

Discovery of *Rhinolophus beddomei* (Chiroptera: Rhinolophidae) from Thailand with a Brief Comparison to Other Related Taxa

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ABSTRACT.— *Rhinolophus beddomei* is reported from mainland Southeast Asia for the first time. It was collected in April, 2008, in Ratchaburi Province, Thailand, in a harp trap set over a stream in a dense evergreen forest. Morphometric and acoustic characters of the specimen are given with a brief comparison to other species of the *R. trifolius* group. Currently, it is not clear whether the Thai specimen represents an eastern extension of the Indian Subcontinent population or whether it is a member of an isolated population which is restricted to continental Southeast Asia. It is suggested that a further review, which would involve material from southern and Southeast Asia, together with *R. formosae* from Taiwan would be of considerable interest.

KEY WORDS: *Rhinolophus beddomei*, *R. trifolius* group, first record, Southeast Asia, Thailand, disjunct distribution

INTRODUCTION

Following a series of intensive bat surveys by members of the Prince of Songkla University bat team from 2003 to July 2008, eleven bat species were recorded from Thailand for the first time (Bumrungsri et al., 2006; Thong et al., 2006; Bates et al., 2007; Soisook et al., 2007). This brought the total for the country to 122 species of which 18 belong to the genus *Rhinolophus*, including *R. microglobosus* Csorba and Jenkins, 1998, which has recently been elevated to specific rank (Soisook et al., 2008).

In April, 2008, a field survey was conducted in Ratchaburi Province, western Thailand. Of particular interest was a single male specimen of a taxon not recorded previously from Thailand. The specimen is here referred to *Rhinolophus beddomei* Andersen, 1905 on the basis of size and morphology. *Rhinolophus beddomei* is one of five species which are assigned to the *R. trifolius* group (sensu Csorba et al., 2003). They are characterised by the presence of lateral lappets at base of the sella in the noseleaf. Three of the five species, *R. luctus* Temminck, 1834, *R. trifolius* Temminck, 1834, and *R. sedulus* Andersen, 1905, have been recorded previously from mainland

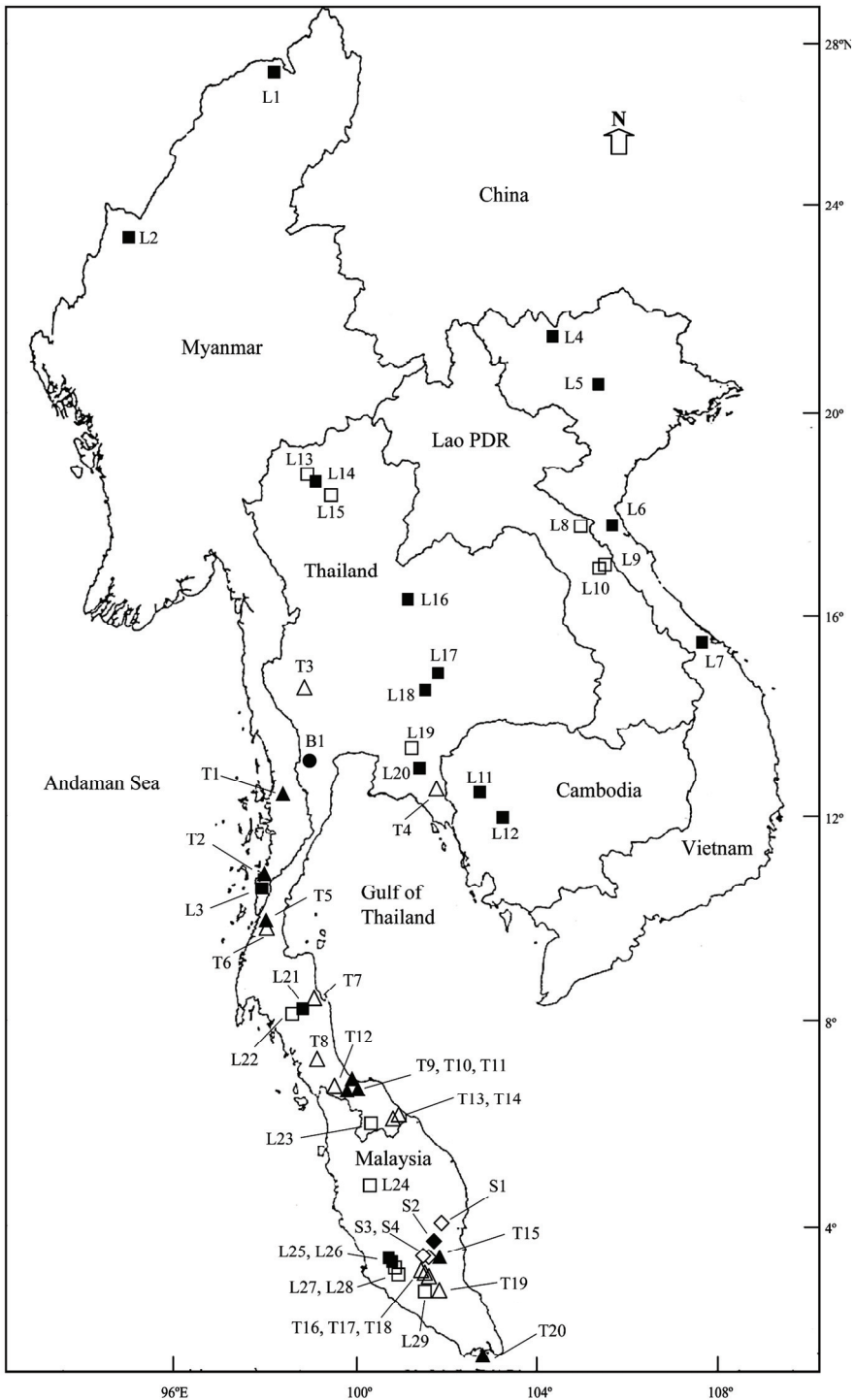


FIGURE 1. The known distribution of *R. beddomei* (circle), *R. luctus* (squares), *R. trifolius* (triangles) and *R. sedulus* (diamonds) in mainland Southeast Asia. Black symbols represent localities from which specimens have been examined, whereas localities with hollow symbols have not been examined. Locality information is included in the Appendix.

Southeast Asia (Corbet and Hill, 1992; Simmons, 2005), whilst the fourth, *R. formosae* Sanborn, 1939 is endemic to Taiwan.

Rhinolophus beddomei is regarded as distinct from *R. luctus* on the basis of its smaller size and the shape of the upper canine (Topál and Csorba, 1992; Csorba et al., 2003). Until now, its range was thought to be restricted to western and southern India and Sri Lanka (Bates and Harrison 1997). However, here we report the discovery of *R. beddomei* from Thailand with information on its echolocation and morphometrics. It is compared to the four other species of the *trifoliatatus* group.

MATERIALS AND METHODS

The specimen of *R. beddomei* was collected from Mae Nam Pha Chi Wildlife Sanctuary, Ratchaburi Province, western Thailand (13° 15' N, 99° 21' E) (loc. B1 in Fig. 1) at an altitude of 431 m a.s.l on 20 April 2008 during a wildlife diversity survey by staff of the Department of National Park, Wildlife and Plant Conservation (DNP) and the Prince of Songkla University. The wildlife sanctuary covers an area of 489.31 km² and is characterised by steeply rugged mountains which are part of the Tenasserim Mountain Range. The Pha Chi River runs through the western part of the sanctuary. The vegetation comprises four main forest types; dry evergreen forest, which is the predominant forest type with additional primary evergreen forest and mixed deciduous and dipterocarp forest. The underlying geology is granite. The wildlife sanctuary is in the rainshadow of the Tenasserim Mountain Range and consequently there is a relatively low annual

average precipitation of 246 mm (DNP, 2006).

The *R. beddomei* specimen was captured in a four-bank harp trap (Francis, 1989) set across a 3 m wide seasonal streamlet in primary evergreen forest. Five other species of insectivorous bats were also collected; *Nycteris tragata*, *Rhinolophus microglobosus*, *Myotis muricola*, *Kerivoula papillosa* and *Phoniscus jaborii*. The specimen of *R. beddomei* is preserved in 70% (v/v) alcohol with its skull extracted and deposited in the Princess Maha Chakri Sirindhorn Natural History Museum, Prince of Songkla University, Hat Yai, Thailand. External and craniodental characters were measured with a digital caliper following Bates and Harrison (1997) and Csorba et al. (2003). Body mass (MASS) was recorded using a Pesola 50 g scale and is given in grams. Additional specimens of *R. beddomei*, *R. luctus*, *R. trifoliatatus* and *R. sedulus* included in this study were studied at the Harrison Institute, Sevenoaks, UK (HZM), The Natural History Museum, London (BMNH) and Princess Maha Chakri Sirindhorn Natural History Museum (PSUZYC-MM; formerly PSU-M) (see Appendix).

The echolocation calls were recorded using a hand-held Pettersson D-240X time expansion bat detector, which was connected to iRiver iHP-120 Multi-Codec Jukebox recorder. Calls were analysed with BatSound Pro version 3.31 (Pettersson, Elektronik AB). A sampling frequency of 44.10 kHz was used and produced a spectrogram using 1024 samples Fast Fourier Transform (FFT) with Hanning window.

Measurements provided in this paper were taken from specimens examined for this study only, unless otherwise stated.

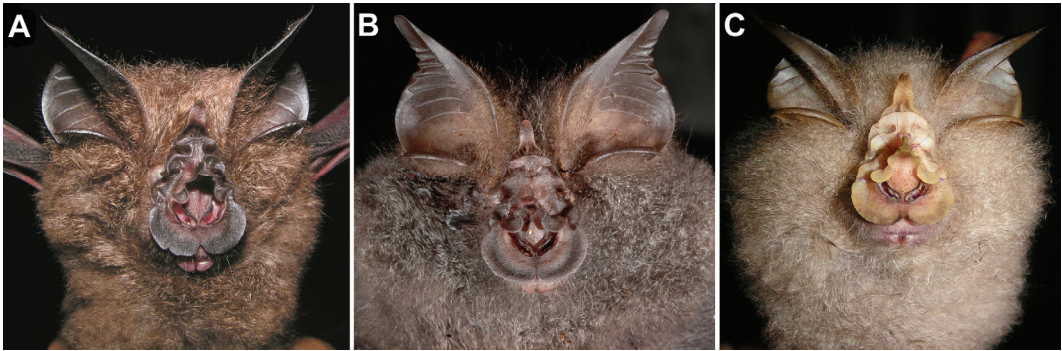


FIGURE 2. Shape of noseleaf and pelage colour of (A) *Rhinolophus beddomei* from western Thailand, (B) *R. luctus* from northeastern Thailand and (C) *R. trifoliatus* from peninsular Thailand.

SYSTEMATICS

Rhinolophus beddomei Andersen, 1905 (Figures 1 and 2; Tables 1 and 2)

Rhinolophus beddomei Andersen, 1905:
253; Wynaad, Madras, India.

Rhinolophus beddomei sobrinus Andersen,
1918: 378; Kala Oya, North Central
Province, Sri Lanka.

Material.— Thailand: Huay Pu Nam Ron, Mae Nam Pha Chi Wildlife Sanctuary, Suan Pueng, Ratchaburi Province (13° 15' N, 99° 21' E, 431 m a.s.l.) (Fig. 1), 20 April, 2008, 1♂ (PSUZYC-MM2008.51) collected by Pipat Soisook and Tuanjit Srithongchuy. This is the first record from Thailand.

Morphometric characters.— Specimen PSUZYC-MM2008.51 from Ratchaburi Province has a forearm length of 53.0 mm (for comparative information on material from India and Sri Lanka, see Tables 1 and 2, and also Bates and Harrison, 1997). The noseleaf is dark brown with well developed lappets at the base of the sella; the horseshoe is broad (12.2 mm) (Fig. 2a). The lower lip has one groove. The ears are 23.8 mm in height. In the wing, the shortest metacarpal is the third, which is

significantly shorter than the fourth and fifth. The wing membranes are uniformly dark brown and are attached at the base of each outer toe. The length of the second phalanx of the third digit is 1.5 times that of the first. The fur is soft, woolly in texture and rather long, ca. 11 - 13 mm. The dorsal and ventral pelage is uniformly whitish-brown at the base with greyish-brown tips.

The skull has a condylo-canine length of 21.7 mm. Zygomatic breadth exceeds mastoid width (Table 2). The anterior rostral chambers are robust and well inflated when viewed laterally. The sagittal crest is well developed; it bifurcates anteriorly to form two strong supraorbital ridges around a very deep pit in the interorbital region. The bony palate is 34.0% of the length of the maxillary tooththrow (C-M³). The upper canine (C¹) is without a concavity in its posterior base; it is in contact with the first upper premolar (PM²), which is medium sized and lies within the tooththrow. The second lower premolar (PM₃) is absolutely extruded from the tooththrow; the first (PM₂) and third (PM₄) premolars are in contact.

Acoustic characters.— The hand held echolocation call of *R. beddomei* (specimen PSUZYC-MM2008.51) from Ratchaburi Province, Thailand is typical of the genus

Rhinolophus. It starts with a short duration FM component with an initial frequency of around 47.9 kHz. This is followed by a 36 - 39 ms CF segment of the peak frequency at 49.3 kHz (n = 1). It finishes with a short FM sweep with a terminal frequency of 45.6 kHz.

Taxonomic notes.— The external, cranial and dental morphology and pelage colour of the Thai specimen is similar to that of specimens from India and Sri Lanka. However, the Thai specimen is distinctly smaller than the nominate subspecies *R. b. beddomei* from India and slightly smaller than *R. b. sobrinus* from Sri Lanka (Tables 1 and 2, see also Bates and Harrison, 1997). Since only one individual is known, it is unclear whether this is typical of the Thai population or reflects an abnormally small individual.

An additional specimen (BMNH.84.1970) collected in Sabah and housed in the Natural History Museum, London, may also be referable to *R. beddomei*. This wet specimen, with skull not extracted, is currently labelled '*R. trifoliatus*'. However, its dark noseleaf and external measurements (FA 53.1 mm) suggest that it may be a second specimen of *R. beddomei* from Southeast Asia.

Two individuals collected by Struebig et al. (2006) from Kalimantan (Indonesian Borneo) are also comparable in size and morphology to *R. beddomei*. They were provisionally assigned to *R. luctus* but the authors noted that they were intermediate in size between *R. luctus* and *R. sedulus* and 'may represent a distinct taxon'. With forearm lengths of 52.9 mm and 52.6 mm and tibia lengths of 29.5 mm and 28.7 mm, they agree in size with the specimen from Thailand.

Comparison to other related species.— In comparison to *R. luctus*, *R. beddomei* is distinguished by its smaller size (Tables 1 and 2; see also Topál and Csorba, 1992; Bates and Harrison, 1997), absence of a concavity in the posterior base of the upper canine, and differences in pelage colour and echolocation call. Both species have long fur that is woolly in texture. However, the fur of *R. luctus* from peninsular Thailand is dark grey to almost black whereas that of *R. beddomei* from Thailand is greyish-brown (Fig. 2). The hand held frequencies of three individuals of *R. luctus* from peninsular Thailand have CF components of between 31.6 and 32.0 kHz and a duration of 45 - 79 ms (n = 3) (PS, unpublished data). This is much lower than that of the Thai *R. beddomei* (for details see above). The recent Thai data for *R. luctus* are comparable to Francis (2008) who also reported call frequencies of 32 - 34 kHz for *R. luctus* from peninsular Thailand and Lao PDR, but contrasts with the individuals from Sabah and peninsular Malaysia, where a constant frequency of 40 - 42 kHz was recorded (Kingston et al., 2000; Francis, 2008).

Externally, *R. beddomei* can be distinguished from *R. trifoliatus* by its darker pelage and noseleaf colour (Fig. 2) and cranially by its broader rostrum (RW) and anterior rostral chambers (AMSW) (Table 2). However, the echolocation calls of the two species are quite similar, with the CF component of *R. trifoliatus* (50.0 - 53.5 kHz, n = 3: PS, unpublished data) from peninsular Thailand only slightly higher than that of *R. beddomei*.

Rhinolophus beddomei from Thailand greatly exceeds *R. sedulus* in size, whilst the call frequency of *R. sedulus*, 66.8 kHz from peninsular Malaysia (Kingston et al., 2000) and 62 and 76 kHz from Sabah (Francis, 2008) exceeds that of Thai *R. beddomei*.

TABLE 1. External measurements (in mm) and mass (in gram) of *R. beddomei* and *R. luctus*; FA: forearm length; EAR: ear length; HB: head and body length; TAIL: tail length; HF: foot length; TIBIA: tibia length; 5MET, 4MET, 3MET: fifth, fourth and third metacarpal length; 3D1P, 3D2P: first and second phalanx of the third digit; NL: noseleaf width; MASS: body mass. Sample size (*n*), mean, standard deviation and range are shown. Sample sizes differing from those reported under *n* are given in brackets.

<i>n</i> and sex	FA	EAR	HB	TAIL	HF
<i>Rhinolophus beddomei</i> (Thailand) 1♂	53.0	23.8	63.4	30.9	14.1
<i>Rhinolophus beddomei</i> (India and Sri Lanka) 5 (4♂, 1♀)	59.8±3.9 (55.0-63.4)	27.5, 27.6 [2]	67.5 [1]	37.0, 38.5 [2]	12.1, 13.5 [2]
<i>Rhinolophus luctus</i> 19 (8♂, 11♀)	70.5±4.3 (61.8-77.3)	36.3±2.9 (31.5-39.6) [11]	76.8±5.3 (65.4-85.7) [10]	51.5±6.1 (41.0-64.3) [13]	16.3±2.0 (12.0-18.7) [14]
<i>Rhinolophus trifoliatus</i> 8 (3♂, 5♀)	51.8±2.0 (48.9-54.1)	25.8±0.4 (25.4-26.2) [4]	53.8±2.4 (51.1-56.3) [4]	34.3±1.7 (32.3-36.4) [4]	12.0±0.5 (11.4-12.4) [4]
<i>Rhinolophus sedulus</i> * ? (?♂, ?♀)	37.0-48.0 -	17.0-21.0 -	47.0-51.0 -	19.0-30.0 -	- -

* After Kingston et al. (2006)

Rhinolophus beddomei is indistinguishable in size and morphology from *R. formosae*, which is currently regarded as an endemic species to Taiwan (Csorba et al., 2003). The specific status of *R. formosae* was based on its smaller size and differences in karyology from *R. luctus* (Ando et al., 1983; Hood et al., 1988; Yoshiyuki and Harada, 1995). However, no detailed comparison was made by these authors with *R. beddomei*.

Ecological and conservation notes.— The specimen of *R. beddomei* from Thailand was collected in harp trap which was set across a seasonal stream at an altitude of 431 metres (see Methods Section). Since there were apparently no caves in the vicinity, it is possible that its diurnal roost is tree hollows

or in a rock crevice. In India and Sri Lanka, *R. beddomei* was found roosting singly or up to three individuals in hollow trees, small caves and hanging from boulders (Bates and Harrison, 1997).

Based on previous information from India and Sri Lanka, the conservation status of *R. beddomei* is listed as ‘Least Concern’ (Srinivasulu and Molur, 2008). The new material from Thailand greatly extends its known range. However, although Mae Nam Pha Chi Wildlife Sanctuary is officially a protected area, the Sanctuary is still subject to considerable deforestation and hunting pressure. Currently, the Sanctuary, and also other nearby protected areas in southwest Thailand (e.g. Kang Krachan National Park), are being assessed as part of the ‘Wildlife and Its Habitat Assessment in the

TABLE 1. Continued.

TIBIA	5MET	4MET	3MET	3D1P	3D2P	NL	MASS
28.3	44.0	42.5	37.5	18.5	27.8	12.2	16.0
30.2±1.3 (28.9-31.9)	45.3, 46.3 [2]	41.1, 41.1 [2]	37.8, 37.8 [2]	19.5, 21.6 [2]	27.8, 28.4 [2]	11.0 [1]	- -
36.8±2.0 (33.7-40.2) [13]	59.5±2.8 (55.2-62.4) [6]	57.7±2.4 (54.1-60.1) [6]	50.3±2.0 (47.7-53.4) [6]	28.5±1.0 (27.2-29.6) [6]	40.0±2.2 (38.0-44.0) [6]	15.3±2.0 (11.7-17.2) [7]	56.2 [1]
26.1±1.0 (24.9-27.4)	43.3±0.8 (42.3-44.1) [4]	41.4±1.0 (40.2-42.4) [4]	36.5±1.1 (35.5-38.0) [4]	21.1±0.8 (20.3-22.1) [4]	29.2±1.6 (27.7-30.9) [4]	11.2±0.2 (11.0-11.4)	14.0±1.3 (12.5-15.0) [3]
19.0-20.5 -	- -	- -	- -	- -	- -	- -	5.6-11.5 -

Corridor Zone under the Biodiversity Conservation Corridors Initiative Pilot Site in the Tenasserim WFCOM Thailand' which is a joint project of WCS Thailand and DNP (see www.wcsthailand.org).

DISCUSSION

The specimen from Thailand has been referred to *Rhinolophus beddomei* on the basis of its size and morphology. However, it is not clear whether this specimen represents an eastern extension of a population contiguous with those in southwest India or whether it is a member of an isolated population which is somehow restricted to continental Southeast Asia. This situation is similar to that of the endangered Molossid, *Otomops wroughtoni*

(Thomas, 1913), which for many years had been considered an endemic to western India, but was subsequently recorded from Cambodia (Walston and Bates, 2001).

The balance of probability suggests that the population of *R. beddomei* is not contiguous. Unlike *Otomops wroughtoni* (Thabah and Bates, 2002), there are no records from north or eastern India and it has also not been found in Myanmar despite many recent faunal surveys (Bates et al., 2004). If the population is isolated then there is the possibility that the phenotypic similarity of the Thai specimen to *R. beddomei* from the Indian Subcontinent may not be reflected in its genotype. This would mirror the findings of Thabah et al. (2006) who in their study of the *Hipposideros larvatus* species complex discovered an

TABLE 2. Cranial and dental measurements (in mm) of *R. beddomei* and *R. luctus*; GTL: greatest length of skull; SL: skull length; CCL: condylo-canine length; ZB: zygomatic breadth; BB: breadth of braincase; MW: mastoid width; PC: postorbital constriction; C-M³: upper toothrow length; PL: palate length; M²-M³: posterior palatal width; C¹-C¹: anterior palatal width; C-M₃: lower toothrow length; M: mandible length; AMSW: anterior median swelling width; RW: greatest rostral width. Sample size (*n*), mean, standard deviation and range are shown. Sample sizes differing from those reported under *n* are given in brackets.

<i>n</i> and sex	GTL	SL	CCL	ZB	BB	MW	PC
<i>Rhinolophus beddomei</i> (Thailand) 1♂	25.9	24.4	21.7	12.2	9.9	11.3	2.4
<i>Rhinolophus beddomei</i> (India and Sri Lanka) 6 (4♂, 2♀)	26.9±0.9 (26.1-28.5)	26.1±1.0 (25.0-27.2)	23.4±0.8 (22.4-24.5)	13.6±0.7 (12.5-14.5)	10.8±0.7 (9.8-11.5)	11.8±0.5 (11.0-12.3)	2.5±0.3 (2.1-3.0)
<i>Rhinolophus luctus</i> 17 (5♂, 12♀)	31.6±1.7 (28.2-33.7) [13]	30.5±1.5 (26.8-32.1) [16]	27.4±1.0 (25.1-28.6) [16]	15.4±0.7 (14.5-16.5) [17]	12.2±0.4 (11.6-13.1) [17]	13.4±0.4 (12.6-13.9) [16]	3.2±0.4 (2.6-3.9) [17]
<i>Rhinolophus trifoliatus</i> 8 (4♂, 4♀)	23.6±1.0 (22.3-24.6) [4]	22.8±0.8 (22.0-23.9) [6]	20.3±0.7 (19.5-21.4) [6]	11.7±0.4 (11.2-12.5) [7]	9.5±0.4 (8.8-10.0) [7]	10.6±0.3 (10.1-10.9) [6]	2.2±0.2 (1.9-2.5) [7]
<i>Rhinolophus sedulus</i> * 3 (2♂, 1♀)	20.3±0.6 (19.7-21.0)	19.6±0.6 (19.0-20.2)	16.9, 17.8 [2]	9.9±0.4 (9.7-10.4)	8.3±0.2 (8.1-8.5)	9.0, 9.6 [2]	2.2±0.1 (2.1-2.4)

* Included specimens from Borneo

interesting but confused pattern involving a lack of congruence between phenotype, genotype and acoustic characters. The situation in '*R. beddomei*' may prove to be analogous. Therefore a more thorough review, which includes *R. beddomei* from India and Sri Lanka, the new specimen from Thailand and previous specimens from Sabah (BMNH collection) and Kalimantan (Struebig et al., 2006) would be of considerable interest. It would also be valuable to include *R. formosae* in the study, since despite its morphological similarity, its relationship with *R. beddomei* has never been clearly elucidated. It is very probable that future field surveys in forest areas using harp traps may show that *R. beddomei* is quite widespread in Southeast Asia.

In terms of acoustics, it is interesting to note that as might be predicted by previous studies (Robinson, 1996; Francis and Haber-setzer, 1998; Zhang et al., 2000; Soisook et al., 2008), the call frequency of *R. beddomei* from western Thailand (49.3 kHz), with its smaller body size, is higher than the closely related larger species *R. luctus* from peninsular Thailand (32.0 kHz). However, it is distinctly lower than that of the smallest member of the *trifoliatus* group, *R. sedulus* from peninsular Malaysia, which has a call of 66.8 kHz (Francis, 2008). The hand held frequency of *R. beddomei* in Thailand is only slightly lower than *R. trifoliatus* from peninsular Thailand (50.0 - 53.5 kHz), which averages slightly smaller.

TABLE 2. Continued.

C-M ³	PL	M ³ -M ³	C ¹ -C ¹	C-M ₃	M	AMSW	RW	C-M ³
9.3	3.2	8.9	6.1	10.0	17.2	4.8	6.5	9.3
9.8±0.5 (9.3-10.5)	3.8±0.3 (3.3-4.2)	9.6±0.5 (9.2-10.2)	6.7±0.4 (6.1-7.2)	10.5±0.5 (9.9-11.1)	18.3±0.7 (17.5-19.1)	4.9±0.3 (4.5-5.2)	6.8±0.4 (6.2-7.2)	9.8±0.5 (9.3-10.5)
11.9±0.5 (11.1-12.8) [17]	4.6±0.3 (4.1-5.3) [17]	11.0±0.6 (10.2-12.9) [17]	7.7±0.3 (7.2-8.5) [17]	12.7±0.6 (11.8-13.8) [17]	22.1±1.0 (20.1-23.7) [17]	5.9±0.3 (5.4-6.7) [17]	8.6±0.4 (7.7-9.1) [17]	11.9±0.5 (11.1-12.8) [17]
8.6±0.3 (8.2-8.9)	2.9±0.3 (2.5-3.4)	8.3±0.2 (7.9-8.5)	5.5±0.3 (5.1-5.8)	9.1±0.3 (8.6-9.5)	15.7±0.6 (14.9-16.4) [7]	4.2±0.1 (4.0-4.3)	6.0±0.1 (6.0-6.1)	8.6±0.3 (8.2-8.9)
7.2±0.5 (6.6-7.6)	2.2±0.2 (2.1-2.5)	5.6±2.7 (2.5-7.2)	4.6±0.1 (4.6-4.7)	7.7±0.5 (7.1-8.1)	13.4 [1]	4.0±0.1 (3.9-4.1)	5.3±0.2 (5.1-5.5)	7.2±0.5 (6.6-7.6)

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LITERATURE CITED

- Andersen, K. 1905. On the bats of the *Rhinolophus philippinensis* group, with description of five new species. *Annals and Magazine of Natural History*, 16: 243–257.
- Andersen, K. 1918. Diagnoses of new bats of the families Rhinolophidae and Megadermatidae. *Annals and Magazine of Natural History*, 2: 374–384.
- Ando, K., Yasuzumi, E., Thgawa, A. and Uchida, T. A. 1983. Further study on the karyotypic evolution in the genus *Rhinolophus*. *Caryologia*, 36: 101–111.
- Bates, P. J. J. and Harrison, D. L. 1997. The bats of the Indian Subcontinent. Harrison Zoological Museum Publications, Sevenoaks, UK, 258 pp.
- Bates, P. J. J., Mar Mar Thi, Tin Nwe, Si Si Hla Bu, Kin Mie Mie, Nyo Nyo, Aye Aye Khaing, Nu Nu Aye, Thida Oo and Mackie, I. 2004. A review of *Rhinolophus* (Chiroptera: Rhinolophidae) from Myanmar, including three species new to the country. *Acta Chiropterologica*, 6: 23–48.
- Bates, P. J. J., Struebig, M. J., Hayes, B. D., Furey, N. M., Khin Mya Mya, Thong, V. D., Tien, P. D., Son, N. T., Harrison, D. L., Francis, C.M. and Csorba, G. 2007. A new species of *Kerivoula* (Chiroptera: Vespertilionidae) from Southeast Asia. *Acta Chiropterologica*, 9: 323–337.
- Bumrungsri, S., Harrison, D.L., Satasook, C., Prajukjitr, A., Thong-Aree, S. and Bates, P.J.J. 2006. A review of bat research in Thailand with eight new species records for the country. *Acta Chiropterologica*, 8:325-359.
- Corbet, G. B. and Hill, J. E. 1992. The mammals of the Indomalayan Region. Natural History Museum and OUP Press, Oxford, 488 pp.
- Csorba, G., Ujhelyi, P. and Thomas, N. 2003. Horseshoe bats of the world (Chiroptera: Rhinolophidae). Alana Books, Shropshire, UK, 160 pp.
- DNP. 2006. Mae Nam Pha Chi Wildlife Sanctuary. Department of National Park, Wildlife and Plant Conservation. Available from: <http://www.dnp.go.th/wildlifeweb/animConserveDepView.aspx?depId=93>. [in Thai]. (June 20, 2009)
- Francis, C. M. 1989. A comparison of mist nets and two types of harp traps for capturing bats. *Journal of Mammalogy*, 70: 865-870.
- Francis, C. M. 2008. Mammals of Thailand and South-East Asia. Asia Books, Bangkok, Thailand, 392 pp.
- Francis, C. M. and Habersetzer, J. 1998. Inter-and intra specific variation in echolocation call frequency and morphology of horseshoe bats, *Rhinolophus* and *Hipposideros*. In: Kunz, T.H. and Racey, P.A. (Eds). *Bat Biology and Conservation*. Smithsonian Institution Press, Washington D.C., pp. 169–179
- Heller, K. G. and Volleth, M. 1988. Fledermäuse aus Malaysia. 1. Beobachtungen zur Biologie, Morphologie und Taxonomie (Mammalia: Chiroptera). *Senckenbergiana Biologica*, 69: 243–276.
- Heller, K. G., Archmann, R. and Witt, K. 1993. Monogamy in bat *Rhinolophus sedulus*? *Zeitschrift für Säugetierkunde*, 58: 376-377.
- Hood, C. S., Schlitter, D. A., Georgudaki, J. I., Yenbutra, S. and Baker, R. 1988. Chromosomal studies of bats (Mammalia: Chiroptera) from Thailand. *Annals of Carnegie Museum*, 57: 99–109.
- Kingston, T., Jones, G., Akbar, Z. and Kunz, T. 2000. Resource partitioning in rhinolophoid bats revisited. *Oecologia*, 124: 332–342.
- Kingston, T., Liat L. B. and Akbar, Z. 2006. Bats of Krau Wildlife Reserve. Penerbit University Kerbangsaan Malaysia, Bangi, Malaysia. 145 pp.
- Medway, L. 1969. The wild mammals of Malaya and offshore islands including Singapore. Oxford University Press, Kuala Lumpur, Malaysia, 106 pp.
- Robinson, M. F. 1996. A relationship between echolocation calls and noseleaf widths in bats of the genera *Rhinolophus* and *Hipposideros*. *Journal of Zoology (London)*, 239: 389–393.
- Robinson, M.F., Bumrungsri, S. and Hill, J.E. 1996. Chiroptera from Thung Yai Naresuan and Huai Kha Khaeng Wildlife Sanctuaries. *Natural History Bulletin of the Siam Society*, 44: 243–247.
- Robinson, M. F. and Webber, M. 1998. Small mammal survey Khammouan Limestone National Biodiversity Conservation Area, Lao PDR. *Natural History Bulletin of the Siam Society*, 48: 21–45.
- Sawada, I. and Harada, M. 1985. A survey on bat cestodes from Thailand with description of six new species. *Zoological Science*, 2: 271–283.
- Shamel, H. H. 1942. A collection of bats from Thailand (Siam). *Journal of Mammalogy*, 23: 317–328.
- Simmons, N. B. 2005. Order Chiroptera. In: Wilson, D.E. and Reeder, D.M. (Eds). *Mammal species of the World: a taxonomic and geographic reference*. Johns Hopkins University Press, Baltimore. pp. 312–529.

- Soisook, P., Bumrungsri, S., Dejtardol, A., Francis, C. M., Csorba, G., Guillén, A. and Bates, P. J. J. 2007. First records of *Kerivoula kachinensis* (Chiroptera: Vespertilionidae) from Cambodia, Lao PDR and Thailand. *Acta Chiropterologica*, 9: 339–345.
- Soisook, P., Bumrungsri, S., Satasook, C., Thong, V. D., Si Si Hla Bu, Harrison, D. L. and Bates, P. J. J. 2008. A taxonomic review of *Rhinolophus stheno* and *R. malayanus* (Chiroptera: Rhinolophidae) from continental Southeast Asia: an evaluation of echolocation call frequency in discriminating between cryptic species. *Acta Chiropterologica*, 10: 221–242.
- Srinivasulu, C. and Molur, S. 2008. *Rhinolophus beddomei*. In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.1. <www.iucnredlist.org>. Downloaded on 15 September 2009.
- Struebig, M. J., Benton-Browne, A., Rachmad, A., Yusliati, N., Atmoko, T., Witono, R., Fredriksson, G. and Meijaar, E. 2006. A bat survey in Sungai Wain Protection Forest, East Kalimantan, Indonesia. *Malayan Nature Journal*, 59:189–196.
- Thabab, A. and Bates, P. J. J. 2002. Recent record of *Otomops wroughtoni* (Chiroptera: Molossidae) from Meghalaya, North-East India. *Acta Zoologica Academiae Scientiarum Hungaricae*, 48: 251–253.
- Thabab, A., Rossitter, S. J., Kingston, T., Zhang, S., Parsons, S., Khin Mya Mya, Zubaid, A. and Jones, G. 2006. Genetic divergence and echolocation call frequency in cryptic species of *Hipposideros larvatus* s.l. (Chiroptera: Hipposideridae) from the Indo-Malayan region. *Biological Journal of the Linnean Society*, 88: 119–130.
- Thomas, O. 1913. On a remarkable new free-tailed bat from southern Bombay. *Journal of the Bombay Natural History Society*, 22: 87–91.
- Thong, V. D., Bumrungsri, S., Harrison, D.L., Pearce, M. J., Helgen, K. M. and Bates, P. J. J. 2006. New records of Microchiroptera (Rhinolophidae and Kerivoulinae) from Vietnam and Thailand. *Acta Chiropterologica*, 8: 83–94.
- Topál, G. and Csorba, G. 1992. The subspecific division of *Rhinolophus luctus* Temminck, 1835, and the taxonomic status of *R. beddomei* Andersen, 1905 (Mammalia, Chiroptera). *Miscellanea Zoologica Hungarica*, 7: 101–116.
- Walston, J. and Bates, P. J. J. 2001. The discovery of Wroughton's free-tailed bat *Otomops wroughtoni* (Chiroptera: Molossidae) in Cambodia. *Acta Chiropterologica*, 3: 245–256.
- Yenbutra, S. and Felten, H. 1986. Bat species and their distribution in Thailand according to the collection of TISTR and SMF. In: Felten, H. (Ed). *Contributions to the knowledge of the bats of Thailand*. Courier Forschungsinstitut Senckenberg, 87: 9–45.
- Yoshiyuki, M. and Harada, M. 1995. Taxonomic status of *Rhinolophus formosae* Sanborn, 1939 (Mammalia, Chiroptera, Rhinolophidae) from Taiwan. *Special Bulletin of the Japanese Society of Coleopterology*, Tokyo, 4: 497–504.
- Zhang, S., Zhao, H. H., Feng, J., Sheng, L., Wang, H. and Wang, L. 2000. Relationship between echolocation frequency and body size in two species of hipposiderid bats. *Chinese Science Bulletin*, 45: 1587–1590.
- Zubaid, A. 1993. A comparison of the bat fauna between a primary and fragmented secondary forest in Peninsular Malaysia. *Mammalia*, 57: 201–206.
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APPENDIX

List of examined specimens and localities, including previous records shown in Figure 1.

Rhinolophus beddomei – **INDIA**: Wynaad, Madras (11°45'N, 76°02'E): BMNH.82.3.3.1. (type of *beddomei*); Konkan, Maharashtra (not located): BMNH.11.3.16.1.; Sirsi, Karnataka (14°40'N, 74°51'E): BMNH.12.11.28.5.; Kannadimazhligai, Courtallum Hills, Tirunelveli District, Tamil Nadu (08°45'N, 77°43'E): HZM.2.36212; Rojampela Range (not located): BMNH.30.5.24.60.; **SRI LANKA**: Kala Oya, North Western Province (08°12'N, 80°04'E): BMNH.18.8.3.3. (type of *sobrinus*); Mapalagama, Talgaswela, Southern Province (appr. 06°15'N, 80°15'E): HZM.1.27643.; **THAILAND**: Huay Pu Nam Ron, Mae Nam Pha Chi Wildlife Sanctuary, Suan Pueng, Ratchaburi Province (13°15'N, 99°21'E) [loc. B1]: PSUZC-MM.2008.51.; **MALAYSIA**: Sabah (not located): BMNH. 84.1970 (labelled as *R. trifoliatus*).

Rhinolophus luctus – **MYANMAR**: Nam Tamai, Upper Myanmar (27°42'N, 97°54'E) [loc. L1]: BMNH.50.396, BMNH.50.397; Sokleik (not located): BMNH.21.1.6.1.; Chin Hill (appr. 23°40'N, 94°15'E) [loc. L2]: BMNH.21.1.6.3.; Bankachon, S. Tenasserim (appr. 10°12'N, 98°37'E) [loc. L3]: BMNH.21.1.6.2.; **VIETNAM**: Nui Hoang Lien Nature Reserve, Sa Pa District, Lao Cai Province (appr. 22°10'N, 103°57'E) [loc. L4]: BMNH.1997.336; Pu Mat Reserve (20°19'N, 105°37'E) [loc. L5]: HZM.1.31766; Phong Nha-Ke Bang Prop. NP (17°39'N, 105°59'E) [loc. L6]: HZM.2.32212, HZM.2.32213; Bach Ma NP (16°12'N, 107°45'E) [loc. L7]: T129 (I.E.B.R.); **LAO PDR**: Tam Nong Seng (18°05'N, 104°28'E) [loc. L8]; Tam Dinphye (17°36'N, 104°58'E) [loc. L9]; Khammouan: including Tam Lort and Tam Lom (17°35'N, 104°48'E) [loc. L10]; Robinson and Webber (1998); **CAMBODIA**: Mt. Samkos Wildlife Sanctuary, Cardomom Mountains (appr. 12°22'N, 103°02'E) [loc. L11]: HZM.4.32764; Tatai Lieu (11°49'N, 103°32'E) [loc. L12]: HZM.6.36475; Cambodia (no exact locality): HZM.5.36141; **THAILAND**: Amphoe Samung, Chiang Mai (18°55'N, 98°40'E) [loc. L13]: Sawada and Harada (1985); Doi Pui, Chiang Mai (appr. 18°49'N, 98°53'E) [loc. L14]: BMNH.78.2310.; Chiang Mai (not located): BMNH.9.10.11.2.; Khun Tan, Lampang (appr. 17°15'N, 100°10'E) [loc. 15]: Shamel (1942); Nam Nao cave, Petchabun Province (16°57'N, 100°14'E) [loc. L16]: PP070915.27; KM 79, Highway 23, Nakhon Ratchasima Province (appr. 14°58'N, 102°06'E) [loc. L17]: BMNH.70.1463.; Pak Thong Chai, Sakaerat, Nakhon Ratchasima Province (appr. 14°35'N, 101°50'E) [loc. L18]: BMNH.78.2309.; Prachin Buri (appr. 14°14'N, 101°50'E) [loc. L19]: Yenbutra and Felten (1986); Khao Ang Runai Wildlife Sanctuary, Chacherngsao Province (13°24'N, 101°52'E) [loc. L20]: PSUZC-MM2005.36; Krung Ching, Nakhon Si Thammarat Province (8°47'N, 99°38'E) [loc. L21]: PP071108.1; Kao Luang, Nakhon Si Thammarat (appr. 8°24'N, 99°58'E) [loc. L22]: Shamel (1942); Yala (appr. 6°06'N, 101°18'E) [loc. L23]: Yenbutra and Felten (1986); **MALAYSIA**: Tanah Rata, Pahang (4°28'N, 101°23'E) [loc. L24]: Csorba et al. (2003); Semangko, Selangor (appr. 3°40'N, 101°44'E) [loc. L25]: BMNH.1.3.9.3.; Taiping, Perak (appr. 3°41'N, 101°45'E) [loc. L26]: BMNH.56.127.; Genting Highland (appr. 3°25'N, 101°47'E) [loc. L27]: Heller and Volleth (1988); Ulu Gombak (3°20'N, 101°45'E) [loc. L28]: Fain (1982); Bangai Forest Reserve, Selangor (2°55'N, 101°45'E) [loc. L29]: Zubaid (1993);

Rhinolophus trifolius – **MYANMAR**: Murgui, Tenasserim (12°26'N, 98°34'E) [loc. T1]: BMNH.85.8.1.110, BMNH85.8.1.111; Bankachon, S. Tenasserim (appr. 10°12'N, 98°37'E) [loc. T2]: BMNH.14.12.8.244.; **THAILAND**: Thung Yai Naresuan WS (15°19'N, 98°49'E) [loc. T3]: Robinson et al. (1996); Kao Soi Dao, Chantaburi Province (appr. 13°06'N, 102°13'E) [loc. T4]: Csorba et al. (2003); Ban Bang Non, Muang Ranong (appr. 9°60'N, 98°39'E) [loc. T5]: BMNH.78.2311., BMNH78.2312; Ranong Province (appr. 9°55'N, 98°35'E) [loc. T6]: Yenbutra and Felten (1986); Ban Sichon, Nakhon Si Thammarat (9°00'N, 99°56'E) [loc. T7]: Shamel (1942); Trang Province (appr. 7°04'N, 99°36'E) [loc. T8]: Yenbutra and Felten (1986); Khao Kor Hong, Hat Yai, Songkhla Province (7°00'N, 100°30'E) [loc. T9]: PSUZC-MM2006.167; Namom, Songkhla Province (6°57'N, 100°33'E) [loc. T10]: PSUZC-MM2005.160; Wildlife Education Centre, Hat Yai, Songkhla Province (6°57'N, 100°14'E) [loc. T11]: PSUZC-MM2006.140, PSUZC-MM2006.141; Satun Province (appr. 6°40'N, 100°00'E) [loc. T12]: Yenbutra and Felten (1986); Narathiwat Province (appr. 6°28'N, 101°51'E) [loc. T13]: Shamel (1942); Bangnara, Narathiwat Province (6°28'N, 101°51'E) [loc. T14]: Csorba et al. (2003); **MALAYSIA**: Gunung Tahera, Pahang (appr. 3°35'N, 102°15'E) [loc. T15]: BMNH.6.10.4.8., BMNH.65.337.; Ulu Gombak (3°20'N, 101°45'E) [loc. T16]: Heller and Volleth (1988); Templer Park (appr. 3°17'N, 101°37'E) [loc. T17]: Heller and Volleth (1988); Kepong Cubitt Forest Reserve (appr. 3°12'N, 101°27'E) [loc. T18]: Csorba et al. (2003); Bangai Forest Reserve, Selangor (2°55'N, 101°45'E) [loc. T19]: Zubaid (1993); **SINGAPORE** (appr. 1°23'N, 103°50'E) [loc. T20]: BMNH74.4.18.1. (*type of R. t. edax*).

Rhinolophus sedulus – **MALAYSIA**: Kuala Tekah (appr. 4°10'N, 102°19'E) [loc. S1]: Medway (1969); Jenka, Temerloh, Pahang (3°27'N, 102°25'E) [loc. S2]: BMNH.65.334.; Ulu Gombak (3°20'N, 101°45'E) [loc. S3]: Heller et. al. (1993); Kepong Cubitt Forest Reserve (appr. 3°12'N, 101°27'E) [loc. S4]: Csorba et. al. (2003); Sarawak (not located): BMNH7.1.1.292. (*type of R. sedulus*); **BORNEO**: Paitan (not located): BMNH.94.7.2.48.