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The Diet of the Cave Nectar Bat (*Eonycteris spelaea* Dobson) Suggests it Pollinates Economically and Ecologically Significant Plants in Southern Cambodia

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Hoem Thavry, Julien Cappelle, Sara Bumrungsri, Lim Thona, and Neil M. Furey (2017) The importance of the cave nectar bat *Eonycteris spelaea* as a pollinator of economically significant crops and ecologically important plant species is increasingly documented, although information on the plants visited by this widely distributed bat species is currently confined to Thailand and Peninsular Malaysia. We undertook a dietary study on *E. spelaea* by sampling faecal rain produced by a colony in Kampot, southern Cambodia each month for one year and identifying plant taxa visited by the bats by their pollen. Our results indicate the diet of *E. spelaea* in Cambodia includes at least 13 plant taxa, eight of which were identified to genus or species. Pollen of *Sonneratia* spp. and *Musa* spp. had the highest mean monthly frequency at 30.9% and 16.9% respectively, followed by *Oroxylum indicum* (11.3%), *Bombax anceps* (11.2%), *Parkia* spp. (9.8%), *Durio zibethinus* (6.3%), *Ceiba pentandra* (6.0%) and *Eucalyptus* spp. (0.3%). With one exception, all of the plant taxa recorded at our study site are also visited by the bat species in Peninsular Malaysia and Thailand, although their relative dietary contributions differ. This variation likely reflects local differences in the availability, proximity and flowering phenology of chiropterophilous plants between regions, but also suggests a reliance of Cambodian bats on species that flower continuously, coupled with periodic shifts to species that flower profusely for short periods. Only three significant colonies (> 1,000 bats) of cave-roosting pteropodids are currently known in Cambodia, all of which are in Kampot and threatened by bushmeat hunting and roost disturbance. We recommend public education and law enforcement efforts to conserve these colonies, not least because Kampot is the premier region for Cambodian durian and this crop depends on nectarivorous bats for fruit set. Protection of mangroves would also benefit durian farmers because these are an important resource for nectarivorous bat populations.

Key words: Nectarivorous bats, Caves, Plant pollination, Mangrove, Durian, Cambodia.

BACKGROUND

Nectarivorous animals play an important role in maintaining forest structure and restoring disturbed forests in tropical regions, as almost all (98~99%) flowering plants in tropical forests rely on these for pollination (Bawa 1990). This role has major significance as pollination failure of food plants has become a global concern in recent years (Allen-Wardell et al. 1998; Kevan and Phillips

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2001). As a result, information about the resource needs of native pollinators, such as diet (*e.g.*, Gonçalves et al. 2012), is of considerable interest and can be used to guide efforts to protect and restore pollinator populations (Bumrungsri et al. 2013).

The cave-dwelling bat *Eonycteris spelaea* is the largest of three exclusively nectarivorous bat species in mainland Southeast Asia and an important pollinator of economically significant crops, including durian (*Durio zibethinus*), tree bean (*Parkia timoriana*) and petai (*P. speciosa*) (Bumrungsri et al. 2008, 2009), alongside other ecologically important plant taxa (Bumrungsri et al. 2013; Stewart and Dudash 2016; Nor Zalipah et al. 2016). The species occurs throughout South & Southeast Asia, Indonesia and the Philippines and forages in agricultural areas, primary and secondary forests and coastal mangroves (Bates and Harrison 1997; Francis 2008). Research suggests it has a nightly foraging area of up to 38 ha and travels up to 8 km between feeding trees (Acharya et al. 2015), whereas commuting distances of up to 17.9 km and 38 km have been recorded between roost sites and foraging areas in Thailand and Malaysia (Start and Marshall 1976; Acharya et al. 2015). The species reproduces throughout the year (Beck and Lim 1973; Bhat et al. 1980; Heideman and Utzurrum 2003; Furey et al. 2011) and is threatened by bushmeat hunting and roost disturbance in several range countries (Francis et al. 2008; Furey et al. 2011; Thomas et al. 2013). As information on its diet is currently limited to southern Thailand and Peninsular Malaysia where 11 and 31 plant species have been documented respectively (Start and Marshall 1976; Bumrungsri et al. 2013), the goal of our study was to determine the composition and relative frequency of plant species visited by *E. spelaea* in southern Cambodia.

MATERIALS AND METHODS

Sampling was conducted from February 2014 to January 2015 and comprised ten days of faecal sample collection each month from a colony of *E. spelaea* (1,000~1,400 bats) in Bat Khteas cave (10.644053°N, 104.271282°E) at Chhngauk hill in Kampot province. Bat Khteas is the second longest cave in southern Cambodia (978 m in length, described by Denneborg et al. 2002) and the isolated karst hill where the cave is located is surrounded by seasonal wet rice cultivation, with many local farmers also cultivating small amounts of durian (*D. zibethinus*), banana (*Musa* spp.), mango (*Mangifera indica*), coconuts (*Cocos nucifera*), guava (*Psidium guajava*) and cashew (*Anacardium occidentale*). Live-trapping conducted at the cave entrance each month between February 2014 and January 2016 inclusive indicates that 11 bat species comprising ten insectivorous taxa and one pteropodid (our study species) occur at the site (Furey et al. 2016). Chhngauk hill is located ≈16 km east of a large mountainous forest area (Bokor National Park, 1,490 km^2: Goes 2013) and ≈9 km north of the Cambodian coast, where riverine and basin mangroves including *Sonneratia* spp. occur (FAO 2007) (Fig. 1). Local climate is monsoonal with an average annual rainfall of 1,920 mm, an average humidity of 79% and an average annual temperature of 27°C (Kampot Department of Meteorology, unpublished data). The wet season typically lasts from May to October and the dry season from November to April, with 20% of the annual rainfall falling in the latter months.

Sampling was undertaken over the second and third week of each month, during which ten 1 m^2 sheets of clear plastic were placed beneath the roost colony. These were situated in two areas where faecal rain was concentrated, with distances between individual sheets varying from 0~3 m. Thirty faecal samples were collected from the sheets after five days (when the sheets were replaced) and another 30 samples after ten days and placed into individual labelled vials. Of the 60 samples available for each month, 30 (comprising 15 samples collected after five days and 15 collected after ten days) were randomly selected for subsequent processing which followed the methods of Bumrungsri et al. (2013). Three slides were made from each sample and examined under a compound light microscope at 40 times magnification. Pollen were identified to species where possible through comparisons with a reference collection and illustrations in Start (1974). Following Thomas (1988), identified pollen were categorised as present/absent, and following Bumrungsri et al. (2013), species were categorised as present in two cases: 1) at least two pollen grains were found on any of the three slides prepared from each sample, and 2) one pollen grain was found on at least two of the three slides prepared. Monthly frequencies were then calculated by dividing the number of presences of each plant species in samples for a given month by the total number of presences for all species in the same month.

RESULTS

Our results indicate the diet of *Eonycteris spelaea* in south Cambodia includes at least 13 plant species, eight of which were identified to genus or species (Fig. 2) (representing 92.7% of monthly samples on average). Pollen of *Sonneratia* spp. and *Musa* spp. had the highest mean monthly frequency at 30.9% (range = 4.4~48.5%, SD = 16.3%) and 16.9% (4.4~32.9%, 9.7%) respectively, followed by *Oroxylum indicum* (11.3%, 0~25.6%, 9.6%), *Bombax anceps* (11.2%, 0~28.0%, 10.9%), *Parkia* spp. (9.8%, 0~41.2%, 11.5%), *D. zibethinus* (6.3%, 0~32.4%, 10.1%), *Ceiba pentandra* (6.0%,

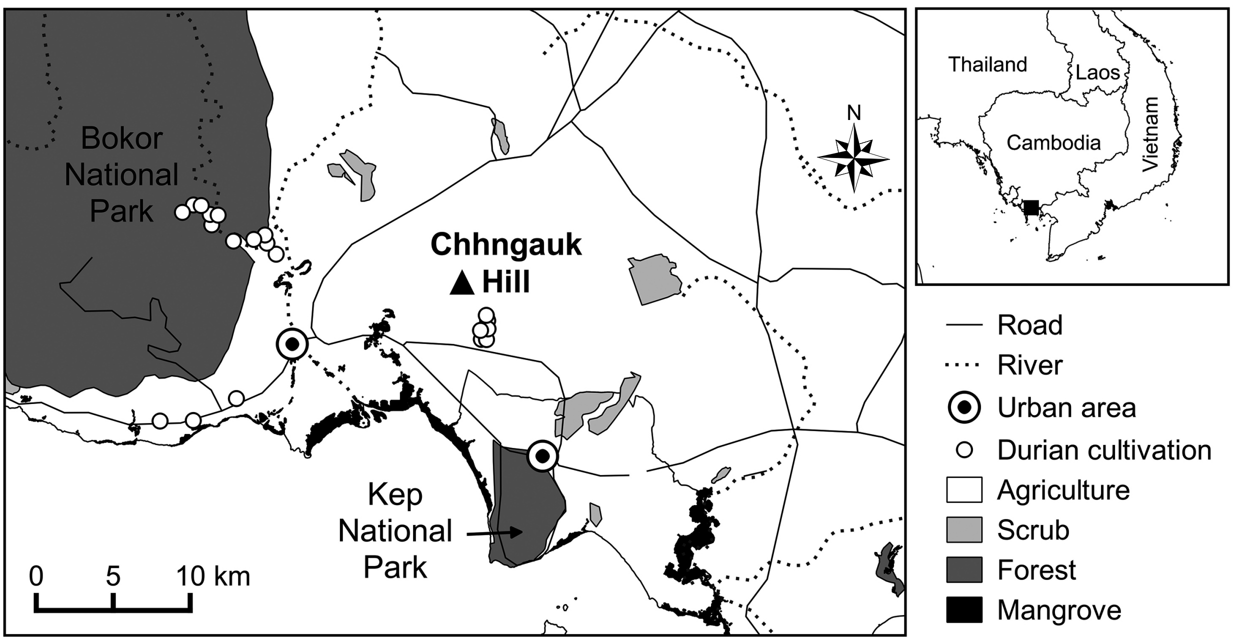

Fig. 1. Location of study site and distribution of major land uses in Kampot province, southern Cambodia.

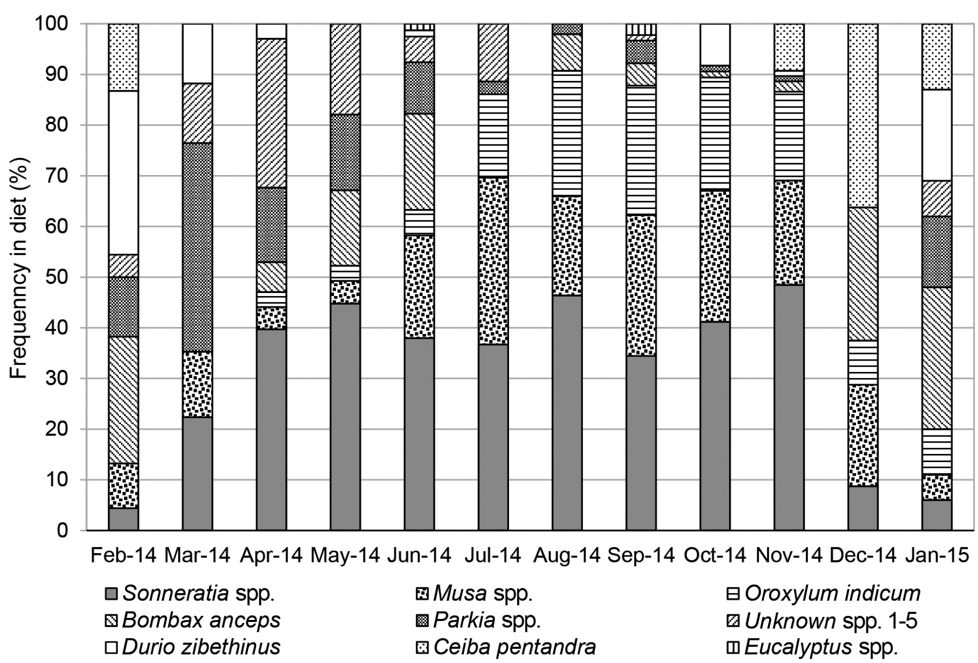

Fig. 2. Frequency of plant species in the diet of *Eonycteris spelaea* in Kampot, southern Cambodia from February 2014 to January 2015.

0~36.3%, 10.9%) and *Eucalyptus* spp. (0.3%, 0~2.2%, 0.7%). The remaining five unknown species typically formed a small portion of the diet each month (mean = 7.3%, SD = 9.1%), although this was somewhat greater in March~May (11.8~29.4%). Numbers of plant species present each month varied from 5~9, with no distinct difference between the dry and wet seasons (5~8 vs. 5~9, respectively). *Sonneratia* spp. was the most important diet item in April~November (34.4~48.5%), followed by *Musa* spp. in June~July and September~November (20.3~32.9%). These taxa were present every month, whereas *Parkia* spp. was present for 11 months (peaking in January~May at 11.8~41.2%). *Oroxylum indicum* and *B. anceps* were present for ten months, peaking in July~November (16.5~25.6%) and December~February (25.0~28.0%) respectively, whereas *D. zibethinus* and *C. pentandra* formed variably important components in January~March (11.8~32.4%) and November~February (13.0~36.3%) respectively.

DISCUSSION

With one exception (*Eucalyptus* spp.), all of the plant genera and species recorded in the diet of the cave nectar bat in southern Cambodia are also visited by the species in Peninsular Malaysia and southern Thailand (Start and Marshall 1976; Bumrungsri et al. 2013), although their relative contributions differ compared to the latter. For example, Bumrungsri et al. (2013) found that *Parkia* spp. was the most important diet item (33.9%), forming over half of the diet in May~July, whereas its overall contribution was markedly lower and peaked in January~May in our study. Conversely, *Sonneratia* spp. was the most important diet item in our study, whereas its contribution was minor in southern Thailand (5.2%). Relative proportions of *Musa* spp. were more consistent between the two regions, albeit somewhat lower in Cambodia (28 vs. 16.9%). These variations likely reflect local differences in the availability, proximity and flowering phenology of chiropterophilous plants between sites, but also suggest a reliance of Cambodian bats on species that flower continuously *e.g.*, *Sonneratia* spp., *Musa* spp. and *O. indicum* (Srithongchuay et al. 2008; Nor Zalipah 2014), coupled with periodic shifts to species such as *D. zibethinus* and *C. pentandra* that flower profusely for short periods (Bumrungsri et al. 2013).

Because several economically important plant taxa including durian and *Parkia* spp. are obligate or highly self-incompatible (Bumrungsri et al. 2008; 2009), existing populations of cave nectar bats are very important for fruit set in these species. In southern Thailand alone, the annual economic contribution of the species in pollinating durian and petai was valued at > 137 million US dollars in 2008 (Petchmunee 2008). Recent studies have also shown that durian fruit set is negatively affected by distance to the nearest cave inhabited by nectarivorous bats (Srithongchuay et al. 2016). Further, *E. spelaea* and other nectar-feeding bats are important pollinators of *Sonneratia* spp. (Stewart and Dudash 2016; Nor Zalipah et al. 2016; Nor Zalipah and Ahmad Fadhli 2017), although the importance of this service in maintaining the long-term viability of Cambodian mangroves remains unclear as their floral composition and ecology is poorly documented. Nonetheless, only three significant colonies (> 1,000 bats) of cave-roosting pteropodids are currently known in Cambodia, all of which are in Kampot province and threatened by bushmeat hunting and roost disturbance (Furey et al. 2016). Examination of live bats caught each month at the study site between February 2014 and January 2016 inclusive indicates that *E. spelaea* reproduces in most months of the year and suggests that birth peaks occur in January and June~August (supplementary material). Threats to the species also appear to worsen around April (the Khmer new-year) each year and awareness of the pollination services it provides is non-existent among the public, including durian farmers. We consequently recommend sustained public education and law enforcement efforts to conserve these colonies, not least because Kampot is the premier region for durian nationally and has been earmarked to apply for the World Trade Organization’s influential proof of origin status (Chan and deCarteret 2014; Hor 2014). Further, because mangroves are an important resource for nectarivorous bat populations in southern Cambodia, their protection would benefit durian farmers. Local farmers should also be encouraged to grow *Musa* spp. around their orchards to promote site fidelity among foraging bats, because these flower continuously and have high relative dietary importance.

CONCLUSIONS

Our study suggests the cave nectar bat *E.*

spelaea is an important pollinator of economically significant crops and other ecologically important plant species in Cambodia. Only three significant colonies of cave-roosting pteropodids are currently known in the country, all of which are in Kampot and in danger of extirpation. Public education and law enforcement efforts are required to conserve these colonies. Protection of mangroves would also benefit durian farmers because these are an important resource for nectarivorous bat populations and local farmers should be encouraged to grow *Musa* spp. to promote site fidelity among foraging bats.

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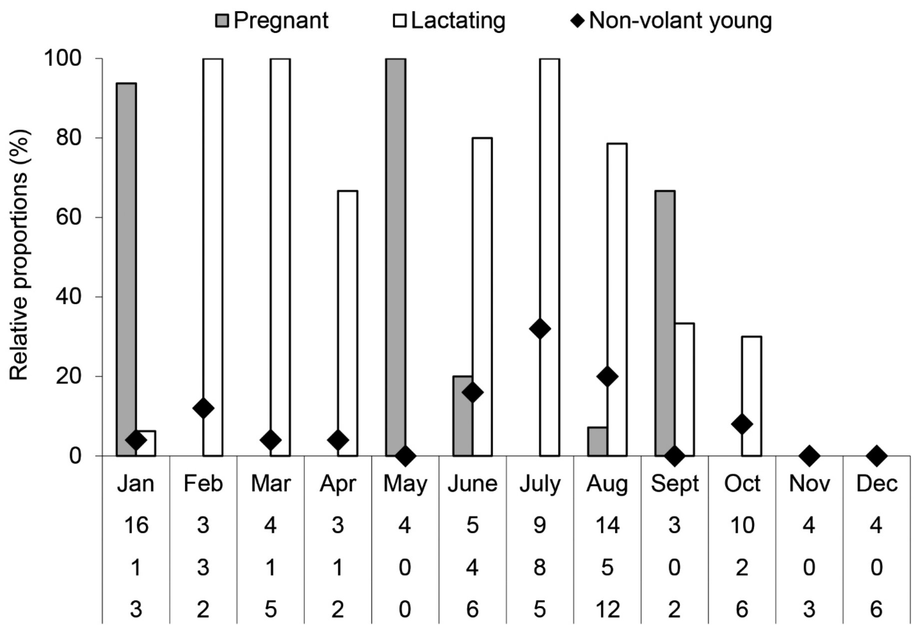

Supplementary Material

Reproduction of *E. spelaea* from February 2014 to January 2016 (except May 2015 due to no data) at Chhngauk hill in southern Cambodia. The first row of figures below each graph represents the total number of parous, pregnant (*i.e.* palpably or visibly pregnant) and lactating females caught each month, while the second and third rows show the total number of females carrying non-volant young and juveniles (volant young with unfused epiphyses), respectively. The 'pregnant' category is confined to non-lactating pregnant bats, while the 'lactation' category includes all lactating bats, whether pregnant or not. Relative proportions for non-volant young were derived by dividing the respective monthly total by the study total x 100. The figure is based on live captures of 131 bats and data from the same month of each year during the study period are combined.