Acta Chiropterologica, 10(2): 213–220, 2008
PL ISSN 1508-1109 © Museum and Institute of Zoology PAS
doi: 10.3161/150811008X414809

A new species of tube-nosed bat *Murina* (Vespertilionidae, Chiroptera) from Vietnam

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A new species of *Murina* is described from Lam Dong province, Vietnam. The new form is a very small tube-nosed bat with a forearm length less than 30 mm. Externally it looks similar to *Harpiola isodon* from which it is well differentiated by teeth shape. From other small *Murina* species the new species can be defined by pelage coloration and texture, longer nasal tubes, dark skin on muzzle and smaller anterior upper premolar. Provisional analysis of mitochondrial DNA sequence also supports its species status. This species is known only from mountainous forests of the Da Lat plateau.

Key words: *Murina*, new species, Vietnam, taxonomy, skull morphology

INTRODUCTION

Within the subfamily Murininae inter- and intraspecific taxonomy is still insufficiently known. Potential revisions are difficult because of the relative rareness of most named forms in scientific collections and low abundance of these bats in the wild. This, together with the highly mosaic nature of habitats in tropical Asia can explain the regular finding of new or revalidation of missed taxa of different ranks (Maeda and Matsumura, 1998; Csorba and Bates, 2005; Kuo *et al*., 2006; Csorba *et al*., 2007), even on the northern edge of the group's distribution (Kruskop, 2005). Recent collections of bats in south east Asia and south west China, indicate that bats of this subfamily are more common in pristine habitats (Tordoff *et al*., 2000; Csorba *et al*., 2007; Lim *et al*., 2008). Currently, 12 species of *Murina* are known from the Asian mainland and Sunda region (Simmons, 2005; Csorba *et al*., 2007). These species usually are divided into two species groups defined mainly by the shape of dentition. However the real significance of such characters is in doubt as indicated by ongoing molecular studies (J. L. Eger, B. K. Lim, C. M. Francis, and P. Ross, unpublished data; C. M. Francis, A. V. Borisenko, N. V. Ivanova, J. L. Eger, B. K. Lim *et al*., unpublished data). In addition to these species, two morphologically distinct genera of tube-nosed bats inhabit the same region: *Harpiocephalus* with one or two species and *Harpiola* with two species. At least six species of *Murina* and one species of both *Harpiocephalus* and *Harpiola* are represented in the fauna of Vietnam (Tordoff *et al*., 2000; Hendrichsen *et al*., 2001; Kruskop *et al*., 2006; Csorba *et al*., 2007). The increased frequency of recent descriptions of new species in Southeast Asia suggests that this number could increase in the future.

An adult female of a very small tube-nosed bat (No. S-173401 in the mammalian collection of Moscow Zoological Museum) was captured in the northeast part of the Da Lat plateau in Lam Dong province, Vietnam, in 2002 during the field work session organized by the Vietnamese-Russian Tropical Center. Initially, based on identification features provided by Corbet and Hill (1992), this individual was identified as *Murina aurata* (Kruskop, 2005; Borisenko *et al*., 2006). The second specimen of the same species (young male No. S-182119) was captured in 2008 close to the previous locality. Further comparison with collections stored in Royal Ontario Museum revealed certain morphological differences from *M. aurata* as well as from other small tube-nosed bats, particularly in cranial proportions and fur coloration and texture. Therefore, we describe

these individuals as a new species of the genus *Murina*.

Materials and Methods

During field work, bats were captured using nylon mist nets 2 × 7 m, set across potential flyways, e.g. over small streams or across trails. The new species was captured in a mist net set in a forest ravine near the field camp of the expedition. Fifty eight specimens of eight small species of tube-nosed bats (from the genera *Murina* and *Harpiola*) were used as comparative material (adult individuals of both sexes; dry or alcohol preserved skins with extracted skulls — see Appendix).

The following 19 cranial measurements, followed by abbreviations in parentheses, were taken to the nearest 0.01 mm with electronic calipers in combination with a binocular microscope: condylocanine length (CCL), condylobasal length (CBL), mastoid width of the skull (MW), width of braincase (BCW), occipital height of the skull from occipital condyles to the occiput-parietal suture (OH), width of postorbital constriction (POC), rostral width at the level of the infraorbital foramina (RW), rostral length from infraorbital foramen to the anterior margin of the upper jaw (RL), C–M^3 length (CM^3), length of the upper canine at the base of crown (C), width between outer margins of upper canines (C^1C^1), crown width between outer margins of M^3 (M^3M^3), length of the palate from the anterior margins of canines to the most posterior point of palate midline (Pal); width of the palate posterior to tooth rows (PalW), width of M^3 (M^3W), length of M^3 (M^3L), crown length of mandibular tooth row (CM_3), lower jaw length from alveolus of i_1 to the articulated process condyle (MdL), lower jaw height to the tip of coronoid process (MdH).

Skull measurements were analyzed with the use of Statistica for Windows 5.5 software (StatSoft, 2001). Discriminant Function analysis (DFA) and Principal Component analysis (PCA) were used for statistical treatment of the data. In the DFA, seven samples of *Murina* species were used to calculate squared Mahalanobis distances. For the PCA measurements were standardized [(row score-mean)/standard deviation]. *Murina cyclotis* and *M. aenea* were excluded from the final analysis because of extreme influence of overall size.

Results

Principal components (PC) I–IV explain ca. 77.3% of total variance and are correlated (loadings > 0.7) with CM^3, CM_3, Pal, CCL, MdL, CBL, RL and C; BCW and POC; OH and C^1C^1; and M^3L, respectively. PC I clearly separates the new species from other small *Murina* species except for one small specimen of *M. aurata* and to a lesser degree, *M. suilla*. PC III also separates the new species from *M. aurata* (Fig. 1). According to this analysis, the new tube-nosed bat is morphologically most closely aligned with *Murina aurata* and *M. suilla*.

Squared Mahalanobis distances calculated from the Discriminant function analysis demonstrate the dissimilarity of ZMMU S-173401 from all the smaller *Murina* (Table 1). Distances from the Da Lat specimen to the centroids of other species samples (47.01–176.78) are double the intraspecific distances (5.58–27.04). The greatest affinities are with *M. ussuriensis*, *M. tubinaris* and *M. aurata*; the distance from the latter species is three times greater than the maximum intraspecific variance in *M. aurata*.

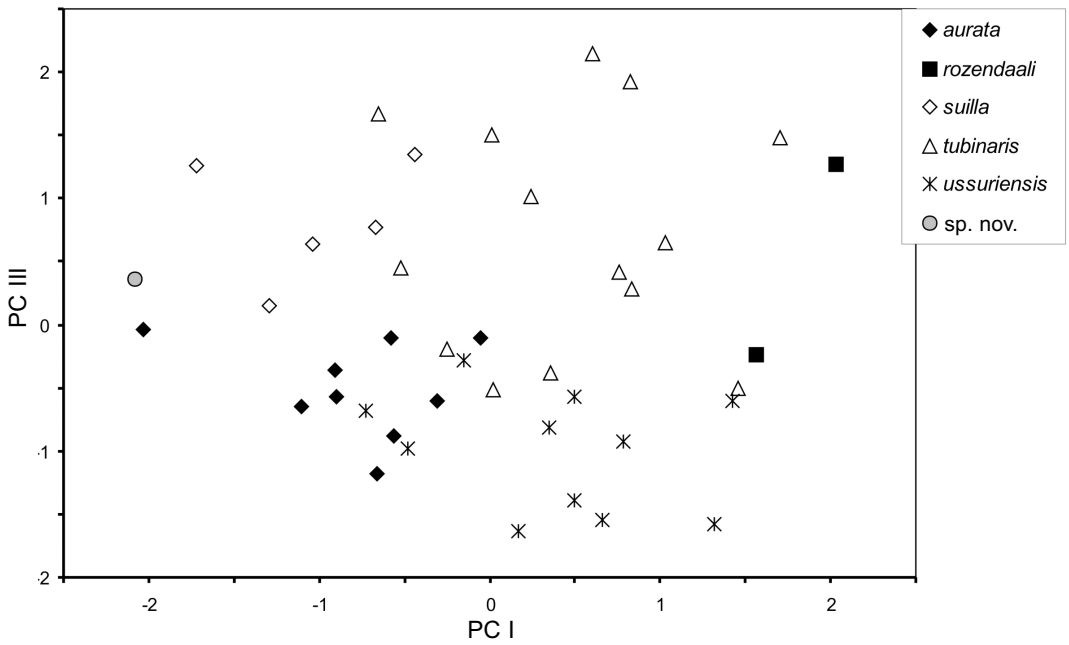

Fig. 1. Scatterplot of six small tube-nosed bat species from principal components I (eigenvalue = 9.25, total variance explained = 48.70%) and III (eigenvalue = 1.74, total variance explained = 9.18%) of a PCA

Murina harpioloides sp. nov.

Holotype

ZMMU S-173401, adult female originated from the north-eastern part of the Da Lat plateau, 30 km north-east from Da Lat, Lam Dong Province, Vietnam (12°09'N, 108°39'E); captured at about 1,800 m a.s.l. on 17 April 2002. Paratype: ZMMU S-182119, subadult male from the same area; captured at about 1,400 m a.s.l. on 21 April 2008.

Diagnosis

The new species is a very small tube-nosed bat with a forearm length of 28.4–29.7 mm and a body mass of ca. 3.0–4.2 g. Teeth are not robust and the tooth rows are somewhat convergent anteriorly. Anterior upper premolar is relatively small, about half the height and less than one third of the crown area of the posterior premolar. The lower canine possesses a small but distinct additional anterior cusp.

The dorsal fur looks bicoloured owing to dark-brown underfur and bright golden tips of guard hairs, resembling *M. aenea*, *H. isodon* and to some extent *M. rozendaali*. In skull proportions the new species resembles *M. aurata*, *M. suilla* and *M. ussuriensis* but has a smaller skull size, a smaller anterior upper premolar and a better developed supplementary cusp on the lower canine.

Description

This tube-nosed bat is a typical member of the morphological '*suilla*' species group (sensu Koopman, 1994). Its size is very small and represents one of the smallest members of the genus. Measurements of the holotype (in mm) are: CCL = 12.34, CBL = 13.02, M^3W = 7.42, BCW = 7.21, OH = 5.81, POC = 4.09, RW = 4.12, RL = 3.13, C^1C^1 = 3.39, M^3M^3 = 4.88, CM^3 = 4.68, C = 0.70, Pal = 6.37, PalW = 3.1, M^3W = 1.11, M^3L = 0.42, CM_3 = 5.13, MdL = 9.31, MdH = 3.32; head and body length = 35, tail length = 30.5, forearm length = 29.7, ear conch height = 12.3, body mass = 4.2 g.

Proportions are typical for Murininae with the body short and stocky; and the wings are wide with blunt tips. The tail is slightly shorter than the head and body, and the last vertebra is not included in tail membrane. The wing membranes are attached to the distal phalanx of the outer digit. The ears are wide and rounded, with a small emargination on posterior edge. The tragus is narrow and pointed, with a small additional lobe at base. The nasal tubes are relatively long, about 2.5 mm from the midline of the nose. The muzzle, wing membranes and ears are dark-pigmented.

Dorsally the fur appears bicoloured; it is medium thick and the under fur is thin and somewhat curly, very dark brown (almost black) with somewhat paler tips. Guard hairs are about 9 mm in length, and are found both dorsally and ventrally. The dorsal guard hairs are dark-brown at the base and. the distal half are tricoloured with pale-brown and more dark brown rings and bright orange-gold tips. Hair on the belly is dark-brown at the base and tipped with pale silver-gray. The entire tail membrane from the proximal to distal edge, and about one third of the plagiopatagium next to the body, are covered dorsally with fur similar to guard-hairs covering

TABLE 1. Squared Mahalanobis distances from the group centroids. Accepted groups are mentioned in the upper row; diagonal (in bold) demonstrates distances inside each group. $P = 0.15$ in all cases, sample sizes in parentheses

Species	Specimen/statistics	*aenea*	*aurata*	*cyclotis*	*rozendaali*	*suilla*	*tubinaris*	*ussuriensis*
aenea	ROM MAM-113014	**10.45**	174.21	103.27	182.43	164.76	117.70	176.67
	ROM MAM-117935	**10.45**	135.23	80.33	163.23	121.63	125.45	151.80
aurata (9)	min	134.16	**5.58**	80.98	92.75	31.52	60.84	70.00
	max	186.49	**15.88**	109.18	135.35	63.12	90.51	108.67
cyclotis (14)	min	55.33	53.61	**9.22**	59.16	43.51	35.88	104.45
	max	135.18	140.55	**24.30**	122.15	121.63	118.86	201.59
rozendaali	ROM MAM-117953	156.44	112.36	93.48	**12.13**	103.34	111.38	224.40
	ROM MAM-112312	192.57	123.54	93.36	**12.13**	89.06	104.23	194.45
suilla (5)	min	101.91	31.32	63.67	82.32	**10.16**	45.99	69.29
	max	171.81	67.56	112.98	120.86	**22.78**	108.51	170.51
tubinaris (14)	min	99.07	46.24	54.49	89.66	63.83	**10.58**	36.40
	max	165.50	107.95	101.16	158.16	105.00	**21.95**	93.91
ussuriensis (11)	min	142.09	68.67	124.93	176.83	110.05	53.07	**10.23**
	max	211.82	111.32	178.38	254.35	167.26	95.19	**27.04**
harpioloides	ZMMU S-173401	139.65	69.37	138.09	176.78	96.18	57.49	47.01

the body. Toes (up to the bases of claws), thumb, upper side of the forearm and proximal part of the fifth metacarpal are covered with bright golden hairs.

The skull has a rounded brain case and relatively gracile facial parts (Fig. 2). The anteorbital opening is situated above the first root of the anterior upper molar, and the lacrimal opening is above the second root of the same tooth (Fig. 3A). Both sagittal and occipital crests are absent. The basisphenoid pits continue backward only slightly beyond the midline of the cochlea (Fig. 4A), similar to *M. aurata* and *M. suilla*. The pterygoids are relatively strong and are somewhat curved inwards posteriorly. The posterior palatal emargination is not large and possesses a wide medial projection (Fig. 4A). The posterior palate is shorter proportionally than in *M. aurata*, *M. ussuriensis*, and *M. tubinaris* (Fig. 3B–D). The ends of the angular and articular processes of the mandible are at the same level (Fig. 2).

The upper tooth rows are slightly convergent anteriorly. The outer upper incisor is only slightly shorter in height than the inner one and is about twice as large in crown area (Figs. 2A–B and 3A). Upper canine is relatively small and shorter than the posterior premolar (PM^4 — Fig. 2A). The anterior upper premolar (PM^2) is small and compressed between the canine and posterior premolar; it is less than half the height of PM^4 and at least $^1/_4$ the size of the crown area (Fig. 2A–B). Upper molars have weak traces of mesostyles and very narrow postcingular shelves. Posterior upper molar possesses reduced but distinct post-paracrista (Fig. 2B). Lower molars have well-developed entoconids and reduced hypoconulids, joined with entoconids. The postcristid connects directly to hypoconulid, so the type of molars can be referred to as nyctalodont (Fig. 2D). The cusp pattern in *M. suilla* and *H. isodon* are different, better corresponding to myotodont type (Kruskop *et al*., 2006). The talonid of the posterior lower molar is greatly reduced, about ¼ of the trigonid area. The lower canine possesses an additional small anterior cusp (Fig. 2C).

Etymology

The name ‘harpioloides’ refers to the similarity of external features and lower canine between the new species and *H. isodon*.

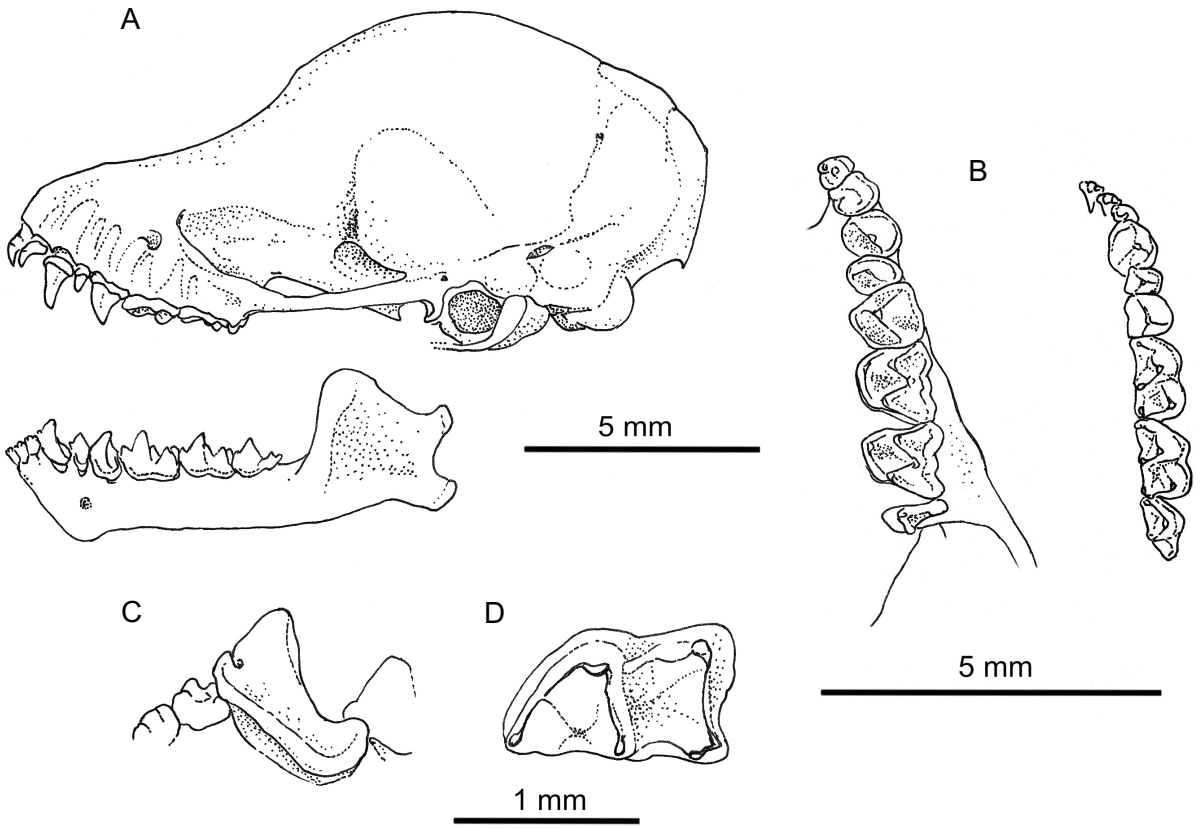

FIG. 2. Skull and teeth of *M. harpioloides* sp. nov.: A — skull and mandible lateral view; B — occlusal view of upper and lower tooth rows; C — lingual view of the lower canine; D — occlusal view of the second lower molar

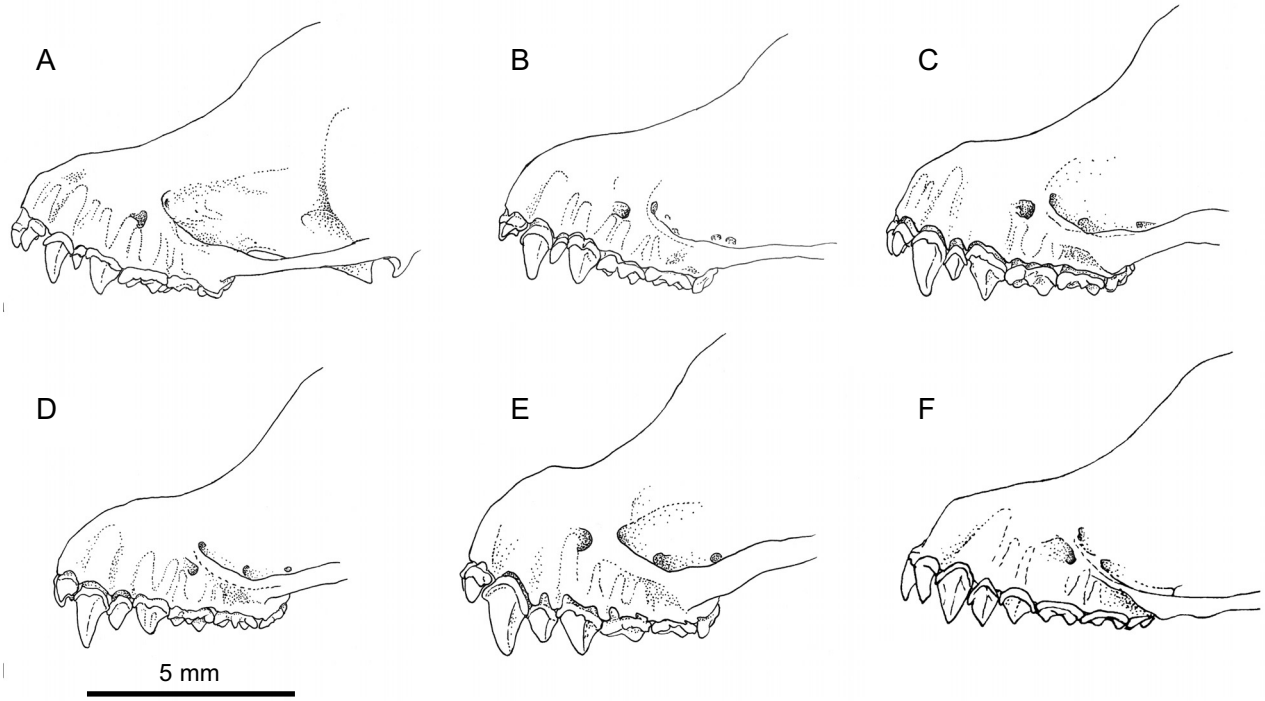

FIG. 3. Comparison of rostra of selected Murininae in lateral view: A — *M. harpioloides* sp. nov., holotype; B — *M. aurata*, ROM MAM-111386; C — *M. tubinaris*, ROM MAM-111302; D — *M. rozendaali*, ROM MAM-112312; E — *M. aenea*, ROM MAM-113014; F — *H. isodon*, ZMMU S-180001

Distribution and Ecology

Known only from the type locality. Type specimen was captured in a small humid ravine surrounded by deciduous mixed forest with distinct presence of *Manglietia* and *Solonea* trees (Kuznetsov *et al*., 2006). In the same biotope and place, several individuals of *Rhinolophus affinis* were captured (Borisenko *et al*., 2006).

Comparison with Other Species

The small *Murina* can be separated from the rest of genus by a condylo-basal length of skull that rarely exceeds 15 mm (usually less than 14.5 mm) and upper tooth row usually shorter than 5.5 mm. This size-group includes *M. aurata*, *M. rozendaali*, *M. tubinaris*, *M. ussuriensis* and *M. suilla* (Table. 2). Both species of *Harpiola* also belong to the same size group (Kruskop *et al*., 2006). *Murina aenea* and *M. cyclotis* are slightly larger species.

Murina harpioloides can be easily distinguished from *Harpiola isodon*, which it resembles in general external appearance, by somewhat smaller size, shorter fur on back and distinctly longer nasal tubes. Dental characters also separate *Harpiola* from *Murina* (Kuo *et al*., 2006). *Harpiola isodon* possesses a large anterior upper premolar which is triangular in lateral view, exceeding the posterior premolar in size and only slightly smaller than the canine, whereas in *M. harpioloides* the anterior premolar is distinctly smaller than the posterior one (Fig. 3). Although *M. harpioloides* possesses a visible additional cusp on the lower canine (Fig. 2C), it is much smaller than the same structure of *H. isodon*.

From *M. aenea*, *M. cyclotis* and *M. rozendaali* as well as from other species of the '*cyclotis*' group sensu Koopman (1994), *M. harpioloides* can be distinguished by relatively light dentition, small anterior upper premolar, toothrows convergent anteriorly and outer upper incisor situated in latero-posterior position relative to the inner one (Fig. 4A, 4E, and 4F). Amongst all the '*cyclotis*' group species, only *M. rozendaali* is of comparable size with *M. harpioloides.* The other species in the group, including smallest specimens of *M. cyclotis*, are distinctly larger. *M. harpioloides* possesses longer golden hair tips and darker ventral coloration than *M. rozendaali* and shorter golden hair tips than *M. aenea* (which otherwise looks similar in color).

From *M. tubinaris* and *M. ussuriensis* the newly described species differs in fur coloration (especially from *M. tubinaris*, which possess very characteristic grayish coloration without any golden or even brownish tinges), smaller skull and shorter basisphenoid pits which do not continue backward beyond the cochlea (Fig. 4A and 4C). Morphologically, the

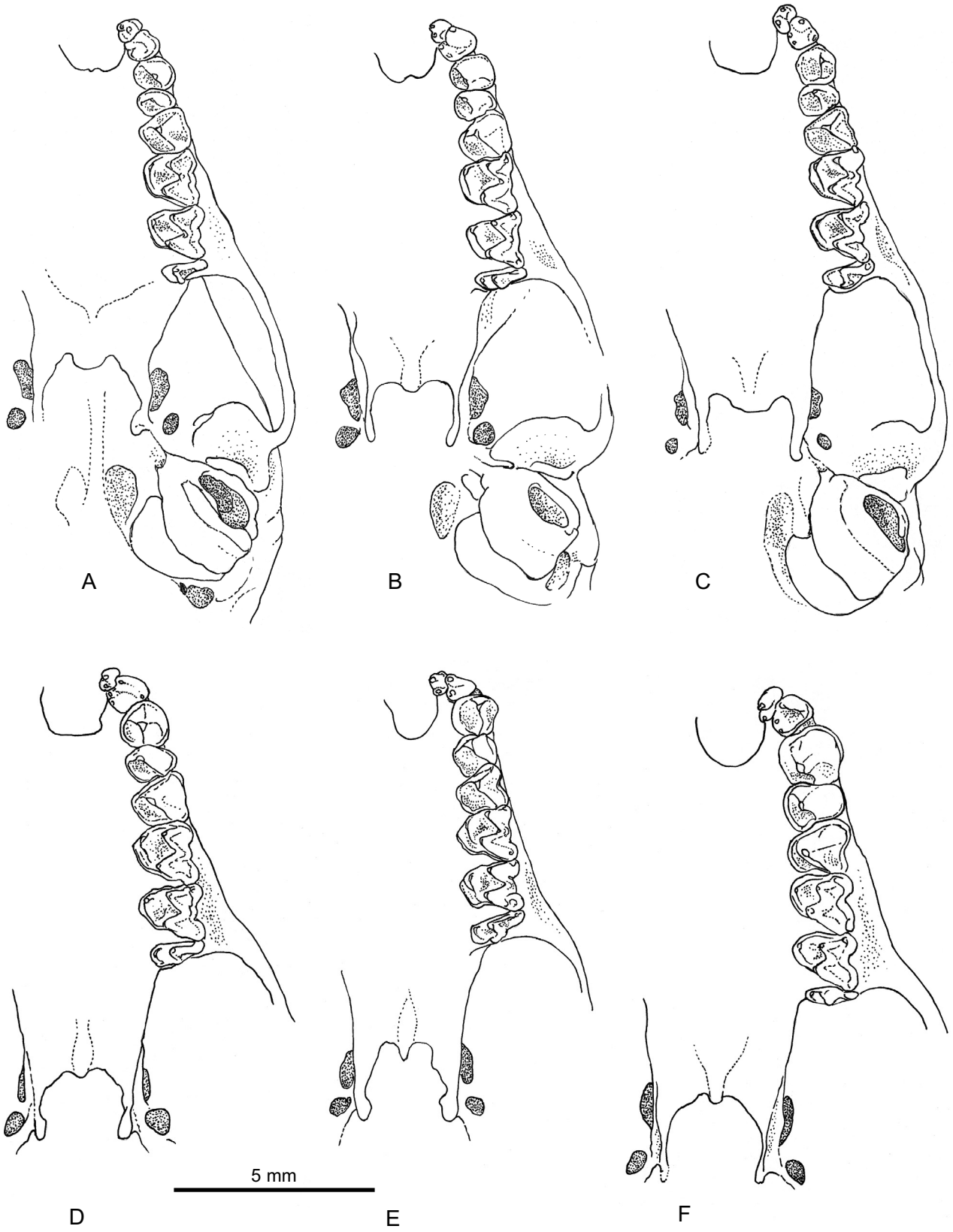

FIG. 4. Comparison of the upper tooth rows and palate shape among some *Murina* species: A — *M. harpioloides* sp. nov., holotype; B — *M. aurata*, ROM MAM-111386; C — *M. ussuriensis*, ZMMU S-173249; D — *M. tubinaris*, ROM MAM-111302; E — *M. rozendaali*, ROM MAM-112312; F — *M. aenea*, ROM MAM-113014

TABLE 2. Selected cranial measurements of smaller species of *Murina*. See text for explanations (sample sizes in parentheses)

Species	Statistics	CCL	CBL	BCW	OH	POC	C^1C^1	M^3M^3	CM^3	C	Pal	CM_3	MdL
aenea (2)	$\bar{x}$	14.87	15.34	7.83	6.79	4.72	4.83	5.96	5.85	1.19	8.00	6.39	11.78
aurata (9)	$\bar{x}$	12.72	13.23	7.13	5.64	4.25	3.56	5.02	4.79	0.74	6.79	5.26	9.88
	min	12.18	12.70	6.93	5.46	4.03	3.43	4.84	4.59	0.71	6.39	5.04	9.46
	max	13.06	13.62	7.33	5.85	4.52	3.73	5.22	4.99	0.78	7.09	5.53	10.26
cyclotis (14)	$\bar{x}$	14.85	15.33	7.71	6.60	4.21	4.22	5.49	5.65	1.08	7.82	6.11	11.53
	min	13.97	14.45	7.48	6.05	4.08	3.93	5.23	5.34	0.93	6.97	5.82	10.90
	max	15.51	15.93	7.92	7.32	4.51	4.92	5.96	5.90	1.22	8.50	6.51	12.33
rozendaali (2)	$\bar{x}$	13.60	13.95	7.15	6.12	3.91	3.93	5.13	5.30	0.95	7.33	5.88	10.64
suilla (5)	$\bar{x}$	12.74	13.23	7.15	6.01	4.00	3.68	5.10	4.87	0.78	6.63	5.29	9.99
	min	12.41	12.75	7.02	5.65	3.90	3.63	4.84	4.62	0.74	6.48	5.13	9.69
	max	12.98	13.50	7.24	6.21	4.10	3.76	5.29	5.17	0.81	6.85	5.51	10.33
tubinaris (14)	$\bar{x}$	13.70	14.15	7.44	6.16	4.31	3.77	5.26	5.16	0.86	7.14	5.54	10.36
	min	13.32	13.65	7.11	5.78	4.19	3.56	5.08	4.86	0.75	6.78	5.19	9.78
	max	14.43	14.86	7.91	6.76	4.48	3.99	5.47	5.51	0.98	7.62	5.89	11.07
ussuriensis (11)	$\bar{x}$	13.51	14.08	7.26	5.46	4.28	3.54	5.16	5.01	0.77	7.16	5.43	10.22
	min	13.11	13.60	6.99	5.09	3.93	3.37	4.95	4.73	0.67	6.64	5.19	9.77
	max	13.89	14.51	7.65	6.02	4.60	3.82	5.43	5.25	0.87	7.44	5.58	10.64
harpioloides ZMMU S-173401		12.34	13.02	7.21	5.81	4.09	3.39	4.88	4.68	0.70	6.37	5.13	9.31

new species looks most similar to *M. aurata* and *M. suilla*, from which it can be distinguished by somewhat smaller skull (comparable in size with the skull of the smallest *M. aurata* male) with more swollen braincase, smaller posterior palatal emargination with wide medial projection and by dark skin on the muzzle tip. *Murina harpioloides* has less pronounced orange tinges in coloration and more obvious dark underfur, than *M. aurata* and particularly *M. suilla*. From all of the four species, *M. harpioloides* differs in having a better developed fur cover on tail and wing membranes and by proportionally smaller talonids on the lower molars.

The taxonomic distinctiveness of *M. harpioloides* is also supported by preliminary data from cytochrome *c* oxidase subunit I (COI) gene sequences (C. M. Francis, A. V. Borisenko, N. V. Ivanova, J. L. Eger, B. K. Lim *et al*., unpublished data). However, further investigation including analysis of DNA nucleotides, and the search for additional specimens is needed to uncover the actual relationship of this new species with other tube-nosed bats.

ACKNOWLEDGEMENTS

We would like to express gratitude to many people who rendered us variable help on different stages of work. Field survey of the first author in Vietnam became possible due to support of the Joint Russian-Vietnamese Tropical Centre and personal efforts of Dr. V. V. Suntsov, Dr. Vu Van Tieu, Dr. A. N. Kuznetsov; we would like to express sincere gratitude to Dr. Phan Luong who really did much for the success of the Tropical Centre field expeditions and to Alex Borisenko and Burton Lim for discussions on the systematics of *Murina*. Dr. M. Ruedi (Geneva Museum of Natural History), Dr. A. O. Averiyanov, G. I. Baranova (Zoological Institute of Russian Academy of Sciences) and Dr. V. V. Rossina (Paleontological Institute of Russian Academy of Sciences) kindly provided the opportunity to process collections of the mentioned organizations. Field work of the second author was supported by grants from the Royal Ontario Musuem, Royal Ontario Museum Governors Fund and the US National Science Foundation (DEB-0344430).

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Received 28 May 2008, accepted 02 September 2008

APPENDIX

Collections visted and specimens used in the present study

Acronyms of depositories of the processed collections are as follows: ROM — Royal Ontario Museum, Toronto; ZMMU — Zoological Museum of Moscow State University; SDM — State Darwin Museum, Moscow; ZISP — Zoological Institute of Russian Academy of Sciences, St. Petersburg; MHNG — Natural History Museum of Geneva; Ros — personal collection of Valentina Rossina, Paleontological Institute of RAS, Moscow.

Murina aurata: China — ROM MAM-106411, ROM MAM-106445, ROM MAM-116099; Vietnam — ROM MAM-111286, ROM MAM-111308, ROM MAM-111360, ROM MAM-111399; Laos — ROM MAM-106478; Malaysia — ROM MAM-112309.

M. aenea: Malaysia — ROM MAM-113014; Borneo — ROM MAM-117935.

M. cyclotis: China — ROM MAM-116048, ROM MAM-116053, ROM MAM-116076, ROM MAM-116149, ROM MAM-116206, ROM MAM-116369, ROM MAM-116398; Borneo — ROM MAM-117930; Vietnam — ROM MAM-107548, ROM MAM-107666, ROM MAM-107693, ROM MAM-111287, ROM MAM-111375; Laos — MHNG-1926.033.

M. suilla: Borneo — ROM MAM-117936, ROM MAM-117940, ROM MAM-117944, ROM MAM-117950, ROM MAM-117956.

M. tubinaris: China — ROM MAM-116137, ROM MAM-116202, ROM MAM-116409; Laos — MHNG-1926.034, MHNG-1926.035, MHNG-M1167, ROM MAM-106379, ROM MAM-106380, ROM MAM-106475, ROM MAM-106376, ROM MAM-106477, ROM MAM-110482; Vietnam — ROM MAM-111285, ROM MAM-111302.

M. rozendaali: Borneo — ROM MAM-117953; Malaysia — ROM MAM-112312.

M. ussuriensis: Russia, Primorie — ZMMU S-96386, ZMMU S-42508, ZMMU S-173249, ZMMU S-175399, ZISP-10849, ZISP-44102, SDM-10221/536, Ros-46; Russia, Sakhalin — ZMMU S-50955, ZMMU S-175206-207; Japan — MHNG-1703.33, ZISP-59106.

Harpiola isodon: Vietnam — ZMMU S-180001.