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Geographic Variations in the Common Skink *Sphenomorphus maculatus* (Blyth, 1853) in Thailand, with Re-validation of *Lygosoma mitanense* Annandale, 1905 as Its Subspecies

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ABSTRACT.–*Sphenomorphus maculatus* (Blyth, 1854) is a common skink broadly distributed in Thailand and adjacent regions. Geographic variations were analysed for meristic and morphometric characters of this species by principal component analyses. Results of the analyses consistently indicated differentiation of the species into two regional forms, one from eastern India, southern China and northern Thailand, and the other from southern Myanmar and southern Thailand. We recognized them as distinct subspecies, *S. m. maculatus* (Blyth, 1854) and *S. m. mitanensis* (Annandale, 1905) comb. nov., respectively, using conditions of a few head scales as diagnostic characters. *Lygosoma melanochlorum* Vogt, 1932 was assumed to be a junior synonym of the latter.

KEY WORDS: *Sphenomorphus maculatus*; *Lygosoma mitanense*; geographic variations; principal component analysis; taxonomy

INTRODUCTION

Many of the terrestrial reptiles of Southeast Asia are currently regarded as occurring in broad areas of the continental part, as well as on some adjacent continental shelf islands (Taylor, 1965; Manthey and Grossmann, 1997; Cox et al., 1998). Recent studies, however, revealed that some of these "broadly distributed species" actually include morphologically poorly diverged but reproductively, genetically, and/or phylogenetically more or less distinct entities (e.g., Wüster et al., 1995; Ota et al., 2001). Overlooking of such "cryptic taxa" will lead to erroneous biogeographical characterization of a given area through underestimations of actual biodiversity and endemicity there. Such underestimations may further lead to insufficent conservation efforts for a regional biota, which may actually include a larger number of endangered taxa with limited geographic distributions than are realized at present.

When live or fresh-frozen materials are available, genetic approaches using chromosomal, biochemical, and molecular markers would be most effective for the detection of

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such morphologically confusing taxa (see Wüster et al. [1995], Ota et al. [2001], and Toda et al. [2001], for example). However, genetic approches would be not applicable when available specimens representing taxa in problem have long been stored in preservative (especially in formalin: see Hillis et al., 1993). Nevertheless, elucidation of taxonomic diversity using long preserved specimens may still be possible through detailed investigations of geographic patterns of variations in their morphological characters. For such a purpose, multivariate approaches, such as those using principal component analysis and canonical discriminant analysis, are particularly useful (Thorpe, 1987), as is exemplified by several recent studies on Southeast Asian reptiles (Wüster and Thorpe, 1992; Wüster et al., 1992).

In the present study, we analyzed geographic variations in external characters of preserved and newly collected specimens of *Sphenomorphus maculatus*, a scincid species broadly distributed in Southeast Asia, including almost whole of Thailand (Taylor, 1965; Welch et al., 1990; Cox et al., 1998). Results strongly suggest a certain degree of differentiation between northern and southern populations, which deserves taxonomic recognition as below.

MATERIALS AND METHODS

A total of 77 specimens from at least 18 localities, all fixed in 10% formalin and preserved in 70-75% ethanol, were used (Fig. 1; Table 1; Appendix). Each specimen was examined for 21 quantitative characters, of which 13 were meristic and eight were morphometric characters.

Meristic characters examined included the numbers of: presuboculars, moderate-sized scales forming a longitudinal row in presubo-

TABLE 1. Specimens of *Sphenomorphus maculatus* used for the present analyses. Locality codes (A—Q) refer to those given in Fig. 1.

Locality	Locality Code	N			
		Male	Female	Unknown	Total
Sikkim	A	0	1	0	1
Assam	B	0	1	0	1
Triangle	C	2	0	0	2
Yunnan	D	0	2	0	2
Doi Chiang Dao	E	3	3	0	6
Mae Hong Son	F	1	0	0	1
Doi Inthanon	G	6	7	1	14
Phrae	H	0	2	0	2
Pegu	I	2	0	0	2
Moulmein	J	0	1	0	1
Sakaerat	K	2	0	0	2
Khao Sa Bap	L*	4	3	0	7
Chantaboon	L*	2	3	0	5
Elphinstone I.	M	2	0	0	2
Ko Chang	N	4	3	0	7
Ranong	O	1	2	0	3
Khao Sok	P	3	7	1	11
Trang	Q	0	1	0	1
"Burma"	R	2	0	0	2
"Fr. Indo-China"	S	1	2	0	3
Unknown loc.	T	1	1	0	2

* Very close to each other, and thus were not separated in Fig. 1 or in the analyses.

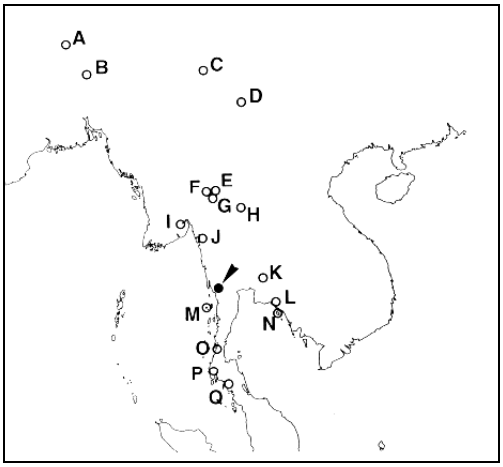

FIGURE 1. A map of Thailand and the vicinity showing sampling localities of specimens used for the analyses. See Table 1 for names of localities denoted by letters A—Q. Arrow indicates Tenasserim, the type locality of *Lygosoma mitanense* Annandale, 1905.

cular region, surrounded by posterior loreal, preoculars, supralabials, and granules beneath eye (PRSBO); supraoculars contacting frontal (FSO); distinctly smaller scales following PRSBO, contacting supralabials just beneath orbit (SBO); postsuboculars, moderate-sized scales forming a longitudinal row beneath orbit, surrounded by SBO, supralabials, primary temporals, and granules covering lower eyelid (POSBO); primary temporals (PT); minute scales above posterior corner of eye, contacted by posteriormost supraciliary (USC); POSBO contacting supralabials (PSBONSL); supraciliaries (SC); subdigital lamellae on fourth toe (LHT); midbody scale rows (MSR); preorbital supralabials, supralabials anterior to enlarged one just beneath orbit (PROSL); lower labials (LL); and secondary temporals (ST)(Fig. 2). Morphometric characters, taken to the nearest 0.1 mm by dial calipers, included: snout to vent length (SVL); axilla to groin length (AGL); distance from snout to anterior margin of forelimb base (SFL); head length, measured from snout to posterior end of parietal (HL); snout to eye length (SE); snout to anteromedial margin of ear opening (SEO); forelimb length, measured from base of forelimb to distal tip of finger II exclusive of claw (FLL); and hindlimb length, measured from base of hindlimb to

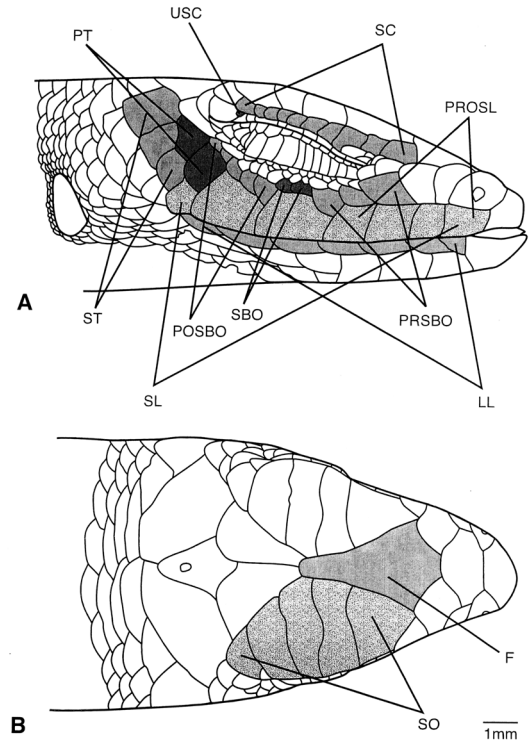

FIGURE 2. Lateral (A) and dorsal views (B) of head of *Sphenomorphus maculatus* (male from Khao Sa Bap: KUZ R35581) showing meristic characters used for the present analyses. See text for details of characters denoted by abbreviations.

distal tip of toe IV exclusive of claw (HLL). Symmetrical characters were examined on the right side as long as possible. When body portions bearing given characters were damaged on the right side, however, examinations for their states were made on the left side.

Data for these quantitative characters were subjected to principal component analysis (PCA) using the PRINCOMP procedure of SAS (1990). Due to the small size of most samples, data for meristic characters in males and females were analyzed together. Because sex-specific allometric growths causing significant intersexual variations were reported for several morphometric characters in other skinks (see Hikida et al. [2001] and publications cited therein, for example), data for characters of this category were analyzed for males and females separately.

TABLE 2. Factor loadings for the first three principal components of variation (PRINs 1, 2 and 3) in meristic characters. See "MATERIALS AND METHODS" for abbreviations of characters.

Characters	PRIN1	PRIN2	PRIN3
PRSBO	0.2817	0.2386	-0.3334
FSO	0.1408	-0.0224	-0.0973
SBO	0.4070	-0.0837	-0.0710
POSBO	0.3253	0.1001	-0.0802
PT	-0.1019	0.5374	-0.0621
USC	0.4279	-0.1433	0.0365
PSBONSL	0.3460	-0.3399	-0.0364
SC	0.3906	-0.0819	0.3073
LHT	0.3531	0.2415	0.2147
MSR	0.0083	0.2337	0.6143
PROSL	0.1688	0.4176	-0.3256
LL	0.0848	0.3280	-0.2061
PT	0.0561	0.3147	0.4416
Eigenvalue	3.3971	1.9817	1.5247
Difference	1.4155	0.4569	0.3655
Proportion	0.2613	0.1524	0.1173
Cum. Proportion	0.2613	0.4138	0.5310

RESULTS

PCA of those meristic characters revealed 26.1%, 15.2%, and 11.7% of the total variation expressed in the first, second, and third principal components, respectively (Table 2). In the first principal component, scores of most northern Thailand specimens, as well as those of Assam, Triangle, and Yunnan specimens, were relatively small, whereas scores for most southern Thailand specimens tended to be somewhat greater. Geographic variations were not prominent either in the second or third principal component. Even so, however, two dimensional plots of scores of the first and the second components more clearly separated those northern specimens exclusive of the one

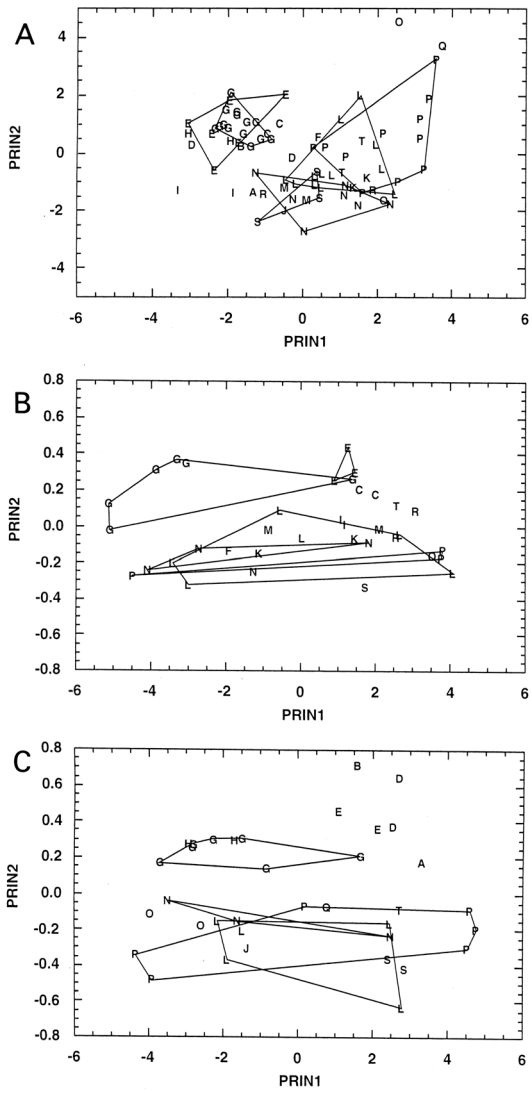

FIGURE 3. Two-dimensional plots of scores of the first against the second principal components of meristic characters (A), and male (B) and female morphometric characters (C) in *Sphenomorphus maculatus*. Letters denoting individual scores correspond to locality codes defined in Table 1.

from Mae Hong Son (F) from specimens from more southern region (Fig. 3A). Values of factor loadings indicate that USC (positive) and SBO (positive) most greatly contributed to their separation in the first principal component, whereas PT (positive) made the greatest contribution in the second principal component (Table 2).

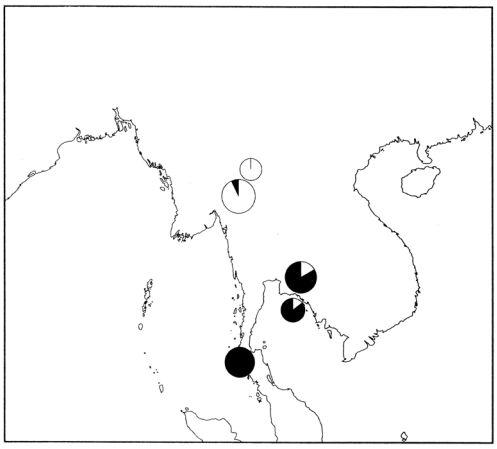

FIGURE 4. Condition of USC (see text and Fig. 2) in samples of *Sphenomorphus maculatus* from Thailand, which sizes are larger than five. Total area of each circle and the ratio of darkened area therein, respectively, represent the total number of specimens and the frequency of individuals having USC in each sample.

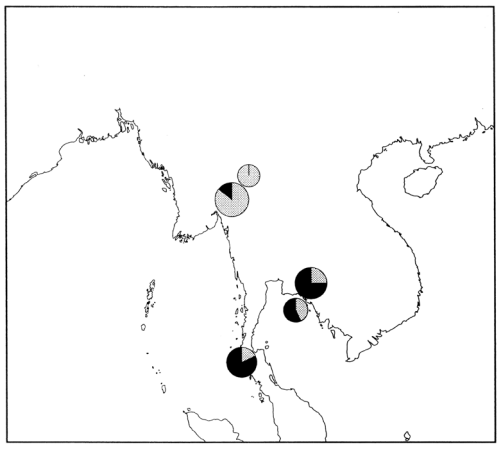

FIGURE 5. Condition of SBO (see text and Fig. 2) in samples of *Sphenomorphus maculatus* from Thailand, which sizes are larger than five. Total area of each circle and the ratios of stippled and darkened areas therein, respectively, represent the total number of specimens and the frequencies of individuals having one and two SBO in each sample.

Comparisons of individual characters among populations represented by more than five specimens suggested that in the southern Thailand populations, most individuals have USC, whereas most northern Thailand specimens lack this scale (Fig. 4). Likewise, majority of southern Thailand specimens had two SBO, whereas there was only one SBO in most northern Thailand specimens (Fig. 5).

For morphometric characters in males, PCA revealed 98.6%, 0.6%, and 0.4% of the total variation expressed in the first, second, and third principal components, respectively (Table 3). Of these, the first and the third principal components showed little separation of the samples. In the second principal component, however, scores of specimens from Triangle and northern Thailand exclusive of Mae Hong Son were largely greater than those of specimens from southern Thailand, southern Myanmar, and Mae Hong Son (Fig. 3B). Values of factor loadings indicate that AGL (positive) and HL (negative) most greatly contributed to their separation in this component in order (Table 3).

With respect to the female morphometric characters, PCA revealed 97.8%, 1.3%, and 0.4% of the total variation expressed in the first, second, and third principal components, respectively (Table 3). Like in PCA for the male morphometric characters, most samples were not clearly separated from each other in the first and third principal components, whereas in the second principal component, scores of specimens from northern Thailand, as well as from Assam, Sikkim, and Yunnan, were distinctly greater than those of specimens from southern Thailand and southern Myanmar (Fig. 3C). Values of factor loadings indicate that also in females, such a separation was most greatly accounted for by differences in AGL (positive) and HL (negative) in order (Table 3).

Results of PCA for morphometric characters suggested that in both males and females, northern Thailand specimens tend to have relatively elongated body and short head when compared with specimens from southern Thailand. Even so, however, two dimensional plots of scores for AGL and HL did not separate specimens from these regions clearly (not shown).

TABLE 3. Factor loadings for the first three principal components of variation (PRINs 1, 2 and 3) in male and female morphometric characters. See "MATERIALS AND METHODS" for abbreviations of characters.

Characters	Males			Females		
	PRIN1	PRIN2	PRIN3	PRIN1	PRIN2	PRIN3
SVL	0.3547	0.3561	-0.1689	0.3540	0.3940	0.2537
AGL	0.3515	0.7368	-0.0905	0.3474	0.7206	0.1547
SFL	0.3540	-0.1059	-0.1980	0.3537	-0.1942	0.1952
HL	0.3531	-0.4748	-0.0754	0.3535	-0.4083	0.2276
SE	0.3533	-0.2400	-0.4585	0.3541	-0.2475	0.3021
SEO	0.3551	-0.1507	-0.1714	0.3556	-0.2279	0.0763
FLL	0.3536	-0.1157	0.5543	0.3549	0.0508	-0.6188
HLL	0.3532	-0.0027	0.6095	0.3550	-0.0735	-0.5846
Eigenvalue	7.8852	0.0446	0.0325	7.8217	0.1049	0.0285
Difference	7.8406	0.0121	0.0157	7.7168	0.0763	0.0046
Proportion	0.9856	0.0056	0.0041	0.9777	0.0131	0.0036
Cum. Proportion	0.9857	0.9912	0.9953	0.9777	0.9908	0.9944

DISCUSSION

Results of PCAs for meristic, and male and female morphometric characters in *S. maculatus* consistently suggest differentiation between populations from eastern India, southern China and northern Thailand, and those from southern Myanmar and southern Thailand. Of the 29 specimens from the former area examined (Table 1), 27 had no USC and 26 had one SBO (Fig. 2), whereas no individuals possessed USC and two SBO simultaneously. Of the 41 specimens from the latter area, on the other hand, only five lacked USC, one lacked SBO, and ten had only one SBO: remaining 36 and 30 specimens had one or two USC and two SBO, respectively, and only three had no USC and fewer than two SBO simultaneously. It seems thus appropriate to recognize populations of *S. maculatus* from the two areas as separate taxa.

In determining the taxonomic rank at which the northern and the southern assemblages of populations as defined above (henceforth referred to as the northern form and the southern form, respectively) are to be separated, affinity of a population around Mae Hong Son ("F" in Fig. 1) deserves a particular attention, because, although its locality is located close to those of the northern form, PCAs of meristic and morphometric characters yielded scores for the unique specimen (female) from Mae Hong Son much closer to those for the southern form. If such a similarity reflects actual relationships of the Mae Hong Son population, it is probable that the northern and the southern forms represent two separate biological species, because their contiguous distributions in northern Thailand are likely. However, considering that no clear-cut diagnostic characters exist between the two forms (see above) and that only one representative of the Mae Hong Son population was examined, it seems appropriate at present to retain their taxonomic separation at subspecies level.

Scores for the three specimens labelled as from "French Indochina" (i.e., Vietnam, Laos, and/or Cambodia) were located within the range of those for the southern Thailand specimens. Moreover, all of those three

specimens had one USC, and two of them also had two SBO (the remainder had only one SBO). It is thus likely that they also belong to the southern form.

Sphenomorphus maculatus was first described from Assam as *Lissonota maculata* by Blyth (1854). The oldest available name, currently synonymized to *S. maculatus*, is *Lygosoma mitanense*, which was described on the basis of a specimen from Meetan around Tenasserim (Fig. 1) by Annandale (1905). We thus propose the taxonomic arrangement as below. Further studies on the basis of more specimens from various localities, especially from around Mae Hong Son, are needed to verify this account.

Sphenomorphus maculatus maculatus
(Blyth, 1854)

Lissonota maculata Blyth, 1854:653.
Hinulia maculata Theobald, 1868:25 (part).
Lygosoma maculatum, Boulenger, 1887:242 (part); Smith, 1935:285 (part).
Sphenomorphus maculatus, Pope, 1935:483 (part); Taylor, 1963:1010 (part); Cox et al., 1998:118 (part).

Diagnosis.–Relatively small-sized *Sphenomorphus*, up to 55.1 mm SVL in males, and 62.0 mm SVL in females. Nasals broadly separated; nostril central in nasal; supranasals and postnasals absent; loreals two; presuboculars three; postsuboculars 4--6 in a continuous row; preorbital supralabials four; prefrontals separated; supraoculars five, usually anterior three (but rarely two) contacting frontal, posterior three contacting frontoparietal; supraciliaries 9--11 in an uninterrupted series; frontoparietals contacting; parietal eye present in interparietal; parietals in contact behind interparietal; primary temporals two or three; secondary temporals usually three, but rarely four; lower labials usually seven, but rarely eight; midbody scale rows 36--44; subdigital lamellae on fourth toe 16--22. Usually distinguished from the other subspecies by lacking minute scales above posterior corner of eye, contacted by posteriormost supraciliary (USC in Fig. 2), and by having only one suboculars (SBO in Fig. 2).

Distribution.–From eastern India and southern China to northern Thailand.

Remarks.–The type is lost (Smith, 1935). We have had no opportunities of examining specimens from Bangladesh and most northern Myanmar (Welch et al., 1990; Cox et al., 1998). Judging from the known ranges of the two subspecies, however, it seems likely that populations from those areas belong to the nominotypical subspecies.

Sphenomorphus maculatus mitanensis
(Annandale, 1905) comb. nov.

Hinulia maculata Theobald, 1868:25 (part).
Lygosoma maculatum, Boulenger, 1887:242 (part); Smith, 1935:285 (part).
Lygosoma mitanense Annandale, 1905:144.
?*Lygosoma melanochlorum* Vogt, 1932:282 (see below).
Sphenomorphus maculatus, Pope, 1935:483 (part); Taylor, 1963:1010 (part); Cox et al., 1998:118 (part).
?*Sphenomorphus melanochlorus*, Mittleman, 1952:27 (see below).

Diagnosis.–Relatively small-sized *Sphenomorphus*, up to 66.2 mm SVL in males, and 68.0 mm SVL in females. Nasals broadly separated; nostril central in nasal; supranasals and postnasals absent; loreals two; presuboculars usually three, but rarely four; postsuboculars 3--7 in a continuous row; preorbital supralabials usually four, but rarely three or five; prefrontals separated; supraoculars five, usually anterior three, but rarely two contacting frontal, posterior three contacting frontoparietal; supraciliaries 9--12 in an uninterrupted series; frontoparietals contacting; parietal eye present in interparietal; parietals in contact behind interparietal; primary temporals two or three; secondary temporals usually three, but rarely four; lower labials usually seven, but rarely eight; midbody scale rows 36--44; subdigital lamellae on fourth toe 15--23. Usually distinguished from the nominotypical subspecies by having one or two USC and two SBO (Fig. 2).

Distribution.–From southern Myanmar to southern Thailand. Populations from eastern Indochina (i.e., former French Indochina) are likely to belong to this subspecies as well (see above).

Remarks.–The holotype is currently deposited in the Zoological Survey of India as ZSI 5399 (Das et al., 1998). Shea and Greer (1998) synonymized *Sphenomorphus melanochlorus*, a species described as *Lygosoma melanochlorum* by Vogt (1932) on the basis of a single specimen, to *S. maculatus*. In the original description, the unique type of that species was referred to as being collected from New Guinea (Vogt, 1932), but Shea and Greer (1998) considered this locality record to be erraneous. It is obvious from drawings of head of the type and its brief redescription by Shea and Greer (1998) that this specimen has two SBOs. On the other hand, USC was not depicted nor referred to in the text by these authors. However, considering the very small size of this scale (see Fig. 2) and general ignorance of its taxonomic value, it is probable that Shea and Greer (1998) simply overlooked it, and we thus tentatively assume *Lygosoma melanochlorum* to be a junior synonym of *Sphenomorphus maculatus mitanensis*.

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APPENDIX

Specimens of *Sphenomorphus maculatus* examined. Numbers of specimens deposited in the Natural History Museum (London), Kyoto University Museum, and the Private Collection of Jarujin Nabhitabhata were preceded by BMNH, KUZ, and JNPC, respectively.

Sikkim, India: BMNH 53.8.12.11. Assam, India: BMNH 1956.1.12.38. Triangle, Myanmar: BMNH 1940.6.4.4, 1940.6.4.5. Yunnan, China: KUZ R51148; BMNH 1923.11.10.20. Doi Chiang Dao, Thailand: KUZ R38117—119, 38132—134. Mae Hong Son, Thailand: KUZ R32891. Doi Inthanon, Thailand: KUZ R27404, 27450, 27451, 27454, 27456, 27457, 27459—466. Phrae, Thailand: KUZ R40050, 40051. Pegu, Myanmar: BMNH 68.4.3.78, 68.4.3.79. Moulmein,Myanmar: BMNH 87.2.26.14. Sakaerat, Thailand: KUZ R39849, 39850. Khao Sa Bap, Thailand: KUZ R35579, 35581, 35608, 35611, 35616, 35631, 35636. Chantaboon, Thailand: BMNH 98.4.2.10—14. Elphinstone Island, Myanmar: BMNH 86.7.19.11—12. Ko Chang, Thailand: KUZ R35428, 35455, 35472, 35534, 35557, 35560, 35562. Ranong, Thailand: KUZ R39649, 39674, 39675. Khao Sok, Thailand: KUZ R39600—603, 39610, 39620, 39621, 39629—632. Trang, Thailand: KUZ R37978. "Burma" (detailed locality unknown): BMNH 70.8.14.9, 70.8.14.10. "French Indo-China" (detailed locality unknown): BMNH 1933.11.25.5—7. Locality unknown: JNPC 5987, 8169.

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