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# The discovery of *Kerivoula krauensis* (Chiroptera: Vespertilionidae) in southern peninsular Thailand provides new information on the distribution and conservation status of this data deficient species.

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**Abstract**

In August 2013, an adult male *Kerivoula krauensis* was captured in a harp trap set in forest understorey in Bala Forest, Hala-Bala Wildlife Sanctuary, Narathiwat Province, Thailand. This is only the second locality record for the species, the first outside Malaysia and represents a range extension of 254 km, northwards from Krau Wildlife Reserve, Malaysia. This discovery has important conservation implications suggesting that the species is more widespread than previously thought but also confirms previous findings that it appears to live in very low population densities as compared to other *Kerivoula* found in the same habitat. Information on its taxonomy, echolocation call, distribution and ecology is included. In addition, the new material from Thailand is briefly compared to other known species from the country.

Keywords: *Kerivoula krauensis*, first record, echolocation, Thailand

## 1. Introduction

The first specimen of *K. krauensis* was collected in October, 1991 from Kuala Lompat, Krau Wildlife Reserve, Pahang, peninsular Malaysia. Based on its distinctive pelage it was presumed to be a new taxon. However, on the advice of the late John Edwards Hill of the Natural History Museum London, there was considered to be insufficient evidence to support its description as a new species, especially as the cranial morphology closely resembled *K. hardwickii* (Francis et al., 2007). Subsequently, in 1992 another individual was collected from the same locality. Between 1996 and 2004, a total of 56 individuals were collected in harp traps in the reserve, all but three of which were subsequently released. Finally, it was described as a new species by Francis et al. (2007). The discriminating characters were its distinctive pelage colour, minor cranial and dental differences, and a genetic divergence of 11% from all other species of *Kerivoula* based on 648 base pairs of the cyctochrome oxidase I gene (DNA barcode).

Until now, the known geographical range of *K. krauensis* was restricted to just five trapping stations within the Krau Wildlife Reserve and even here it was very rare in comparison to other species of *Kerivoula* (Francis et al., 2007; Chiozza, 2008; Francis, 2008). Subsequent research targeting Malaysian *Kerivoula* provided no new data on this species (Khan et al., 2010; Hasan and Abdullah, 2011).

In Thailand, Bumrungsri et al. (2006) published a summary of bat research with a checklist of species for the country. Since this publication, there have been a number of additions and the species count has gradually increased (Thong et al., 2006; Bates et al., 2007; Soisook et al., 2007, 2008, 2010; 2013a,b; Wu et al., 2009; Douangboubpha et al., 2010; Csorba, 2011; Csorba et al., 2011; Soisook, 2011; Francis and Eger, 2012). Today, the total number of bat species for the country is 140 species of which eight belong to the genus *Kerivoula*, namely: *K. papillosa, K. kachinensis, K. titania, K. hardwickii, K. pellucida, K. picta, K. whiteheadi* and *K. minuta*.

In August, 2013, a bat survey was conducted in Hala-Bala Wildlife Sanctuary, Narathiwat Province, peninsular Thailand. Amongst other bat taxa, four species of *Kerivoula* were collected including *K. papillosa, K. pellucida* and *K. minuta* and in addition there was a single male specimen of *Kerivoula krauensis.* This represents only the second geographical record of the species; the first record for Thailand and the first outside Malaysia.

## 2. Material and Methods

### 2.1. Field Work

An adult male was captured in Bala Forest, Hala-Bala Wildlife Sanctuary, Narathiwat Province, Thailand (Fig. 1) using a four-bank harp trap (Francis, 1989). The harp trap was set in the understorey of a patch of forest at 18.00 h and closed at 22.00 h. The sex and age of the individual was determined in the field. The relative age of the bat (adult or juvenile) was determined by the fusion of the epiphyses in the phalanges and metacarpal joints (Brunet-Rossinni and Wilkinson, 2009).

### 2.2. Sound Records and Analysis

Echolocation calls were recorded with a Pettersson Ultrasound Detector D 1000 (10x time expansion) whilst the bat was free-flying in a room (5x5x3 m). They were analysed using the software BatSound Pro version 4.1 (Pettersson Elektronik AB) and followed the procedures of Kingston et al. (1999) and Preatoni et al. (2005). For each call, six parameters were measured. These were: **PD:** pulse duration (ms) – measured automatically, from the beginning to the end of the call pulse on the spectrogram, using the Tool/Mark distance function; **PI:** pulse interval (ms) – measured automatically from the beginning of one pulse to the beginning of the next pulse using the Tool/Mark distance function; **MinF:** minimum frequency (kHz) – measured on the spectrogram with the large measurement cursor; **MaxF:** maximum frequency (kHz) – measured on the spectrogram with the large measurement cursor; **MaxEF:** maximum energy frequency (kHz) – measured by evaluating the maximum power spectrum, using the Power spectrum function, FFT (Fast Fourier Transforms) size 1024 and a Hanning window; **MidF:** middle frequency (kHz) – measured by evaluating a power spectrum

maximum at the middle of the call, using the Power spectrum function, FFT size 1024 and Hanning window.

### 2.3. Measurements

The adult male is held as a voucher specimen in the collection of the Princess Maha Chakri Sirindhorn Natural History Museum, Prince of Songkla University, Thailand (PSUZC).

Measurements were taken with a digital caliper, except body mass which was taken with a Pesola spring balance and followed Bates and Harrison (1997) and Bates et al. (2004). They included: **HB:** head and body – from the tip of the snout to the anus, ventrally; **FA:** forearm length – from the extremity of the elbow to the extremity of the carpus with the wing folded; **EL:** ear length – from the lower border of the external auditory meatus to the tip of the tail; **TL:** tail length – from the tip of the tail to its base adjacent to the anus; **TIB:** tibia length – from the knee joint to the extremity of the heel behind the *os calcis*; **HF:** foot – from the extremity of the heel behind the *os calcis* to the extremity of longest digit, not including the hairs or claws; **3MT, 4MT, 5MT:** third, fourth, fifth metacarpal lengths, respectively – from the extremity of the carpus to the distal extremity of the third, fourth and fifth metacarpals, respectively; **3D1P, 3D2P, 4D1P, 4D2P:** first and second phalanges of third and fourth digits, respectively – taken from the proximal to the distal extremity of the phalanges; **3D1Px100/3MT** – % length of the first phalanx of the third digit relative to the metacarpal length; **GTL:** greatest length of the skull – the greatest antero-posterior diameter of the skull, from the most projecting point at each extremity regardless of what structure forms these points; **CCL:** condylo-canine length – from the exoccipital condyle to the anterior alveolus of the canine; **CBL:** condylo-basal length – from the exoccipital condyle to the alveolus of the anterior incisor; **MW:** mastoid width – the greatest distance across the mastoid region; **ZB:** zygomatic breadth – the greatest width of the skull across the zygomata; **BB:** breadth of the braincase – width of the braincase at the posterior roots of the zygomatic arches; **BH:** braincase height – taken from the basisphenoid to the highest part of the skull; **BHx100/BB** – % height of the braincase relative to its breadth; **PC:** postorbital constriction – the narrowest width across the constriction posterior to the orbits; **ML:**

mandible length – from the most posterior part of the condyle to the most anterior part of the mandible, including the lower incisor; **$C^1$-$C^1$:** anterior palatal width – taken across the outer borders of the upper canine; **$M^3$-$M^3$:** posterior palatal width – taken across the outer borders of the third upper molar; **C-$M^3$:** upper toothrow length – from the front of the upper canine to the back of the crown of the third upper molar; **C-$M_3$:** lower toothrow length – from the front of the lower canine to the back of the crown of the third lower molar; **W:** body mass (in g).

## 3. Systematic Description

***Kerivoula krauensis* Francis et al., 2007**

Krau Woolly Bat

*Kerivoula krauensis* Francis, Kingston and Zubaid, 2007; Kuala Lompat, Krau Wildlife Reserve, Pahang, peninsular Malaysia (3°43'N, 102°10'E).

*New material*

PSUZC-MM2013.50 ♂, Bala Forest, Hala-Bala Wildlife Sanctuary, Waeng District, Narathiwat Province, Thailand (5°48'10"N, 101°49'45"E, 100 m a.s.l.).

*External characters*

The specimen of *Kerivoula krauensis* from Thailand has a forearm length of 30.8 mm (Table 1), which compares favourably to previous measurements of 28.7-32.2 mm reported in Francis et al. (2007) and 29.0-33.0 mm in Francis (2008). The pelage colour of the Thai specimen is closely similar to that described for the holotype by Francis et al. (2007). The fur on the dorsal surface is long, woolly, dark-brown basally and with shiny golden tips. The pelage on the ventral surface is dark-brown at the base with greyish-white tips (Fig. 2). The ears are relatively short and broadly funnel-shaped. The tragus is tall (7.4 mm in length) and slightly curved; it has an expanded base and is distinctly narrower towards the tip; it has a well-defined basal lobe. The muzzle, including the lips but excluding the nostrils, is hairy. There is a yellowish gland between the eye and the nose. In the wings, the fourth metacarpal exceeds the fifth in length, but is shorter than the third. The first phalanx of third digit is short, 43.0 % of

the length of the relatively long third metacarpal. The foot is relatively large, covered with long golden hairs, with the wing attached to the base of the outer toe. The interfemoral membrane is dark brown, thinly covered with dark brown hairs with golden tips.

*Cranial and dental characters*

The Thai specimen of *Kerivoula krauensis* has a condylo-basal length of 12.5 mm (Table 1), which is slightly larger than those (11.5-11.8 mm) previously reported in Francis et al. (2007). However, the Thai specimen is similar in all other diagnostic cranio-dental characters to those of *K. krauensis* as described in Francis et al. (2007). The skull is relatively broad. The braincase is globular (HB: 5.5 mm) and without a sagittal crest, the braincase height is 43.7% of the condylo-basal length, and arises abruptly from the rostrum (Fig. 3). The rostrum itself is relatively short and narrow, with a well-defined sulcus. The narial pit of the rostrum is V-shaped. Each zygoma is slender and without a dorsal process on the posterior part.

The length of upper toothrow (C-$M^3$) is 5.0 mm, which compares favourably to those (4.9-5.0 mm) previously reported in Francis et al. (2007). The first upper incisor ($I^2$) is relatively small and unicuspid; the second ($I^3$) is small, about half the height of $I^2$. The upper canine ($C^1$) is relatively large, with a well-defined cingulum and a longitudinal groove on its postero-internal border. The first upper premolar ($P^2$) exceeds the second ($P^3$) in height but is shorter than the third ($P^4$). The upper molars are well-developed with typical W-shaped cusps, which are characteristic of the genus. The lower incisors are tricuspid; the lateral cusps are reduced in the third ($I_3$). The lower canine ($C_1$) is small, with a small cingulum on its anterior-internal border and a shallow longitudinal groove on its posterior border. The first lower premolar ($P_2$) is similar in height to the second ($P_3$) and slightly exceeds the third ($P_4$). The lower molars have well-developed W-shaped cusps.

For a detailed comparison of *K. krauensis* with the other species of *Kerivoula* in Southeast Asia, see Francis et al. (2007).

*Echolocation calls*

*Kerivoula krauensis* from Thailand has a steep broadband, frequency-modulated (FM) call of low intensity and short duration (2.6-4.1 ms), which is typical of the genus. The start frequency (205.0-241.0 kHz) was higher than those reported from Malaysia (174 ± 6 kHz) (Francis et al., 2007) but this may reflect differences in recording technique and equipment rather than a natural phenomenon. The minimum frequency was 44.0-62.0 kHz (50 ± 11 kHz for Malaysia); the peak frequency was 136.8-166.8 kHz and the middle frequency was 114.3-140.2 kHz (Table 2).

*Conservation status and distribution*

*Kerivoula krauensis* was included as 'Data Deficient' in IUCN (Chiozza, 2008). Subsequently, Francis (2008) classified it as 'Vulnerable' based on the continuing loss of lowland rainforest.

*Kerivoula krauensis* is only known from peninsular Malaysia and Thailand (Francis et al., 2007; Francis, 2008; Chiozza, 2008; this study). Its distribution range is mapped in Fig. 1.

*Ecological and behavioural notes*

The single *K. krauensis* from Thailand was collected in the understorey of a lowland, primary, tropical rainforest, at an altitude of 330 m, adjacent to a swamp and small stream. In peninsular Malaysia, it was also caught in the understorey of mature lowland rainforest (Francis et al., 2007). Both areas have high annual rainfall (> 2,500 mm). Pregnant females have been found in February and April, and lactating females have been found in April, May, June and September (Kingston et al., 2006).

## 4. Discussion

This recent discovery of *K. krauensis* in Thailand is a northern range extension of 254 km and shows that it is more widespread than previously thought. This has implications for its conservation. Until now, its known range was restricted to a small area of approximately 530 km$^2$ in Krau Wildlife Reserve (Kingston et al., 1999, 2003, 2006). However, despite the range extension, it still appears that population density is

relatively low. In Krau Wildlife Reserve, its capture rate was < 0.4% of all bats (56/14,000 individuals); this is in comparison to 15.3% for *K. intermedia,* 7.8% for *K. papillosa* and 5.9% for *K. pellucida* (Francis et al., 2007). This apparent low density of the population is mirrored in Hala Bala, where despite intensive netting and harp trapping since 2003 (S. Bumrungsri, unpublished data), only one specimen has ever been collected.

*K. krauensis* is the fourth new species record of *Kerivoula* from Thailand since 2006; the others are: *K. pellucida* (Bumrungsri et al., 2006), *K. titania* (Bates et al., 2007) and *K. kachinensis* (Soisook et al., 2007). Others, such as *K. intermedia*, and *K. lenis* are also thought likely to be found.

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**Figure 1:** Distribution map of *K. krauensis*. Black circle represents new locality in Thailand and black star is the type and only known locality from Malaysia.

**Figure 2:** Latero-ventral view (A) and the mid-dorsal (B) and mid-ventral (C) pelage of *Kerivoula krauensis*, PSUZC-MM2013.50, ♂, from Hala-Bala Wildlife Sanctuary, Thailand.

**Figure 3:** Lateral, dorsal and ventral views of the skull of *K. krauensis*, PSUZC-MM2013.50, ♂, Hala-Bala Wildlife Sanctuary, Thailand. Scale: 5 mm.

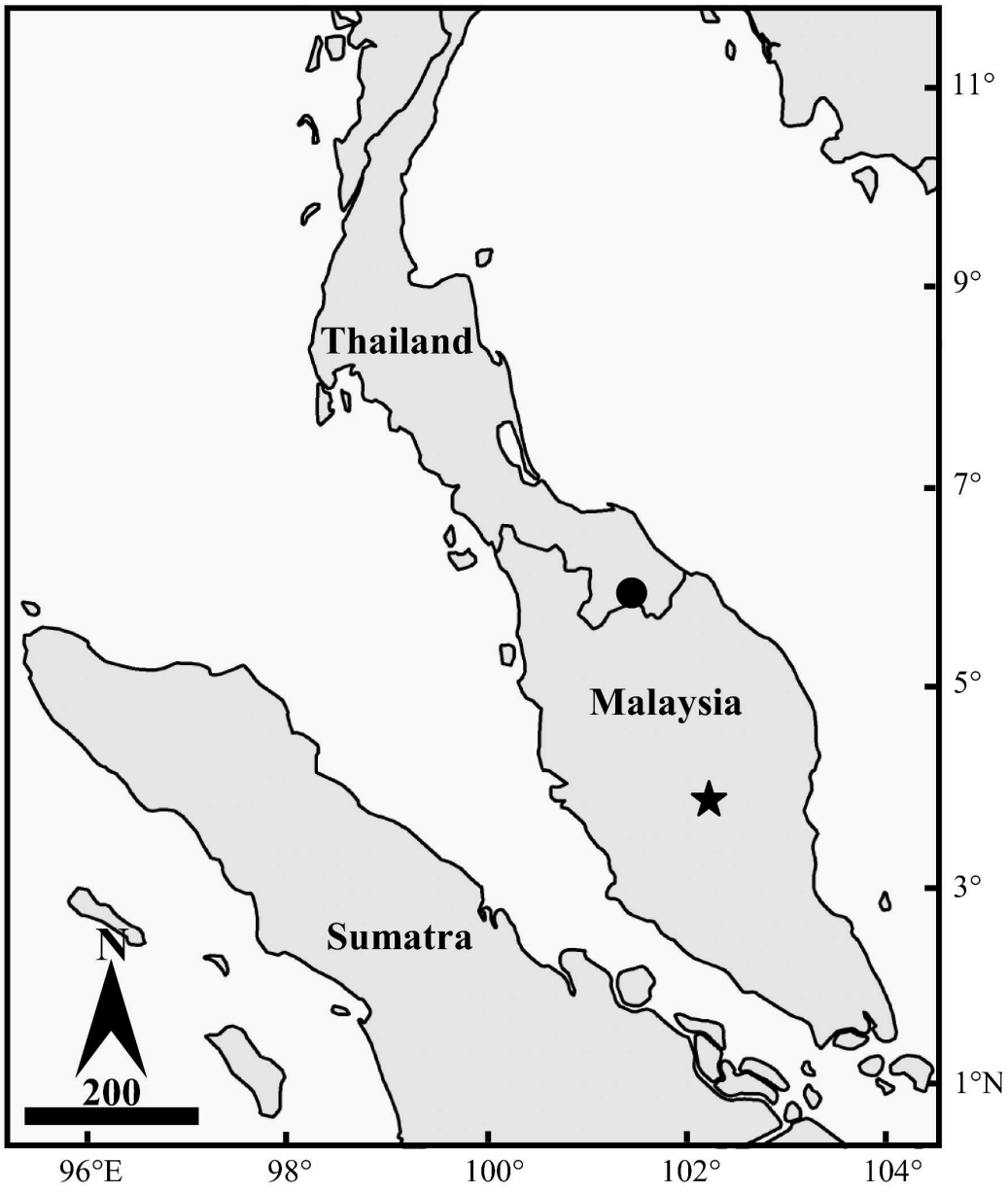


**Figure 1**


**Figure 2**

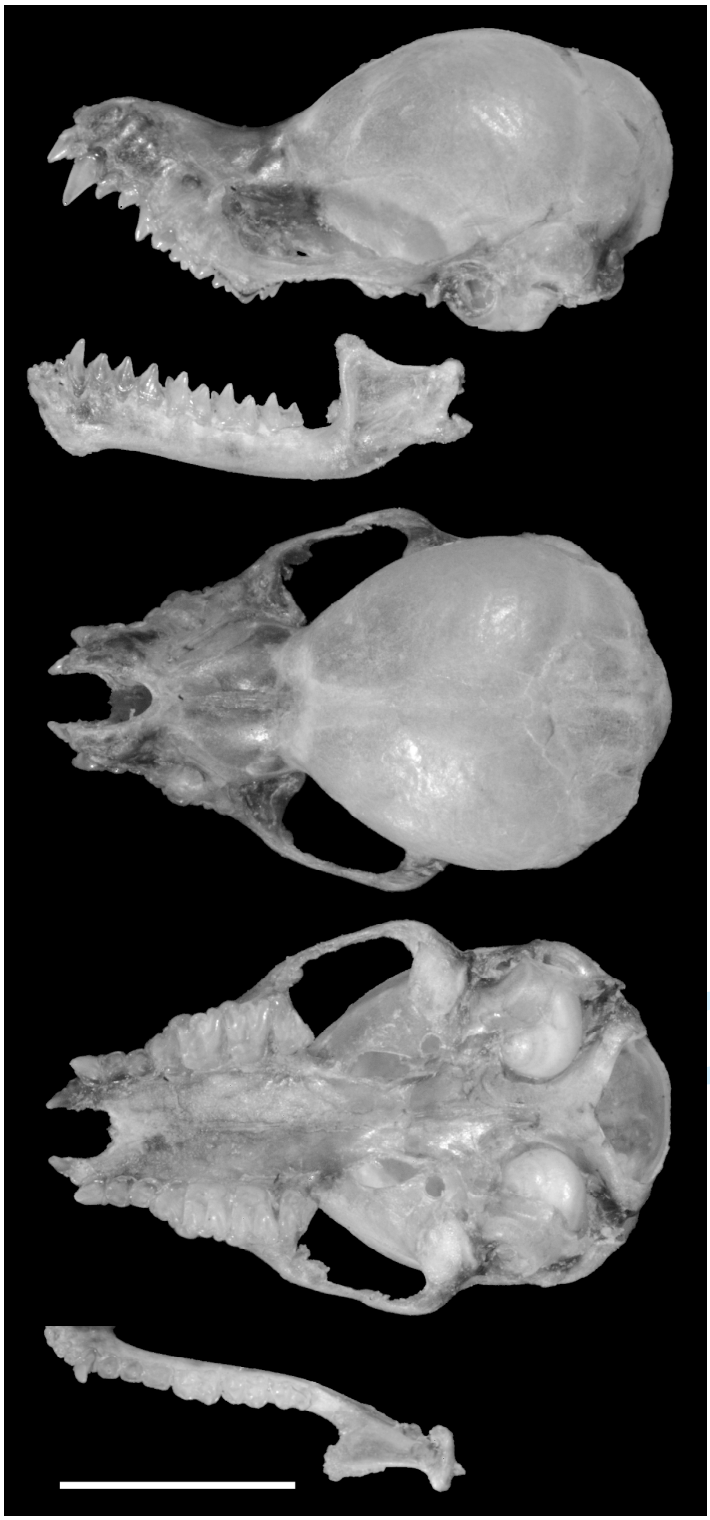

**Figure 3**

**Table 1:** External and cranio-dental measurements (mm), and body mass (g) of a single male specimen of *K. krauensis* from Thailand and, together with those measurements of Malaysian specimens included in Francis et al. (2007).

| Character | This study | Francis et al. (2007) |
|---|---|---|
| HB | 31.6 | 38.0-39.0 |
| FA | 30.8 | 28.7-31.2 |
| EL | 12.1 | 12.0 |
| TL | 33.1 | 34.0-37.0 |
| TIB | 14.6 | - |
| HF | 7.5 | - |
| 3MT | 31.5 | - |
| 4MT | 29.9 | - |
| 5MT | 28.3 | - |
| 3D1P | 13.6 | - |
| 3D2P | 13.0 | - |
| 4D1P | 8.3 | - |
| 4D2P | 6.3 | - |
| 3D1Px100/3MT | 43.0 | - |
| W | 3.2 | 2.7-3.2 |
| GTL | 13.3 | - |
| CCL | 12.0 | 11.3-11.5 |
| CBL | 12.5 | 11.5-11.8 |
| MW | 7.0 | - |
| ZB | 8.1 | 8.0-8.1 |
| BB | 7.0 | 6.8-6.9 |
| BH | 5.5 | - |
| BHx100/BB | 78.3 | - |
| PC | 3.2 | 3.1-3.1 |
| ML | 9.4 | - |
| $C^1$-$C^1$ | 3.0 | 2.9-3.1 |
| $M^3$-$M^3$ | 5.1 | 4.9-5.1 |
| C-$M^3$ | 5.0 | 4.9-5.0 |
| C-$M_3$ | 5.2 | 5.2-5.3 |

**Table 2:** Call parameters of *K. krauensis*. Minimum, maximum, mean and standard deviation. Number under *n* represents number of call pulse.

| Parameters | *n* | *K. krauensis* |
|---|---|---|
| MinF | 67 | 44.0-62.0 |
| | | 51.3, 4.4 |
| MaxF | 67 | 205.0-241.0 |
| | | 224.8, 9.3 |
| MaxEF | 67 | 136.8-166.8 |
| | | 146.7, 8.7 |
| MidF | 67 | 114.3-140.2 |
| | | 134.6, 4.5 |
| PD | 67 | 2.6-4.1 |
| | | 3.3, 0.4 |
| CI | 46 | 10.6-20.7 |
| | | 15.8, 2.8 |