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Research Article

Research Article

A new species of Tube-nosed Bat (Chiroptera: Vespertilionidae: *Murina*) from Qinghai–Tibet Plateau, China

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Abstract

In 2018, an adult male of a small-sized Tube-nosed Bat (Chiroptera: Vespertilionidae: *Murina*) was captured at an arid cave located on the Qinghai–Tibet Plateau in Yushu City, Qinghai Province, China. Despite external morphological similarities with those of *M. harpioloides* and *M. chrysochaetes*, the individual in question displays explicit craniodental differences that distinguish it from either species. Morphological and morphometric evidence, coupled with phylogenetic analyses utilizing the mitochondrial *COI* gene, confirmed that it represents a distinct and still unknown species of *Murina*, described herewith as *M. yushuensis* sp. nov. Our research highlights the importance of future surveys aimed at exploring cryptic species diversity in the Qinghai–Tibet Plateau and adjacent under-surveyed regions.

Key words: morphometrics, Murininae, phylogeny, systematics, taxonomy.

中国青藏高原一管鼻蝠新种的发现

本研究于2018年在中国青海玉树1个河流旁的干燥洞穴中捕获1只雄性小型管鼻蝠(翼手目Chiroptera：蝙蝠科Vespertilionidae：管鼻蝠属*Murina*)。其主要特征为, 前臂长31.34 mm, 颅全长14.14 mm；耳小而圆, 无缺刻；背毛呈现基部黑色, 顶端为棕金色；腹毛基部较长, 呈深黑色, 顶部呈灰白色。基于形态学证据和COI构建的系统发育树, 本研究将其鉴定为管鼻蝠属的新物种, 命名为玉树管鼻蝠(*Murina yushuensis* sp. nov. Han, Csorba *et* Wu, 2024)。该发现不仅丰富了翼手目物种多样性, 还说明了在青藏高原及周边区域等特殊生境开展翼手目调查的重要性。

关键词: 形态度量学, 管鼻蝠亚科, 系统发育关系, 系统学, 分类学.

Murina is the second-largest genus of Vespertilionidae, presently comprising 40 species (Burgin et al. 2020; Yu et al. 2020) distributed in Asia and Australasia, from South Asia to NE Russia, Japan, and New Guinea (Moratelli et al. 2019). Over half of the currently accepted species were discovered and described in the past 2 decades (Csorba and Bates 2005; Csorba et al. 2007, 2011; Kruskop and Eger 2008; Furey et al. 2009; Kuo et al. 2009; Eger and Lim 2011; Francis and Eger 2012; Ruedi et al. 2012; Soisook et al. 2013a, 2013b; He et al. 2015; Son et al. 2015; Chen et al. 2017; Zeng et al. 2018; Yu et al. 2020). Previously poorly surveyed areas in China contributed a considerable part to this boom of discovery. Before 2003, the country was only known to have 8 *Murina* species (Wang 2003). However, the recent combination of expanded survey efforts and upgraded research techniques such as DNA barcoding has led to a discovery of 10 new species from the country, predominantly described from the evergreen forests of South and Southeast China including Taiwan (*M. bicolor*, *M. gracilis*, and *M. recondita*; Kuo et al. 2009), Guangxi (*M. chrysochaetes* and *M. lorelieae*; Eger and Lim 2011), Guizhou (*M. fanjingshanensis*, *M. liboensis*, *M. rongjiangensis*, and *M. shuipuensis*; Eger and Lim 2011; He et al. 2015; Chen et al. 2017; Zeng et al. 2018), and Sichuan (*M. jinchui*; Yu et al. 2020). Currently, 21 *Murina* species have been recognized in China (Wei et al. 2022). In the meantime, regions such as Northeast and Northwest China and the Qinghai–Tibet Plateau remain poorly explored despite the fact

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that their unique environments could easily lead to adaptation and speciation (Keller and Seehausen 2012).

In 2018, a small-sized Tube-nosed Bat was collected during a field survey in a high-altitude arid valley in Yushu, Qinghai Province, China. Based on multivariate statistics of morphometric data and phylogenetic analyses of molecular data, the referred specimen differs from all previously recognized *Murina* species and is described herein as a new species.

Materials and methods.

Morphological measurements and morphometric analysis.

Altogether 127 specimens of 17 Tube-nosed Bat species were used in the morphometric analyses (Appendix I).

External and craniodental measurements were taken by the authors using digital calipers accurate to 0.01 mm (MNT-150, Shanghai Menet Industrial Co., Ld). External measurements include total body length (HB), tail length (T), ear length (E), hind foot length without claw (HF), forearm length (FA), and tibia length (Tib). Craniodental measurements include greatest length of skull (GTL), condylocanine length (CCL), braincase width (BCW), braincase height (BCH), zygomatic width (ZYW), mastoid width (MAW), interorbital width (IOW), maxillary toothrow length (C^1M^3L), width across upper canines (C^1C^1W), width across upper molars (M^3M^3W), ratio of C^1C^1W to M^3M^3W (RCM), mandibular toothrow length (LC_1M_3L), greatest length of mandible (ML), and coronoid process height (CPH). These external and craniodental measurements followed those from Yu et al. (2020) for consistency.

Based on these morphometric data, we performed principal component analysis (PCA) to discriminate species using the "phych" package in R (Jombart 2008).

Phylogenetic analysis.

DNA of the representative of the new species (GZHU 20077) and a representative of *M. aurata* (GZHU 17074) was extracted from fresh tissues with the DNeasy Blood & Tissue Kit (QIAGEN, Hilden, Germany). Handling of live animals followed ASM guidelines (Sikes et al. 2016). The mitochondrial cytochrome c oxidase subunit 1 (*COI*) fragment of 670 bp was amplified and sequenced with BatCO1F (TTT TCA ACC AAY CAY AAA GAY ATY GG) and BatCO1R (TAT ACT TCY GGG TGR CCR AAG AAY CA) primers, adapted from Kuo et al. (2014). We aligned our sequence with publicly available data from other species of *Murina* using MAFFT v7.450 (Katoh and Standley 2013). Genetic distances between species were conducted using the Kimura 2-parameter model (Kimura 1980) in MEGA 7 (Kumar et al. 2016). Maximum likelihood (ML) inference in IQTREE (Nguyen et al. 2015) was used to reconstruct phylogeny, with a TPM2u+F+R3 model. Branch support was estimated by 1,000 replications using the ultrafast bootstrap algorithm (UFBoot) embedded in IQTREE.

Results

The PCA of 6 external measurements revealed that principal component 1 (PC1) and principal component 2 (PC2) explained 61.7% and 14.9% of total variance, respectively (Fig. 1A). PC1 was mainly related to total body length, tail length, hind foot length, and forearm length—while ear size and tibia length had high positive loadings in PC2 (Table 1). This pattern from PC1 and PC2 indicated that the new species could be easily distinguished from other small *Murina* species, except for *M. rongjiangensis* and *M. shuipuensis* (Fig. 1A). The PCA of 12 craniodental measurements explained 80.78% of total variance, with PC1 and PC2 accounting for 71.6% and 9.2%, respectively (Fig. 1B). PC1 was positively associated with

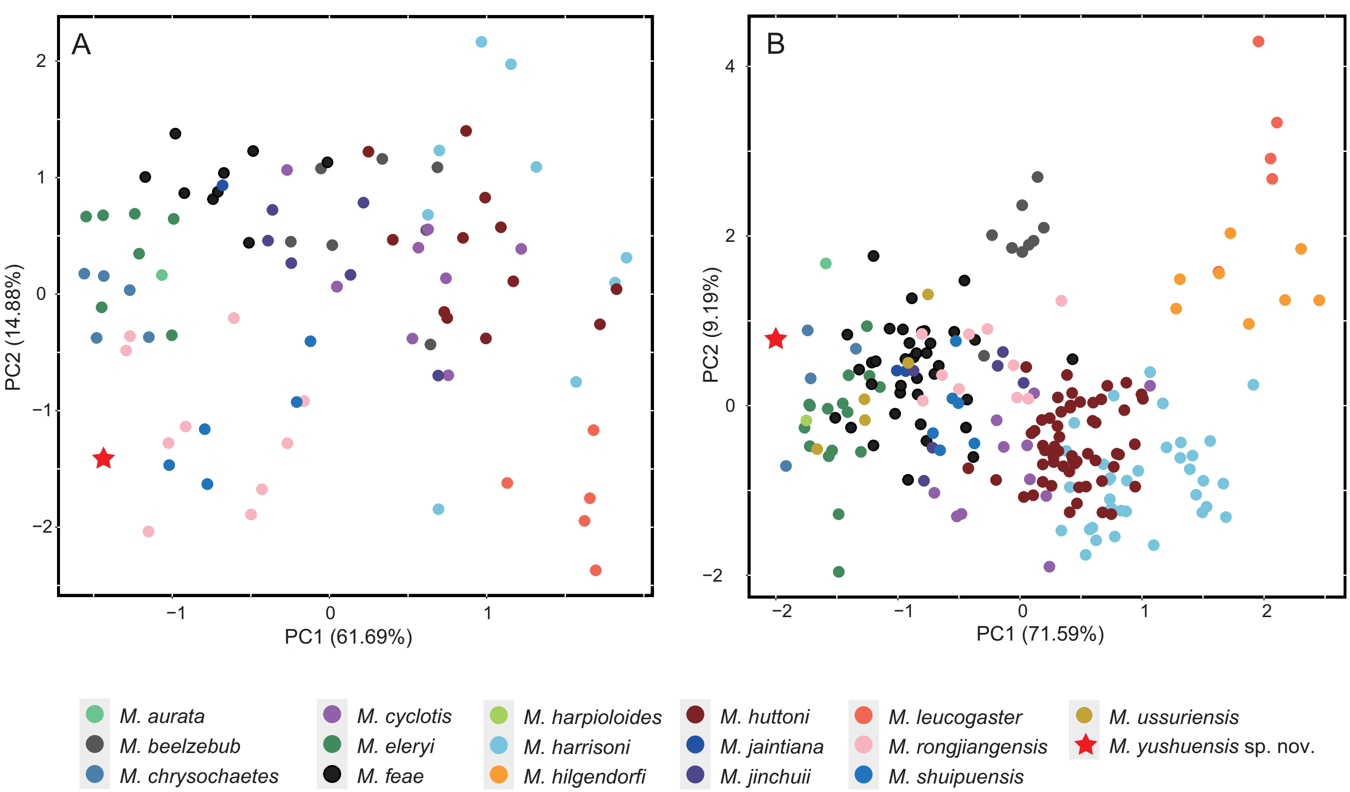

Fig. 1. PCA plots based on external (A) and craniodental (B) measurements of selected *Murina* species.

Table 1. Variable loadings on PCs from external and craniodental measurements.

Variable	PCA			
	PC1	PC2	PC1	PC2
HB	0.85	−0.18	—	—
T	0.80	0.25	—	—
E	0.60	0.63	—	—
HF	0.69	−0.55	—	—
FA	0.86	−0.25	—	—
Tib	0.87	0.19	—	—
CCL	—	—	0.97	−0.02
BCW	—	—	0.84	0.35
BCH	—	—	0.63	−0.08
MAW	—	—	0.67	0.28
IOW	—	—	0.56	0.75
C^1M^3L	—	—	0.94	−0.12
C^1C^1W	—	—	0.97	−0.15
M^3M^3W	—	—	0.91	0.09
RCM	—	—	0.71	−0.48
LC_1M_3L	—	—	0.90	−0.16
ML	—	—	0.97	−0.04
CPH	—	—	0.94	−0.14

7 measurements related to skull and dentition lengths (Table 1). Unlike the PC1, most measurements in PC2 except for interorbital had low loadings that were mainly related to skull width. The PC1 and PC2 of craniodental measurements separated the new species from most *Murina* species except *M. chrysochaetes* (Fig. 1B).

According to phylogenetic tree reconstruction using the *COI* gene, the new species (highlighted with pink in Fig. 2), is clustered with *M. aurata* (GZHU17074) sampled from Wolong, Sichuan, China (only 50 km from the type locality of the species); *M. harpioloides* (HM 540975.1 and JF 443974.1) sampled from Lam Dong, Vietnam (Kruskop and Eger 2008); and *M. chrysochaetes* (HM 540986.1) sampled in Diding Nature Reserve, Guangxi, China (Eger and Lim 2011). These 4 species formed a group (ultrafast bootstrap = 84), hinting at a unique biogeographic history for this group. The new species was found to be second basal within this group (ultrafast bootstrap = 92), but not closely related to the other species; *P*-distances ranged between 8.5% and 19.8%, which explicitly indicates species-level divergence (Supplementary Data SD1).

Systematics

Murina yushuensis Han, Csorba, Wu, new species

Holotype

GZHU 20077, adult male, collected on 20 December 2018 by Xuesong Han. The specimen is preserved as body in alcohol with the skull extracted and is presently deposited in the Key Laboratory of Conservation and Application in Biodiversity of South China, Guangzhou University, Guangdong, China. The nucleotide sequence of the mitochondrial gene *COI* has been submitted to GenBank with accession number OR990561. A 3D image of the skull is provided as Supplementary Data SD2.

Type locality.

Batang River valley, 32°55′53″N, 97°2′23″E, 3,770 m a.s.l., approximately 8 km from Yushu City, Qinghai Province, China.

Measurements (in mm) of holotype.

External measurements: HB: 30.44, T: 28.08, E: 11.08, HF: 8.46, FA: 31.34, Tib: 15.22. Craniodental measurements: GTL: 14.14, CCL: 13.85, BCW: 7.23, BCH: 6.05, ZYW: 7.94, MAW: 6.89, IOW: 4.31, C^1M^3L: 4.42, C^1C^1W: 3.26, M^3M^3W: 4.83, RCM: 0.67, LC_1M_3L: 4.09, ML: 9.08, CPH: 2.96.

Etymology

The specific epithet is derived from the type locality of the new species, Yushu City, Qinghai Province, China. Proposed vernacular names: Yushu Tube-nosed Bat, Yushu Guanbifu, 玉树管鼻蝠.

Diagnosis

A small-sized Tube-nosed Bat with forearm length of 31.34 mm and greatest skull length of 14.14 mm (Table 2). The dorsal fur has 2 color bands, black basally with a brown-gold tip (Fig. 3A and B). The ventral fur has a long dark base and a pale tip (Fig. 3C).

The rostrum is long and deep, gradually rising to the forehead (Fig. 4). Crown area of upper canine less than that of P^4. The mesostyles of the first (M^1) and the second upper molar (M^2) are low but clearly recognizable. The canines are slightly higher than the corresponding second premolars.

Description

A small-sized *Murina* species. The skin including the nose and chin is dark. The ears are small and round without a notch. The dorsal fur is bicolored, the basal 7 mm black with a 3 mm brown-gold tip. The dorsal surface of the uropatagium is also covered with similarly colored fur; tibia and the hindfeet are also densely furred. Short brown-gold hair covers the forearm, thumb, second, and third digit. On the venter, the fur is bicolored, the base is black at 6 mm with a pale tip 3 mm long. The plagiopatagium is attached to the base of the first toe.

The skull has a pronounced rostrum which slopes gently to the forehead. Sagittal and lambdoidal crests are lacking. The width of

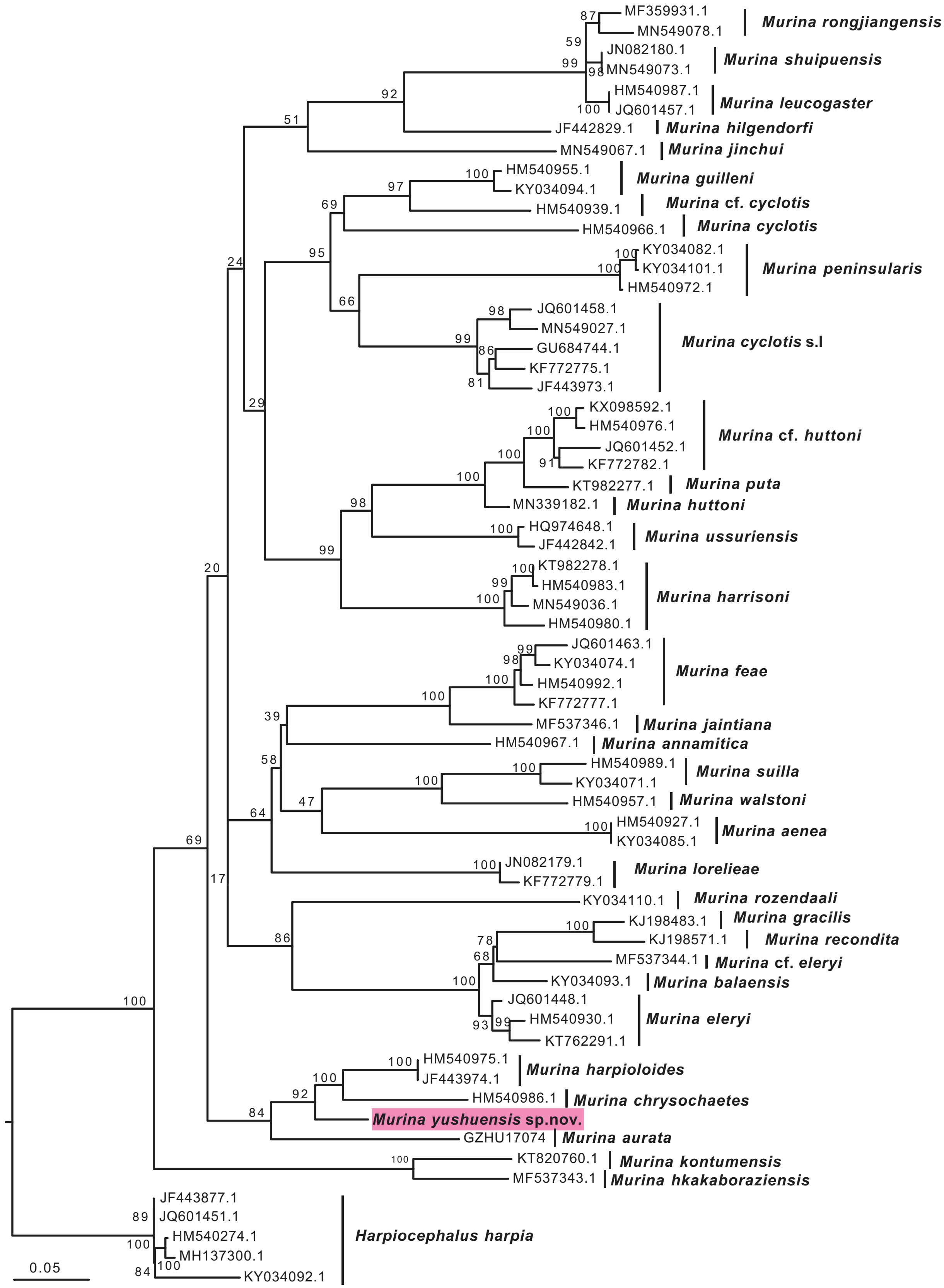

Fig. 2. Phylogenetic tree of *Murina*. Phylogenetic tree was reconstructed with ML methods based on *COI* gene. Number in the branch indicated ultrafast bootstrap values.

the nasal emargination exceeds its depth. The basisphenoid pits are shallow but well defined. Dental formula is I 2/3, C 1/1, P 2/2, M 3/3 = 34 and is of "*suilla*-type." The first upper incisor (I^2) and second upper incisor (I^3) are bicuspidate and approximately equal in height, and do not reach half the height of the upper canine (C^1). C^1 is clearly higher than P^4. P^2 is small, basally approximately 1/3 the size of the

Table 2. External and craniodental measurements (in mm) of *Murina yushuensis* sp. nov. and 4 closely related *Murina* species.

	***M. yushuensis* sp. nov. ♂**	***M. aurata* Wolong, China ♂**	***M. eleryi* holotype, ♂**	***M. chrysochaetes* holotype, ♂**	***M. harpioloides* holotype, ♀**
HB	30.44	40.00	—	—	35.00
T	28.08	30.00	28.70	28.00	30.50
E	11.08	14.00	12.60	11.00	12.30
HF	8.46	7.00	6.20	7.00	—
FA	31.34	30.99	28.40	26.35	29.70
Tib	15.22	13.76	14.70	10.92	—
GTL	14.14	15.36	14.90	14.05	—
CCL	13.85	13.06	12.59	12.45	12.34
BCW	7.23	7.72	7.11	6.98	7.21
BCH	6.05	6.65	5.77	—	5.81
ZYW	7.94	8.23	7.84	7.85	—
MAW	6.89	7.30	7.07	7.07	7.42
IOW	4.31	4.39	4.27	—	4.09
C^1M^3L	4.42	4.58	4.50	4.36	4.68
C^1C^1W	3.26	3.35	3.21	3.18	3.39
M^3M^3W	4.83	5.36	4.62	4.36	4.88
RCW	0.67	0.64	0.69	0.73	0.69
LC_1M_3L	4.09	4.17	4.89	4.36	5.13
ML	9.08	9.61	9.55	8.42	9.31
CPH	2.96	3.46	2.86	3.06	3.32

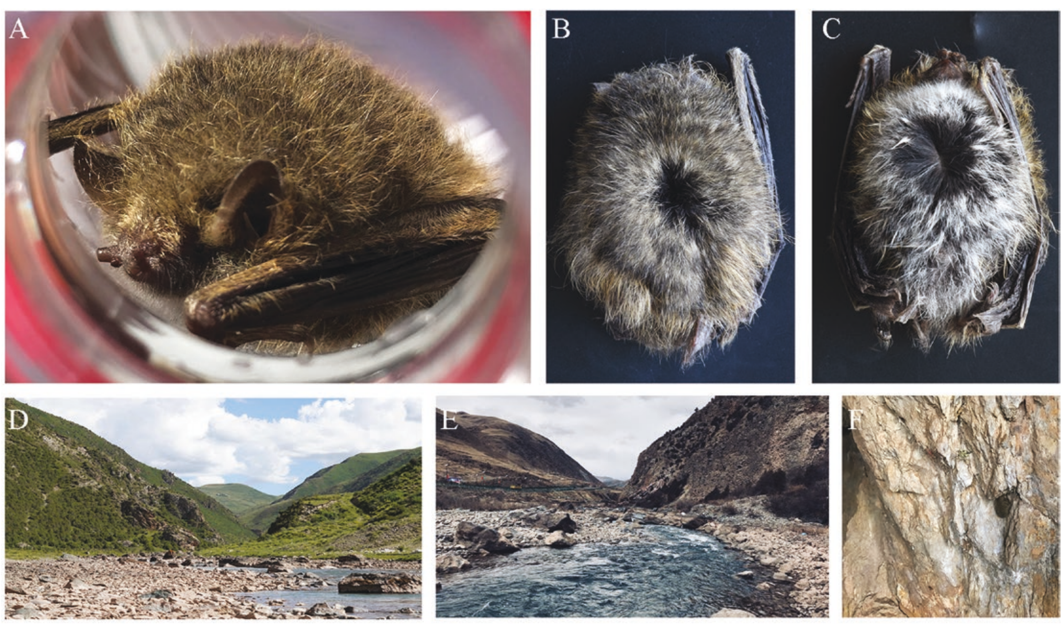

Fig. 3. External features and habitat of *Murina yushuensis* sp. nov. (Holotype, GZHU 20077). (A) Live individual. (B) Dorsal, and (C) ventral aspect of the body. (D) Surrounding environment of the cave in July, and (E) in March. (F) Type specimen hibernating in the cave. Photos by XH, YW, and WY.

crown area of P^4. The basal area of P^4 is twice that of C^1. The paracone, protocone, metacone, and parastyle are well developed on M^1 and M^2, but the mesostyle is low, although well defined. The posterior upper molar (M^3) lacks metacone, mesostyle, and metastyle and has a reduced postparacrista. All 3 lower incisors are nearly equal in width and length, small and tricuspidate. C_1 is a little higher than the first and second lower premolars (P_2 and P_4). P_2 and P_4 are subequal in height. The talonid of the first (M_1) and second (M_2) lower molars is almost the same size of the trigonid. The paraconid, protoconid, and metaconid of M_3 are intact and well developed, while the talonid of M_3 is greatly reduced.

Comparison with other species.

Based on morphological dentition, *M. yushuensis* sp. nov. evidently belongs to the "*suilla*-morphogroup," as demonstrated by the basal area of P^4 which is clearly larger than that of the C^1. This

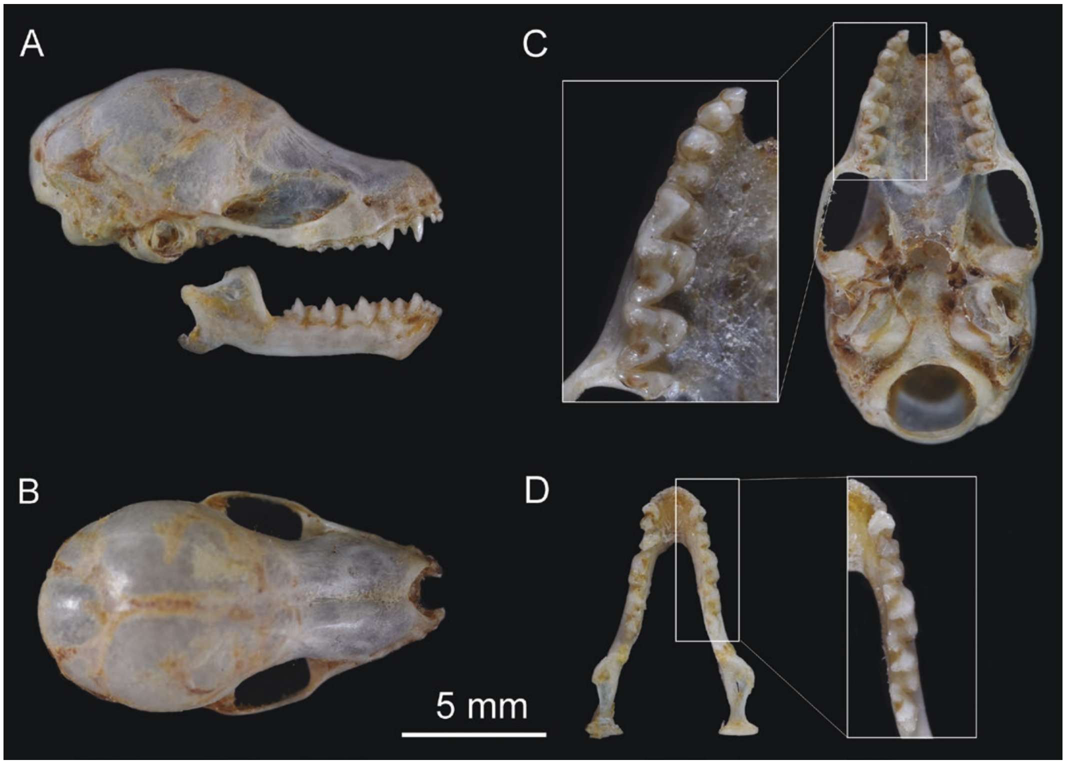

Fig. 4. Skull and dentition of *Murina yushuensis* sp. nov. (Holotype, GZHU 20077). (A) Lateral view of skull and mandible. (B) Dorsal view of skull. (C) Ventral view of skull with details of the upper toothrow. (D) Occlusal view of mandible with details of the lower toothrow.

diagnostic character differentiates *M. yushuensis* sp. nov. from all species belonging to "*cyclotis*-morphogroup." Among other members of the "*suilla*-morphogroup," *M. yushuensis* sp. nov. can be easily distinguished from larger-sized species (FA over 37 mm, CCL more than 15 mm), such as *M. hilgendorfi* (including *sibirica* and *ognevi*), *M. fanjingshanensis*, *M. leucogaster*, and *M. bicolor*. Fur coloration and the presence of a lambdoidal crest readily distinguish *M. jinchui*, *M. rongjiangensis*, and *M. shuipuensis* from *M. yushuensis* sp. nov. The dorsal fur of *M. jinchui* is brownish gray (as opposed to brown-gold in *M. yushuensis* sp. nov.), whereas the ventral fur of *M. rongjiangensis* and *M. shuipuensis* is orange yellow (vs. black and white in *M. yushuensis* sp. nov.). Among smaller members with predominantly reddish or brownish dorsal pelage of the "*suilla*-group" such as *M. aurata*, *M. chrysochaetes*, *M. kontumensis*, *M. hkakaboraziensis*, *M. balaensis*, *M. eleryi*, *M. gracilis*, *M. harpioloides*, and *M. ussuriensis*, there is a degree of overlap in cranial and external dimensions (Fig. 1; Table 1). Nevertheless, *M. yushuensis* sp. nov. could be distinguished from all of these species by having a wing attachment point at the base of the first toe (contrary to attachment at the ungual phalanx) and several additional key features listed herewith. Unlike *M. aurata*, the dorsal hairs of *M. yushuensis* sp. nov. lack the abundant shiny golden crown hairs; C^1 exceeds P^4 in height, the upper molars have distinct mesostyles (vs. C^1 lower, and mesostyles are much reduced in *M. aurata*). The dorsal fur of *M. chrysochaetes* is with conspicuous shiny golden hairs (similarly colored as *M. aurata*), and its skull is abruptly elevated toward the braincase, giving the skull a more domed appearance as compared with *M. yushuensis* sp. nov. Both *M. kontumensis* and *M. hkakaboraziensis* are characterized by a more grayish ventral aspect, developed lambdoid crest, and more domed skull (vs. long white distal part on ventral fur, no lambdoid crest, and not high braincase in *M. yushuensis* sp. nov.). The dorsal fur is generally bright reddish in *M. balaensis* (duller in *M. yushuensis* sp. nov.), but more grayish ventrally (distally clear white in *M. yushuensis* sp. nov.); upper canine with particularly developed cingular cusp (vs. without this trait in *M. yushuensis* sp. nov.). In *M. eleryi* the dorsal pelage is light reddish (more brownish in *M. yushuensis* sp. nov.), the rostrum short and the braincase is highly domed (vs. elongated and not bulbous in the new species). *Murina gracilis* has a more grayish ventral pelage and a basally relatively larger upper canine, but the ventral fur is distally clear white and the basal area of C^1 is half that of P^4 in *M. yushuensis* sp. nov. The ears of *M. harpioloides* are wide and rounded with a small emargination on the posterior edge (vs. *M. yushuensis* sp. nov. has smaller ears without notches); the talonid of M_2 exceeds that of the trigonid in *M. harpioloides* but the 2 are equal in the case of *M. yushuensis* sp. nov. Of the above smaller tube-nosed bats, *M. ussuriensis* is the only temperate zone species living under similarly harsh conditions and externally (both in terms of pelage color and the distribution of fur) quite like *M. yushuensis* sp. nov. Nevertheless, *M. ussuriensis* is not only phylogenetically very distinct (Fig. 2.) and geographically widely separated but has a more robust upper canine and a more developed anterior upper premolar that reaches half the height and half the basal area of P^4.

Habitat and ecology.

As a primary tributary of the upper Yangtze River on the Qinghai–Tibet Plateau, the Batang River runs through a deep valley with the river elevation between 3,860 and 3,530 m a.s.l. The region is dominated by typical alpine climate with annual average temperature at 2.9 °C, and annual precipitation at 487 mm. Under such climate, apart from boulders and weathered cliffs, the narrow valley is covered with meadow dominated by *Stipa capillacea*, *Potentilla fruticose* shrubland, and sparse *Sabina tibetica* forest (Fig. 3D and E).

The specimen was discovered in an L-shaped cave on 15 March 2018. The cave lies directly on the riverbank, with an entrance about 3.6 m wide and 1.2 m high, and an inner chamber about 3 m high and 1.3 m in diameter. The bat hibernated in the entrance part (and not in the inner chamber), similar to the case of *M. leucogaster* described from Henan Province (Niu 2006). When spotted, *M. yushuensis* sp. nov. was at first disturbed by a tap on its back, since its small size and dorsal fur greatly resemble the lichens in the region. Subsequently, it gradually awoke and started to make long and high-pitched noises. It was not captured at the time since its uniqueness was not realized and unnecessary killings are tabooed in the region. After learning that the species could be new to the region and even science, the cave was subsequently revisited many times. However, no bat but some other mammals were found (by personal observations or identified from scats and spraints) visiting the cave, including *Prionailurus bengalensis*, *Lutra lutra*, *Mustela altaica*, *Ochotona gloveri*, *Przewalskium albirostris*, and *Nectogale elegans*.

Nine months later, on 20 December 2018, the bat was found hibernating again at the exact same crevice (indicating a strong site fidelity) and was finally captured. Neither other bats nor bat feces were found in the cave. The specimen was captured alive because of its unclear identity and was kept in a paper box but was found dead the next morning.

Nearby villagers claimed that there is only 1 species of bat known in the region which helped exclude the possibility that the specimen was a recent vagrant from other areas. Therefore, unlike its tropical and subtropical relatives, it is reasonable to assume that *M. yushuensis* sp. nov. has developed a mechanism to cope with the harsh environment in the region—the lowest temperature could be under −30 °C and the oxygen level is only approximately 65% of the sea level. Two more valleys were also confirmed by interviews where this "astonishingly small bat" occurs, yet no specimens were found during our field surveys.

Discussion

As the first *Murina* species ever recorded in Qinghai Province, *M. yushuensis* sp. nov. was discovered in a habitat characterized with cold temperatures, high elevations, low levels of oxygen, and high levels of UV radiation, far from the known distribution area of congeners. Of the phylogenetically most closely related species, *M. chrysochaetes* and *M. harpioloides* are typically found in warm subtropical and tropical forests at much lower elevations (*M. aurata* has been recorded from higher terrains up to 2,500 m a.s.l.). Considering the limited long-distance flight abilities of tube-nosed bats in general, the huge distance that separates *M. yushuensis* sp. nov. from its relatives should indicate the presence of still undiscovered *Murina* species in the Hengduan Mountains that connect the Tibetan Plateau and Yunnan–Guizhou Plateau.

Intensified surveys in South China in recent years have led to the recognition of several new *Murina* species, indicating a remarkably high level of cryptic species diversity (Yu et al. 2020). In this case, not only does *M. yushuensis* sp. nov. add to this wave of discoveries, but also highlights the importance and urgency of exploring understudied regions, especially on the Qinghai–Tibet Plateau. As the amplifier of global climate change, associated extreme weather conditions on the plateau (Immerzeel et al. 2010) clearly add more uncertainty to the survival of flora and fauna in the region.

It should be noted that fieldwork in these areas faces specific obstacles. In chiropteran surveys, harp traps and mist nets are used to capture bats along foraging paths in forests. However, sparse forests and strong winds on the plateau make these widely applied methods barely feasible. Moreover, the Ahimsa Doctrines prevailing in many parts of the region also pose significant challenge to using traps—local inhabitants would destroy the traps set to capture wildlife once they find any. Such regional culture surely protects the local biodiversity to a great degree, but also restrict the efficiency of field surveys and render the understanding of bat diversity in the Qinghai–Tibet Plateau a difficult task.

Supplementary data

Supplementary data are available at *Journal of Mammalogy* online.

Supplementary Data SD1. Estimates of evolutionary divergence over *COI* sequences between species.

Supplementary Data SD2. 3D image of the skull for *Murina yushuensis* sp. nov.

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Author contributions

WY, YW, and ZL conceptualized the study; XH, HC, XZ, and ZD collected the samples; XW and WY wrote the original manuscript, and analyzed the data; XW, WY, GC, XH, YW, and ZL revised the manuscript.

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Conflict of interest

None declared.

Data availability

All sequence data used in this study are available in GenBank.

References

Burgin C, Wilson DE, Mittermeier RA, Rylands AB, Lacher TE, Sechrest W. 2020. Illustrated checklist of the Mammals of the World. Vol. 2. Barcelona (Spain): Lynx Edicions.

Chen J, Liu T, Deng HQ, Xiao N, Zhou J. 2017. A new species of *Murina* bats was discovered in Guizhou Province, China. Cave Research 2(1):1–10. http://dx.doi.org/10.1016/j.rgo.2013.10.012

Csorba G, Bates PJJ. 2005. Description of a new species of *Murina* from Cambodia (Chiroptera: Vespertilionidae: Murininae). Acta Chiropterologica 7(1):1–7. https://doi.org/10.3161/1733-5329(2005)7[1:doanso]2.0.co;2

Csorba G, Son NT, Saveng I, Furey NM. 2011. Revealing cryptic bat diversity: three new *Murina* and redescription of *M. tubinaris* from Southeast Asia. Journal of Mammalogy 92(4):891–904. https://doi.org/10.1644/10-mamm-a-269.1

Csorba G, Thong VD, Bates PJJ, Furey NM. 2007. Description of a new species of *Murina* from Vietnam (Chiroptera: Vespertilionidae: Murininae). Occasional Papers, Museum of Texas Tech University 268:1–9.

Eger JL, Lim BK. 2011. Three new species of *Murina* from southern China (Chiroptera: Vespertilionidae). Acta Chiropterologica 13(2):227–243. https://doi.org/10.3161/150811011x624730

Francis CM, Eger JL. 2012. A review of tube-nosed bats (*Murina*) from Laos with a description of two new species. Acta Chiropterologica 14(1):15–38. https://doi.org/10.3161/150811012x654231

Furey NM, Thong VD, Bates PJJ, Csorba G. 2009. Description of a new species belonging to the *Murina* '*suilla*-group' (Chiroptera: Vespertilionidae: Murininae) from north Vietnam. Acta Chiropterologica 11(2):225–236. https://doi.org/10.3161/150811009X485477

He F, Xiao N, Zhou J. 2015. A new species of *Murina* from China (Chiroptera: Vespertilionidae). Cave Research 2:2–6.

Immerzeel WW, van Beek LP, Bierkens MF. 2010. Climate change will affect the Asian water towers. Science 328(5984):1382–1385. https://doi.org/10.1126/science.1183188

Jombart T. 2008. Adegenet: a R package for the multivariate analysis of genetic markers. Bioinformatics 24(11):1403–1405. https://doi.org/10.1093/bioinformatics/btn129

Katoh K, Standley DM. 2013. MAFFT multiple sequence alignment software version 7: improvements in performance and usability. Molecular Biology and Evolution 30(4):772–780. https://doi.org/10.1093/molbev/mst010

Keller I, Seehausen O. 2012. Thermal adaptation and ecological speciation. Molecular Ecology 21(4):782–799. https://doi.org/10.1111/j.1365-294X.2011.05397.x

Kimura M. 1980. A simple method for estimating evolutionary rate of base substitutions through comparative studies of nucleotide sequences. Journal of Molecular Evolution 16(2):111–120. https://doi.org/10.1007/BF01731581

Kruskop SV, Eger JL. 2008. A new species of tube-nosed bat *Murina* (Vespertilionidae, Chiroptera) from Vietnam. Acta Chiropterologica 10(2):213–220. https://doi.org/10.3161/150811008x414809

Kumar S, Stecher G, Tamura K. 2016. MEGA7: molecular evolutionary genetics analysis version 7.0 for bigger datasets. Molecular Biology and Evolution 33(7):1870–1874. https://doi.org/10.1093/molbev/msw054

Kuo HC, Chen SF, Fang YP, Flanders J, Rossiter SJ. 2014. Comparative rangewide phylogeography of four endemic Taiwanese bat species. Molecular Ecology 23(14):3566–3586. https://doi.org/10.1111/mec.12838

Kuo HC, Fang YP, Csorba G, Lee LL. 2009. Three new species of *Murina* (Chiroptera: Vespertilionidae) from Taiwan. Journal of Mammalogy 90(4):980–991. https://doi.org/10.1644/08-mamm-a-036.1

Moratelli R, Burgin C, Cláudio V, Novaes R, López-Baucells A, Haslauert R. 2019. Family Vespertilionidae (Vesper Bats). In: Wilson DE, Mittermeier RA, editors. Handbook of the mammals of the world. Vol. 9, bats. Barcelona (Spain): Lynx Editions; p. 855–996.

Nguyen LT, Schmidt HA, von Haeseler A, Minh BQ. 2015. IQ-TREE: a fast and effective stochastic algorithm for estimating maximum-likelihood phylogenies. Molecular Biology and Evolution 32(1):268–274. https://doi.org/10.1093/molbev/msu300

Niu H. 2006. Studies on the fauna and phylogeny of Chiroptera in Henan Province [PhD thesis]. Shijiazhuang: Hebei Normal University.

Ruedi M, Biswas J, Csorba G. 2012. Bats from the wet: two new species of Tube-nosed bats (Chiroptera: Vespertilionidae) from Meghalaya, India. Revue Suisse de Zoologie 119(1):111–135. https://doi.org/10.5962/bhl.part.150145

Sikes RS, The Animal Care and Use Committee of the American Society of Mammalogists. 2016. 2016 Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. Journal of Mammalogy 97(3):663–688. https://doi.org/10.1093/jmammal/gyw078

Soisook P, Karapan S, Satasook C, Bates PJ. 2013a. A new species of *Murina* (Mammalia: Chiroptera: Vespertilionidae) from peninsular Thailand. Zootaxa 3746(4):567–579. https://doi.org/10.11646/zootaxa.3746.4.4

Soisook P, Karapan S, Satasook C, Thong VD, Khan FAA, Maryanto I, Csorba G, Furey N, Aul B, Bates PJJ. 2013b. A review of the *Murina cyclotis* complex (Chiroptera: Vespertilionidae) with descriptions of a new species and subspecies. Acta Chiropterologica 15(2):271–292. https://doi.org/10.3161/150811013x678928

Son NT, Csorba G, Tu VT, Thong VD, Wu Y, Harada M, Oshida T, Endo H, Motokawa M. 2015. A new species of the genus *Murina* (Chiroptera: Vespertilionidae) from the central highlands of Vietnam with a review of the subfamily Murininae in Vietnam. Acta Chiropterologica 17(2):201–232. https://doi.org/10.3161/15081109acc2015.17.2.001

Wang YX. 2003. A complete checklist of mammal species and subspecies in China. A taxonomic and geographic reference. Beijing: China Forestry Publishing House.

Wei FW, Yang QS, Wu Y, Jiang XL, Liu SY. 2022. Taxonomy and distribution of mammals in China. Beijing: Science Press.

Yu WH, Csorba G, Wu Y. 2020. Tube-nosed variations—a new species of the genus *Murina* (Chiroptera: Vespertilionidae) from China. Zoological Research 41(1):70–77. https://doi.org/10.24272/j.issn.2095-8137.2020.009

Zeng X, Chen J, Deng HQ, Xiao N, Zhou J. 2018. A new species of *Murina* from China (Chiroptera: Vespertilionidae). Ekoloji 103(27):9–16.

Appendix I

Specimens used in morphometric analyses. The museum acronyms are as follows: AMNH: American Museum of Natural History, New York; BM(NH): The Natural History Museum, London, formerly British Museum (Natural History); FMNH: Field Museum of Natural History, Chicago; GZHU: Guangzhou University, China; HNHM: Hungarian Natural History Museum, Budapest; HZM: Harrison Institute, Sevenoaks, formerly Harrison Zoological Museum; IEBR: Institute of Ecology and Biological Resources, Hanoi, Vietnam; KMC: Kishio Maeda Collection, Nara; MHNG: Natural History Museum of Geneva, Switzerland; ROM: the Royal Ontario Museum, Toronto; ZMMU: the Zoological Museum of Moscow University, Moscow.

Murina aurata: Wolong, Sichuan, China—GZHU87052.

Murina beelzebub: Ba To, Quang Nai, Vietnam—IEBR-M-3867, IEBR-M-3870, IEBR-M-3873; Huong Hoa, Quang Tri, Vietnam—HNHM_2007.50.24, HNHM_2007.50.7, HNHM_2007.50.6; Ngoc Linh, Kon Tum, Vietnam—IEBR/TVT-VN11-1208, IEBR/TVT-VN11-1244, IEBR-M-3636, IEBR-M-3904, IEBR-M-4149; Kon Ka Kinh, Gia Lai, Vietnam—HZM-3.32053.

Murina chrysochaetes: Nanling, Guangdong, China—GZHU12448, GZHU13523, GZHU13508, GZHU13527, GZHU13531.

Murina cyclotis: Darong Mountain, Guangxi, China—GZHU13030, GZHU13508; Heishiding, Guangdong, China—GZHU14128, GZHU14153, GZHU14163, GZHU14169, GZHU14127, GZHU14152.

Murina eleryi: Nanling, Guangdong, China—GZHU12446, GZHU13128, GZHU13129; Jinggang Mountain, Jiangxi, China—GZHU13334, GZHU13413, GZHU13294, GZHU13319.

Murina feae: Phong Saly, Laos—AMNH32199; Ba Be, Vietnam—HNHM2000.84.4, HNHM2000.84.7; Mondol Kiri, Cambodia—HNHM2005.81.35, HNHM2005.81.36, HNHM2005.81.49, HNHM2005.81.50, HNHM2005.81.51, HNHM2005.81.52, HNHM2005.81.53, HNHM2006.34.40, HNHM2010.42.2; Chu Mom Rai, Kon Tum, Vietnam—IEBR/ThongColl.32CMRay; Bach Ma NP, Thua Thien–Hue, Vietnam—IEBR/Thong Coll.T112; Kim Hy, Bac Kan, Vietnam—IEBR/ThongColl.T83; Na Hang, Tuyen Quang, Vietnam—HNHM22823, HZM1.31780.

Murina harpioloides: Da Lat, Lam Dong, Vietnam—ZMMU-S-173401.

Murina harrisoni: Jinggang Mountain, Jiangxi, China—GZHU13479; Nanling, Guangdong, China—GZHU14287, GZHU14290, GZHU14292; Jiulianshan, Jiangxi, China—GZHU15158, GZHU15159, GZHU15160, GZHU15162, GZHU15201.

Murina hilgendorfi: Heilongjiang, China—ROM112822, ROM112832; Honshu, Japan—HZM2.2975, HZM1.2974; Kangwon, South Korea—HNHM2000.64.1; Kyongsang-bukto, South Korea—HNHM2003.37.12; Primorje, Russia—MHNG1935.028, MHNG1935.029.

Murina huttoni: Nanling, Guangdong, China—GZHU09229, GZHU09244, GZHU12193, GZHU12196, GZHU12198, GZHU12199, GZHU09230, GZHU09231, GZHU09232, GZHU12192, GZHU12194, GZHU12195.

Murina jaintiana: Jaintia Hills, India—MHNG_M1619, MHNG1976.027; Chin Hills, India—BM(NH)16.3.26.85, BM(NH)16.3.26.86, BM(NH)16.3.26.87, BM(NH)16.3.26.88, BM(NH)16.3.26.7, BM(NH)16.3.26.8, BM(NH)16.3.26.5, HNHM2000.20.1; Chungtang, Sikkim, India—FMNH35829; Lushai Hills, India—FMNH76053; Mawryngkueng, Khasi, India—FMNH76054; Dening, Mishmi Hills, India—FMNH82775, FMNH82776.

Murina jinchui: Wolong, Sichuan, China—GZHU14453, GZHU14454, GZHU14455, GZHU14463, GZHU14462, GZHU14461.

Murina leucogaster: Pingwu, Sichuan, China—GZHU06002, GZHU06003, GZHU06004, GZHU06005; Yaan, Sichuan, China—GZHU10122.

Murina rongjiangensis: Rongjiang, Guizhou, China—GZHU15116, GZHU15118, GZHU15119, GZHU15120, GZHU15200, GZHU15375, GZHU15100, GZHU15096, GZHU15139, GZHU15240.

Murina shuipuensis: Libo, Guizhou, China—GZHU15423, GZHU15424, GZHU15619, GZHU15403, GZHU15420, GZHU15416.

Murina ussuriensis: Hokkaido, Japan—KMC3093, KMC3211, KMC12366, KMC12367; Primorskij Kraj, Russia—ZMMU-S-181388.