1095-8312.2006.00602.x

Thorbjarnarson J, Mazzotti F, Sanderson E et al (2006) Regional habitat conservation priorities for the American crocodile. Biol Conserv 128:25–36. doi:10.1016/j.biocon.2005.09.013

Whittaker RJ, Jones SH (1994) The role of frugivorous bats and birds in the rebuilding of a tropical forest ecosystem, Krakatau, Indonesia. J Biogoegr 245:245–258. doi:10.2307/2845528

Wiles GJ, Brooke AP (2008) Conservation threats to bats in the tropical Pacific islands and insular Southeast Asia. In: Fleming TH, Racey P (eds) Island bats: evolution, ecology and conservation. University of Chicago, Chicago (in press)

Yoshiyuki M, Lim BL (2005) A new horseshoe bat, *Rhinolophus chiewkweeae* (Chiroptera, Rhinolophidae), from Malaysia. Bull Natl Sci Mus Ser A 31:29–36