On the validity of *Tadarida latouchei*, with reference to morphological divergence among *T. latouchei*, *T. insignis* and *T. teniotis* (Chiroptera, Molossidae)

Kimitake Funakoshi¹ and Toshihiro Kunisaki²

¹Biological Laboratory, Faculty of Intercultural Studies, The International University of Kagoshima, 8850 Shimofukumoto-cho, Kagoshima 891-0191, Japan

²Toso 3-29-10, Kagoshima 890-0088, Japan

Abstract. A rare species of free-tailed bat, *Tadarida latouchei*, was found on Kuchinoerabu-jima Island of the Osumi group, northern Ryukyu Islands, Japan; the second record of the species from Japan. In addition to the description of the newly collected specimen, we examined relationships among this species and two other closely related species, *T. insignis* and *T. teniotis*, on the basis of univariate and multivariate analyses of morphometric characters. External and skull characters, with the exception of tail and tibia lengths, showed no substantial range overlap between *T. latouchei* and *T. insignis* or *T. teniotis*, and these characters in *T. latouchei* were significantly smaller than those in either *T. insignis* or *T. teniotis*, confirming *T. latouchei*'s independence at the specific level. This view is supported further by its relatively short dorsal hairs, thin and roundish ear and large upper anterior premolar.

Key words: Kuchinoerabu-jima, morphological analyses, *Tadarida*, taxonomy.

The free-tailed bat *Tadarida latouchei* was first described by Thomas (1920) on the basis of two specimens (one adult and one immature) collected from Chin-wang-tao, on the sea-coast of north-eastern Chihli, China. This taxon has also been recorded from Amami-Oshima, an island in the Amami Group, southern Japan, with Yoshiyuki et al. (1989) following Thomas's (1920) position that it was a "good" species. Because of the small sample size examined by Thomas (1920), several authors have treated *T. latouchei* as a synonym of *Tadarida teniotis insignis* (Allen 1938; Ellerman and Morrison-Scott 1951; Corbet 1978; Corbet and Hill 1991; Wilson and Reeder 1993) or of *T. insignis* (Maeda 1996).

A second specimen of a free-tailed bat was recently obtained from Kuchinoerabu-jima, an island in the Osumi Group, Japan. It clearly differed from both *T. teniotis* and *T. insignis*, while its morphological features agreed well with those of *T. latouchei* in Thomas (1920). In this paper we first describe the newly collected Kuchinoerabu-jima specimen, and then examine the validity of *T. latouchei* on the basis of morphological comparisons with *T. teniotis* and *T. insignis*.

¹E-mail: funakoshi@int.iuk.ac.jp

Materials and methods

A specimen of *Tadarida latouchei* was obtained on the ground near the schoolhouse at the village of Honmura on Kuchinoerabu-jima, Kagoshima Prefecture, on 3 October 1998 (specimen code KF-216: Figs. 1 and 2). This is the first record of this genus from the island. The bat appeared to be different from *T. insignis*, a species that is frequently recorded from Japan, and which has recently been found to reside on Birou-jima, an islet in Miyazaki Prefecture (Funakoshi et al. 1999). A number of *T. insignis*, captured in mist nets on Birou-jima, were examined for sex, age, and external characters, and then were marked with a wing-band and released during 1996–1999. One individual was retained for osteological investigations on 11 October 1996 (specimen code KF-217: Figs. 1 and 2). The two specimens of *T. latouchei* and *T. insignis* are deposited in the International University of Kagoshima.

The following six external and 10 cranial dimensions were measured to the nearest 0.1 mm with slide calipers: head and body length (HB), forearm length (FAL), tibia length (Tibia), hind foot length with claw (HFL), tail length (Tail), ear length (Ear), greatest length of skull (GLS), condylobasal length (CBL), rostral width (RW), zygomatic width (ZW), mastoid width (MtW), brain-case width (BCW), brain-case depth (BCD), mandible length (MdL), length of upper tooth row from the canine to the third molar (C-M³), and length of lower tooth row from the canine to the third molar (C-M₃). Univariate and multivariate analyses were made for three external (FAL, Tibia, Tail), and five skull (CBL, ZW, BCW, MdL, C-M³) characters.

It is known that in *T. teniotis* FAL, Tail, CBL and BCW do not differ significantly

Fig. 1. Dorsal views of *Tadarida insignis* from Birou-jima (upper: specimen code, KF-217) and *T. latouchei* from Kuchinoerabu-jima (lower: KF-216).

Fig. 2. Dorsal (A, B) and lateral (C, D) views of cranium and mandible of *Tadarida insignis* from Birou-jima (A, C: specimen code, KF-217) and *T. latouchei* from Kuchinoerabu-jima (B, D: KF-216). Bars=5 mm.

between individuals of different ages (adult vs subadult) or sexes (cf. Kock and Nader 1984). In *T. insignis*, the young weaned in summer reached adult size in autumn, and there were no significant differences in external sizes between males and females or between subadults and adults in our samples (Funakoshi et al. 1999). The analyses were computed on external and skull characters, with age (adult, subadult) and sex groups combined.

Additional data for *T. latouchei* were obtained from Thomas (1920) and Yoshiyuki et al. (1989). Additional data for *T. insignis* from Japan were obtained from various published sources (e.g. Abe 1961; Tomita 1979; Hamaguchi and Chokki 1985; Funakoshi et al. 1987; Yoshiyuki 1989), data for *T. insignis* from Korea were obtained from Ognev (1962) and from China from Allen (1938). Further data for the external measurements of *T. insignis* were based on the individuals at Birou-jima. All of the data for *T. teniotis* distributed in the Western Palearctic were obtained from Kock and Nader (1984).

Results

External characters

The specimen of *T. latouchei* found on Kuchinoerabu-jima was identified as a subadult male because its finger joints were a little knobby, testes were not yet developed, and its teeth were scarcely worn. The measurements (in mm) of the external characters of the specimen were: HB 67.3, FAL 53.6, Tibia 17.2, HFL 12.5, Tail 41.2, and Ear 22.2. The specimen of *T. insignis* collected on Birou-jima was also classified as a subadult male for the same reasons. The measurements of its external characters were: HB 89.8, FAL 63.3, Tibia 20.0, HFL 12.0, Tail 49.5, and Ear 30.5.

The specimen of *T. latouchei* was clearly smaller than that of *T. insignis*, and was similar in size to the type specimen of *T. latouchei* in size (Fig. 3). In *T. latouchei*, the plagiopatagium was inserted to a point level with the basal third of the tibia, while in *T. insignis* the insertion point was at a point between one third and one fourth of the length of the tibia. In *T. latouchei*, the fur was rather soft and dense. The dorsal hairs were blackish brown and their length averaged 6.1 ± 0.56 (SD) mm ($n=20$), whereas those of *T. insignis* were velvety and dark brown, and their length averaged 9.1 ± 0.49 (SD) mm ($n=20$). Ears of *T. latouchei* were thinner, smaller and rounder than those of *T. insignis*. These characters of the Kuchinoerabu-jima *T. latouchei* specimen were similar to the previous specimen described from Amami.

Skull characters

The measurements (mm) of the skull characters of the Kuchinoerabu-jima *T. latouchei* were: GLS 21.2, CBL 20.0, RW 5.2, ZW 11.6, MtW 11.4, BCW 10.3, BCD 8.3, MdL 14.8,

Fig. 3. Relationship between forearm length and tail length in three species of *Tadarida*. a: Kuchinoerabu-jima, b: Amami-Oshima, c: China, d: Korea.

Fig. 4. Relationship between condylobasal length and zygomatic width in three species of *Tadarida*. a: Kuchinoerabu-jima, b: Amami-Oshima, c: China.

Fig. 5. Relationship between condylobasal length and brain-case width in three species of *Tadarida*. a: Kuchinoerabu-jima, b: Amami-Oshima.

C-M³ 7.8, and C-M₃ 8.3, whereas, those of the Birou-jima *T. insignis* specimen were: GLS 25.1, CBL 24.6, RW 6.5, ZW 14.8, MtW 13.2, BCW 11.8, BCD 10.0, MdL 18.0, C-M³ 9.3, C-M₃ 10.6. The *T. latouchei* skull was smaller than the *T. insignis* skull, but similar in size to the type specimen and to that of the Amami specimen (Figs. 4 and 5). The lower part of the parietal bone was not so well expanded posteriorly in *T. latouchei* as in *T. insignis*

(Fig. 2). The upper anterior premolar (P²) of *T. latouchei* was distinctly larger than that of *T. insignis*. The basal width of P², viewed laterally, was 1.1 mm (79% of the basal width of the upper canine) in *T. latouchei*, but just 0.7 mm (41% of the basal width of the upper canine) in *T. insignis*.

Univariate and multivariate analysis

On the basis of our own data, and on published records in the literature, three external and five skull measurements (mean, standard deviation, range, and sample size) from *T. latouchei*, *T. insignis* and *T. teniotis* were able to present in Table 1. The differences of the means of two external (FAL, Tail) and three skull (CBL, ZW and C-M³) characters among the three species were tested using Mann-Whitney's *U*-test (Table 1). All of the characters were significantly smaller in *T. latouchei* than in either *T. insignis* or *T. teniotis*. Hence, both the body and the skull of *T. latouchei* are clearly smaller than those of the other two species. *T. insignis* was significantly larger than *T. teniotis* (FAL, Tail and C-M³), but had a significantly smaller BCW than *T. teniotis*.

The principal component analyses extracted two significant factors from five skull characters (CBL, ZW, BCW, MdL, C-M³) which collectively explained 93.2% of the total variation. The first factor reflected overall size since all characters had large, positive loadings (>0.7) for this factor (Table 2). The specimens of *T. latouchei* were clearly separated from those of *T. insignis* and *T. teniotis* on the first factor (Fig. 6). Characters loading heavily (>0.5) on the second factor were C-M³ (positive) and BCW (negative; Table 2). On this factor, *T. insignis* and *T. teniotis* were clearly separated, whereas *T. latouchei* was located in an intermediate position (Fig. 5).

Table 1. External and skull measurements (mm) of *Tadarida latouchei*, *T. insignis* and *T. teniotis*. Ranges of values are given in parentheses. Different letters (a–c) denote significant differences in *U*-test ($P < 0.01$).

	<i>T. latouchei</i>			<i>T. insignis</i>			<i>T. teniotis</i>		
	<i>n</i>	Mean	<i>U</i> -test	<i>n</i>	Mean $\pm$ SD	<i>U</i> -test	<i>n</i>	Mean $\pm$ SD	<i>U</i> -test
FAL	3	55.3 (53.6–56.5)	a	70	62.7 $\pm$ 1.32 (60.4–65.3)	b	28	60.4 $\pm$ 1.30 (58.0–64.0)	c
Tibia	2	17.0 (16.9–17.2)		46	20.7 $\pm$ 1.31 (17.0–23.0)		—	— —	
Tail	3	43.1 (41.2–45.0)	a	46	54.6 $\pm$ 2.36 (48.0–60.0)	b	28	52.3 $\pm$ 2.76 (45.0–58.0)	c
CBL	3	20.6 (20.0–21.2)	a	13	23.4 $\pm$ 0.70 (22.4–24.6)	b	26	23.3 $\pm$ 0.53 (22.1–24.2)	b
ZW	3	12.0 (11.6–12.3)	a	13	14.1 $\pm$ 0.43 (13.3–14.8)	b	25	14.0 $\pm$ 0.54 (12.8–14.7)	b
BCW	2	10.5 (10.3–10.7)		12	11.6 $\pm$ 0.29 (11.2–12.2)	a	24	11.9 $\pm$ 0.34 (11.2–12.7)	b
MdL	2	14.6 (14.5–14.8)		13	17.3 $\pm$ 0.39 (16.6–18.0)	a	25	17.1 $\pm$ 0.42 (16.3–18.0)	a
C-M ³	3	8.0 (7.8–8.1)	a	13	9.1 $\pm$ 0.15 (8.8–9.3)	b	27	8.6 $\pm$ 0.21 (8.2–8.9)	c

Table 2. Principal component factor scores for the first two principal components based on five skull characters in *Tadarida latouchei*, *T. insignis* and *T. teniotis*.

Characters	Factor 1	Factor 2
CBL	0.970	0.061
ZW	0.957	-0.093
BCW	0.782	-0.583
MdL	0.947	0.033
C-M ³	0.774	0.587

Fig. 6. Scatter plots for the first two factor scores extracted from principal component analysis based on five skull characters of three species of *Tadarida*. a: Kuchinoerabu-jima, b: Amami-Oshima, c: China.

Discussion

Specimens of *T. latouchei* have so far been described only from Chin-wang-tao (Thomas 1920), Amami-Oshima (Yoshiyuki et al. 1989) and Kuchinoerabu-jima (this study). Hence, the range of *T. latouchei* may be confined to the coastal area of East Asia, at least from 28° to 40°N. This range overlaps with the southern part of the range occupied by *T. insignis*. The skull and external characters of *T. latouchei*, with the exception of tail and tibia lengths, showed little overlap with either *T. insignis* or *T. teniotis* (Table 1), clearly indicating that *T. latouchei* is distinct from the other two species. Results of both univariate and multivariate analyses also indicate that *T. latouchei* is the smallest of the three taxa and that it is a valid species (Figs. 3–6). The specific validity of *T. latouchei* is further supported by its relatively short dorsal hair, blackish brown colourating, thin rounded ears, relatively large P² and probable overlap in distribution.

Notes on the taxonomic status of *T. insignis*.

Both *T. insignis* and *T. teniotis* are similar in shape and the range of their external and skull characters overlap. Some authors, including Allen (1938), Ellerman and Morrison-Scott (1951), Corbet (1978), Corbet and Hill (1991), have treated *T. insignis* as a subspecies of *T. teniotis*. However, the two species differ significantly from one another in both FAL and Tail length (Table 1). Comparisons of their skull characters have revealed that BCW and C-M³ also differ significantly between the two taxa (Table 1). According to the principal component analysis, these characters greatly contributed to separating these two species on factor 2 (Table 2, Fig. 6). The most important difference was C-M³, with *T. insignis* having a significantly greater value than *T. teniotis*. The ranges of this character overlapped only slightly between these two species. Furthermore, Yoshiyuki (1989) indicated that the ratio of the depth of the braincase to the mastoid width of *T. insignis* is 65.6%, which is considerably higher than in *T. teniotis* (54.1%). In *T. insignis*, the plagiopatagium was inserted at a point level with the basal third or quarter of the tibia, whereas in *T. teniotis* it was inserted at a point near the distal end of the tibia just above the ankle. The wing membrane of *T. teniotis* from India was also found to be inserted on the tibia just above ankle (Bates and Harrison 1997). The dorsal hairs of *T. insignis* are much darker than those of *T. teniotis* (see also Yoshiyuki (1989)). Taking all of these factors in to account, the two taxa *insignis* and *teniotis* should be treated as two separate species, as was proposed by Yoshiyuki (1989). Further biochemical and molecular studies may serve to verify this account.

Acknowledgements: We thank Mr. F. Yonezawa, retired Principal of Kanagadake Junior High School for providing the specimen of *T. latouchei*. We are also indebted to Mr. F. Maeda of the University of the Ryukyus for helping with the field work, and to Dr. M. Brazil for critically reading and comments on the final manuscript. This work was supported in part by a grant from the International University of Kagoshima.

References

- Abe, H. 1961. Two rare mammals obtained in Hokkaido. *Journal of the Mammalogical Society of Japan* 2: 3–7 (in Japanese with English summary).
- Allen, G. M. 1938. The mammals of China and Mongolia. American Museum of Natural History, New York, 620 pp.
- Bates, P. J. J. and Harrison, D. L. 1997. Bats of the Indian Subcontinent. Harrison Zoological Museum, Kent, 258 pp.
- Corbet, G. B. 1978. The Mammals of the Palaearctic Region: a taxonomic review. Cornell University Press, London, 314 pp.
- Corbet, G. B. and Hill, J. E. 1991. A World List of Mammalian Species. 3rd ed., Natural History Museum Publications, London, 243 pp.
- Ellerman, J. R. and Morrison-Scott, T. C. S. 1951. Checklist of Palaearctic and Indian Mammals. Pp. 133–136. British Museum (Natural History), London.
- Funakoshi, K., Maeda, F., Sato, M. and Ono, K. 1999. Roost selection, population dynamics and activities of the Oriental free-tailed bat, *Tadarida insignis* on the islet of Biroujima, Miyazaki Prefecture. *Honyurui Kagaku [Mammalian Science]* 39: 23–33 (in Japanese with English abstract).
- Funakoshi, K., Matsuzawa, K., Nishida, T. and Miura, E. 1987. Notes on the Japanese free-tailed bat, *Tadarida insignis* found in Fukuoka City, with special reference to the morphological features and the weight changes. *Biologia Fukuoka* 27: 25–28 (in Japanese with English summary).

- Hamaguchi, T. and Chokki, H. 1985. Notes on Oriental wrinkled bat *Tadarida insignis* found in Minamiashigara City. Kanagawa Sizenshi Shiryo 6: 37–40 (in Japanese).
- Kock, D. and Nader, I. A. 1984. *Tadarida teniotis* (Rafinesque, 1814) in the W-Palaeartic and lectotype for *Dysopes rupelii* Temminck, 1826 (Chiroptera: Molossidae). Zeitschrift für Säugetierkunde 49: 129–135.
- Maeda, K. 1996. Review and comments on the classification of Japanese bats (Chiroptera). Honyurui Kagaku [Mammalian Science] 36: 1–23 (in Japanese).
- Ognev, S. I. 1962. Mammals of eastern Europe and northern Asia vol. 1. Insectivora and Chiroptera. Israel program for Scientific Translations, Jerusalem, 487 pp.
- Thomas, O. 1920. Two new Asiatic bats of the genera *Tadarida* and *Dyacopterus*. Annals Magazine Natural History 5: 283–285.
- Tomita, Y. 1979. Mammalian fauna of Mie Prefecture. Bulletin of Mie Prefecture Museum, Science 1: 5–6 (in Japanese with English summary).
- Wilson, D. E. and Reeder, D. M. 1993. Mammal Species of the World. 2nd ed., Smithsonian Institution Press, Washington and London, 1206 pp.
- Yoshiyuki, M. 1989. A Systematic Study of the Japanese Chiroptera. National Science Museum, Tokyo, 242 pp.
- Yoshiyuki, M., Hattori, S. and Tsuchiya, K. 1989. Taxonomic analysis of two rare bats from Amami Islands (Chiroptera, Molossidae and Rhinolophidae). Memoirs of the National Science Museum, Tokyo 22: 215–225.

Received 19 May 2000. Accepted 25 August 2000.