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FURTHER RECORDS OF *MURINA TIENSA* FROM VIETNAM WITH FIRST INFORMATION ON ITS ECHOLOCATION CALLS

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ABSTRACT - The fairy tube-nosed bat, *Murina tiensa*, is considered to be endemic to Vietnam. It is known only from the original description, when it was found at two localities in limestone karst areas. In 2008, we conducted a series of intensive field surveys throughout the country and obtained additional records of this species from various habitats, including degraded to nearly pristine forests and an offshore island. Our results indicate that *M. tiensa* is a sexually dimorphic species, females being considerably larger than males in all external and craniodental measurements. The species emits broadband, downward frequency-modulated echolocation calls with a dominant first harmonic. When handheld or when flying in a flight tent, signals had a similar structure and were emitted in groups of 2–4 signals. On average, signals swept from 150 to 49 kHz in 2.2 ms for handheld bats, and, from 145 to 50 kHz in 1.9 ms for flying bats. *M. tiensa* often occurred in sympatry with *M. cyclotis* and several rhinolophids.

Key words: Chiroptera, ecology, FM-bats, Murininae, sexual dimorphism, taxonomy.

RIASSUNTO - ***Nuove segnalazioni di* Murina tiensa *in Vietnam e primi dati sulle sue ecolocalizzazioni***. *Murina tiensa* è una specie endemica del Vietnam, rinvenuta in due sole località carsiche. Nel 2008, una serie di campagne di ricerca ha permesso di ottenere ulteriori segnalazioni in diversi habitat, inclusi ambienti forestali, sia degradati sia quasi integri, e insulari. Sulla base dei nuovi reperti, *M. tiensa* è specie dimorfica, con femmine di dimensioni maggiori. Emette eco localizzazioni FM a banda larga, con una prima armonica dominante. I segnali vengono emessi in gruppi di 2-4 e mostrano una struttura simile sia quando gli animali sono trattenuti, sia quando sono in volo. Nel primo caso, in media, il segnale si

estende da 150 a 49 kHz in 2,2 ms, nel secondo da 145 a 50 kHz in 1,9 ms. *M. tiensa* è stato spesso rinvenuto in simpatria con *M. cyclotis* e vari rinolofidi.

Parole chiave: Chiroptera, ecologia, pipistrelli FM, Murininae, dimorfismo sessuale, tassonomia.

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INTRODUCTION

Over the past centuries, the bat fauna of Vietnam has received little attention from scientists. Huynh et al. (1994) provided a checklist of Vietnamese mammals, which includes three species of *Murina* (*Murina cyclotis*, *M. huttoni*, and *M. tubinaris*). Subsequently, *M. leucogaster* was documented from Pu Mat National Park, Central Vietnam (Hendrichsen et al. 2001). Borissenko and Kruskop (2003) identified a small individual collected from the Langbian Plateau, Southern Vietnam as *M. aurata*. These records of *M. leucogaster* and *M. aurata* in Vietnam were not ratified by Simmons (2005) in a global overview of bat species. Csorba et al. (2007) examined a specimen from Pu Mat National Park, which had been previously referred to *M. huttoni* by Hendrichsen et al. (2001), and classified it, together with three other specimens from Kim Hy Nature Reserve, Northern Vietnam, as a new species, namely *Murina tiensa*. Subsequently, Kruskop and Eger (2008) examined the single specimen assigned to *M. aurata* (Borissenko and Kruskop 2003), and classified it, together with another specimen from the same locality (Langbian Plateau, Southern Vietnam), as an additional new species, *M. harpioloides*. Recently, another tube-nosed bat species from Vietnam, *M. eleryi*, was described by Furey et al. (2009). Although the assessment of the taxonomic status of some Vietnamese tube-nosed bat species is still required (Csorba, in litt.), at least seven species of the genus *Murina* occur in the country. Identification of material collected from our field surveys in 2008 revealed further records. Here we provide new records of *M. tiensa* from four additional localities, together with the first data on its echolocation calls and information on its ecology.

MATERIALS AND METHODS

1. Materials

IEBR T.220408.2, adult female, body in alcohol, skull extracted, collected by VDT on 22 April 2008, Cat Ba National Park (CBNP), Hai Phong City, Vietnam, 20°48'N, 107°01'E, 148 m a.s.l; IEBR T.290708.6, adult female; IEBR T.290708.7, adult male, body in alcohol, skull extracted; plus a released adult male, collected on 29 July 2008, Xuan Son National Park (XSNP), Tan Son District, Phu Tho Province, 21°07'N, 104°57'E, 558 m a.s.l.; HNHM 2009.6.2 (field number T.010908.10), adult female, collected on 01 September 2008, Tam Dao National Park (TDNP), Tam Dao District, Vinh Phuc Province, Vietnam, 21°28'N; 105°38'E, 970 m a.s.l.; HNHM 2010.42.1 (field number T.070607.2), adult male, collected on 07 June 2007, Co Ma Proposed Nature Reserve (CMPNR), Thuan Chau District, Son La Province, Vietnam.

2. Comparative materials

HZM.2.38178 (holotype); HNHM 2007.28.1 (paratype); IEBR FT.301006.1 (paratype); HZM 1.31525.
The museum acronyms are as follows: IEBR T. and IEBR FT., the collection of Vu Dinh Thong, Institute of Ecology and Biological Resources, Hanoi, Vietnam; HNHM, Hungarian Natural History Museum, Budapest, Hungary; HZM, Harrison Institute, Sevenoaks, Great Britain, formerly Harrison Zoological Museum.

3. Bat capture and measurements

All bats were captured using four-bank harp traps set across footpaths and narrow streams in forested habitats. The following measurements were taken from both the collected specimens and museum comparative materials using digital callipers accurate to the nearest 0.1 mm: FA, forearm length — from the extremity of the elbow to that of the carpus with the wings folded; SL, total length of the skull — from the anterior rim of the alveolus of the first upper incisor to the most projecting point of the occipital region; MSL, maximum length of the skull — antero-posterior diameter of the skull, taken from the most projecting point at each extremity; CBL, condylobasal length — from the exoccipital condyle to the posterior rim of the alveolus of the first upper incisor; CCL, condylo-canine length — from the exoccipal condyle to the most anterior part of the canine; C1–C1, upper canine width — taken across the outer borders of upper canines; M3–M3, upper molar width — taken across the outer crowns of the last upper molars; ZW, zygomatic width — the maximum width of the skull across the zygomatic arches; IOW, interorbital width — the minimum width of the interorbital constriction; MW, mastoid width — the maximum distance across the mastoid region; BCW, braincase width — the maximum width of the braincase; BCH, braincase height — taken from the basisphenoid at the level of the hamular process; C1–M3, maxillary toothrow length — from the front of the upper canine to the back of the crown of the third molar; C1–P4, upper canine-premolar length — from the front of the upper canine to the back of the crown of the posterior premolar; ml, length of the mandible — from the anterior rim of the alveolus of the first lower incisor to the most posterior part of the condyle; c1–m3, mandibular toothrow length — from the front of the lower canine to the back of the crown of the third lower molar; c1–p4, lower canine-premolar length — from the front of the lower canine to the back of the crown of the posterior premolar; cph, height of the coronoid process — taken perpendicularly from the extremity of the coronoid process to the indentation of the ramus mandibulae.

4. Sound recording and analysis

Echolocation calls of the individuals from CBNP, TDNP, and XSNP were recorded in two different situations (while handheld and flying inside a flight tent) using the PCTape system (480 kHz, 16 bit). Sequences with a good signal-to-noise ratio were analysed using the Selena software (both PCTape and Selena are custom-made at the University of Tübingen, Germany). Signals were displayed as sonograms with a FFT (Fast Fourier Transformation) of 256, Hann-window and zero-padding. A custom-made script written by Peter Pilz (University of Tübingen) was employed to measure the following call parameters: initial frequency (Fi), end frequency (Ft), bandwidth (BW), pulse duration (PD), and pulse interval (PI). All parameters were measured from the first harmonic. The beginning and the end of each signal were set at -30 dB below the maximal amplitude of the signal.

RESULTS

1. Identification

Selected external and craniodental measurements of the five specimens collected during this study are shown in Table 1. Their pelage exhibits the typical fur colour of *M. tiensa*, with a uniform dirty white belly (Fig. 1A). The upper surfaces of the interfemoral membrane, tibia and hind feet are covered by dense and long hairs (Fig. 1B). The ventral surface of the interfemoral membrane and both surfaces of the wings are naked. The ear tips are broadly rounded, and the anterior margin of each is considerably strongly convex (Fig. 1A–B). Females are larger than males in all morphological and craniodental measurements (Tab. 2).

2. Echolocations

Murina tiensa used broadband, downward frequency-modulated (FM) calls of low intensity and short pulse duration with a dominant first harmonic. When either handheld or flying, signals had a similar structure and were emitted-

Table 1 - Selected external and craniodental measurements (in mm) of the five specimens collected during this study. Acronyms are defined in the section "Methods".

Measures	2 ♀♀	3 ♂♂	
	Min–max	Mean ± SD	Min–max
FA	38.2-40.1	34.9 ± 0.5	34.4-35.4
SL	18.2-18.2	18.0 ± 0.4	17.6-18.4
MSL	18.8-19.4	-	18.1 (1)
CBL	16.0-17.0	-	15.8 (1)
CCL	16.1-17.0	16.0 ± 0.3	15.7-16.3
C1–C1	4.9-5.0	4.7 ± 0.2	4.5-4.9
M3–M3	6.0-6.1	5.6 ± 0.2	5.5-5.8
ZW	10.8-11.3	10.4 ± 0.3	10.0-10.6
IOW	4.3-4.6	4.3 ± 0.1	4.2-4.3
MW	9.1-9.5	9.0 ± 0.2	8.7-9.2
BCW	7.9-8.1	7.8 ± 0.2	7.6-8.0
BCH	6.6-6.6	6.4 ± 0.2	6.2-6.6
C1–M3	6.3-6.3	6.1 ± 0.2	5.9-6.3
C1–P4	3.2-3.3	3.1 ± 0.1	3.0-3.2
ml	12.6-13.5	12.6 ± 0.4	12.2-12.9
c1–m3	6.8-6.9	6.7 ± 0.2	6.5-6.8
c1–p4	3.1-3.2	3.0 ± 0.1	2.8-3.1
cph	5.4-5.4	4.7 ± 0.3	4.4-4.9

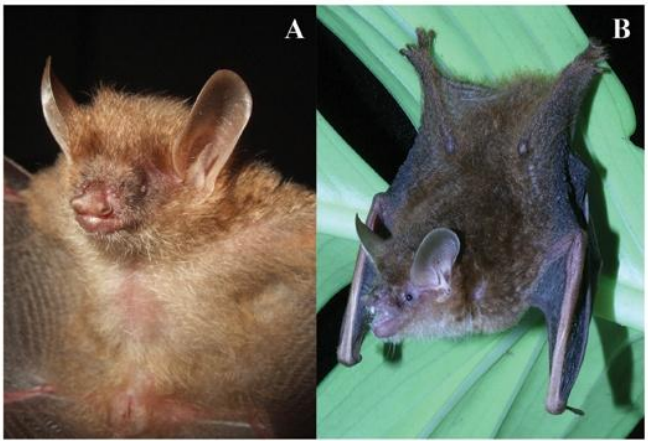

Figure 1 - Ventral and dorsal pelage of *Murina tiensa*.

Table 2 - Comparison of selected external and craniodental measurements (in mm) of known female and male *Murina tiensa*. Acronyms are defined in the section "Methods".

Character	5 ♀♀		4 ♂♂	
	Mean ± SD	Min-max	Mean ± SD	Min–max
FA	38.7 ± 1.4	37.1-40.1	35.0 ± 0.4	34.4-35.4
SL	18.8 ± 0.6	18.2-19.4	17.9 ± 0.5	17.4-18.4
MSL	19.3 ± 0.5	18.6-19.8	—	17.8, 18.1 (2)
CBL	16.8 ± 0.6	16.0-17.3	—	15.6, 15.8 (2)
CCL	16.7 ± 0.5	16.1-17.2	15.9 ± 0.3	15.7-16.3
C1–C1	5.0 ± 0.1	4.9-5.0	4.7 ± 0.2	4.5-4.9
M3–M3	6.1 ± 0.1	6.0-6.3	5.7 ± 0.2	5.5-5.9
ZW	11.0 ± 0.3	10.5-11.3	10.4 ± 0.3	10.0-10.6
IOW	4.4 ± 0.1	4.3-4.6	4.3 ± 0.1	4.2-4.4
MW	9.3 ± 0.3	8.9-9.5	8.9 ± 0.2	8.7-9.2
BCW	8.0 ± 0.1	7.8-8.1	7.9 ± 0.2	7.6-8.0
BCH	6.7 ± 0.1	6.6-6.9	6.4 ± 0.2	6.2-6.6
C1–M3	6.4 ± 0.2	6.3-6.7	6.1 ± 0.2	5.8-6.3
C1–P4	3.2 ± 0.1	3.2-3.4	3.0 ± 0.1	2.8-3.2
ml	13.2 ± 0.4	12.6-13.6	12.4 ± 0.4	12.0-12.9
c1–m3	7.0 ± 0.2	6.8-7.2	6.6 ± 0.2	6.3-6.8
c1–p4	3.2 ± 0.1	3.1-3.2	3.0 ± 0.1	2.8-3.1
cph	5.2 ± 0.2	5.0-5.5	4.6 ± 0.3	4.4-4.9

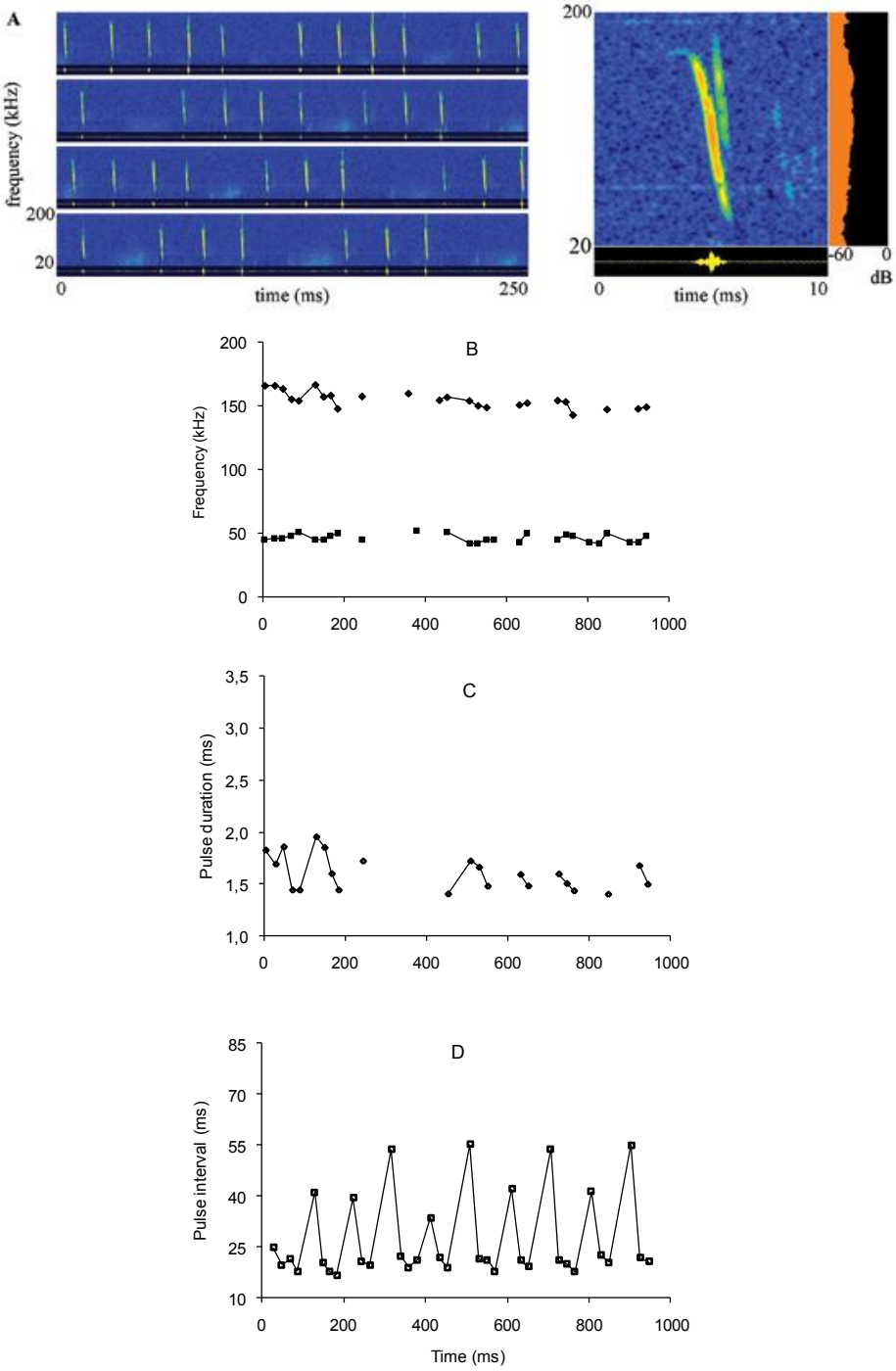

Figure 2 - Echolocation of a hand-held *Murina tiensa*. A: Sonograms and oscillograms of a signal sequence lasting 1 second with close-up view of a single signal; B: Initial (closed diamonds) and terminal (closed squares) frequency; C: duration; D: pulse interval.

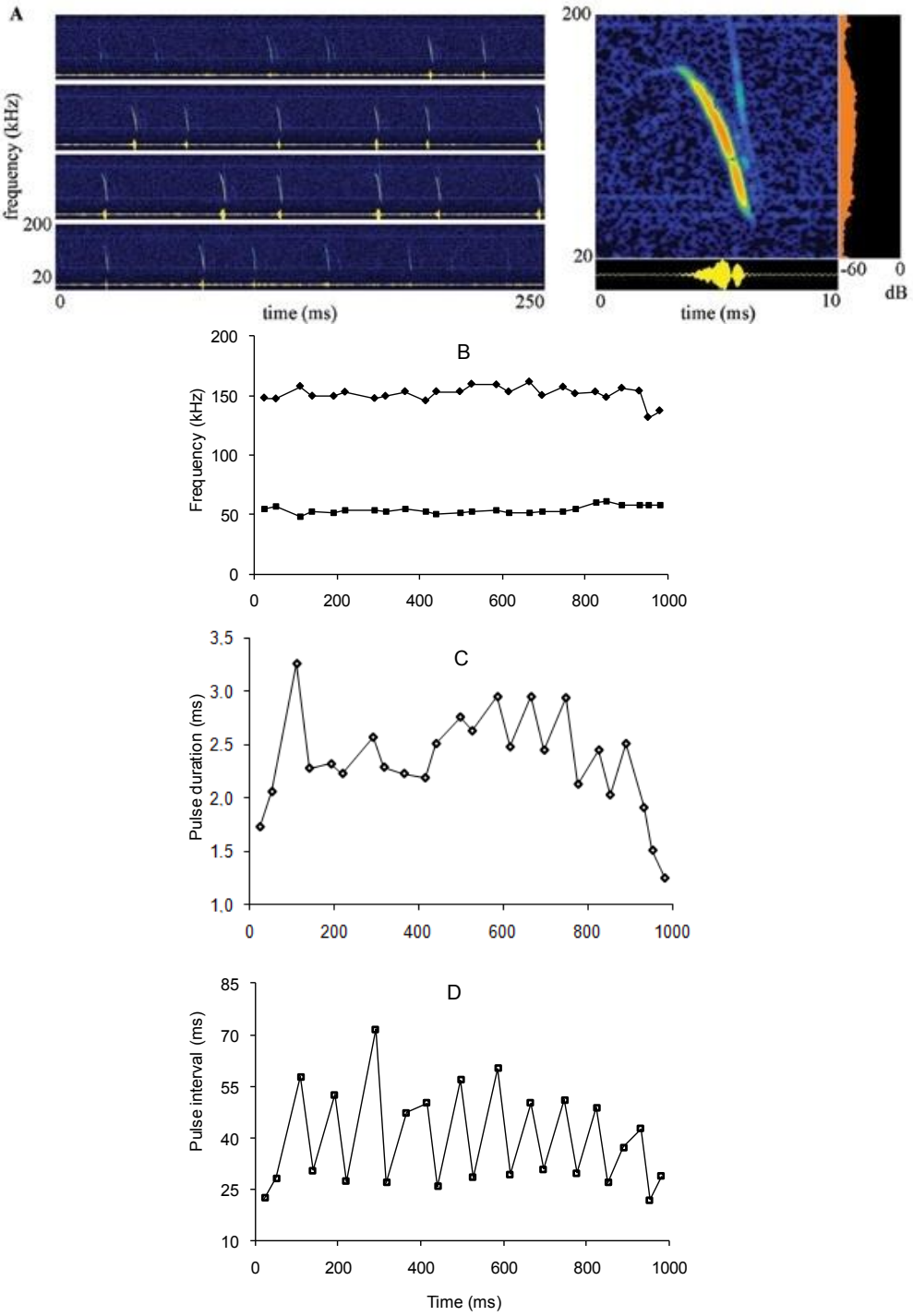

Figure 3 - Echolocation of a *Murina tiensa* flying in a flight tent. See Figure 2.

Table 3 - Selected parameters of echolocation calls of *Murina tiensa*. Fi: initial frequency; Ft: end frequency; BW: bandwidth; PD: pulse duration. Values are given as mean ± SD and min-max; in brackets: number of pulses.

Recording situation	No. of ind.	Call parameters			
		Fi	Ft	BW	PD
Handheld	3	150.1 ± 11.2	48.8 ± 4.4	100.3 ± 13.8	2.2 ± 0.8
		101.7-166.9 (54)	42.3-59.8 (58)	44.0-121.6 (49)	1.4-4.2 (49)
Flight	5	145.1 ± 8.1	50.1 ± 2.2	95.6 ± 8.9	1.9 ± 0.4
		122.2-164.8 (53)	45.8-55.8 (39)	74.8-115.9 (33)	1.3-3.1 (33)

in groups of 2–4 (Fig. 2, 3). For handheld bats, signals swept on average from 150 to 49 kHz in 2.2 ms and from 145 to 50 kHz in 1.9 ms for flying bats (Tab. 3).

DISCUSSION

Compared with other Vietnamese tube-nosed bat species, *M. tiensa* is distinctly larger than *M. tubinaris*, *M. harpioloides*, and *M. eleryi* in almost all features and measurements (Borissenko and Kruskop 2003; Kruskop and Eger 2008; Furey et al. 2009; Tab. 2). Its body size partially or fully overlaps that of three other species, *M. cyclotis*, *M. huttoni*, and *M. leucogaster*. However, *M. tiensa* differs clearly from these three species in the colour of its pelage, "insertion point of plagiopatagium and dental features" (Csorba et al. 2007). The characteristics and measurements of the five recently collected specimens agree with the original diagnosis for *M. tiensa*.

The description of the echolocation parameters of frequency-modulated signals depends on the criterion used to determine the beginning and the end of each signal (in our case: -30 dB below the maximal amplitude of the signals). Additionally, the initial frequency of a signal can only be measured accurately if the sampling rate of the recording system is at least twice as high. As a consequence, we have some difficulties in comparing our data with those reported for other *Murina* species (Kingston et al. 1999; Schmieder et al. 2010; Sun et al. 2008). However, most descriptions (including ours) agree that the bats of the genus *Murina* emit short broadband downward frequency-modulated signals with a dominant first harmonic, starting frequencies between 165 and 152 kHz and end frequencies between 45 and 55 kHz. The slightly higher terminal frequencies reported in Schmieder et al. (2010) (around 70 kHz) may be due to the different criterion of used to determine the beginning and the end of each signal (-25 dB). The low starting frequencies reported in Sun et al. (2008) (between 101–113 kHz) were probably the result of a low sampling rate. We therefore assume that all *Murina* species have rather similar FM signals with starting frequencies between 165–145 kHz and terminal frequencies between 45–55 kHz. The described emission pattern is also rather similar for all species and corresponds to that of small vespertili-

onid bats foraging for flying prey near vegetation. It clearly differs from that of narrow space active gleaners, such as *Coelops frithii* (Thong et al., submitted) and bats belonging to the genus *Kerivoula* (Schmieder et al., 2010), which emit groups of many, very short broadband signals. We agree with Kingston et al. (1999), who suggested that Murininae forage in more open areas than Kerivoulinae. We therefore propose to assign Murininae bats to the guild of "edge space active aerial-hawking foragers" (Schnitzler et al. 2003). The Murininae are highly adapted to hunt in confined spaces, as suggested by their agile flight and high pitched broadband signals which improve the separation of prey from the background (Siemers and Schnitzler 2004).

While XSNP and CBNP comprise limestone karst habitats, as the sites for which *M. tiensa* was already known (Csorba et al. 2007), with forests ranging from degraded to almost primary, TDNP, CMPNR and their surroundings include no limestone karst. At TDNP, an individual was collected in an area dominated by bamboo and small trees. Within CMPNR, natural forest habitats, which are mostly restricted to mountain peaks, were strongly degraded and fragmented. At CMPNR, an individual was captured in a secondary forest with bamboo and bushes at the foot of a mountain (656 metres above sea level) and nearby a village. Each individual from these two national parks was collected from within their core zones, where forests are nearly pristine. Caves of various sizes were situated next to each capture locality. With a record from CBNP, the distribution range of *M. tiensa* is now expanded from the Vietnamese mainland to an offshore island.

A number of other bat species were also captured together with *M. tiensa* at the study sites, *Hipposideros larvatus*, *H.* cf. *turpis*, *Rhinolophus pusillus*, *R. pearsonii*, and *M. cyclotis* (CBNP); *Harpiocephalus harpia*, *Rhinolophus affinis*, and *M. cyclotis* (TDNP); *H. larvatus*, *R.* cf. *macrotis*, *R. pearsonii*, *R. thomasi*, *Miniopterus* cf. *fuliginosus*, and *M. cyclotis* (XSNP); *H. larvatus* and *H. armiger* (CMPNR). These records suggest that *M. tiensa* coexists with *M. cyclotis* and several rhinolophids at most sites where it occurs.

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