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A new mouse-eared bat (Mammalia: Chiroptera, Vespertilionidae) from South China

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A small *Myotis* species belonging to the *Myotis siligorensis* group was found in four caves in Yunnan province, South China. Twenty specimens of this bat were compared with other East Asian *Myotis* species. Statistical and physical analysis of this sample demonstrates that, despite their similarity to *M. siligorensis*, the Yunnan specimens have characteristics of baculum morphology and cranial proportions suggesting that they represent a distinct species.

Key words: *Myotis* sp. nov., taxonomy, baculum, South China

INTRODUCTION

The genus *Myotis* is amongst the largest mammalian genera (Simmons, 2005). Its internal structure is very problematic since the traditionally accepted affiliations between *Myotis* species were called into question by recent molecular studies (Ruedi and Mayer, 2001; Zang *et al*., 2009; Lack *et al*., 2010). Thus the genus includes numerous species complexes with questionable and uncertain taxonomy. One of these is the *Myotis* '*siligorensis*' species group. This group was initially proposed for only one species (Tate, 1941), characterized by small size, formal features of the subgenus *Selysius*, low rostrum, abruptly elevated frontal profile and small canines. Within this species four geographical races were usually recognized (Ellerman and Morrison-Scott, 1966; Simmons, 2005). This species group was accepted by e.g. Koopman (1994) but not defined in the latest published checklist (Simmons, 2005). It was considered to be a good taxonomic unit by Borisenko *et al*. (2008) and an additional species — *Myotis phanluongi* — was described. Here we suggest inclusion into this group of several other Asiatic species of similar size and skull proportions, namely *Myotis laniger*, *M. longipes*, *M. annamiticus*, *M. taiwanensis* and *M. csorbai*. This proposal is supported by molecular data (Borisenko *et al*., 2008; Zhang *et al*., 2009; Francis *et al*., 2010). Being distributed sporadically and not very well represented in scientific collections, bats of this species group are insufficiently investigated taxonomically.

In June 2006, during joint field work supported by the Russian Foundation for Basic Research (RFBR) and the National Natural Science Foundation of China (NNSFC), scientific voucher specimens of bats were collected from Yunnan province (southern China). The collection includes several specimens of small mouse-eared bats (genus *Myotis*) of uncertain taxonomic status. An analysis and comparison of the external and cranial morphological characteristics of these *Myotis* specimens indicate that they possess features that set them apart from other South Asian representatives of the genus *Myotis*. In our opinion, these mouse-eared bats, captured in Longxu, Xianren, Dashi, and Huyan caves (Yunnan province), represent a distinct species.

MATERIALS AND METHODS

Two males and 12 females of *Myotis* sp. nov. were captured in a mist net from Longxu Cave (24°30'N, 102°20'E); two females from Xianren Cave at Fagudian Village (24°30'N, 102°20'E); one male and two females from Dashi Cave (24°29'N, 102°22'E); and one male from Huyan Cave at Shuanghechang Village (24°29'N, 102°22'E). All are preserved in 75% ethanol with skulls extracted.

Forty-nine specimens of morphologically similar species were used for qualitative and quantitative morphological comparison (adult individuals of both sexes; dry or alcohol

preserved skins with extracted skulls). Acronyms of repositories of the processed collections are as follows: FMNH — Field Museum of Natural History, Chicago, USA; HNHM — Hungarian Natural History Museum, Budapest, Hungary; ROM — Royal Ontario Museum, Toronto, Canada; ZMMU — Zoological Museum of Moscow State University, Moscow, Russia; IBSS — Institute of Biology and Soil Science, Far East Branch of the Russian Academy of Sciences, Vladivostok, Russia.

Myotis csorbai Topal, 1997 — Central Nepal (including five paratypes of the species): ZMMU S-164475 ♀, ZMMU S-164476 ♀, ZMMU S-164478 ♀, ZMMU S-164481 ♀, ZMMU S-164483 ♀, ZMMU S-164484 ♀, ZMMU S-164485 ♂, ZMMU S-164487 ♂, ZMMU S-164490 ♂. *Myotis annamiticus* Kruskop and Tsytsulina, 2000 — Central Vietnam (from the type series of the species): ZMMU S-167123 ♂, ZMMU S-167126 ♂, ZMMU S-167127 ♀, ZMMU S-167128 ♀, ZMMU S-167132 ♀, ZMMU S-167134 ♀, ZMMU S-167135 ♀. *Myotis* cf. *annamiticus* — Laos: ROM 110661 ♂. *Myotis siligorensis* — Vietnam Central Highlands: ZMMU S-175152 ♀, ZMMU S-175157 ♂, ZMMU S-175159 ♀; Central Vietnam: ZMMU S-167188 ♂; Northern Vietnam (Tuen Quang, Sa Pa and Muon Muon; including three females from the type series of *M. s. alticraniatus*): ROM 107649 ♀, ROM 107652 ♀, ROM 107657 ♀, ROM 107677 ♀, ROM 112447 ♂, ROM 112456 ♂, ROM 112458 ♂, FMNH 32173 ♀, FMNH 32175 ♀, FMNH 32178 ♀; China, Fujian (= Fokien): FMNH 33858 ♂, FMNH 33859 ♂, FMNH 44109 ♀. *Myotis laniger* (Peters, 1871) — Northern Vietnam: ROM 107655, ROM 107665 ♀, ROM 112492 ♂, ROM 111269 ♂, HNHM 93.57.1 ♀; India: HNHM 92.108.1 ♂, HNHM 92.108.2 ♂, HNHM 92.108.3 ♀; Southern China: IBSS u-06-75, IBSS u-06-106. *Myotis taiwanensis* Linde, 1908 — Taiwan: HNHM 2005.65.43. *Myotis muricola* (Gray, 1846) — Southern Vietnam: ZMMU S-173413 ♂, ZMMU S-172616 ♂, ZMMU S-172626 ♂; Central Vietnam: ZMMU S-165048 ♀, ZMMU S-165055 ♂.

External measurements were taken to the nearest 0.1 mm with a dial caliper. A set of 19 cranial measurements was taken in the laboratory to the nearest 0.01 mm with an electronic caliper in combination with a binocular microscope.

The following external measurements were taken: head and body length (HB), tail length (T), length of free tail tip (TT), ear length (E), tragus length (Tr), tibia length (Tib), foot length (without claws and including claws (F), measured to the most remote part of claw), forearm length (FA), length of the first digit including claw, length of the metacarpal of the second digit, and lengths of the metacarpals and phalanxes of the third through fifth digits. All wing measurements were taken on the right wing.

The following cranial characters were measured (appropriate abbreviations are given in parentheses): condylobasal length (CBL), condylocanine length (CCL), width of the skull at the level of the auditory bullae (W), width of braincase (BCW), height of braincase posterior to the auditory bullae (BCH), least interorbital width (IOW), zygomatic width (ZW), rostral width at the level of the preorbital foramina (WR), rostral length from the preorbital foramen to the alveolus of the inner incisor (LR), C–M^3 length (CM3), length of interval between cingulum of upper canine and large premolar ('pseudodiastema', PD), molariform tooth row length (P4M3), width of M^3 (WM3), length of M^3 (LM3), crown measured width between outer margins of upper canines (CC), crown measured width between outer margins of M^3 (M3M3), lower jaw length from alveolus of I_1 to the articulated process (LMD), lower jaw height on the level of the tip of the coronoid process (HMD), crown length of maxillary tooth row (MCM3).

During statistical processing this list of measurements was restricted to 16 due to missing data. To assess the pattern of variation of quantitative characters, principal component (PC) analyses were performed for cranial measurements, using the factor analysis module of STATISTICA for Windows (StatSoft, Inc., 1999). For PC analysis, measurements were standardized [(raw score - mean)/SD] to decrease the influence of the overall size.

Systematic Description

Myotis badius sp. nov.

Holotype

IBSS u-88, adult ♂, body in 75% alcohol, skull and baculum extracted, collected by Li Zhenxin and M. P. Tiunov on June 16, 2006.

Paratypes

IBSS (Field No. u-06-8), adult ♂, body in alcohol, skull extracted, collected by Li Zhenxin and M. P. Tiunov on June 13, 2006 from Longxu Cave; (Field No. u-06-80) adult ♂, body in alcohol, skull extracted, collected by Li Zhenxin and M. P. Tiunov on June 16, 2006 from Dashi Cave; 10 adult ♀♀ (Field Nos.: u-06-13, u-06-14, u-06-15, u-06-16, u-06-20, u-06-22, u-06-28, u-06-35, u-06-34, u-06-34a), all bodies in alcohol with skulls extracted, collected by Li Zhenxin and M. P. Tiunov on June 13, 2006 from Longxu Cave. ZMMU S-186520 (Field No. u-06-9), adult ♂, body in alcohol, skull extracted, collected by Li Zhenxin and M.P. Tiunov on June 13, 2006 from Longxu Cave; S-186521 (Field No. u-06-16), adult ♀, body in alcohol, skull extracted, collected by Li Zhenxin and M. P. Tiunov on June 13, 2006 from Longxu Cave.

Etymology

The species name '*badius*' is connected to colouration of the fur ('badius' (Lat.) = 'chestnut'). We suggest Chestnut Myotis as an appropriate English vernacular name.

Type locality

Dashi Cave, near Shicaohe village, Shuanghe Town, Yunnan Province, China (24°29'N, 102°22'E).

Diagnosis

A species of *Myotis* of small size belonging to the '*siligorensis*' species group: forearm length = 36.8 mm (35.0–38.5 mm, $n = 20$), condylobasal length of skull = 12.2 mm (11.8–12.6 mm, $n = 20$). Margin of

plagiopatagium attached to the metatarsus of first toe. Foot, including claw, ≤ 44% (37–51, *n* = 20) of tibia. Frontal part of skull distinctly elevated above the low rostrum, as in *M. siligorensis*, *M. csorbai* and *M. annamiticus*. Both small upper premolars (P^2 and P^3) present in the tooth row and clearly visible in lateral view. Lower molars belong to seminyctalodon type, as in *M. siligorensis*, *M. phanluongi* and *M. annamiticus*. New form could be clearly distinguished from all the latter species by the shape of baculum.

Measurements of the holotype (in mm) are as follows: body length — 42, tail length — 37, length of free tail tip — 0.5, ear length — 12.5, tragus length — 5.6, tibia length — 15.7, foot length with claws — 6.7, forearm length — 35.7, length of the first digit (without claws/with claws) — 4.7/5.7, Mc2 — 29.2, Mc3 — 32.4, Ph3.1 — 8.5, Ph3.2 — 8.0, Ph3.3 — 6.5, Mc4 — 32.4, Ph4.1 — 8.0, Ph4.2 — 7.5, Mc5 — 31.2, Ph5.1 — 7.5, Ph5.2 — 7.0; and CBL — 12.1, CCL — 11.4, W — 7.0, BCW — 6.5, BCH — 5.0, IOW — 3.25, ZW — 8.2, WR — 4.1, LR — 2.35, CM3 — 4.25, PD — 0.75, P4M3 — 3.45, WM3 — 1.2, LM3 — 0.65, CC — 3.2, M3M3 — 5.25, LMD — 8.9, HMD — 2.6, MCM3 — 4.9.

Description

External characters: The hairs of the dorsal pelage are brownish-chestnut. The fur is a uniform light-brown on the ventral surface. Ear comparatively short, not extending, when laid forward, to anterior end of muzzle. Tragus relatively short, a little less than half as high as the conch; its anterior border straight, its widest portion in the lower third. Wing membrane wide, the fifth finger comparatively long, about 82% of the third finger in length. The calcar is about 37% (33.0–44.9, *n* = 13) the length of the posterior border of the interfemoral membrane when measured from the foot to the tip of the tail, without keel and terminal lobe (Fig. 1). Tail relatively long, on average 85% of head and body length; about 0.45 mm of its tip is free from the membrane. The ventral surface of the interfemoral membrane is sparsely haired, the hairs are about 0.7–0.8 mm in length.

Cranial and dental characters: Frontal part of the skull is distinctly elevated above the low rostrum (as in *M. csorbai* and *M. siligorensis*). Brain case height ca. 75.7% (71.4–80.7, *n* = 20) of skull width. Upper surface of rostrum with a visible middle groove. Interorbital constriction remarkably narrow; interorbital width about 46% of skull width. Posterior border of naris extending to the frontal margin of the upper canine. Sagittal crest is scarcely evident,

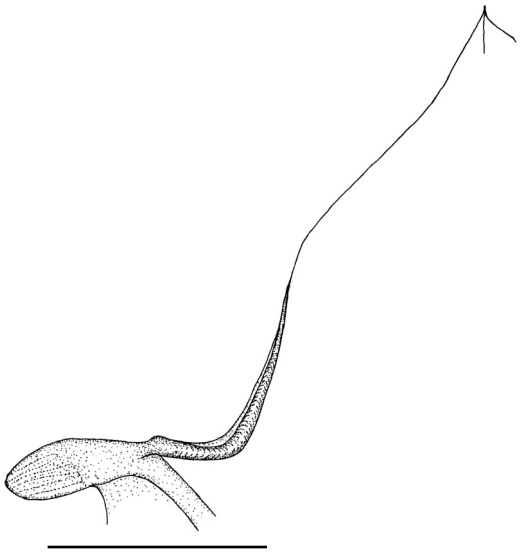

FIG. 1. Calcar of *M. badius*. Scale bar is 10 mm

lambdoid crest is visible laterally, but lacking in the central portion. Outer upper incisor (I^3) trifid, equal or slightly less than internal incisor (I^2). Upper canine is short; it scarcely exceeds the posterior premolar (P^4) in height and has a smaller crown area (Fig. 2). Anterior premolar (P^2) is in contact with the canine and is ≤ 1/2 its height. Middle premolar (P^3) small, about two thirds of P^2 in height and half to two-thirds the crown area. Both small upper premolars are situated in the tooth row and are visible when the skull is viewed laterally. Posterior premolar (P^4) is low, with an antero-internal cusp. Upper molars with well-developed protoconules. In the lower dentition, the first (I_1) and second lower incisors (I_2) are three- or four-lobed when viewed from the front. The inner two incisors are imbricated; there is usually a small gap between I_2 and the third incisor (I_3). The canine is small, its height less than that of the posterior lower premolar (P_4). The first lower premolar (P_2) scarcely exceeds half the height of the canine. The second lower premolar (P_3) is about half to two-thirds of P_2 in height and lies within the tooth-row. The lower first molar is always nyctalodont (the postcristid is connected to the hypoconulid). The second molar is nyctalodont or seminyctalodont dental type (where the postcristid may connect to both entoconid and hypoconulid, or to neither). The third molar is usually myotodont or more rarely nyctalodont (Fig. 3). A similar tooth structure was revealed earlier in *Lasionycteris noctivagans* (Legendre, 1984). Recently nyctalodontia, which is common to the tribe Pipistrellini, was described in other Vespertilionidae lineages

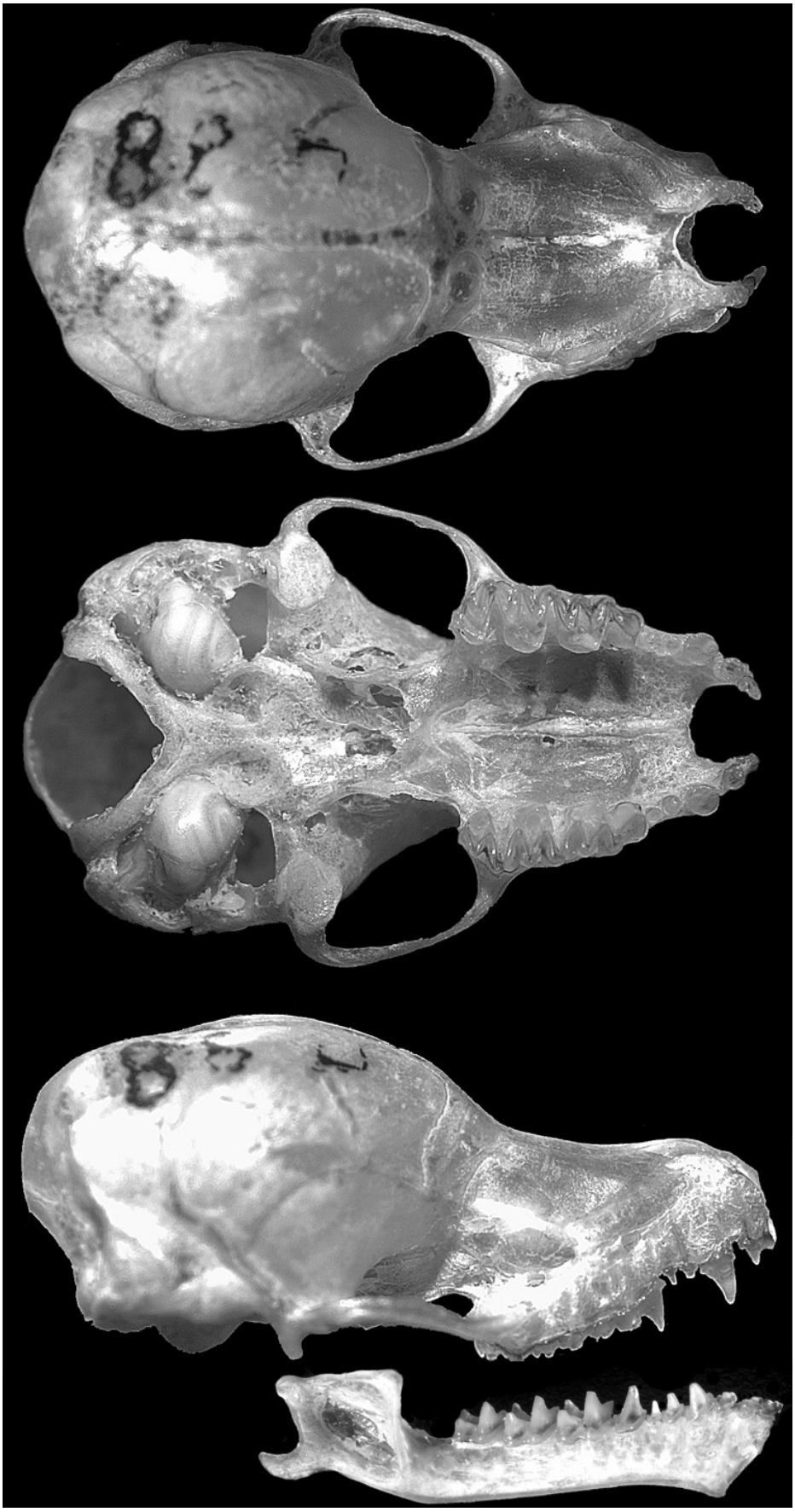

FIG. 2. Dorsal, ventral and lateral views on the cranium and mandible of *M. badius* sp. nov. (holotype)

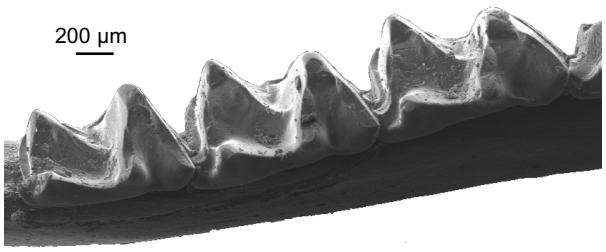

FIG. 3. Lower molar structure of *M. badius* sp. nov. (holotype)

including the genus *Myotis* (Kruskop, 2007). However, in the genus *Myotis* this dentition type is still known only in the '*siligorensis*' species group (Borisenko *et al*., 2008).

Baculum: The baculum of *M. badius* is in general similar to that of other species in this species group. It is very small, straight, narrow, bluntly pointed on the distal tip and slightly widened gradually to the proximal base (Fig. 4A). A reduced urethral groove is present on the bottom of the proximal half as an oval-shaped depression. Greatest length is ca. 0.45 mm, greatest width ca. 0.15 mm (n = 4 adults).

Comparison with Similar Species

Morphometric comparisons

In a two-dimensional projection of the first two principal components the newly described taxon is clearly segregated without overlap from *M. siligorensis* samples, including similar sized *M. phanluongi* (Fig. 5), and even more so from other *Myotis* species used as comparative material. PC1 is highly correlated with overall skull size and upper and lower tooth rows; while PC2 has high positive correlation with rostral width and length (Table 1), suggesting that corresponding measurements are of particular identification value. The only specimen not well separated from the new species sample is a *M.* cf. *annamiticus* specimen from Laos, which, nonetheless, can be differentiated from *M. badius* by the same physical features as *M. annamiticus*.

Physical comparisons

The newly described *Myotis* is most similar to *M. siligorensis*, which is widely distributed from northern India to Vietnam and south to Malaysia and Borneo (Simmons, 2005) and also in south China

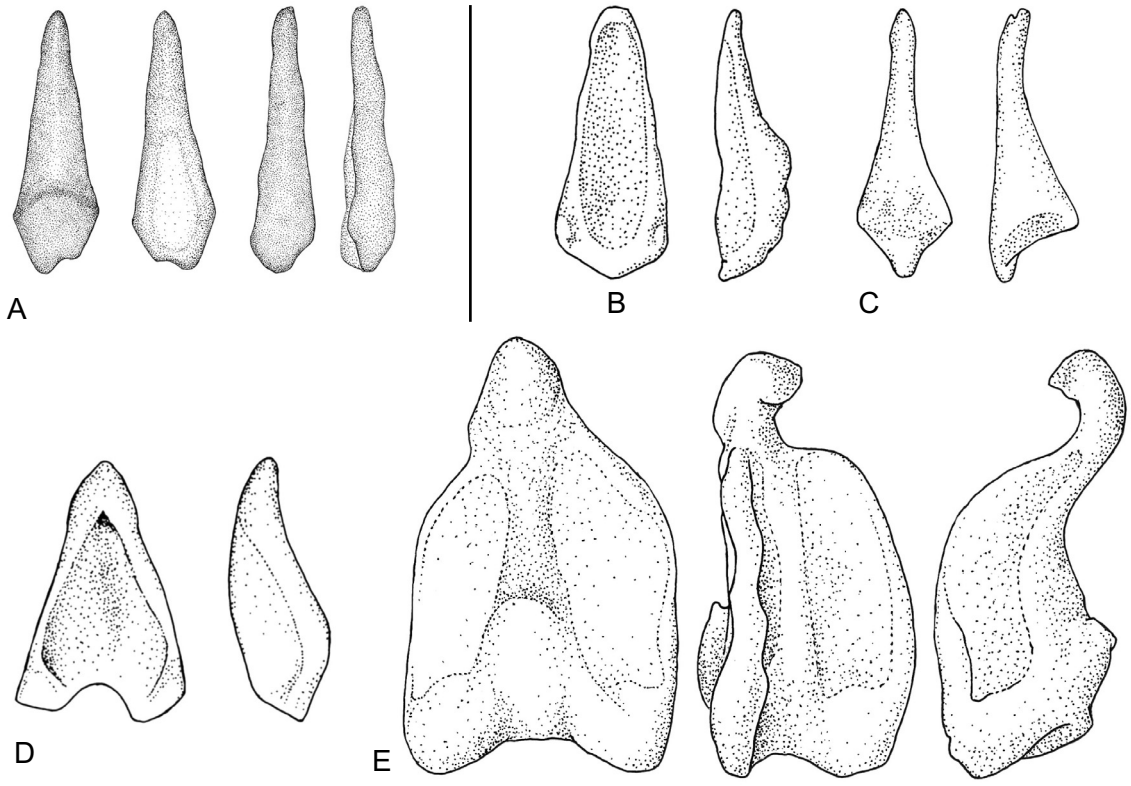

FIG. 4. Camera lucida tracings of bacula of selected Asiatic *Myotis* spp.: A — *M. badius* sp. nov. (dorsal, ventral, lateral, ventro-lateral views); B — *M. siligorensis* from Central Vietnam (ventral and left lateral views); C — *M. phanluongi* (dorsal and left lateral views); D — *M. csorbai* from Nepal (ventral and left lateral views); E — *M. muricola* from Southern Vietnam (dorsal, ventro-lateral and left lateral views). Scale bar = 0.5 mm

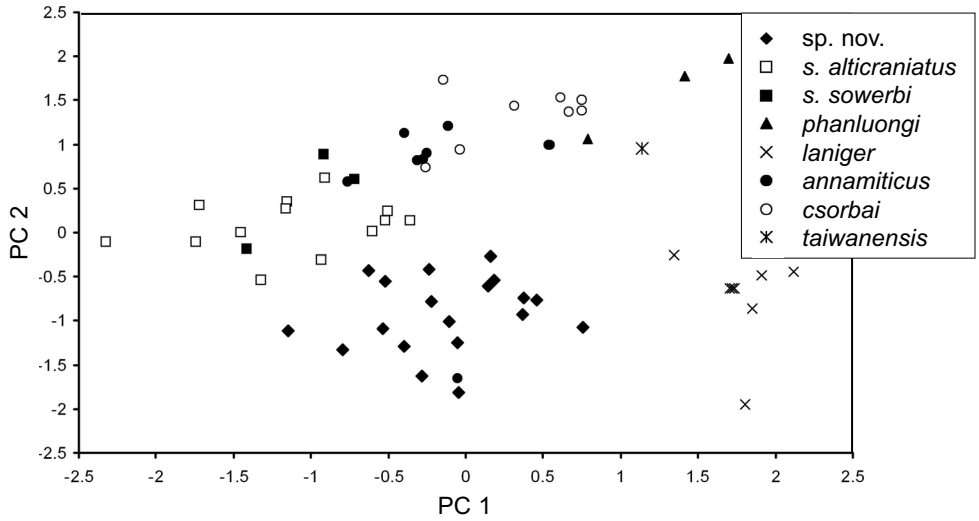

FIG. 5. Bivariate scatterplot of the first two principal components, calculated on the basis of 16 cranial measurements for 64 specimens of *Myotis*. See Table 1 for eigenvalues and component loadings

(Wang, 2003). However, these two species differ in several features. The new species is a little larger than *M. siligorensis*: mean forearm length 36.8, condylo-canine length 11.3; vs. 33.9 and 10.5 mm in *M. s. alticraniatus* (our data) or 30.8 and 11.2 mm, in *M. s. siligorensis* (Bates and Harrison, 1997), respectively. Unfortunately, we have no available material from Thailand. However, according to original description (Shamel, 1942), *M. s. thaianus* is much smaller then *M. badius* (forearm 31.6 mm, CBL 11.0 mm) and with considerably narrower rostrum (M3M3 4.2 mm). Amongst named forms terra typica of *M. s. sowerbi* is closest to that of *M. badius*. *Myotis s. sowerbi* is of similar size, but based on Howell's (1926) original description it differs from the new species by darker coloration, lacking brown, and by distinctly longer tragi. Available specimens from Fujian have considerably longer rostral portions of the skull and the two males are smaller than males of *M. badius* in overall skull dimensions. The new species has shorter ears than *M. siligorensis*, not extending, when laid forward, to the anterior end of the muzzle. Average length of the calcar in the new species is about 13.0 mm (12.0–14.0, n = 14), while only 4–5 mm in *M. siligorensis* (Bates *et al*., 1999). The baculum of *M. badius* is generally similar to that of *M. siligorensis* but about half as wide in the proximal part and with a less pronounced depression on the ventral side. The new species differs from the similar-sized and recently described *M. phanluongi* in the shape of the baculum (Fig. 4) and in rostrum shape. *Myotis phanluongi* has a quite slender rostrum (Borisenko *et al*., 2008), while that of *M. badius* is distinctly wider and more robust.

Myotis badius differs from *M. muricola* in overall size, a less robust skull with a prominently concave frontal profile, distinctly smaller canine teeth and by the shape of its baculum. The baculum in *M. muricola* is much larger, wide, and saddle-shaped, with a rounded tip and well developed

TABLE 1. Component loadings and other indices derived from the principal component analysis of 16 cranial measurements of 64 *Myotis* specimens. See text for measurement abbreviations

Character	Principal component		
	1	2	3
CBL	0.850	0.001	0.106
CCL	0.851	0.057	0.161
W	0.465	-0.216	0.007
BCW	0.598	-0.044	0.148
BCH	0.623	-0.043	0.048
IOW	0.417	-0.050	-0.011
WR	0.016	0.938	-0.209
LR	-0.066	0.877	0.341
CM3	0.900	-0.093	0.095
PD	0.081	0.032	0.973
P4M3	0.808	0.006	-0.171
CC	0.688	0.001	-0.136
M3M3	0.461	-0.118	-0.065
LMD	0.485	0.023	0.070
HMD	0.662	-0.260	-0.169
MCM3	0.815	0.007	0.123
CBL	0.850	0.001	0.106
CCL	0.851	0.057	0.161
W	0.465	-0.216	0.007
BCW	0.598	-0.044	0.148
BCH	0.623	-0.043	0.048
IOW	0.417	-0.050	-0.011
Eigenvalue	10.190	1.860	1.230
% of total variance	63.72	11.63	7.71

urethral groove (Fig. 4E). The upper canine of *M. muricola* is proportionally longer and exceeds the third premolar (P^4) in height (Bates *et al*., 1999; Borisenko and Kruskop, 2003).

The newly described *Myotis* differs from *M. annamiticus* and *M. csorbai* by the location of attachment of the wing membrane and by the distinct shape of the baculum (Kruskop and Tsytsulina, 2001). The new species can be easily distinguished from *M. csorbai*, as well as from *M. longipes* and *M. laniger*, by the semi-nyctalodont lower molars.

Unfortunately, we could not compare our specimens directly to another Chinese *Myotis* of similar size, *M. davidi*. According to available descriptions, the latter species also has a long calcar, as in *M. badius*. *Myotis davidi* appears to be distinct from the new species in having P^3 reduced and displaced inward in the tooth-row and by a low, flattened braincase, as well as by smaller external size (Allen, 1938; Smith and Yan Xie, 2008).

We have yet to provide any molecular-based comparison of the new species with its relatives. As can be seen from recent publications (Borisenko *et al*., 2008; Francis *et al*., 2010) genetic markers do not always segregate morphologically distinct forms within the '*siligorensis*' species group. Further investigation into the molecular characteristics of *M. badius* should be undertaken, using acceptable comparative sequences with selection of an adequate genetic marker.

Habitat

Myotis badius was captured in limestone caves at about 2,000 m a.s.l. These caves are situated at the edge of a limestone range, surrounded and partly covered with heavily disturbed semi-evergreen subtropical forest and scrubs. Other bat species found in association with *M. badius* in these caves include *Rhinolophus sinicus*, *R. pusillus*, *Hipposideros armiger* and *M. laniger*.

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