

ORIGINAL ARTICLE

The first record of *Coelops frithii* (Blyth, 1848) to Penang, Malaysia, with a note of the potential acoustic plasticity of the species

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ABSTRACT

The East Asian Tailless Leaf-nosed Bat (*Coelops frithii*) is a small hipposiderid species that widely distributed in the Asian tropics and subtropics, but rarely recorded across its distribution range. Here, we present the first record of *C. frithii* to Penang, Malaysia. An adult female was captured in Tropical Spice Garden in March 2015 by a harp trap. The record confirms the presence of the species nearly two decades after the last report from the country. We found that the bat used two varieties of echolocation calls. It typically used short frequency-modulated calls with high pitch and low duty cycles, which is similar to the calls reported from its congeneric. The second type of echolocation contains a short but higher duty cycle quasi-frequency-modulated call, used alternatively with the low duty cycle type call. The results indicate the potential plasticity of the echolocation strategy in the species. Our finding of the species from Penang also highlights the conservation value of man-managed forest-like habitats in maintaining bat species in urbanized landscapes.

INTRODUCTION

The East Asian Tailless Leaf-nosed Bat (*Coelops frithii*) is a small sized species in the Old-World Leaf-nosed bat family (Hipposideridae) from Asia. The species was first described from the Lower Bengal region in Bangladesh-India (Blyth 1848). The current understanding of its distribution is extent from South Asia continent, through all countries in the mainland Southeast Asia to the southeastern China as well as the islands of Bali, Java, Sumatra, Hainan and Taiwan. Despite its wide distribution, this species is rarely recorded from most countries within the distribution range (Bates et al. 2008). The species is found to roost in small groups, constituting a few individuals, to up to hundred individuals in caves and tree cavities (Fang & Cheng 2011, Molur et al. 2002). Recent studies on the subspecies, *C. frithii formosanus*, in Taiwan suggest the species flies slow and feeds on small arthropods close to understory vegetation in the forest (Fang & Cheng 2011). The species also represents an interesting member of the family in terms of its echolocation call design. While most hipposiderid species are known to use calls characterized with a long constant component, the species shows convergent evolution to other echolocating species in forest by using short low-duty cycle frequency-modulated component calls (Ho et al. 2013, Mc Arthur et al. 2015).

In Malaysia, only a handful of records have been reported from Selangor (Ulu Gombak Forest Reserve, Medway et al. 1978; Bukit Kutu Wildlife Reserve, Lim et al. 1999) and Kedah (Ulu Muda Nature Reserve, Norsham et al. 1999) in the peninsula. These data were exclusively from intact lowland forest, suggesting the species might be highly associated with undisturbed forest such as its conspecifics in Taiwan (Fang & Cheng 2011). However, there has been no update of the occurrence of the species since then, despite several intensive surveys in forest (Kingston et al. 2003a, Struebig et al. 2008, Lim et al. 2014, Nurul-Ain et al. 2017) have been conducted in the region in the last two decades. Species in genus *Coelops* are predicted to be sensitive to the loss and fragmentation of forest (Struebig et al. 2009, Furey et al. 2016) as well as disturbances to cave roosts (Fang & Cheng 2011). The population in Malaysia is likely declining due to the continuous deforestation and urbanization in the country in the last few decades. However, further evaluations of the vulnerability of Malaysia's population are not possible without any additional information of this species from the country.

MATERIALS AND METHODS

A bat trapping survey was conducted in the Tropical Spice Garden (5°27'N, 100°13'47"E) on Penang Island, Penang, Malaysia, on 20th March 2015 (Fig. 1). The island has a

typical tropical climate, which is characterized by a raining season from April to November and a dry season from December to the following March. While the northern and central part of the island is still largely covered by tropical hill dipterocarp forest (Ibrahim et al. 2008), most the lowland in the eastern and southwestern parts are occupied either by human settlements in high density or converted into various anthropogenic habitats, e.g. plantations and abandoned grassland. Along the east coast area, the landscape is more dominated by mangroves and mudflats. The garden is located on the northern coast of the island and adjacent to the island's largest forest on Penang Hill. With over 500 plant species, the garden represents a species-rich and man-managed forested habitat on this highly populated and urbanized tropical island. A total of two ground mist nets (9 m × 4 m with mesh size about 2.5 mm) were deployed from 7 pm to 10 pm and four 4-bank harp traps (2 m²) were deployed from 7 pm to 6 am of the next day. The harp traps were placed along trails with dense vegetation around, whereas the mist nets were placed at the open areas and pond side of the garden.

All captured bats were primarily identified following Corbet & Hill (1992), Kingston et al. (2006) and Francis (2008) based on external traits and measurements. Additional acoustic information was also used for species identification for families Hipposideridae and Rhinolophidae. Identification of cryptic species in the families Hipposideridae and Rhinolophidae were made following the call descriptions of Malaysia's bat species by Kingston et al. (2000), Kingston et al. (2001), Morni et al. (2016) and Murray et al. (2018). Length measurements and body mass of each captured bat were taken using a dial caliper (± 0.1 mm) and a 20-g Pesola spring scale (± 0.2 g), respectively. Echolocation calls from bats of Hipposideridae and Rhinolophidae were recording in hand using a full spectrum bat detector (M500 Ultrasonic Mic, Pettersson Elektronik AB) with a sample rate of 500 kHz.

Call description

Echolocation calls from bats were analyzed with Fast Fourier transform in Hanning window of 256 points for both spectrogram and power spectrum using BatSound 4.01 (Pettersson Elektronik AB). Five measurements were taken, namely the call duration (D), pulse interval (PI), the highest frequency (HF), the lowest frequency (LF) and the frequency with maximum energy level (FMAXE). The measures of D and PI are in ms and the three frequency measures are in kHz. Two derived measures, the duty cycle (DC) and swipe rate, were estimated by the proportion of the duration of a call to the interval to the next pulse in percentage and as the ratio of the frequency bandwidth to the duration, respectively. The number of harmonics were counted in spectrograms visually and the position of the dominant harmonic (HD) was identified based on where the FMAXE was located along the frequency axis in the power spectrum. The definitions of all call measurements and trait descriptions are following Huang (2015), except the two derived measures which follow Ho et al. (2013).

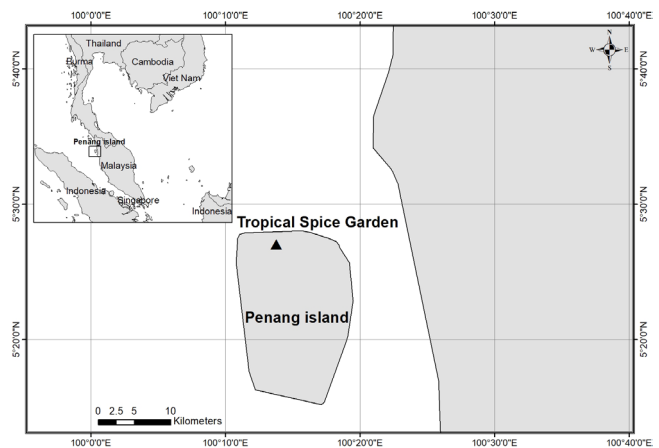


Fig. 1 - Location of the study site in Penang Island, Malaysia.

RESULTS AND DISCUSSION

In total 59 individuals belonging to nine bat species, *Cynopterus horsfieldii*, *Cynopterus brachyotis*, *Hipposideros kunzi*, *Hipposideros bicolor*, *Coelops frithii*, *Rhinolophus affinis*, *Rhinolophus lepidus*, *Kerivoula hardwickii*, *Hesperoptenus blanfordi*, were captured using both trapping techniques. Among the captures, an adult female *Coelops* bat (family Hipposideridae) was captured on a trail at the forest edge during drizzly rain at approximately midnight. The bat presented the general appearance of the tailless leaf-nosed bat. While hipposiderid bats typically have point ear tips and a visible tail, species of the genus *Coelops* have round ear tips and a heavily reduced tail that is not visible externally. *Coelops* bats also can be distinguished from other hipposiderids by its extremely well-developed protapagium and dactylopagium, in which nearly the entire phalange of the thumb is embedded. It had a small body size with a forearm length of 38.0 mm and weighted 4.2 g. The ears were round with a large antitragus at the base of the posterior end of the pinna. The posterior noseleaf was primarily straight and smooth, except the central protuberance was enlarged. The anterior nose leaves were broad in general and acute at the lower part. The supplementary lower leaflets were elongated and acute at the tips (Fig. 2). Comparing against descriptions for *Coelops frithii* and *Coelops robinsoni*, and some subpopulations of the two species in the literature (Table 1), the forearm length overlapped with *C. frithii* (36 - 43mm) but was larger than *C. robinsoni* (34 - 37mm). The noseleaf was more resemble to *C. frithii* compared to *C. robinsoni*, where the lower leaflets are rounder and not elongated (Bonhote 1908). Therefore, we identified this bat as *Coelops frithii*. Noteworthy, there is a need of taxonomic revision of our sample since none of the materials from Malaysia have been assigned into any of the five named subspecies under *C. frithii* (Simmons 2005).

Our sample presents the first record of the genus *Coelops* for Penang, and the fourth record of *C. frithii* for the country, despite some extensive surveys having been undertaken in forested habitats across the Penang island (Shahrul et al. 2006) and the peninsula (Kingston et al. 2003a, Struebig et al. 2009, Lim et al. 2014) since the last record in 1999. The general low detectability of the genus may simply reflect its rarity in the region. Alternatively, it could be a result of sampling bias since *Coelops* species use short and high-

pitched echolocation calls (Ho et al. 2013, Mc Arthur et al. 2015) and can flight slow and with high maneuverability (Lai 2000), which allows them to detect and avoid mist nets and harp traps easily (Huang per. obs.). Many of the recent records of *Coelops*, especially those in large quantity, were reported by researches based at roost sites (Rahman et al. 2010, Fang & Cheng 2011). The shortage of systematic cave bat surveys in the peninsular Malaysia (Nur Atiqah AR per. com.) may also explain the scarcity of *C. frithii* in inventory studies for this region. Nevertheless, our finding of *Coelops* from Penang highlights the conservation value of the human-managed, forest-like habitats in maintaining bat biodiversity for this highly urbanized tropical island.

The bat was immediately released on a tree branch at the capture point after processing. Unfortunately, the bat was found dead at the releasing point the next morning. We then collected it as a voucher specimen (TSG0102011) and preserved it in 95% ethanol. The sample is currently deposited in the Biology Lab of School of Distance Education of Universiti Sains Malaysia.

Potential acoustic plasticity

We unexpectedly detected within-individual variations in the echolocation call design of the Penang’s *C. frithii*. The bat emitted two varieties of echolocation call in our samples (Fig. 3). It typically used very short calls (D = 0.5 - 1.2 ms, n = 22) with up to three harmonics (hereafter as Type I). Peak frequency (FMAXE) ranges 163.7 - 184.8 kHz predominantly on the second harmonic (n = 22) and the pulse intervals (PI) range from 8.8 - 23.7 ms (n = 17). The duty cycles of the calls are low, always less than 10 % (2.7 - 9.7%, n = 17). The dominant harmonic (HD) is characterized by a downward broadband frequency-modulated (FM) component. The highest frequency (HF) and the lowest frequency (LF) of the dominant harmonic are 188 - 195 kHz and 105 - 108 kHz, respectively (n = 22). It has a large swipe rate (71.7 - 168.0 kHz/ms, n=22). The third harmonic (H3) represents the second strongest harmonic, despite its higher frequency portion is not appropriately shown due to the insensitivity of our detector to frequencies higher than 198 kHz. The terminal end of the H3 has no identifiable gaps

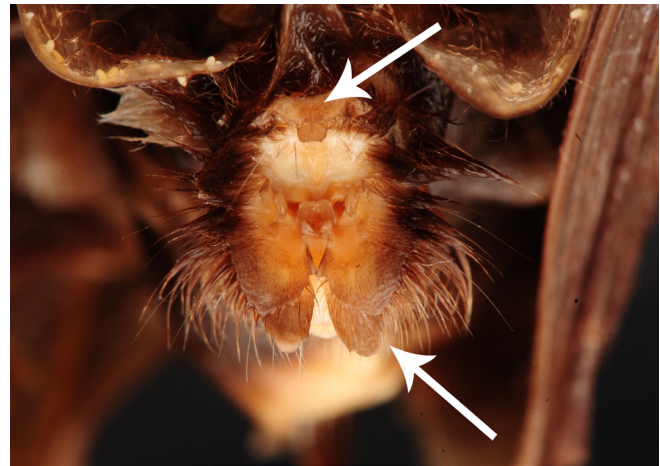


Fig. 2 - The front view of the face of the *Coelops* bat collected from Penang in this study. The upper arrow indicates the central protuberance in the posterior noseleaf and the lower arrow indicate the supplementary lower noseleaves (Photo credit to Mohd Abdul Muin).

to HD along both time and frequency axes, and it seems to connect to the HD near the position with highest frequency. The fundamental harmonic (H1) is sometimes visible on spectrogram but is usually very weak where only part of the lower part can be identified visually (Fig. 3).

The bat sometimes also emitted another variety of call that was composed of two different types of pulses alternatively (here after Type II) (Fig. 3). The first pulse contains a single harmonic, characterized by an arch-shaped, quasi-constant frequency (QCF) component with a short duration (D = 0.6 – 1.2 ms, n = 7), a short interval (PI = 3.0 - 3.8 ms, n = 7) and an intermediate DC (19.2 - 40.0%, n = 7). All frequency measures of the QCF call are high (FMAXE = 169.4 - 177.1 kHz, HF = 172 - 180 kHz, LF = 105 - 108 kHz, n = 7). It has a smaller swipe rate (5.0 - 16.7 kHz/ms, n=7), about half of the typical calls. The second pulse of the Type II is alike to the typical calls, which also has three harmonics and dominated at the H2 with high frequencies (FMAXE = 165.4 - 178.3 kHz, HF = 189 - 192 kHz, LF = 104 - 108 kHz, n = 7). It has a slightly short duration (D = 0.8 - 1.6 ms, n = 7), but a longer PI (10.4 - 28.9 ms, n = 6); therefore, a lower duty cycle

Table 1. Comparisons of selected morphological traits between the *Coelops* sample in this study and the type of *C. frithii* (Blyth 1852), *C. frithii* from southeastern China (Zhang et al. 2009), *C. frithii formosanus* from Taiwan (Fang & Cheng 2011; Huang per. obs.), the type of *C. robinsoni* (Bonhote 1908) and other samples of *C. robinsoni* from peninsular Malaysia (Kingston et al. 2006) and Borneo (Rahman et al. 2010). *As 1.75 inches in the original publication (Blyth 1852).

	This study	<i>C. frithii frithii</i> (type)	<i>C. frithii ?inflatus</i>	<i>C. frithii formosanus</i>	<i>C. robinsoni</i> (type)	<i>C. robinsoni</i> (Malaya)	<i>C. robinsoni</i> (Borneo)
Location	Penang, Malaysia	Lower Bengal, Bangladesh/India	Fujian province & Hainan Island, China	Taiwan	Gunung Tahan, Pahang, Malaysia	Krau Wildlife Reserve, Pahang, Malaysia	Niah Cave, Sarawak, Malaysia
N	1	1	21	66	1	5	1
Forearm length (mm)	38.0	44.5*	35.0-39.1	36.8-42.6	37.0	34.0-36.4	35.9
Body mass (g)	4.2	-	5.0-5.5	3.7-7.0	-	3.0-4.5	2.5
Supplementary lower leaflet	Acutely pointed, elongated	Acutely pointed, elongated	-	Acutely pointed, elongated	Broader, rounder	Broader, rounder	Broader, rounder

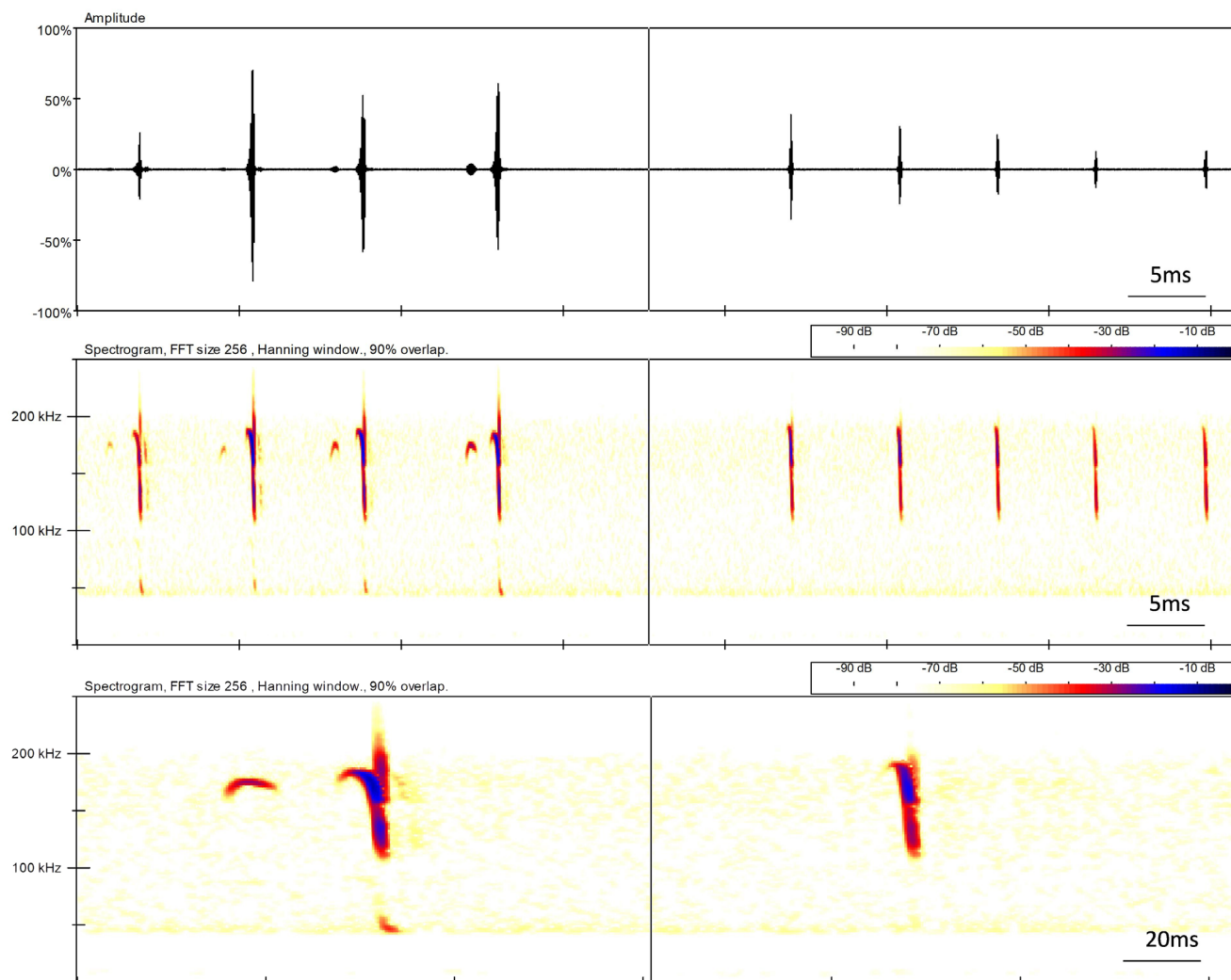


Fig. 3 - The oscillogram and sonograms of the Type I (the right panels) and Type II (the left panels) of the echolocation calls from the *Coelops frithii* (TSG0102011) in this study. A high-pass filter of 45kHz was applied to remove low frequency noises and the interval between the two call varieties has been shortened for presentation purposes.

(3.5 - 12.9%, $n = 6$). It has an intermediate swipe rate (53.8 - 102.5 kHz/ms, $n = 7$) between the first pulse of the Type II and the Type I call variety. It is different from the typical calls by containing a narrow-band upward FM element at the initial end of the H2 (Fig. 3). Similar call structure has been reported from several vespertilionid species, subfamilies Murininae and Kerivoulinae in Malaysia (Schmieder et al. 2010, 2012). Both the H3 and H1 are stronger in this call variety than those of the first call variety. In certain cases, the initial end of the H1 can be identified with an estimated frequency of c. 92 kHz.

The function of the alternation strategy of the Type II of echolocation calls in *C. frithii* is not clear. The potential plasticity of the echolocation strategy may allow the bat to explore more diverse microhabitats by using the short QCF pulses alternatively with the typical FM pulses. Similar strategies have been observed in vespertilionids, molossids and emballonurids (Denzinger et al. 2001, Kingston et al. 2003b). We do not reject the possibility that the short QCF pulse is a non-echolocation, distress call produced during the hand recording. Previous studies found that bats' distress calls are substantially louder than echolocation calls (Russ 2012). In contradictory, the short QCF pulses

(-50.7 – -30.7 dB) of the second variety were approximately 10 to 1000 times weaker than the follow-up pulses (-30.2 – -16.0 dB), suggesting it is less likely to be a distress call. Further observations of the natural echolocating behaviors of bats during flight and at rest are necessary to confirm the function of this alternation sounds.

Call diversification in genus *Coelops*

The echolocation designs of the Penang's *C. frithii* are generally similar to the calls reported from *C. frithii* in southeastern China (Zhang et al. 2009), Thailand (Hughes et al. 2010), and Taiwan (Ho et al. 2013) as well as *C. robinsoni* in Sarawak, Malaysia (Mc Arthur et al. 2015). The calls in our samples, regardless of the varieties, are short with low duty cycles, high frequency and broad frequency band, which is presumably suitable for the detection of non-fluttering prey in clutter environment (Ho et al. 2013). The Type II call represents a novel echolocation strategy, which has never been reported from the genus *Coelops* (Zhang et al. 2009, Hughes et al. 2010, Ho et al. 2013, Mc Arthur et al. 2015) or other genera in the family Hipposideridae (Kingston et al. 2000, Churchill 2008, ACR 2018). It is important to consider our acoustic samples show different features from its

congeneric. The Type I call from the Penang's *Coelops* have a FMAXE higher than *C. frithii* in China (c. 141 kHz in average) (Zhang et al. 2009), *C. frithii formosanus* in Taiwan (c. 132 kHz in average) (Ho et al. 2013) and *C. robinsoni* from Sarawak (c. 155 kHz in average) (Mc Arthur, pers. com.). Like the Sarawak's *C. robinsoni* (Mc Arthur, pers. com.) and China's *C. frithii* (Zhang et al. 2009), our sample does not contain any CF component; whereas the Taiwan's *C. frithii* usually has a short CF component at the fundamental harmonic during flight as well as at the H2 in the calls when stationary (Ho et al. 2013). In both *C. f. formosanus* and *C. robinsoni*, the H1 are always stronger than the third harmonics. In *C. robinsoni*, there is usually a short temporal gap between the initial end of the H2 and the terminal end of H3 in a single call (Huang per. obs.). Our simple data demonstrates increased acoustic diversification among species and geographic populations of *Coelops* bats than was previous known.

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