metadata, citation and similar papers at core.ac.uk
brought to you by CO
provided by UKM Journal Article Rep

THE MALAYSIAN BAT CONSERVATION RESEARCH UNIT: FROM A NATIONAL MODEL TO AN INTERNATIONAL NETWORK

KINGSTON, T.[1*], JULIANA, S.[1,2], NURUL-AIN, E.[3], HASHIM, R.[4] and ZUBAID, A.[5]

[1]*Department of Biological Sciences, Texas Tech University, Lubbock, Texas 79409, USA*
[2]*Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia.*
[3]*School of Biological Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia.*
[4]*Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia.*
[5]*School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia.*
[*]*Email: tigga.kingston@ttu.edu*

ABSTRACT

To have even a small chance of averting the crisis decimating Southeast Asian biodiversity, conservation researchers and practitioners need to provide policy makers with information that can guide their decisions. Particularly needed are realistic projections of the responses of diversity to different planning or policy decisions, and the attendant ecological and economic consequences of these responses. Unfortunately, there is a substantial short-fall between the information needed and our capacity to provide it, but we suggest that collaborative efforts that integrate research, capacity building and outreach can both accelerate knowledge development and transfer within the research community, and promote public understanding and appreciation of biodiversity, particularly of low-profile or unpopular taxa. The Malaysian Bat Conservation Research Unit (MBCRU) was established in 2001 to promote the conservation of Malaysia's unique but threatened bat diversity through long-term conservation research, capacity building and outreach. Here we summarize the main activities of this integrated program, and trace the scale-up of the MBCRU model to the regional level with the launch in 2007 of the Southeast Asian Bat Conservation Research Unit (SEABCRU).

Key words: Chiroptera, biodiversity research, capacity building, outreach, networks, SEABCRU

INTRODUCTION

Southeast Asia is one of the most biologically rich regions of the world, but rapid rates of land-use conversion in recent decades have precipitated an internationally recognized biodiversity crisis, with high levels of observed and projected species extinctions (Sodhi *et al.,* 2004, 2010a,b; Lane *et al.,* 2006). With less than 10% of forests in protected areas (Sodhi *et al.,* 2010a), biotic sustainability will ultimately hinge on species' ability to persist in human-modified landscapes, but our knowledge of the immediate and long-term response of most taxa to different disturbance regimes is limited by the paucity of studies (Sodhi *et al*., 2010b). Beyond the constraints imposed by limited funding opportunities, research effort has often been hindered by the lack of in-country capacity to implement research, particularly for species-rich, but conventionally "uncharismatic" taxa such as bats, rodents, reptiles, and amphibians. Moreover, political and public interest in these groups is often minimal or negative, which can affect both *in situ* conservation efforts, and funding and policy decisions.

The bats of Southeast Asia exemplify this situation. They are a highly diverse group; with 343 species described to date, they comprise over a quarter of the global bat fauna, and can make up more than half the mammal species in the region's rainforest ecosystems (Kingston *et al.,* 2003). Populations are severely threatened by habitat loss, logging, hunting, and quarrying of or disturbance at cave roosts, and only 18% of populations are considered by the IUCN to be stable (Kingston, *in press*). Although there have been a growing number of taxonomic and phylogenetic papers in recent years, inventories of bat diversity in undisturbed

* To whom correspondence should be addressed.

habitats are scattered and often incomplete and there remains little published research on the response of bat diversity to anthropogenic land uses (see Kingston, *in press* for review).

Within Southeast Asia, Malaysia is a pivotal country for bat conservation. Simmons (2005) recognized 109 species from Peninsular Malaysia, 94 from Sabah and 76 from Sarawak. With the recent descriptions of *Rhinolophus chiewkweeae* (Yoshiyuki & Lim, 2005) and *Kerivoula krauensis* (Francis *et al.,* 2007) from the Peninsula, and publications from Sarawak (Jayaraj *et al.,* 2006; Khan *et al.,* 2008; Sazali *et al.,* 2011) the national total is 133, and the Sarawak count 84. This represents over 10% of the world's bat fauna, and about 40% of Malaysian mammal species. Doubtless this is an underestimate of true species richness, as genetic analyses continue to uncover hitherto cryptic species or identify distinct lineages which have yet to be described (e.g., Kingston *et al.,* 2001; Campbell *et al.,* 2004; Khan *et al.,* 2010; Wiantoro *et al.,* 2012).

Although only 18% of Malaysian species are considered Threatened or Near Threatened (IUCN, 2012), populations are decreasing in 26% of species and stable in only 15%. Critically for long-term planning and research prioritization, the population trends of 77 species (58%) are unknown (IUCN, 2012). Threats contributing to declines were identified by expert assessors in 30% of species, and, as in the rest of Southeast Asia, the primary threats to species are habitat loss and degradation through logging (Figure 1). Although the prevalence of hunting was proportionally less than across Southeast Asia as a whole (see Kingston, *in press*), hunting pressure on individual species can be severe. Estimated from license sales between 2002 and 2005, hunting of the world's largest bat, *Pteropus vampyrus,* in Peninsular Malaysia exceeds 22,000 bats per year. Population models indicate that this level of hunting is unsustainable, even assuming a highly optimistic starting population of 500,000, and in fact only a population of over 900,000 can support the estimated hunting levels. Moreover, projected time to extinction in Peninsular Malaysia ranges from six years if annual survival probability in the absence of hunting is very high (0.95), initial equilibrium population is 50,000 individuals, and there is a constant total annual removal of 22,000 bats, through to 81 years with the same constant removal but a starting population of 250,000 individuals and an annual survival probability of 0.85 (Epstein *et al.,* 2009). The projected outcomes of these models are heavily

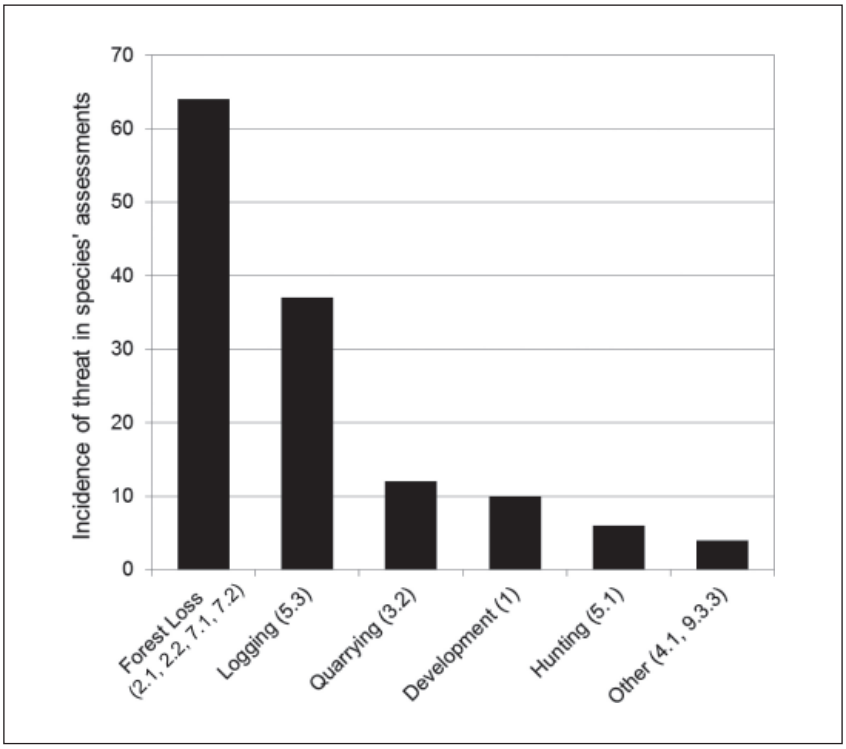

Fig. 1. Frequency of threats listed in IUCN assessments of Malaysian bat species. The listed categories are derived from the IUCN hierarchical classification, with the classification code or codes listed in parentheses – 2.1: annual and perennial non-timber crops, 2.2: wood and pulp plantations, 7.1: fire and fire suppression, 7.2: dams, 5.3: logging and wood harvesting, 3.2: mining and quarrying, 5.1: hunting and trapping terrestrial animals, 4.1: roads and railways, 9.3.3: herbicides and pesticides.

dependent on the initial equilibrium population, and comprehensive population counts are urgently needed. Because of the mobility of *Pteropus vampyrus,* this would be best achieved with a coordinated national and international effort.

Not only is the erosion of Malaysia's bat diversity of inherent conservation concern, but declines in local species richness and abundance are likely to have profound effects on critical ecosystem services that bats provide as insect predators, pollinators and seed dispersers and which underpin forest regeneration (Hodgkison *et al.,* 2003), the sustainability of commercial fruit crops (Bumrungsri *et al.,* 2008, 2009), and control of insect crop pests (Leelapaibul *et al.,* 2005). More than 31 economically important plants in Malaysia rely upon bats to pollinate flowers or disperse seeds (e.g. durian, banana, petai, mango, jackfruit, papaya, kapok), and Malaysian exports of durian in 2011 were valued at nearly US$9 million (United Nations Trade Commodity Database 2012), and are likely to increase substantially with the recent opening of durian trade with China. This industry hinges on the pollination services of bats, primarily the Dawn Cave Bat, *Eoncyteris spelaea* (Start & Marshall, 1975; Bumrungsri *et al.,* 2009). Currently a common and wide-spread species, *E. spelaea* is an obligate cave-roosting species and as such is vulnerable to disturbance at or loss of karst systems. It is also the most effective pollinator of another valuable Malaysian favorite, petai (Bumrungsri *et al.,* 2008).

THE MALAYSIAN BAT CONSERVATION RESEARCH UNIT

The Malaysian Bat Conservation Research Unit (MBCRU) was established in 2001 to promote the conservation of Malaysia's unique bat fauna. It was launched by the Director General of the Department of Wildlife and National Parks in his opening address to the 12th International Bat Research Conference in Kuala Lumpur, 5th August 2001, and is a collaboration between Universiti Kebangsaan Malaysia, University of Malaya, Texas Tech University (USA) and the Department of Wildlife and National Parks. The primary objectives of the unit are: long-term research on bat diversity and conservation; capacity building, specifically the development and acquisition of skills by young Malaysian scientists through workshops, internships and student support; and environmental education to highlight the diversity and biology of bats, as well as the international importance of Malaysia to bat conservation. Below we outline the primary activities and achievements of the MBCRU over the last decade with particular reference to these objectives.

RESEARCH: BAT DIVERSITY IN UNDISTURBED AND ANTHROPOGENIC LANDSCAPES

Our research is conducted in and around Krau Wildlife Reserve (KWR), Pahang, the oldest and second-largest protected area in Peninsular Malaysia, with c. 63,000 ha of largely undisturbed rainforest embedded in a landscape dominated by rubber and oil-palm plantations. Although KWR is home to at least 70 species (about 60% of the Peninsula's bat fauna) and boasts the highest diversity of bats known from a single locality in the Old World (Kingston *et al.,* 2006a), efforts have focused on over 30 species of insectivorous bats of the rainforest interior, as this ensemble is predicted to be particularly vulnerable to forest degradation (Kingston *et al.,* 2003).

The central MBCRU research goal has been to understand how forest-interior bat diversity functions in relatively unmodified habitat, so that we can develop and test predictive frameworks of species' vulnerability to anthropogenic disturbance (Kingston *et al.,* 2006b). We ask whether all bats are equally affected by habitat degradation, loss and conversion, and whether it is possible to build vulnerability or risk profiles that predict which species, or groups of species, will be most resilient or susceptible to land-use change. Candidate ecological determinants of extinction risk that could contribute to the profiles include abundance, local and landscape spatial distribution patterns, life history characteristics and reproductive phenology, degree of specialization in diet and roost choice, longevity and population turnover rates, and landscape and temporal population variability (Kingston *et al.,* 2006b). Predictive frameworks are something of a holy grail for conservation biologists, as they have the potential to guide intervention and conservation action before populations decline, but this is an ambitious research goal, and progress has inevitably reflected the opportunities and constraints of particular funding agencies. Consequently, the summary of research below is organized by funding periods and the primary research activity supported.

Conceptual advances in spatio-temporal community dynamics: National Science Foundation (2001-2005)

The initial (and largest) award, which allowed for the establishment of the MBCRU, was from the Population and Community Ecology Program (part of the Division of Environmental Biology, Directorate of Biology) and the East Asia and Pacific Program of the National Science Foundation (NSF). NSF is an independent U.S. government agency responsible for promoting non-medical science and engineering through support of

fundamental research programs. The agency places great emphasis on conceptual or theoretical advances in science which it evaluates under its "intellectual merit" criteria. Consequently, purely applied conservation projects are not supported, and the challenge for conservation biologists is to identify research directions that will make novel intellectual contributions to the field (ecology in this case), but have conservation applications. The funded project (entitled "Spatial Determinants of Insectivorous Bat Diversity: Pattern and Process in a Paleotropical Rain Forest") emphasized the synthesis of community dynamics across spatial and temporal scales, one of the stated interests of the Population and Community Ecology Program.

The research aimed to establish the extent of natural variability in bat species richness and assemblage composition within the large, contiguous, undisturbed rainforest of KWR at the landscape scale (across five spatially-independent replicate 1 km^2 study grids), local scale (trap sites along trail networks (14-22 km) within each study grid), and across time (each grid surveyed a minimum of four times) (Kingston *et al.,* 2006a,b; Rossiter *et al.,* 2012). Preliminary analyses suggest that although species richness varies very little at a grid across surveys (limited temporal variability), and relatively little across the landscape, there are major *compositional* differences at the landscape scale that are driven primarily by cave-roosting species (see Kingston, *in press* for review). Spatial analyses of species distributions within a study grid (local scale) are still in progress, but together the emerging landscape and local patterns provide for explicit tests of assertions (e.g. spatial clustering of species, spatial independence of species) thought to underpin unified theories of biodiversity (McGill, 2010).

Applied recommendations include: i) surveys of large unmodified habitats should make every effort to sample multiple spatially-independent sites if species composition rather than species richness alone is of interest; ii) landscape features (e.g. caves) need to be considered in management plans for bat diversity (see also Struebig *et al.,* 2009), and iii) researchers need to be aware of the influence of caves on assemblage composition in disturbance studies (Kingston, *in press*). The study was also designed to generate data that could feed into the vulnerability profiles, particularly abundance data (rare species are predicted to be more susceptible to disturbance than abundant species), spatial patterns at local and landscape scales (patchily distributed species are more likely to be lost by passive sampling effects as habitats become fragmented or reduced, particularly if clustering is associated with dependence/specialization on a limited or a disjunct resource such as a roost), and population fluctuations (populations that fluctuate substantially over time can be vulnerable to extinction processes when population size is low).

Continued surveys and roosting ecology: National Geographic Society (2006) & Earthwatch Institute (2002 – 2007)

The logistical challenge of the grid surveys, with each survey taking up to three months, meant that the target of four surveys per grid was not met by the end of the NSF funding period. Conservation-oriented support from National Geographic Society (2006) and Earthwatch Institute (2002-2010) enabled the survey work to continue, and funded radio-telemetry studies of the roosting ecology of three contrasting bat species that did not rely upon caves for roosts (Fletcher 2006). Financial constraints (each transmitter costs over USD 100 and lasts < 3 weeks), and the small size of many of the bat species (transmitters shouldweigh< 5% of the bat's body mass) precluded coverage of more species, but the findings supported the idea that while most species are quite selective in their roost choice, it is the availability of their preferred choice that drives local and landscape distribution patterns. Thus cave-dependent bats are highly patchy at the landscape level, but species using forest structures for roosts (cavities, hollows, leaves) show less variance in abundance at this scale (Kingston, *in press*). At the local scale, species selecting low-density limited resources (e.g., large fallen hollow trees) are predicted to be more at risk than those selecting widely-available roosts (e.g. understory palm or rattan leaves), as low roost availability may limit population size in degraded habitats (e.g. those lacking large tree classes) or small fragments (where number of large trees is limited).

Surveys, education and reproductive phenology: Texas Tech University (2007-2009) & British American Tobacco Biodiversity Fund (2008 – 2010)

In 2008, major funding was received from the Vice President for Research's Office at Texas Tech University in support of an Education Research Initiative "The Malaysian Bat Education Adventure", which developed and piloted the first module (Biodiversity) of a learning progression for evolution for 10 and 11 year-olds (detailed further in OUTREACH AND EDUCATION). This support, with that of BAT Biodiversity Partnership which funded fellowships for young Southeast Asian researchers to join the project for 1 month, enabled completion of the fourth round of surveys of the five study grids in 2008. Thereafter surveys were continued at a single site (Kuala Lompat), to facilitate the education project, and to provide for repeated assessments of reproductive condition for

a 20-month study of reproductive phenology (PhD research of N-AE). Reproductive condition of females had been evaluated from external indicators throughout the survey work (Kingston *et al.,* 2006b), but this study assesses the relationship between reproductive phenology, diet, insect availability and local weather patterns to provide a basis for exploring the consequences of climate changes for bat populations. Life history is an important predictor of extinction vulnerability; as a group bats are long-lived, most commonly breed just once a year, and give birth to a single young (Kunz & Pierson 1994). Consequently, they have low intrinsic rates of population increase and are predicted to recover slowly from disturbances that decrease population size. However, very little is known of interspecific differences in life history and reproductive phenology in tropical bats, yet this may ultimately influence differential persistence or recovery in disturbed systems. For example, species that breed aseasonally, and/or have more than one breeding cycle per year should be better able to recover or maintain their numbers than those with limited seasonal breeding.

Roosting ecology and abundance influence persistence in fragmented landscapes: Natural Environment Research Council (NERC) (2003-2007)

Funding from the UK's Natural Environment Research Council to Stephen Rossiter and Matthew Struebig provided the opportunity to survey 27 forest fragments in the landscape surrounding KWR for comparison with the intact KWR assemblages and to test some of proposed ecological correlates of extinction risk. As might be expected, species richness of the forest-interior ensemble was reduced by fragmentation, and correlated negatively with fragment size (Struebig *et al.,* 2008). Moreover, this pattern was driven by the loss of forest-roosting species, those that roost in foliage and tree cavities, tend to forage within close proximity of their roosts, and avoid the forest edge (Shariff, 2003; Allen, 2005; Fletcher, 2006). Within the forest-roosting species, there was a modest, but significant correlation ($p = 0.003$, $R^2 = 0.389$) between the number of fragments occupied by a species, and its capture rate (an index of abundance) in the unmodified forests of KWR (TK unpublished data). Furthermore, a parallel decline in genetic diversity (measured as allelic richness) was observed in fragment populations of two of the forest-roosting species (Struebig *et al.,* 2011). In contrast, species richness of cave-roosting species was independent of fragment size, there was no relationship between number of fragments occupied and abundance in KWR, and allelic richness of the cave-roosting *Rhinolophus lepidus* captured in fragments did not differ from those captured in the continuous forest of KWR.

Roost choice and abundance in unmodified habitat are thus two ecological factors that do appear to influence species representation in the forest fragments around KWR. Future work will focus on characterizing and integrating other predictors (e.g., life history characteristics, dietary breadth, spatio-temporal stability of populations, ecomorphology) into vulnerability profiles and will assess the relative power of different predictors in explaining species persistence in different land uses (e.g. oil palm and rubber plantations, secondary forest (PhD research JS)). Because we are essentially identifying ecological trait combinations that confer vulnerability, or describing "vulnerability ecotypes", it is hoped that our findings can be applied to bat assemblages throughout the region even if the species differ. This seems likely because forest-interior bat assemblages are very similar throughout Southeast Asia (dominated by families Hipposideridae, Rhinolophidae, Kerivoulinae and Murininae). Moreover, because local species richness is highest in Malaysia it is probable that other assemblages comprise a subset of the ecotypes found in KWR.

CAPACITY BUILDING: DEVELOPING IN-COUNTRY EXPERTISE THROUGH IMMERSION IN RESEARCH

Since 1997, merit review of NSF proposals has emphasized two components: "intellectual merit" with the requirement of transformative or novel contributions to science; and "broader impacts" of the project on society at large. It was under the "broader impacts" statement of the 2001 NSF proposal that the capacity building and outreach components of the MBCRU were supported. NSF support for capacity building included full support (tuition, stipend, field work) for three local masters students and 1 PhD student registered at UKM, and the development and implementation of a five-day capacity building workshop "Bat Identification and Survey Techniques" conducted three times between 2002 and 2004, with over 50 participants primarily drawn from DWNP officers, NGO staff, and students. Later support from Earthwatch Institute and the BAT Biodiversity Fund broadened participation by providing 2-week to one-month fellowships on the research project to young researchers from NGO's within Malaysia, and institutes around Southeast Asia (c. 30 fellows from 10 countries), and ten Malaysian undergraduates on 10-week industrial training placements also participated in the

MBCRU's research. Graduate students sponsored by the project now hold positions with DWNP, FRIM, UKM, USM and the Forestry Department (Indonesia), and two Malaysian PhD students (co-authors JS and N-AE) are currently registered at Texas Tech University (with TK). Most of the international fellows remained networked with the MBCRU, and many play a key role in the Southeast Asian Bat Conservation Research Unit (see below).

Lack of technical materials, particularly field guides, systematic keys and guidance on field methods can also hamper research capacity. Notably, the last field guide for Peninsular Malaysia was published in 1983 (Medway, 1983), and lacked some 27 currently known bat species. This lead to publication of "The Bats of Krau Wildlife Reserve" by UKM Press (Kingston *et al.,* 2006a) which provides a photographically illustrated key to external features for all bats (known at that time) of Peninsular Malaysia, and full species accounts (description and ecology) for the ~70 species of KWR. In addition, the MBCRU developed and disseminated a manual that described bat handling techniques, species identification using dichotomous keys, survey methods, data collection protocols, and specimen preparation.

OUTREACH AND EDUCATION: ENVIRONMENTAL EDUCATION IN MALAYSIA AND FORMAL EDUCATION RESEARCH IN THE US

The first objective of the MBCRU outreach program was to determine the baseline awareness of the diversity and importance of bats to Malaysia to guide the development of the MBCRU EEP. In response to the general lack of public awareness revealed by over 200 interviews (Kingston *et al.,* 2006b,c), the strategy of the MBCRU EEP has been to emphasize three key elements: the diversity of bats in Malaysia; their ecological and economic role in the country; and their vulnerability to habitat loss and hunting (Kingston *et al.,* 2006b). The materials are designed to not only inform the public of the pertinent facts and knowledge, but to raise public empathy and liking for bats, primarily through familiarization and by correcting misconceptions and myths. Moreover, as the materials were being developed by research scientists, our goal was to tie educational content to research activities and findings wherever possible, and a detailed description of this process is given in Kingston *et al.* (2006c). Materials developed include: an introductory brochure on the bats of Malaysia which was distributed to 8000 secondary school student members of MNS's Nature Clubs; posters illustrating the diversity of bats in Malaysia; a guide for a children's bat workshop for 7-12 year olds (The Malaysian Bat Party Pack – developed with funding from the Organization for Bat Conservation); environmental maths problems for older children; and role play and bat projects for adults and amateur naturalists. All materials can be downloaded from http://www.seabcru.org/index. php/mainresources/outreach-a-education.

Although we have conducted many school visits and ad-hoc workshops, the focus of our dissemination efforts is to train outreach workers and educators to use the materials in their own programs through workshops. To this end, we developed a 3-day 2-night Education Workshop,which culminates in participants putting on the Malaysian Bat Party (Children's Workshop). This has been a highly effective approach, with participants now running their own initiatives or integrating materials into existing programs in Malaysia, Singapore, and the Philippines.

The "Malaysian Bat Education Adventure" was a formal education initiative funded by Texas Tech University which brought the MBCRU's research on bat assemblages directly to 10 and 11 yr-old students in the US as the core component of a Biodiversity Module developed by the team. Students were viewed as research participants, and used real-time nightly capture data posted on the project website (www.ttu-mbea.org) to achieve learning goals centred on students' ability to: 1) describe how scientists measure species diversity and distinguish between the two fundamental components of species diversity – species richness and abundance; 2) recognize that species vary in abundance within an assemblage; 3) describe intraspecific variation using simple physical measurements; 4) enter raw data into tables; and 5) collate these data and construct and interpret frequency histograms and scatter plots. Materials developed include over twenty instructional HD videos, activities to develop and assess student learning, and the research workbook. Materials were developed in 2008, and over 700 students in Texas participated in the MBEA in 2009 and 2010 (presentation materials, background information, videos and lesson plans are available upon request).

MBCRU outreach efforts to date have focused largely on initiatives reaching children and members of the general public that improve awareness of the diversity and importance of bats in Malaysia. Beyond dissemination of publications, reports and presentations to Malaysian government agencies (e.g., EPU, DWNP), the MBCRU has not been involved in direct science advocacy. However, as our work and that of others reveal the catastrophic loss of bat diversity in anthropogenic landscapes, outreach efforts clearly need to shift towards directly reaching policy makers and legislators.

THE SOUTHEAST ASIAN BAT CONSERVATION RESEARCH UNIT (SEABCRU)

The success of the MBCRU inspired the launch in 2007 of the SEABCRU to provide an organizational framework to network and coordinate bat conservation research, capacity building, and outreach across the region. Establishment of a regional network was considered timely for three main reasons. First, research efforts were expanding within some countries (e.g., Malaysia, Thailand, Philippines) to the point that there was sufficient mass to support a network, but programs or individuals were often operating in isolation, and could benefit from the opportunity to exchange experiences and expertise internationally. Second, the fostering of research in countries with few practitioners (e.g., Cambodia, Laos PDR) could be accelerated by exposure to existing programs and inclusion in regional efforts. Third, a need was identified for international collaborative efforts as countries within the region not only share species, but also face largely the same conservation issues (Kingston, 2010).

In 2007, the SEABCRU organized the 1st International Southeast Asian Bat Conference in collaboration with the Harrison Institute (UK) and the hosting institute the Prince of Songkla University, Thailand. The conference was attended by over 125 people from 22 countries, and culminated in an open forum to identify regional priorities for bat research for the next decades. 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. Consensus opinion identified four key areas of research that fulfilled these criteria: flying fox distributions and population ecology; taxonomy and systematics; cave-bat diversity and conservation; and the distribution and conservation of forest-dependent bats (Kingston, 2010).

A small grants program in 2008 provided modest support for activities based on these priorities, and SEABCRU Fellowships were available for three years to bring researchers to the MBCRU research program. In 2011, the SEABCRU received five years of funding from NSF under its Research Coordination Network (RCN) program, to effect a regional assessment of the distribution, abundance and status of Southeast Asian bats through the implementation of conservation research activities centered on the four priority areas identified by the 2007 forum (flying foxes, taxonomy, cave bats, forest bats). The initial steps in this process are ongoing and focus on the development of standardized research protocols for each priority, and recruitment and engagement of students and researchers to promote effective international communication and stimulate collaboration. To this end, the 2nd International Southeast Asian Bat Research Conference was hosted by the Indonesian Institute of Sciences in Bogor, Java, in 2011 with c. 100 participants from 20 countries. During the conference, four 2-hr forums (one for each priority) were held to engage participants in the SEABCRU activities and to gather contacts and data. To provide for international communication year-round, the SEABCRU website was re-designed (www.seabcru.org), with a social network plug-in and a feed of articles to the SEABCRU facebook page to facilitate communication. The SEABCRU is managed by a Steering Committee organized into research priority teams of 3-4 experts with each team supported by 3-4 graduate students currently conducting research in those areas. The steering committee and student teams are a mix of Southeast Asian researchers and those from the US and UK working in the region, with the ~30 people representing eight countries (Brunei, Cambodia, Indonesia, Malaysia, Thailand, Philippines, UK and USA).

In July 2012, the SEABCRU held an "experts" workshop in Hat Yai, Thailand (in collaboration with Prince of Songkla University). The objective was to bring together people with existing expertise and interest in the SEABCRU priority research and conservation areas to work together to: share experiences in addressing the different priorities; refine research and training protocols to provide for better integration and synthesis of research across the region; link research processes and outputs with conservation efforts in and among Southeast Asian countries; work to collate current data on distribution and abundance of Southeast Asian bats; inform database development and parameterization; identify future directions for research within and across priorities; and network expertise across countries. The steering committee and student teams were joined by sponsored participants from Cambodia, Vietnam, Laos, Thailand, Malaysia, Indonesia, Singapore and Philippines. The final output for each priority team will be recommended protocols and best-practices that can not only equip others to initiate or refine research projects, but will also allow for the comparison and synthesis of results across the region. The 2013 SEABCRU workshop will focus on promoting and stimulating bat research in a country currently viewed as a "gap" in the regional network, and those for 2014 and 2015 will emphasize data collation and sharing, and on developing collaborations and proposals for the post-funding period. The 3rd International Southeast Asian Bat Conference is scheduled for 2014.

DISCUSSION

The MBCRU's research at KWR has provided major insights into natural variability in bat diversity within the reserve and differential responses of bat assemblages to fragmentation. Species dependent upon intact forests for both foraging and roosting appear particularly vulnerable, with cave-roosting bats proving more resilient provided that there is at least some natural habitat in the landscape and that of course they are not disturbed at caves. Further research is needed across Malaysia and Southeast Asia to test the generality of these findings, and to characterize the response of bats to other land-uses and land-use configurations. Embedding capacity building within the research program through student sponsorship and fellowships enabled young researchers to gain experience of and directly contribute to the kind of large-scale, collaborative research projects that will increasingly be needed to ameliorate biodiversity losses. Moreover, we have demonstrated that even with a full research program, researchers can design and disseminate engaging and informative outreach materials, and can use their research findings to form an EEP. Adopting a 'train the trainers' approach and posting materials for download maximizes the return on time invested in outreach programs, and information communication technologies can be used to enable scientists to share their research in real time.

Regional scale-up had been originally been envisioned as a network of country-level groups like the MBCRU. However, prior to the launch of the SEABCRU and the International Southeast Asian Bat Conferences, bat research activity and connectivity of activity in other countries varied substantially, ranging from sole practitioners in some countries, to active but unconnected individuals, to highly interactive communities of researchers. Consequently, it was not possible to organize the SEABCRU network around country-level groups. The thematic organization around the consensus research priorities has proved much more flexible and productive for the SEABCRU, engaging sole practitioners and communities alike and allowing for rapid knowledge transfer across borders. Interestingly, engagement in SEABCRU activities appears to have stimulated greater networking of researchers within countries and may ultimately lead to the establishment of more country-level groups.

Clearly, bats are not the only diverse, maligned group in need of conservation research in Southeast Asia, and we hope that the integrative approach of the MBCRU and SEABCRU can act as a model for researchers focused on other taxa. Funding for the MBCRU and SEABCRU came predominantly from entities in the USA and UK. We urge national funding bodies within Southeast Asia to consider adopting a similar approach, and to promote and support inter-institutional research groups that embed capacity building and outreach in long-term research projects and network internationally. Multiple factors have contributed to the success of the MBCRU, and the launch of the SEABCRU, perhaps those that might best assist others are the following:

- An integrated mission that combines research, capacity building, and outreach.
- Acquisition of continuous (or long-term) funding that allows the project to maintain momentum. Cumulative research expenditure over 10 years of the MBCRU research program was approximately USD 500,000, with annual expenditure in Malaysia ranging from c, $20,000 to $60,000. NSF funding of SEABCRU is c. $500,000 over the 5-yr period, most of which is designated for participant support.
- Long-term research goals that can be approached from different angles, such that the project is competitive in funding arenas with different agendas. Thus the MBCRU's efforts were supported by agencies prioritizing conservation (Earthwatch Institute, Organization for Bat Conservation, BAT Biodiversity Partnership), theoretical ecological advances (NSF, NERC) and education research (Texas Tech University).
- Steady academic output (publications, dissertations), particularly to maintain funding from research-oriented agencies (e.g. NSF). All told, the MBCRU's research efforts in the Krau landscape have resulted in >25 publications to date, the description of a new species named for the reserve (*Kerivoula krauensis* (Francis *et al.,* 2007)), seven masters theses, two PhD dissertations, with a further two PhD projects in progress, and 10 more publications in preparation.
- Financial support of and involvement of in-country nationals (e.g., Malaysian undergraduate and post-graduate students of the MBCRU, Southeast Asian SEABCRU committee and student members).
- Long-term international collaborative relationships among faculty and institutions.

ACKNOWLEDGEMENTS

We are especially grateful to the Economic Planning Unit of the Malaysian Government for granting permission to TK to conduct bat research in Malaysia, and the Malaysian Department of Wildlife and National Parks (DWNP) for the long-standing

support of the research in Krau Wildlife Reserve. Activities of the MBCRU were supported by the National Science Foundation (NSF Award No. 0108384, DEB & East Asia and Pacific Program), Earthwatch Institute, National Geographic (Committee for Research & Exploration; Conservation Trust), Organization for Bat Conservation, Texas Tech University, and the Natural Environment Research Council (NERC). Support for the SEABCRU has come from BAT Biodiversity Partnership and NSF Research Coordination Networks Program (Award No. 1051363). TK would like to thank all members of the SEABCRU steering committee and student support teams for their enthusiasm and commitment to the SEABCRU's mission.

REFERENCES

Allen, D. 2005. Foraging ecology of *Kerivoula papillosa*. Unpublished Masters Thesis, University of East Anglia, UK.

Bumrungsri, S., Harbit, A., Benzie, C., Carmouche, K., Sridith, K. & Racey, P.A. 2008. The pollination ecology of two species of *Parkia* in southern Thailand. *Journal of Tropical Ecology,* **24(5):** 467-475.

Bumrungsri, S., Sripaoraya, E., Chongsiri, T., Sridith, K. & Racey, P.A. 2009. The pollination ecology of durian (*Durio zibethinus*, Bombacaceae) in southern Thailand. *Journal of Tropical Ecology,* **25(1):** 85-92.

Campbell, P., Schneider, C.J., Adnan, A.M., Zubaid, A. & Kunz, T.H. 2004. Phylogeny and phylogeography of Old World fruit bats in the *Cynopterus brachyotis* complex. *Molecular Phylogenetics and Evolution,* **33(3):** 764-81.

Epstein, J.H., Olival, K.J., Pulliam, J.R.C., Smith, C., Westrum, J., Hughes, T., Dobson, A.P., Zubaid, A., Rahman, S.A., Basir, M.M., Field, H.E. & Daszak, P. 2009. *Pteropus vampyrus*, a hunted migratory species with a multinational home-range and a need for regional management. *Journal of Applied Ecology,* **46(5)**: 991-1002.

Fletcher, C.D. 2006. Roosting ecology of insectivorous bats in Krau Wildlife Reserve, Pahang, Peninsular Malaysia. Unpublished PhD Dissertation, Universiti Kebangsaan Malaysia.

Francis, C.M. 1989. A comparison of mist nets and two types of harp traps for capturing bats. *Journal of Mammalogy,* **70(4):** 865-870.

Francis, C.M., Kingston, T. & Zubaid, A. 2007. A new species of *Kerivoula* (Chiroptera: Vespertilionidae) from peninsular Malaysia. *Acta Chiropterologica,* **9(1):** 1-12.

Furey, N.M., Mackie, I.J., Racey, P.A. 2010. Bat diversity in Vietnamese limestone karst areas and the implications of forest degradation. *Biodiversity and Conservation,* **19(7):** 1821-1838.

Hodgkison, R., Balding, S.T., Zubaid, A. & Kunz, T.H. 2003. Fruit bats (Chiroptera, Pteropodidae) as seed dispersers and pollinators in a lowland Malaysian rain forest. *Biotropica,* **35(4):** 491-502.

IUCN. 2012. *The IUCN Red List of Threatened Species*. Version 2012.1. http://www.iucnredlist.org. Downloaded on 1 September 2012.

Jayarak, V.K., Besar, K., Faisal, A.A.K., Hall, E.S. & Abdulla, M.T. 2006. Bat survey of Mount Penrisen and notes on the rare *Kerivoula minuta, Kerivoula intermedia* and *Hipposideros coxi* in Sarawak, Borneo. *Journal of Biological Sciences,* **6(4):** 711-716.

Khan, F.A.A., Swier, V., Solari, S., Larsen, P.A., Besar Ketol, Wahap Marni, Ellaguipillay, S., Lakim, M., Abdulla, M.T. & Baker, R.J. 2008. Using genetics and morphology to examine species diversity of Old World bats: Report of a recent collection from Malaysia. *Occasional Papers of the Museum of Texas Tech University,* **281**: 1-28.

Khan, F.A.A., Solari, S., Swier, V.J., Larsen, P.A., Abdullah, M.T. & Baker, R.J. 2010. Systematics of Malaysian woolly bats (Vespertilionidae: *Kerivoula*) inferred from mitochondrial, nuclear, karyotypic, and morphological data. *Journal of Mammalogy,* **91(5):** 1058-1072.

Kingston, T., Lara, M.C., Jones, G., Akbar, Z., Kunz, T.H. & Schneider, C.J. 2001. Acoustic divergence in two cryptic *Hipposideros* species: a role for social selection? *Proceedings of the Royal Society of London. Series B: Biological Sciences,* **268(1474):** 1381-6.

Kingston, T., Francis, C.M., Zubaid, A. & Kunz, T.H. 2003. Species richness in an insectivorous bat assemblage from Malaysia. *Journal of Tropical Ecology,* **19(1):** 67-79.

Kingston, T., Lim, B.L. & Zubaid, A. 2006a. *Bats of Krau Wildlife Reserve*. Penerbit Universiti Kebangsaan Malaysia, Bangi. pp. 145.

Kingston, T., Juliana, S., Rakhmad, S.K., Fletcher, C.D., Benton-Browne, A., Struebig, M., Wood, A., Murray, S.W., Kunz, T.H. & Zubaid, A. 2006b. The Malaysian Bat Conservation Research Unit: Research, capacity building and education in an Old World hotspot In: *Proceedings of the National Seminar On Protected Areas.* S. Othman, S.H. Yatim, S. Elaguipillay, S. Md. Nor, N. Ahmad, S.A. Md. Sah (Eds.). Department of Wildlife and National Parks, Malaysia. pp 41-60.

Kingston, T., Zubaid, A., Lim, G. & Hatta, F. 2006c. 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.* Noor Azlin Yahya, Philip, E. Ong, T. (Eds.). FRIM, Kuala Lumpur, Malaysia.

Kingston, T. 2010. Research priorities for bat conservation in Southeast Asia: a consensus approach. *Biodiversity and Conservation,* **19(2):** 471-484.

Kingston, T. *In press*. Bat diversity, assemblage composition and response to habitat disturbance in Southeast Asia In: *Bat evolution, ecology, and conservation*. R.A. Adams and S.C. Pedersen (Eds.). Springer Science Press.

Kunz, T.H. & Pierson, E.D. 1994. Bats of the world: an introduction. In: *Walker's Bats of the World.* R.M. Nowak (Ed.). Johns Hopkins University Press.

Lane, D., Kingston, T. & Lee, B. 2006. Dramatic decline in bat species richness in Singapore, with implications for Southeast Asia. *Biological Conservation,* **131(4):** 584-593.

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 Chiropterologica,* **7(1):** 111-119.

McGill, B.J. 2010. Towards a unification of unified theories of biodiversity. *Ecology Letters,* **13(5):** 627-642.

Medway, Lord. 1983. *The wild mammals of Malaya (Peninsular Malaysia) and Singapore.* Second edition, revised. Oxford University Press, Kuala Lumpur, Malaysia. pp. 156.

Rossiter, S.J., Zubaid, A., Adura, A., Struebig, M.J., Kunz, T.H., Gopal, S., Petit, E.J. & Kingston, T. 2012. Social organisation and gene flow: insights from co-distributed bat populations. *Molecular Ecology,* **21(3):** 647-661.

Sazali, S.N., Besar, K. & Abdullah, M.T. 2011. Phylogenetic analysis of the Malaysian *Rhinolophus* and *Hipposideros* inferred from partial mitochondrial DNA cytochrome *b* gene sequences. *Pertanika Journal of Tropical Agricultural Science,* **34(2):** 281-294.

Simmons, N. 2005. Chiroptera. In: *Mammal species of the World: a taxonomic and geographic reference.* D.E. Wilson and D.M. Reeder (Eds.). John Hopkins University Press, Baltimore. pp 312-529.

Sodhi, N.S., Koh, L.P., Brook, B.W. & Ng, P.K.L. 2004. Southeast Asian biodiversity: an impending disaster. *Trends in Ecology & Evolution,* **19(12):** 654-660.

Sodhi, N.S., Posa, M.R.C., Lee, T.M., Bickford, D., Koh, L.P. & Brook, B.W. 2010a. The state and conservation of Southeast Asian biodiversity. *Biodiversity and Conservation,* **19(2):** 317-328.

Sodhi, N.S., Koh, L.P., Clements, R., Wanger, T.C., Hill, J.K., Hamer, K.C., Clough, Y., *et al.* 2010b. Conserving Southeast Asian forest biodiversity in human-modified landscapes. *Biological Conservation,* **143(10):** 2375-2384.

Shariff, Y. 2003. Recapture data as an index of home range of insectivorous forest bats in Krau Wildlife Reserve. Unpublished Masters Thesis, Universiti Kebangsaan Malaysia.

Start, A. & Marshall, A.G. 1975. Nectarivorous bats as pollinators of trees in West Malaysia. In: *Tropical trees: variation, breeding, and conservation.* J. Burley & B.T. Styles (Eds.). pp. 141-150.

Struebig, M.J., Kingston, T., Zubaid, A., Mohd-Adnan, A. & Rossiter, S.J. 2008. Conservation value of forest fragments to Palaeotropical bats. *Biological Conservation,* **141(8):** 2112-2126.

Struebig, M.J., Kingston, T., Zubaid, A., Le Comber, S.C., Mohd-Adnan, A. *et al.* 2009. Conservation importance of limestone karst outcrops for Palaeotropical bats in a fragmented landscape. *Biological Conservation,* **142(10):** 2089-2096

Struebig, M.J., Kingston, T., Petit, E.J., Le Comber, S.C., Zubaid, A., Mohd-Adnan, A. & Rossiter, S.J. 2011. Parallel declines in species and genetic diversity in tropical forest fragments. *Ecology Letters,* **14(6):** 582-590.

United Nations Commodity Trade Statistics Database. 2012. http://comtrade.un.org/db/dqBasicQueryResults.aspx?px=H2&cc=081060&r=458&y=2011 Downloaded 12 September 2012.

Wiantoro, S., Maryanto, I. & Abdullah, M.T. 2012. Phylogeny and phylogeography of *Myotis muricola* (Gray, 1846) (Chiroptera: Vespertilionidae) from the west and east of Wallace's Line inferred from partial MtDNA cytochrome b gene. *Pertanika Journal of Tropical Agricultural Science,* **35(2):** 271-292.

Yoshiyuki, M. & Lim, B.L. 2005. A new horseshoe bat, *Rhinolophus chiewkweeae* (Chiroptera, Rhinolophidae), from Malaysia. *Bulletin of the National Science Museum, Tokyo,* **31(1):** 29-36.