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A new species of vespertilionid bat from Taiwan and a revision of the taxonomic status of *Arielulus* and *Thainycteris* (Chiroptera: Vespertilionidae)

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Abstract

On morphological and chromosomal grounds *Pipistrellus (Arielulus)* subgenus is elevated to generic rank and the recently described genus *Thainycteris* has been synonymized with *Arielulus*. Besides this taxonomic revision, a new species of bat *Arielulus torquatus* is described from the central mountains of Taiwan which differs from its congeners chiefly by its size and colouration.

Key words: taxonomy, *Arielulus*, *Thainycteris*, new species, Taiwan

INTRODUCTION

The phenetically similar, very diverse and widely distributed genera of *Pipistrellus* and *Eptesicus* have resulted in a long lasting debate concerning the taxonomic distinctness and systematic relations of the different named forms. By means of traditional taxonomic comparisons of the two taxa no reliable differences were found other than the presence or absence of the first upper premolar (Koopman, 1975) but the taxonomic value of this character is highly dubious (see Heller & Volleth, 1984). Therefore, it was supposed that the generic separation was provisional and probably both traditionally accepted genera are of polyphyletic origin (Koopman, 1975; Volleth & Tidemann, 1991). The first work using the results of cytological investigations and of comparative bacular morphology to clarify the phylogenetic separation between *Pipistrellus* and *Eptesicus* was published by Heller & Volleth (1984) who characterized the genus *Eptesicus* by its distinct karyotype ($2n = 50$, fundamental number = 48) and the small, not stick-like baculum. The genus *Pipistrellus* has great chromosomal variability with $2n = 44$ or less, and an elongate, narrow baculum is typical. Later, *P. savii*, one of the most controversial species was placed by Horacek & Hanak (1986) in the separate genus *Hypsugo* on bacular and on other osteological grounds, which was confirmed on the basis of dental characteristics (Menu, 1987) and by means of isozyme electrophoresis (Ruedi & Arlettaz, 1991). Hill & Harrison (1987) provided a large-scale comparison of the os penis of all related Vespertilioninae genera, and erected a new subgenus *Arielulus* within the genus *Pipistrellus*. As a result of this work and numerous subsequent karyological studies, several former *Eptesicus* species were included in different subgenera of *Pipistrellus* (Hill & Harrison, 1987; Koopman, 1994) and further data were provided for the clearer separation of *Pipistrellus* and *Eptesicus* on a much wider basis (McBee, Schlitter & Robbins, 1987; Morales *et al.*, 1991; Rautenbach, Bronner & Schlitter, 1993). Beside the *Hypsugo*, two other subgenera of *Pipistrellus* have been elevated to generic level, namely *Falsistrellus* (Kitchener, Caputi & Jones, 1986) and *Vespadelus* (Volleth & Tidemann, 1991).

The latest described subgenus *P. (Arielulus)* comprises three species which are identified by their small Y-shaped baculum and greatly reduced second incisor and PM^2 (Corbet & Hill, 1992). *Pipistrellus circumdatus*, the type species of this new subgenus was originally described from Java by Temminck (1840) and further specimens were obtained from Myanmar, Malaysia (Hill, 1972), Yunnan (as *P. circumdatus drungicus* Wang, 1982, in Corbet & Hill, 1992), India (Das *et al.*, 1995), Nepal (Bates & Harrison, 1997) and Thailand (specimens in Senckenberg Museum, Frankfurt). From Malaysia, Hill (1972) described a new species *P. societatis* and discussed its very close affinities to *P. circumdatus*. Also from Malaysia, Heller & Volleth (1984) recorded a series of five specimens of the former species and considered *P. societatis* to be a lowland subspecies of *P. circumdatus*. They transferred both taxa to *Eptesicus* on bacular and karyological grounds which, however, has not been accepted by subsequent authors (Hill & Francis, 1984; Koopman, 1994). The third hitherto known species *P. cuprosus* was named by Hill & Francis (1984) from Borneo. This species is more

closely allied to *P. societatis* than to *P. circumdatus*. However, the unique combination of several different characters (cranial, dental, bacular, and karyological) not found in other *Pipistrellus* subgenera or in *Eptesicus* suggests that the recently accepted taxonomic position of *P. (Arielulus)* is not appropriate.

During a series of intensive bat surveys carried out in Taiwan in recent years, three *Arielulus* specimens were collected. Their distinctive coloration, measurements, craniodental, and other morphological characteristics were very different from any bat species recorded in Taiwan in the past. Based on comparative studies with other similar species and basic karyological work, they are described and reported here as a new species.

Meanwhile, a newly described genus and species *Thainycteris aureocollaris* Kock & Storch, 1996 was also placed close to *Eptesicus* and *Vespertilio*; its coloration and the given craniodental characteristics are very similar to those of the new *Arielulus* species from Taiwan. Therefore, this taxon is also taken into consideration.

MATERIALS AND METHODS

Abbreviations used for institutions in this paper are: NTU – National Taiwan University, Taipei; BM(NH) – The Natural History Museum, London, formerly the British Museum (Natural History); HNHM – Hungarian Natural History Museum, Budapest; ZMMU – Zoological Museum of Moscow State University, Moscow; NNM – Nationaal Natuurhistorisch Museum, Leiden; SMF – Senckenberg Museum, Frankfurt.

Besides the 3 known specimens of the new species described in detail below the following comparative specimens were examined: *Pipistrellus circumdatus* – Indonesia: Java (NNM 35433 [holotype], 35434 [paratype], 14898–9, 15314, 30965–6, BM(NH) 73.1805, 7.11.401); Malaysia: Pahang (BM(NH) 73.618); Nepal: Mechi (HNHM 98.5.23), Gandaki (ZMMU 164469, 164472–3); Thailand: Chiang Mai (SMF 75344–8). *Pipistrellus societatis* – Malaysia: Pahang (BM(NH) 67.1605 [holotype], 81.1802), Selangor (SMF 60079–82, 69336–7). *Pipistrellus cuprosus* – Malaysia: Borneo (BM(NH) 83.351 [holotype], 84.1989). *Thainycteris aureocollaris* – Thailand: Chiang Mai (SMF 75443 [holotype], 84361–4 [paratypes]).

The forearm measurements were taken from dry and alcoholic museum specimens to the nearest 0.1 mm. Cranial and dental measurements were collected by digital caliper of 0.01 mm accuracy using a binocular microscope and included: greatest length of skull, from front of incisors to occiput; condylocanine length, from front of canines to back of condyles; palatal bridge length, from the posterior edge of palatal emargination to the end of palatinum excluding post-palatal spine; width across anteorbital foramina; lachrymal width, between the outermost points of lachrymal bones; width across supraorbital processes; zygomatic width, the distance between the outermost points of zygomatic plates; interorbital width, the least width of the interorbital constriction; braincase width, measured above the processus zygomaticus temporalis; mastoid width, between mastoid knobs; width across canines, the distance between the ectocingula of canines; width across M^3–M^3, measured over crowns; upper toothrow length, the crown length of C-M^3; mandible length, the distance from the most posterior portion of the articular process to the most anterior edge of the alveolus of I_1; lower toothrow length, the crown length of C-M_3.

The karyotype was obtained by preparing metaphase spreads from bone marrow cells of 1 yeast-stimulated individual (Lee & Elder, 1980) and stained with 5% Giemsa stain. The diploid number ($2n$) was determined by examining 10 cells which showed complete and visible metaphase spreads.

RESULTS

Accepting the diagnostic value of karyological data by which the distinct and invariable *Eptesicus* is separable from the heterogeneous *Pipistrellus*, the same separation is found in *P. (Arielulus)* which also possesses 50 chromosomes ($FN = 48$) (Heller & Volleth, 1984). *Arielulus* also differs from *Pipistrellus* by its myotodont M_1–M_2. However, the generic distinctness from *Eptesicus* is supported by the very broad and short rostrum, more inflated braincase, tricuspid first upper incisor and the very small baculum typically curved when viewed laterally, with two widely separated basal lobes and short, narrow shaft (instead of being flattened, triangular and the base only slightly lobed) (Hill & Harrison, 1987). Therefore, we propose the elevation of *Arielulus* to generic level.

The diagnosis given by Kock & Storch (1996) for the new taxon *Thainycteris* seems to be sufficient for the separation at generic level from *Eptesicus* and *Pipistrellus* but the cranial and dental characters are essentially the same as those typical for *Arielulus*. The first detailed description of the type species *A. circumdatus* (based on specimens from Java and Myanmar) was given by Hill (1972) and included the following features: broad rostrum; prominent supraorbital ridges terminating in small tubercles; deeply excavated frontal depression. These features are even more definite in the most northern (Nepalese) representatives of the species where some specimens (e.g. ZMMU 164472) have similarly strong supraorbital and lachrymal processes to those of *Thainycteris* (Fig. 1). In addition, the dental characteristics of *Thainycteris* (large and tricuspid first incisor, very small second incisor, rudimentary or missing PM^2, not reduced M^3 and myotodont lower molars) are also typical for all the known *Arielulus* species. As a consequence, the genus *Thainycteris* Kock & Storch, 1996 is here regarded as the junior subjective synonym of *Arielulus* Hill & Harrison, 1987.

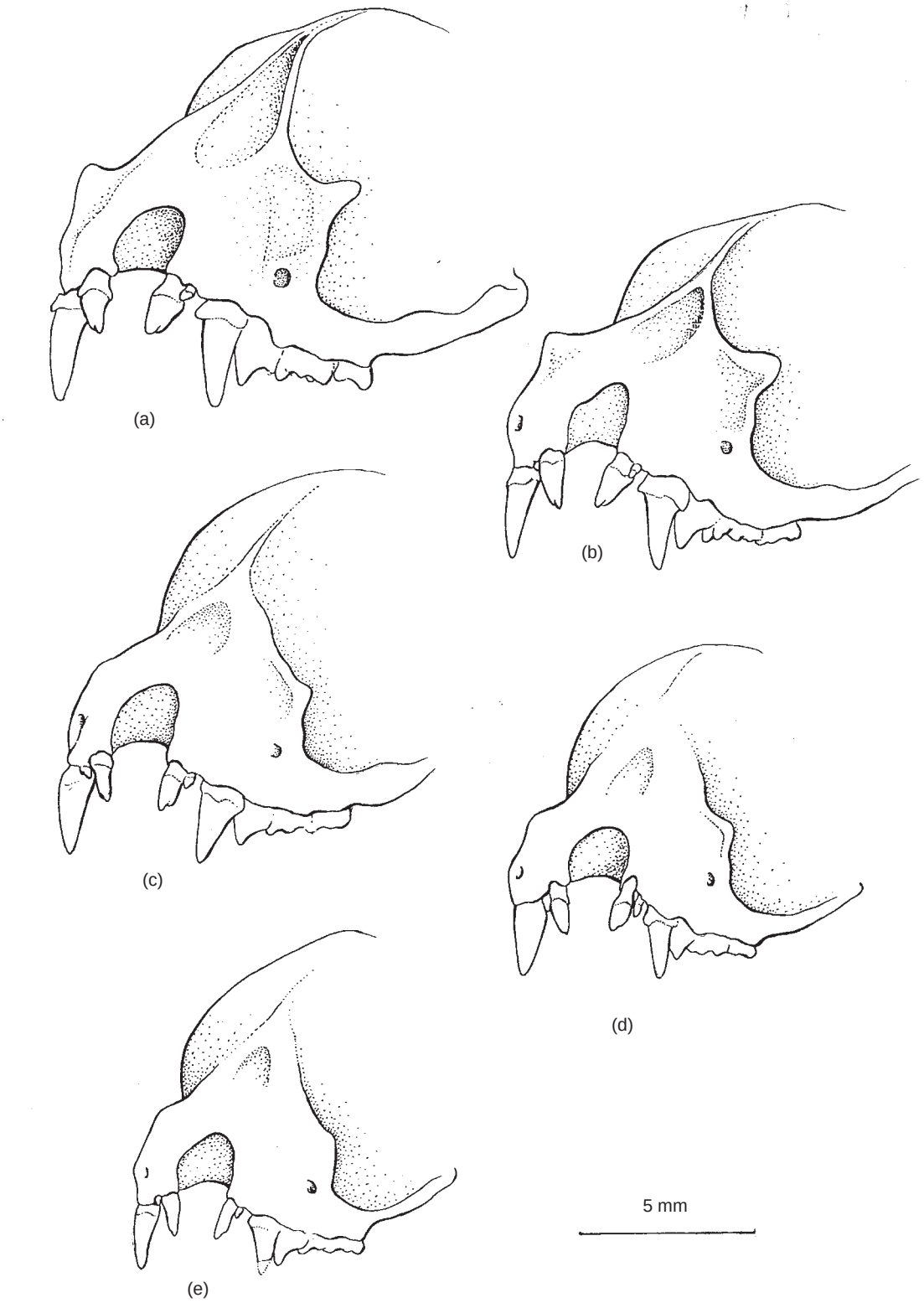

Fig. 1. Front view of rostral part of skull of: (a) *A. aureocollaris* (holotype, SMF 75443); (b) *A. torquatus* n. sp. (holotype, NTU 019); (c) *A. circumdatus* (NNM 15314); (d) *A. societatis* (holotype, BM(NH) 67.1605); (e) *A. cuprosus* (holotype, BM(NH) 83.351).

Table 1. External and craniodental measurements of *Arielulus* species (in mm). Sample sizes are in parentheses

	A. aureocollaris	*A. torquatus* n. sp.	*A. circumdatus*	*A. societatis*	*A. cuprosus*
Forearm length	47.5–51.8 (5)	43.6–45.5 (2)	38.6–43.6 (14)	35.95–40.7 (7)	34.8–36.4 (2)
Greatest length of skull	17.55–17.66 (2)	16.25–16.86 (2)	15.15–16.78 (9)	14.68–15.50 (8)	13.88–14.04 (2)
Condylocanine length	16.22–16.28 (2)	15.19–15.81 (2)	14.01–15.46 (11)	13.59–14.25 (8)	12.26–12.70 (2)
Palatal bridge length	6.02–6.43 (2)	6.03–6.41 (2)	5.95–6.94 (14)	4.97–5.46 (8)	4.78–4.83 (2)
Width across anteorbital foramens	6.31–6.80 (5)	5.88–6.27 (2)	5.19–5.80 (12)	5.05–5.43 (8)	4.81–4.96 (2)
Lachrymal width	8.66–8.70 (2)	7.72–8.18 (2)	6.63–7.69 (12)	6.33–6.69 (8)	6.02–6.09 (2)
Width across supraorbital processes	8.69–9.15 (2)	7.57–7.74 (2)	6.16–7.15 (12)	5.93–6.33 (8)	5.57–5.77 (2)
Zygomatic width	13.34–13.50 (2)	12.43–12.57 (2)	10.69–11.62 (13)	10.31–11.21 (7)	9.60–9.98 (2)
Interobital width	4.85–5.11 (2)	4.36–4.44 (2)	4.28–4.64 (17)	3.89–4.37 (8)	4.12–4.14 (2)
Braincase width	9.23–9.64 (2)	8.38–8.54 (2)	7.66–8.50 (11)	7.50–7.95 (8)	7.46–7.75 (2)
Mastoid width	10.24–10.29 (2)	9.05–9.36 (2)	8.45–9.16 (13)	8.06–8.65 (8)	7.54–8.03 (2)
Width across canines	6.04–6.37 (5)	5.26–5.52 (2)	4.94–5.65 (17)	4.54–4.98 (7)	4.30–4.34 (2)
Width across M^3–M^3	8.25–8.57 (5)	7.78–8.19 (2)	7.07–7.70 (17)	6.56–7.14 (8)	6.38–6.40 (2)
Upper toothrow length	6.70–7.06 (5)	6.44–6.58 (2)	5.87–6.50 (17)	5.31–5.72 (8)	4.85–4.94 (2)
Mandible length	13.20–14.43 (5)	12.39–12.77 (2)	10.97–12.62 (18)	10.71–11.21 (8)	9.85–10.11 (2)
Lower toothrow length	7.25–7.78 (5)	6.86–6.93 (2)	6.22–6.86 (17)	5.71–6.08 (7)	5.15–5.31 (2)

ARIELULUS TORQUATUS N. SP.

Holotype

Adult male, skin and skull; NTU FB 019. Collected by S. S. Tsao and C. S. Ding on 4 June 1992.

Type locality

Wu-ling Farm, Taichung County, Taiwan, 1800 m elevation, 24°24′N, 121°18′E.

Paratypes

Adult female, skin, NTU FB030, Tsui Fong Lake, Ilan County, 1840 m, collected by S. H. Yang and P. J. Jiang on 31 October 1996; adult female, skull, HNHM 98.23.1., Rei-suei logging road, Hualien County, 1500 m, collected by S. H. Yang and P. J. Jiang on 17 July 1996.

Etymology

The specific name is from the Latin word torquis for necklace, which refers to the bright collar of the new species.

Diagnosis

The blackish dorsal pelage over the entire surface is conspicuously tipped with bronze colour; the similarly dark ventral hairs silvery-grey tipped. A bright ochraceous collar spreads across the throat. Forearm length under 46 mm. Supraorbital and lachrymal processes of the skull very strong; length of upper toothrow < 6.6 mm, lower toothrow < 7 mm.

Description

A medium-sized species of the genus, length of forearm 43.6–45.5 mm (Table 1). Fur black, terminal part of individual hairs on the dorsal surface bronze coloured, that of the venter tipped with silvery-grey. A well-defined ochraceous collar runs from the base of ears across throat, paralleled with a narrow greyish-white band spreading between shoulders. Ears broadly triangular, blackish and not marked with white or yellowish edge; tragus short, curved, anterior border concave, posterior border strongly convex. Muzzle short, broad

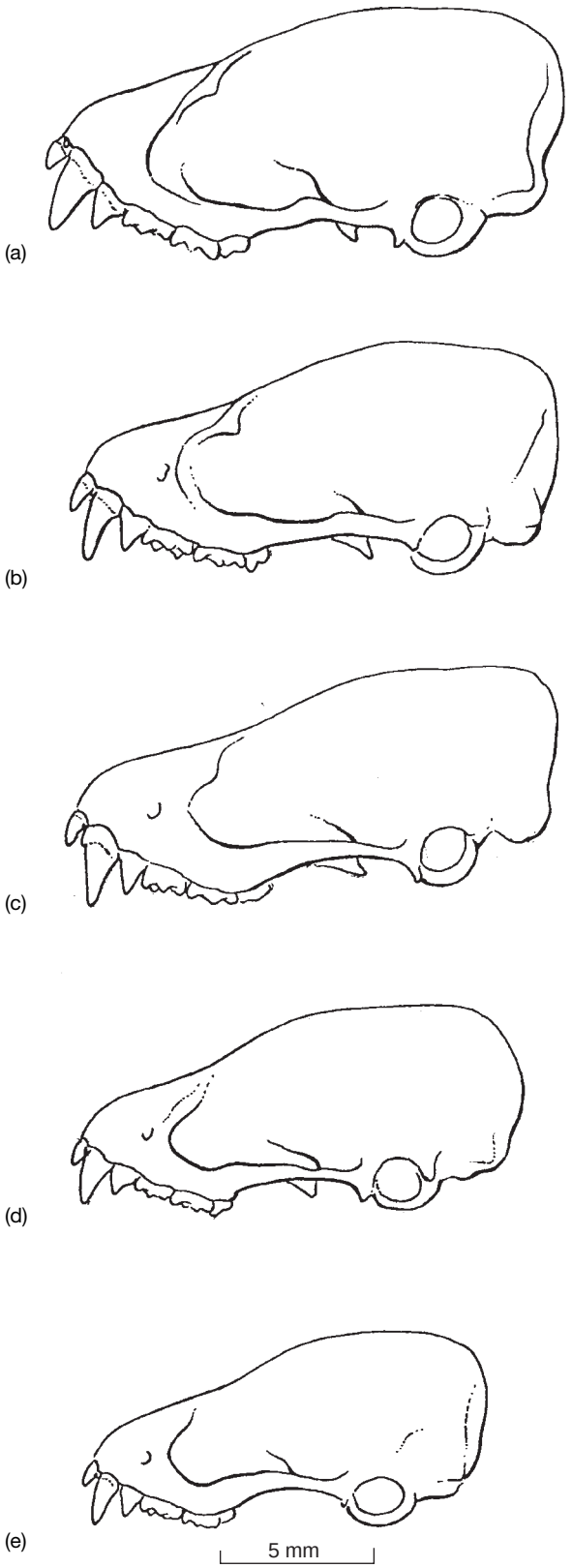

Fig. 2. Lateral view of skulls of: (a) *A. aureocollaris* (holotype, SMF 75443); (b) *A torquatus* n. sp. (holotype, NTU 019); (c) *A. circumdatus* (BM(NH) 73.1805); (d) *A. societatis* (holotype, BM(NH) 67.1605); (e) *A. cuprosus* (holotype, BM(NH) 83.351).

and only sparsely haired. Flight membranes uniformly black and naked except the furred proximal half of dorsal surface of uropatagium; plagiopatagium inserts at the base of fifth toe. Calcar extending along more than half of uropatagial margin; last caudal vertebra free from uropatagium.

Skull massive with short and broad rostrum and inflated braincase (Figs 1 & 2). Sagittal crest low but supraorbital ridges very strong terminating in prominent processes; lachrymal processes also well developed. Frontal (interorbital) depression deeply excavated. Narial emargination V-shaped; palatal emargination wide and relatively shallow, posterior border equal to the middle of canines. Basial pits well-defined. Mandible heavily built, mandibular symphysis enlarged ventrally. Coronoid process broadly triangular, angular process curved upwards.

First upper incisor large, and beside the apical cusps bearing a prominent lingual cusp on the cingulum; second incisor small, just reaching beyond the cingulum of I^1. First upper premolar (PM^2) rudimentary (in the paratype HNHM 98.23.1. missing from the left toothrow) and completely hidden into recess between C^1 and PM^3. Paracone and metacone of M^1 and M^2 well-developed; postprotocrista and metaloph low and gradually sloping towards the base of metacone. M^3 unreduced, third commisure and metacone present (Fig. 3). First lower incisor with four lobes, I_2 and I_3 trilobated. Both lower premolars (PM_2 and PM_4) well-developed (PM_2 more than one-third crown area of PM_4) with distinct main cusp and additional small cingular cusps and situated in the main axis of the toothrow. M_1 and M_2 myotodont, M_3 unreduced.

Karyotype

Due to the small sample size only one adult female (paratype NTU FB30) was examined for its karyotype, and the diploid chromosome number was determined to be 50.

Comparisons with other species

The new species *A. torquatus* is distinguishable from both *A. cuprosus* and *A. societatis* by its overall greater size, more robust skull with protruding supraorbital process and the conspicuous neck collars. *A. circumdatus* is similar in size and in some skull characteristics (e.g. well-defined frontal depression and distinct sagittal crest) but has wider narial emargination, weaker supraorbital ridges, less-developed supraorbital process and different coloration with no collar-like markings. In general the dentition, shape, and proportions of skull of *A. torquatus* is the same as in *A. aureocollaris* but differs in the following: smaller in every measurement (except the palatal bridge length); narial emargination V-shaped; lachrymal width exceeds the supraorbital width; and palatal bridge relatively longer (Table 1).

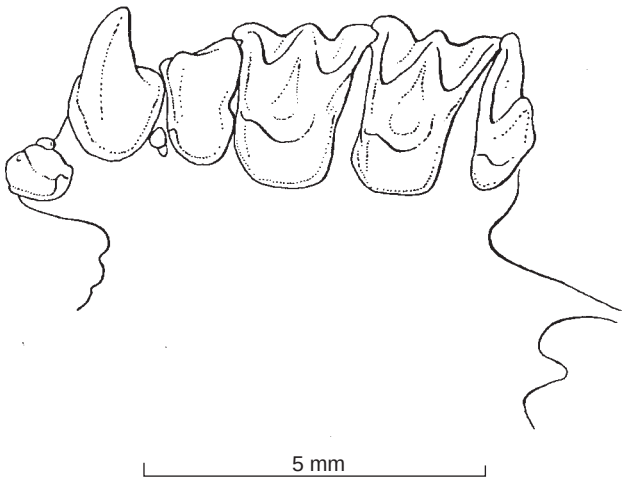

Fig. 3. Occlusal view of left upper toothrow of *Arielulus torquatus* n. sp. (holotype, NTU FB 019).

A. torquatus is further distinguishable from the former species by its distinctive coloration and the blackish dorsal fur being tipped with bronze (hairs above with silver tips in *A. aureocollaris*).

DISCUSSION

Although, on the one hand Heller & Volleth (1984) transferred *P. (A.) circumdatus* and *P. (A.) societatis* to *Eptesicus*, and on the other hand retained *Arielulus* as a subgenus of *Pipistrellus* (Corbet & Hill, 1992; Koopman, 1994) the following unique character combination distinguishes *Arielulus* from all living genera: distinctive coloration; short and wide rostrum; high and globular braincase; tricuspid I^1; greatly reduced I^2; small (often missing) PM^2; myotodont M_1 and M_2; very small Y-shaped baculum; and the chromosome number $2n = 50$. Based on cytological, dental and bacular characteristics the genus is allied to the Vespertilionini tribe (including *Eptesicus* and *Vespertilio*).

The investigation of craniodental features (stated as diagnostic by Kock & Storch, 1996) of the recently described *Thainycteris aureocollaris* showed that this taxon is also referable to *Arielulus*. It is here assigned as *Arielulus aureocollaris*.

The new species *A. torquatus* can be distinguished from the other species in the genus by its size, shape of skull, and coloration. Based on these characters its closest relative is *A. aureocollaris* (from which it is primarily distinguishable by measurements only) and both species have close affinities to *A. circumdatus*, the type species of the genus. It is noteworthy that these three species are known only from remote mountain areas of the Indomalayan Region while the two other species, *A. societatis* and *A. cuprosus*, are distributed in lowlands.

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REFERENCES

Bates, P. J. J. & Harrison, D. L. (1997). *Bats of the Indian subcontinent*. Sevenoaks: Harrison Zoological Museum Publication.

Corbet, G. B. & Hill, J. E. (1992). *The mammals of the Indomalayan region: a systematic review*. London: Natural History Museum Publications, Oxford University Press.

Das, P. K., Ghose, R. K., Chakraborty, T. K., Bhattacharyya, T. P. & Ghosh, M. K. (1995). *Mammalia. State Fauna Series 4: Fauna of Meghalaya*. Part 1: 23–128. Calcutta: Zoological Survey of India.

Heller, K.-G. & Volleth, M. (1984). Taxonomic position of '*Pipistrellus societatis*' Hill, 1972 and the karyological characteristics of the genus *Eptesicus* (Chiroptera: Vespertilionidae). *Z. zool. Syst. Evolut.-forsch.* **22**: 65–77.

Hill, J. E. (1972). The Gunong Benom Expedition 1967. 4. New records of Malayan bats, with taxonomic notes and the description of a new *Pipistrellus*. *Bull. Br. Mus. nat. Hist. (Zool.)* **23**: 23–42.

Hill, J. E & Francis, C. M. (1984). New bats (Mammalia: Chiroptera) and new records of bats from Borneo and Malaya. *Bull. Br. Mus. nat. Hist. (Zool.)* **47**: 305–329.

Hill, J. E. & Harrison, D. L. (1987). The baculum in the Vespertilioninae (Chiroptera: Vespertilionidae) with a systematic review, a synopsis of *Pipistrellus* and *Eptesicus*, and the descriptions of a new genus and subgenus. *Bull. Br. Mus. nat. Hist. (Zool.)* **52**: 225–305.

Horacek, I. & Hanak, V. (1986). Generic status of *Pipistrellus savii* and comments on classification of the genus *Pipistrellus* (Chiroptera, Vespertilionidae). *Myotis* **23–24**: 9–16.

Kitchener, D. J., Caputi, N. & Jones, B. (1986). Revision of Australo-Papuan *Pipistrellus* and of *Falsistrellus* (Microchiroptera: Vespertilionidae). *Rec. West. Aust. Mus.* **12**: 435–496.

Kock, D. & Storch, G. (1996). *Thainycteris aureocollaris*, a remarkable new genus and species of vespertilioninae bats from SE-Asia. *Senckenberg. Biol.* **76**: 1–6.

Koopman, K. F. (1975). Bats of the Sudan. *Bull. Am. Mus. Nat. Hist.* **154**: 354–444.

Koopman, K. F. (1994). *Chiroptera: systematics. Handbook of zoology. Mammalia, part 60*. Berlin: Walter de Gruyter.

Lee, M. R. & Elder, F. F. (1980). Yeast stimulation of bone marrow mitosis for cytogenetic investigation. *Cytogenet. Cell Genet.* **26**: 36–40.

McBee, K., Schlitter, D. A. & Robbins, R. L. (1987). Systematics of African bats of the genus *Eptesicus* (Mammalia: Vespertilionidae). 2. Karyotypes of African species and their generic relationships. *Ann. Carnegie Mus.* **56**: 213–222.

Menu, H. (1987). Morphotypes dentaries actuels et fossiles des chiroptères vespertilioninés. 2ème partie: implications systématiques et phylogénétiques. *Palaeovertebrata* **17**: 77–150.

Morales, J. C., Ballinger, S. W., Bickham, J. W., Greenbaum, I. F. & Schlitter, D. A. (1991). Genetic relationships among eight species of *Eptesicus* and *Pipistrellus* (Chiroptera: Vespertilionidae). *J. Mammal.* **72**: 286–291.

Rautenbach, I. L., Bronner, G. N. & Schlitter, D. A. (1993). Karyotypic data and attendant systematic implications for the bats of southern Africa. *Koedoe* **36**: 87–104.

Ruedi, M. & Arlettaz, R. (1991). Biochemical systematics of the Savi s bat (*Hypsugo savii*) (Chiroptera: Vespertilionidae). *Z. zool. Syst. Evolut.-forsch.* **29**: 115–122.

Temminck, C. J. (1840). *Monographies de Mammalogie, ou description de quelques genres de mammiferes, dont les especes ont été observées dans les différens musées de l Europe*. Leiden: Vander Hoek.

Volleth, M. & Tidemann, C. R. (1991). The origin of the Australian Vespertilioninae bats, as indicated by chromosomal studies. *Z. Säugetirkd.* **56**: 321–330.