

A new species of *Lygosoma* (Squamata: Sauria: Scincidae) from the Central Truong Son, Vietnam, with notes on its molecular phylogenetic position

Thomas ZIEGLER¹, Andreas SCHMITZ², Astrid HEIDRICH^{1,3}, Ngoc Thanh VU⁴ & Quang Truong NGUYEN⁵

¹ AG Zoologischer Garten Köln, Riehler Straße 173, D-50735 Köln, Germany.
E-mail: tziegler@zoo-koeln.de

² Muséum d'histoire naturelle, Department of Herpetology and Ichthyology, C.P. 6434, CH-1211 Geneva 6, Switzerland. E-mail: andreas.schmitz@ville-ge.ch

³ Zoologisches Forschungsmuseum Alexander Koenig, Adenauerallee 160, D-53113 Bonn, Germany. E-mail: astrid_heidrich@web.de

⁴ Centre for Natural Resources and Environmental Studies (CRES), Vietnam National University, Hanoi, University of Science, Faculty of Biology, Department of Vertebrate Zoology, Zoological Museum, 334 Nguyen Trai Str., Thanh Xuan, Hanoi, Vietnam. E-mail: vnthanh@fpt.vn

⁵ Institute of Ecology and Biological Resources (IEBR), Vietnamese Academy of Science and Technology, 18 Hoang Quoc Viet St., Hanoi, Vietnam.
E-mail: truong@iebr.vast.ac.vn

A new species of *Lygosoma* (Squamata: Sauria: Scincidae) from the central Truong Son, Vietnam, with notes on its molecular phylogenetic position. - A new *Lygosoma* species is described from the Central Truong Son (Annamite mountain range) of Quang Binh Province, Vietnam. The description is based on a single female specimen, collected during the dry season in the karst forest of Phong Nha – Ke Bang National Park. The new *Lygosoma* differs from any other congener by the dorsal scales with pseudo-keels in combination with a pair of frontoparietals; a scaly lower eyelid; seven supralabials; seven infralabials; 32 midbody scale rows; 66 middorsal (paravertebral) scales; smooth ventral scales, arranged in 81 transverse rows; 108 smooth, not enlarged median subcaudal scales; the fourth toe with 14 keeled subdigital lamellae; a reddish brown to brownish black dorsum and an orange-yellowish to greyish ventral side in life; as well as greyish black edged sutures of anterior supra- and infralabials. The new *Lygosoma* species is the third karst-adapted scincid species that has been described from Phong Nha - Ke Bang National Park since 2005. A first molecular positioning of the new species within the genus *Lygosoma* is given as well as a key to the Vietnamese *Lygosoma* species.

Keywords: Sauria - Scincidae - *Lygosoma boehmei* sp. n. - taxonomy - phylogeny - Central Truong Son - Vietnam.

INTRODUCTION

During recent herpetofaunal investigations in the Phong Nha – Ke Bang National Park, Central Truong Son (Annamite mountain range) of Quang Binh Province, in Central Vietnam (e.g., Ziegler & Herrmann, 2000; Ziegler & Le, 2005, 2006; Ziegler *et al.*, 2004, 2005, 2006) a remarkable scincid lizard was collected. At first glance, the specimen appeared with its apparently keeled dorsal scales to be another representative of *Lygosoma carinatum*, that was described a decade ago by Darevsky & Orlova (1996) based upon two specimens from the “Tau Nguen (sic)” (= Tay Nguyen) plateau in Kon Tum Province, Vietnam. However, as is pointed out in detail below, our investigations showed the dorsal keels to be pseudo-keels in fact. In addition, the single specimen found by us showed a distinctly differing pholidosis, i.e. larger body scales, resulting in distinctly lower midbody, middorsal, and ventral scale counts compared to *L. carinatum*, and differed as well from the remaining *Lygosoma* (and *Riopa*) species listed in Nguyen *et al.* (2005) for Vietnam. It must be noted that there exists quite some confusion concerning the assignment of species to the genera *Lygosoma* Hardwicke & Gray, 1827 and *Riopa* Gray, 1839, respectively. While *Riopa* was long considered as a valid genus (e.g., Smith, 1937; Mittleman, 1952), Greer (1977) carried out a careful morphological revision and as a result has synonymized the genus *Riopa* with *Lygosoma*. This author gave a missing “close ecological and morphological continuity among [the genus] own species and sharp ecological and morphological discontinuity from its near relatives” as the main reason to place *Riopa* (together with other proposed skink genera) into the synonymy of *Lygosoma*. But this assignment has not been unambiguously followed since. Some more recent authors such as Manthey & Grossmann (1997) again list specimens that bear supranasals under *Riopa*, while others either follow Greer (1977) and accept the synonymization of *Riopa* with *Lygosoma* or simply do not distinguish between both genera (e.g., Honda *et al.*, 2003). A solution to this problem cannot be provided in the framework of this paper and should be treated in a comprehensive phylogenetic approach, preferably based on modern molecular analyses. We preliminarily follow in this paper the definition of Greer (1977) and consider *Riopa* as a synonym of *Lygosoma*. As our specimen was neither assignable to any of the other scincid genera listed by Nguyen *et al.* (2005) for Vietnam (*Dasia*, *Emoia*, *Eumeces*, *Leptoseps*, *Lipinia*, *Eutropis* [see Mausfeld *et al.*, 2002 and Mausfeld & Schmitz, 2003 on the split of *Mabuya* sensu lato and the resulting nomenclatural changes], *Paralipinia*, *Scincella*, *Sphenomorphus*, *Tropidophorus*, and *Vietnascincus*), nor to any of the described *Lygosoma* (or ‘*Riopa*’) species from Vietnam or its neighbouring countries (Bourret, unpubl.; Manthey & Grossmann, 1997; Darevsky & Orlov, 1994, 1997, 2005), we describe it herein as new.

MOLECULAR METHODS

To support our morphological results molecular data were collected to identify the phylogenetic position of the new species in a general framework of related species of the genus *Lygosoma* (including its supposed synonym *Riopa*). We sequenced a portion of the mitochondrial 16S rRNA gene and compared it with the following species, some of which are also present in the key to the Vietnamese species (see

below): *Lygosoma quadrupes* (type species of the genus *Lygosoma*), *L. albopunctatum*, and *Lygosoma* sp. (India). Further, we included specimens from several localities of *L. koratense* (2), *L. lineolatum* (2; used as outgroups), and the widespread *L. bowringii* species-complex (3). For GenBank accession numbers see Table 1.

DNA was extracted from the tissue samples using QuiAmp tissue extraction kits (Quiagen) or a modified Chelex-Protocol (Walsh *et al.*, 1991; Schmitz, 2003). The primers 16sar-L (light chain; 5' - CGC CTG TTT ATC AAA AAC AT - 3') and 16sbr-H (heavy chain; 5' - CCG GTC TGA ACT CAG ATC ACG T - 3') of Palumbi *et al.* (1991) were used to amplify a section of the mitochondrial 16S ribosomal RNA gene. PCR cycling procedure followed Schmitz *et al.* (2005). PCR products were purified using Qiaquick purification kits (Qiagen). Sequences (including complimentary strands for assuring the accuracy of the sequences) were obtained using an automatic sequencer (ABI 377). The obtained sequences (lengths referring to the aligned sequences including gaps) comprised 548 bp. Sequences were aligned using ClustalX (Thompson *et al.*, 1997; default parameters) and manually checked using the original chromatograph data in the program BioEdit (Hall, 1999). We used PAUP* 4.0b10 (Swofford, 2002) to compute the uncorrected pairwise distances for all sequences.

We performed maximum parsimony (MP), maximum likelihood (ML), Neighbor-joining (NJ) and Bayesian (PP) reconstructions. For ML and Bayesian analysis parameters of the model were estimated from the data set using Modeltest 3.7 (Posada & Crandall, 1998) and MrModeltest 2.2 (Nylander, 2005), respectively. The NJ-analysis used the uncorrected 'p-distances'. Additionally, we used bootstrap analyses with 2000 (MP and ML) and 20000 (NJ) pseudoreplicates to evaluate the relative branch support in phylogenetic analysis. For the MP analysis, we used the "heuristic search" with the "random addition" option of PAUP* (Swofford, 2002) with 10 replicates, using the TBR (tree bisection-reconnection) branch swapping option. All Bayesian analyses were performed with MrBayes, version 3.0b4 (Huelsenbeck & Ronquist, 2001). We ran two MCMC analyses for 10⁶ generations each. The initial 100000 (10%) trees were disregarded as "burn-in". We consider probabilities of 95% or greater to be significantly supported. The exact parameters used for the Bayesian analyses followed those described in detail by Reeder (2003).

RESULTS AND DISCUSSION

Lygosoma boehmei sp. n.

HOLOTYPE: Zoologisches Forschungsmuseum Alexander Koenig, ZFMK 86359: female (Figs 1-8), from the karst forest of Cha Noi, 350-400 m a.s.l., Phong Nha – Ke Bang National Park, Quang Binh Province, Vietnam; collected by Astrid Heidrich and Thomas Ziegler at the end of the dry season (21 June) 2006.

ETYMOLOGY: We name this new species in honor of Professor Dr Wolfgang Böhme, vice director of the Zoological Research Museum Alexander Koenig in Bonn, head of the vertebrate section and curator for herpetology, in recognition of his outstanding contributions not only towards lizard systematics throughout the last three decades.

DIAGNOSIS: The new species can be distinguished from any other *Lygosoma* / *Riopa* currently known by the following combination of characters: (1) Body elongate



Figs 1-2

(1) Female holotype of *Lygosoma boehmei* sp. n. (ZFMK 86359) in life. (2) Portrait of the holotype of *Lygosoma boehmei* sp. n. (ZFMK 86359) in life.

(SVL 86.0 mm), the distance between axilla and groin being slightly more than 3 times the length of the forelimb; (2) forelimb and hindlimb short, pentadactyl, fingers and toes widely separated when adpressed, the distance between them corresponding to the length of the hindlimb; (3) dorsum reddish brown in life, brownish grey in preser-

TABLE 1. List of samples used for genetic analysis (geographic origin, locality and GenBank accession numbers). Acronyms are as follows: KUZ for Herpetological Collection of the Department of Zoology, Kyoto University, Japan; MHNG for Muséum d'histoire naturelle, Geneva, Switzerland; ZFMK for Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany

Species	Geographic origin	Locality	Voucher	Accession number
<i>L. albopunctatum</i>	India	Near Ajur, Peryar-Trivandrum	ZFMK 73430	AY308262
<i>L. boehmei</i> n. sp.	Vietnam	Cha Noi, Phong-Nha Ke Bang NP	ZFMK 86359	EF193650
<i>L. bowringii</i>	Indonesia	Pondok Sari, Permuteran, Bali	ZFMK 78822	AY308263
<i>L. bowringii</i> (I)	Thailand	Khao Chong	KUZ 37884	AB028786
<i>L. bowringii</i> (II)	Thailand	Tha Uthen	MHNG 2679.72	EF193649
<i>L. koratense</i>	Malaysia	locality unknown	ZFMK 71715	AY308269
<i>L. koratense</i>	Thailand	locality unknown	KUZ 27358	AB028817
<i>L. lineolatum</i>	Myanmar	Rakhine State, Gwo Township	CAS 206647	AY308270
<i>L. lineolatum</i>	Myanmar	Mandalay Div., Popa Mountain Park	CAS 210669	AY308271
<i>L. quadrupes</i>	Thailand	Bankok	KUZ 40033	AB028818
<i>Lygosoma</i> sp.	India	Ooty-Bandypur	ZFMK 77814	AY308272

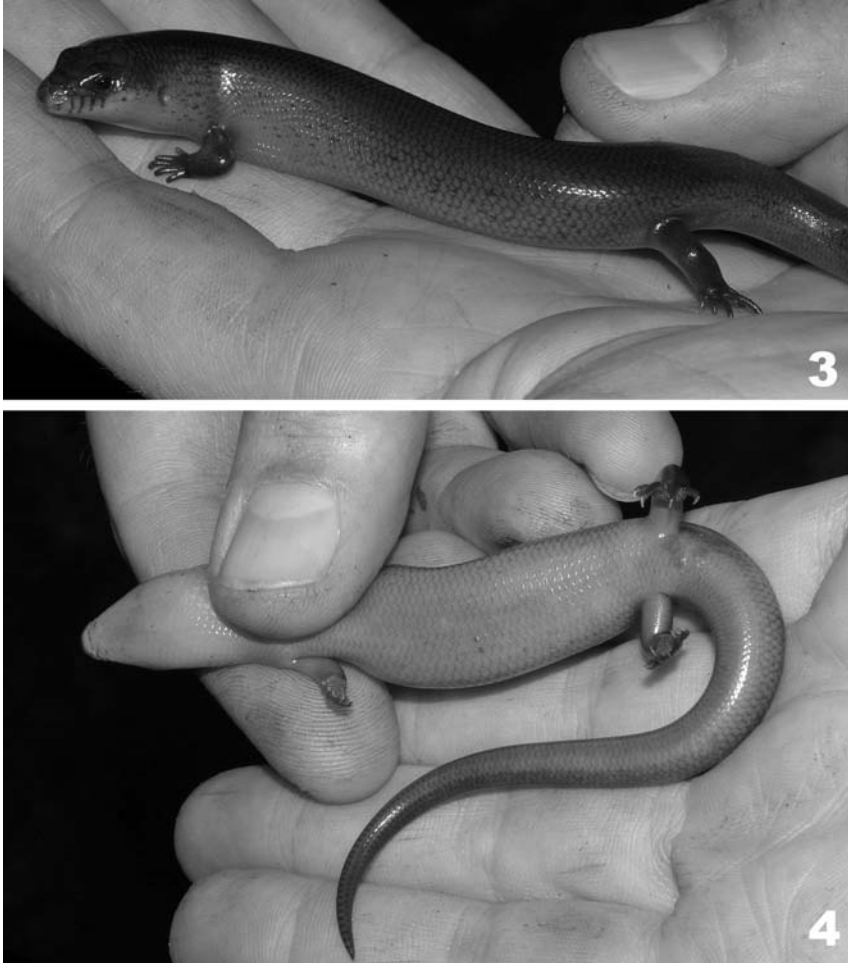
vative, the surfaces of the limbs and tail being brownish black; ventral side yellowish beige to greyish below the tail in preservative, with some indistinct dark marbling; in life, chin and throat are light orange and the remaining ventral side of the body cream to light brownish, turning to greyish at the underside of the tail; sides of body and neck with irregular dark flecking; sutures of anterior supra- and infralabials edged by greyish black; (4) rostral separated from undivided frontonasal by supranasals (5) prefrontals widely separated; (6) parietals forming a suture behind interparietal, no enlarged nuchals; (7) four supraoculars; bordered by six supraciliaries; posteriorly, the fourth supraocular is bordered by a small scale (postsupraocular); (8) lower eyelid scaly; (9) two loreals; (10) seven supralabials, fifth right below the eye; (11) seven infralabials; (12) postmental undivided; (13) first pair of chinshields in broad contact, bordered by six scales; (14) ear opening small, ovoid to roundish; (15) 32 midbody scale rows; (16) 66 middorsal (paravertebral) scales (from the posterior end of parietals to insertion of hindlimb); (17) dorsal and dorsolateral scales notched, appearing as three longitudinal (pseudo-)keels on neck, body, and anterior half of tail; (18) ventral scales smooth, arranged in 81 transverse rows from first gular row between third pair of chinshields to preanals; (19) six slightly enlarged preanals; (20) 108 median subcaudal scales, not enlarged, smooth; (21) fourth toe with 14 keeled subdigital lamellae.

DESCRIPTION OF HOLOTYPE: Female specimen, for measurements see Table 2. Body elongate, the distance between axilla (end of forelimb) and groin (insertion of hindlimb) slightly more than 3 times the length of the forelimb. Forelimb and hindlimb short, pentadactyl. Fingers and toes widely separated when adpressed, the distance between them corresponding to the length of the hindlimb. Head only slightly set-off from neck, snout rounded. Rostral wider than high, visible from above. A pair of

TABLE 2. Measurements (taken by a caliper, in mm) and some scalation features of the female holotype of *Lygosoma boehmei* sp. n. compared to the female holotype of *Lygosoma carinatum* (ZIN 20482) from Kannack, Kon Tum province, Vietnam, studied by us (* = data from Darevsky & Orlova, 1996). SVL: snout-vent length (from snout tip to cloaca); TaL: tail length (from cloaca to tail tip); TL: total length; HL: head length (distance from snout tip to posterior margin of interparietal); HW: maximum head width; SL: maximum snout length (from tip to anterior margin of the eye); ET: maximum eye to tympanum length (from hind margin of the eye to anterior border of tympanum); TW: maximum tympanum width; SFI: maximum snout to forelimb length; AG: maximum axilla to groin length; FIL: maximum forelimb length (from body insertion to beginning of claw of fourth finger); HIL: maximum hindlimb length (from body insertion to claw of fourth toe); IL: Infralabials; MB: midbody scale rows; MD: middorsal scale rows (from posterior end of parietals to insertion of hindlimb / to centre of thigh / and to posterior hindlimb); V: transverse rows of ventral scales (from first gular row subsequent to first pair of chinshields to preanals); MSS: median subcaudal scales; L4T: Lamellae beneath fourth toe.

	<i>Lygosoma boehmei</i> sp. n. ZFMK 86359	<i>Lygosoma carinatum</i> ZIN 20482
SVL	86.0	*71.0
TaL	91.0	*77.0
TL	177.0	*148.0
HL	12.3	10.0
HW	10.5	8.9
SL	6.1	5.5
ET	6.4	5.6
TW	1.3	1.1
SFI	29.4	23.1
AG	47.0	40.3
FIL	14.7	12.2
HIL	19.0	15.0
IL	7	6-7
MB	32	38
MD	66 / 70 / 72	80 / 82 / 85
V	81	92
MSS	108	115
L4T	14	16

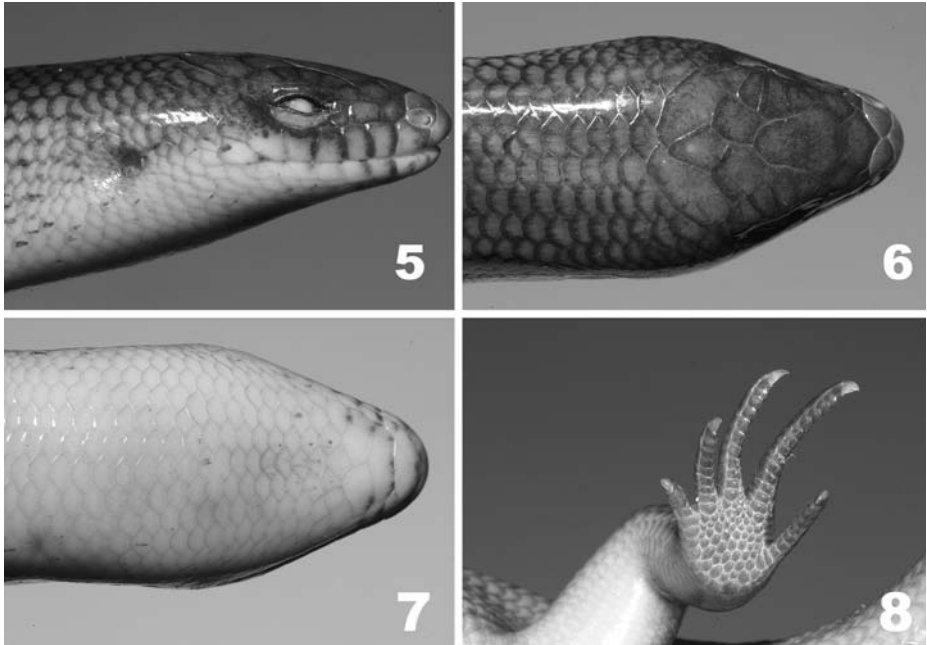
supranasals, somewhat wider than long, forming a distinct median suture, touching nasals and anterior loreal laterally. Prefrontals widely separated, touching both loreals laterally. Frontonasal wider than long, in contact with supranasals, anterior loreals, prefrontals, and frontal. Frontal large, longer than its distance to tip of snout, narrowing posteriorly, in contact with frontonasal, prefrontals, first supraciliary, first and second supraoculars, and frontoparietals. A pair of frontoparietals, about as wide as long. Parietals forming a suture behind the interparietal, that is longer than wide, smaller than frontal and narrowing posteriorly. Small transparent spot on interparietal, showing location of parietal foramen. No distinctly enlarged nuchal scales. Nostril piercing nasal, that is in contact with rostral, first supralabial, anterior loreal, and supranasal. Two loreals, anterior the higher (bordering nasal, first and second supralabials, posterior loreal, prefrontal, frontonasal, and supranasal), posterior the longer. The posterior loreal is in contact with the first supraciliary, the prefrontal, the anterior loreal, the second and third supralabials, and is bordered behind by two large preoculars. The upper one of these large preoculars is posteriorly bordered by a somewhat



FIGS 3-4

(3) Lateral view of the holotype of *Lygosoma boehmei* sp. n. (ZFMK 86359) in life. (4) Ventral view of the holotype of *Lygosoma boehmei* sp. n. (ZFMK 86359) in life.

smaller preocular, that touches the first and second supraciliary above; the lower one of the large preoculars is posteriorly bordered by a somewhat smaller, more elongated preocular (presubocular), that is in broad contact below with the fourth supralabial and further touches the corner of the fifth supralabial. Lower eyelid scaly. Supraoculars four, plus one small posterior supraocular (postsupraocular: small scale posterior to the supraocular series). Supraoculars laterally bordered each by six supraciliaries. Three large postoculars, the upper one bordering the postsupraocular above, the lower one (postsubocular) borders the fifth and sixth supralabials below. Ear opening small, ovoid to roundish. Seven supralabials, fifth right below the eye. Mental in contact with first infralabials and postmental. Undivided postmental in contact with mental, first and



FIGS 5-8

Lygosoma boehmei sp. n. (ZFMK 86359), preserved holotype. (5) Lateral view of the head. (6) Dorsal view. (7) Ventral view. (8) Underside of the left foot.

second infralabials, and first pair of chinshields. First pair of chinshields in broad contact, posteriorly bordered by six scales. Seven infralabials. 32 midbody scale rows. 66 middorsal (paravertebral) scales from posterior end of parietals to insertion of hindlimb (70 to centre of thigh, 72 to posterior hindlimb). Dorsal and dorsolateral scales smooth, appearing as three longitudinal (pseudo-)keels on neck, body, and anterior half of tail. Although visual inspection and the macro-photograph of the dorsal midbody scales of the holotype indicates a keeled appearance of the scale surfaces (Fig. 9), the SEM (scanning electron microscopy) pictures revealed that the scales bear in fact only pseudo-keels (Fig. 10). Contrary to its naming by Darevsky & Orlova (1996), the same is actually true for the holotype of *L. carinatum* (Fig. 11).

Dorsal body scales of the holotype of *L. boehmei* sp. n. as large as ventrals. Ventral scales smooth, arranged in 81 transverse rows from first gular row subsequent to first pair of chinshields to preanals. Six slightly enlarged preanals. 108 median subcaudal scales (without tail tip), not enlarged, smooth. Fourth toe with 14 keeled subdigital lamellae.

Colour in preservative brownish grey on dorsal and dorsolateral surfaces of head and body, the surfaces of the limbs and tail appear brownish black. Especially the dorsal scales are distinctly edged by brownish black. Except for the somewhat darker tail, the lateral parts of the tail base, body, neck and head become lighter. The light ventral side is yellowish beige (lightest below head and neck) to greyish below the tail with

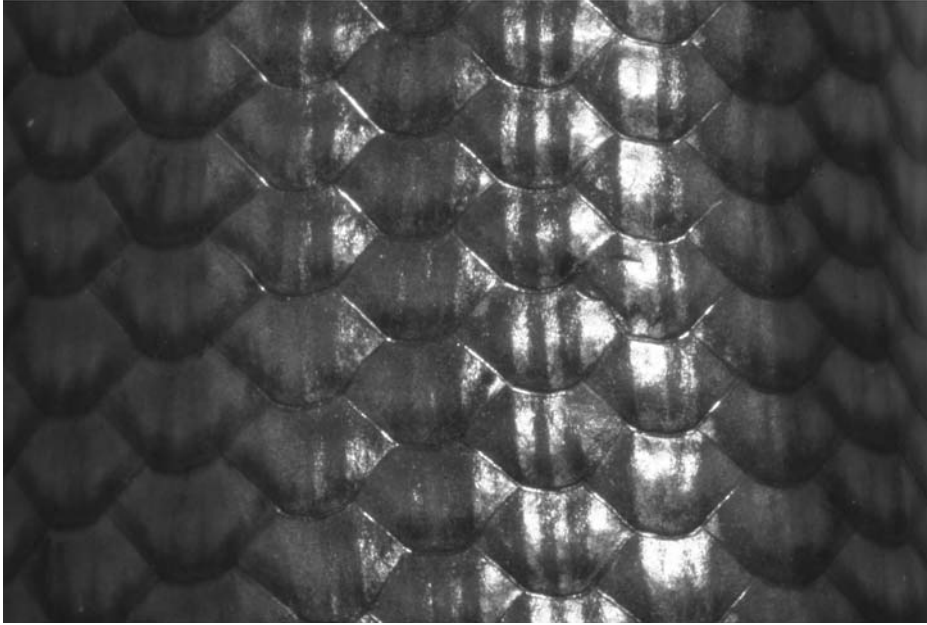


FIG. 9

Macro-photograph of the apparently keeled dorsal midbody scales in the preserved holotype of *Lygosoma boehmei* sp. n. (ZFMK 86359).

some indistinct dark marbling. Sides of body and neck with irregular dark flecking. Sutures of anterior supra- and infralabials edged by greyish black. In life, the dorsal colour is reddish brown. Chin and throat are light orange and the remaining ventral side of the body is cream to light brownish, turning to greyish at the underside of the tail.

COMPARISONS: The new species is easily distinguishable from the skink species listed in the genera *Lygosoma* and *Riopa* known to occur in Vietnam (Darevsky & Orlova, 1996, Nguyen *et al.*, 2005) by a combination of proportions, coloration and scalation features (Table 3). The new species differs:

from *Lygosoma carinatum* by having seven infralabials instead of six lower labials, 32 midbody scale rows instead of 38-40, and only 66 middorsal (paravertebral) scales instead of 81-85 according to Darevsky & Orlova (1996). However, our study of the holotype of *L. carinatum* revealed that the specimen only bears 6 infralabials on the right side, but 7 on the left (see Table 2); the holotype of *L. carinatum* further had 92 transverse rows of ventrals (instead of 81 in the new species), 115 median subcaudal scales (instead of 108), 16 keeled subdigital lamellae beneath the fourth toe (instead of 14), and the holotype of *L. carinatum* had an enlarged nuchal scale on the left side;

from *L. quadrupes* by lacking an extremely elongate body (the length of the forelimb is not contained twelve to fourteen times in the distance between the fore- and hindlimbs), by the rostral not being in contact with the frontonasal, by having 32 midbody scale rows instead of 24-26, by having 14 instead of 5 lamellae beneath the fourth

TABLE 3. Overview of supralabial (SuL), midbody scale (MbS), and middorsal (MdS) scale counts, as well as presence of dorsal keels or pseudo-keels (DK: +/-) and number of lamellae beneath fourth toe (L4T) for the *Lygosoma* / *Riopa* species recorded from Vietnam (after Bourret, unpubl.; Smith, 1935; Taylor, 1963; Darevsky & Orlova, 1996; Manthey & Grossmann, 1997, and own data).

	SuL	MbS	MdS	DK	L4T
<i>albopunctatum</i>	7	26-28	63-72	-	12-15
<i>angeli</i>	?	30	110-115	-	5
<i>boehmei</i> sp. n.	7	32	66	+	14
<i>bowringii</i>	7	26-32	52-58	-/+	10-15
<i>carinatum</i>	7	38-40	80-85	+	15-16
<i>corpulentum</i>	6	36-38	?	-	13-14
<i>punctatum</i>	7	24-28	62-76	-	11-14
<i>quadrupes</i>	6-7	24-26	104-121	-	5

toe, and by lacking the tail being as thick as the body for a considerable part of its length (Smith, 1935);

from *L.* ('*Riopa*') *punctatum* by lacking a lower eyelid with an undivided semi-transparent disc, smooth dorsal scales, by having 32 midbody scale rows instead of 24-28, and by lacking dorsal scales with a dark basal spot, usually confluent into four to six longitudinal lines down the back in the young (Smith, 1935).

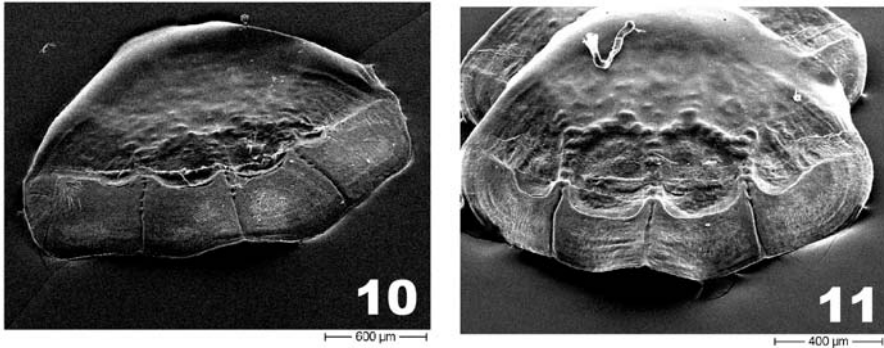
from *L.* ('*Riopa*') *albopunctatum* by having 32 midbody scale rows instead of 26-28, lacking dark brown or black sides of neck and anterior part of the body, and by lacking smooth dorsal scales with a dark spot, forming longitudinal series (Bourret, unpubl.; Smith, 1935);

from *L. angeli* (as '*Riopa angeli*' in Bourret, unpubl.; Nguyen *et al.*, 2005) by lacking a single frontoparietal, having 32 midbody scale rows instead of 30, having pseudo-keeled dorsal scales, 66 middorsal (paravertebral) scales instead of 110-115 scales down the middle of the back, and by having 14 instead of 5 lamellae beneath the fourth toe (Bourret, unpubl.; Darevsky & Orlova, 1996).

from *L. bowringii* (as '*Riopa bowringii*' in Smith, 1935, and as *Riopa bowringii* in Nguyen *et al.*, 2005) in lacking a single frontoparietal and a pair of nuchals, by having 66 middorsal (paravertebral) scales instead of 52-58 scales down the middle of the back, by lacking smooth dorsal scales with a darker spot forming more or less continuous longitudinal lines, and by lacking a dark brown or black dorso-lateral stripe of variable thickness, light-edged above (Bourret, unpubl.; Smith, 1935; Darevsky & Orlova, 1996);

from *L. corpulentum* (as '*Riopa corpulenta*' in Smith, 1935; Nguyen *et al.*, 2005) in having seven supralabials (vs. six in *corpulentum*), pseudo-keeled dorsals (vs. smooth body scales in *corpulentum*), 32 midbody scale rows instead of 36-38, and in coloration and pattern (*Lygosoma corpulentum* is light yellowish-brown and thickly mottled on the back and sides with dark brown) (Smith, 1935; Darevsky & Orlova, 1996).

From the *Lygosoma* / *Riopa* species of the neighbouring countries, the new species differs [e.g. comp. Bourret (unpubl.); Werner (1909); Smith (1935); Taylor (1963); Manthey & Grossmann (1997)] by lacking lower eyelids with disc in combi-



FIGS 10-11

(10) *Lygosoma boehmei* sp. n. (ZFMK 86359), preserved holotype. SEM (scanning electron microscopy) picture of a dorsal midbody scale; the externally visible scale surface is smooth, showing the “keels” being in fact pseudo-keels. (11) SEM picture of a dorsal midbody scale of the holotype of *Lygosoma carinatum* (ZIN 20482); the externally visible scale surface is smooth, showing the “keels” being in fact pseudo-keels.

nation with 22 smooth midbody scale rows, only 6-10 lamellae under the fourth toe, and more or less developed dorso-lateral line (as in the species *anguinum* and *lineolatum*), by lacking a single frontoparietal in combination with a) supranasals fused anteriorly with nasals, and 88-98 middorsal scales (as in *isodactylum*), b) in combination with 40-42 midbody scale rows, and 143 middorsal scales (as in *haroldyoungi*), or c) in combination with 28-30 midbody scale rows, 56-60 middorsal scale rows, 78 slightly enlarged median subcaudal scales, and dorsolateral lines (as in *frontoparietale*), by lacking a combined nasal-supranasal scale in combination with eight supralabials and smooth dorsals (as in *koratense*), by lacking a midbody scale count of 26-30 in combination with six infralabials, 55-57 middorsal scales and a more or less developed stripe from eye along side of body (as in *herberti*), and by having different midbody scale counts from the Indonesian species *bampfyldei* (38-40) and *opisthorhodum* (30), the latter of which has in contrast a light lateral stripe and a blackish brown anterior dorsum, which is getting paler backwards and turning to a light reddish brown tail.

DISTRIBUTION: Currently, the new species is only known from its type locality, the karst forest of Cha Noi, 350-400 m a.s.l., within Phong Nha - Ke Bang National Park in Quang Binh province, central Vietnam (Fig. 12).

NATURAL HISTORY: The female holotype of *Lygosoma boehmei* sp. n. was discovered at night on the forest ground in a steep primary karst forest area (compare Fig. 13). We did not find any water courses in the immediate vicinity, however, the discovery took place at the end of the dry season. The skink was found crawling at the base of a tree stump in the surrounding of karst rock outcrops (Fig. 14).

The stomach content of the holotype of *Lygosoma boehmei* sp. n. contained brown earth-like masses, plant and tissue remains which most probably come from an earth-worm.



FIG. 12

At present, *Lygosoma boehmei* sp. n. is only known from its type locality in the Phong Nha - Ke Bang National Park, Quang Binh Province, Vietnam.

Lygosoma boehmei sp. n. is the third scincid species that has been described from the karst forests of Phong Nha - Ke Bang National Park since 2005 (Darevsky & Orlov, 2005; Ziegler *et al.*, 2005); the discovery of the new species took place at the locus typicus of the recently discovered water skink species *Tropidophorus noggei* (see Ziegler *et al.*, 2006).

MOLECULAR PHYLOGENETIC POSITION OF *LYGOSOMA BOEHMEI* SP. N.

Since *L. carinatum*, the supposed closest relative of *L. boehmei* sp. n. could not be included in the molecular data set (the former species is only known from the type series), we could not make a direct genetic comparison of all Vietnamese *Lygosoma* species (but compare the morphological discussion). Therefore, we decided to analyze the phylogentic position of *L. boehmei* sp. n. within the general framework of the taxa of the genus *Lygosoma*.

All molecular analyses produced an almost identical tree topology shown in Figure 15; the only difference was found in the MP-tree (not shown) where *L. albopunctatum* was not directly clustered within the clade containing *Lygosoma* sp. and the 3 included members of the *L. bowringii* species complex. The heuristic search of the MP analysis produced 2 most-parsimonious tree (tree length = 194; CI = 0.680; RI = 0.682; RC = 0.464). The comparison between the different likelihood scores for each



FIGS 13-14

(13) The steep karst forests of Cha Noi: habitat of *Lygosoma boehmei* sp. n. in the Phong Nha - Ke Bang National Park. (14) Microhabitat of *Lygosoma boehmei* sp. n.: the female holotype was collected at night crawling at the base of this tree stump.

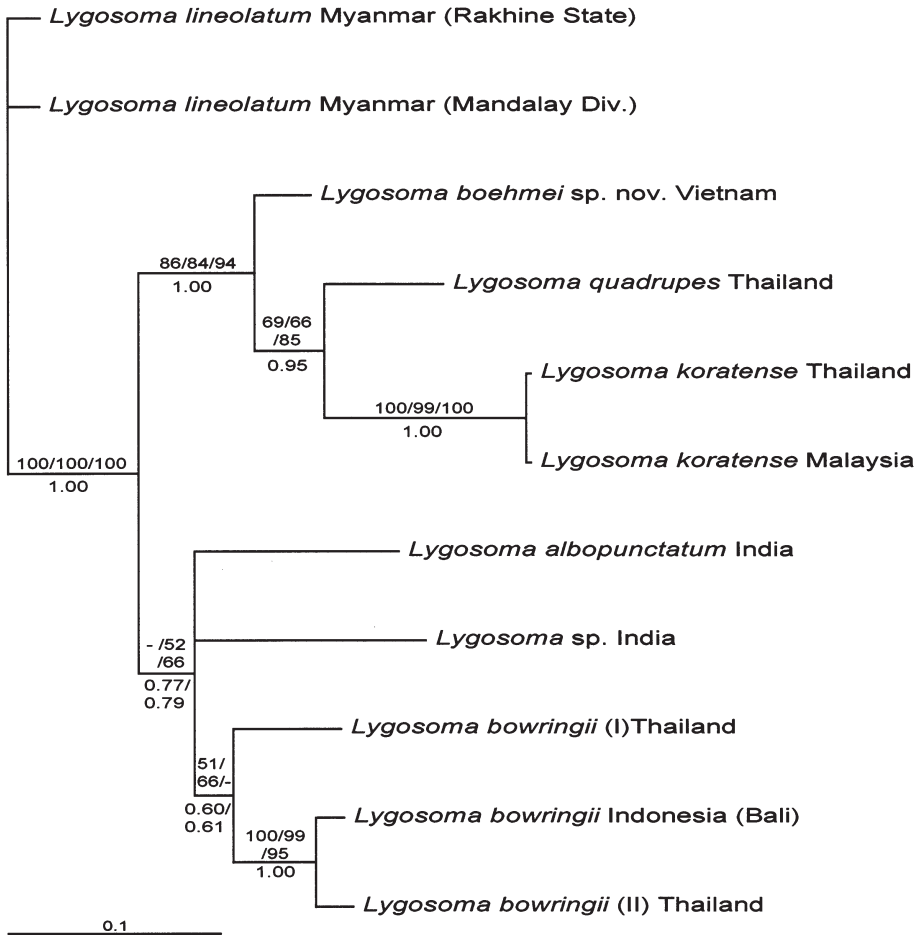


FIG. 15

Phylogram based on 548 bp of the mitochondrial 16S ribosomal RNA gene sequences. Values above the nodes represent bootstrap values in percent for maximum parsimony, neighbor-joining and maximum likelihood analyses, respectively; lower values are Bayesian posterior probabilities. Values below 50% (or 0.50 for the Bayes analyses) not shown.

model showed that the TRN+I+G model (Tamura & Nei, 1993) was determined to be the optimal ML model for data set. This model incorporates unequal base frequencies [$\pi_{(A)} = 0.3461$, $\pi_{(T)} = 0.2335$, $\pi_{(C)} = 0.2448$, $\pi_{(G)} = 0.1756$], a proportion of invariable sites ($I = 0.4165$), and a gamma distribution shape parameter ($\alpha = 0.2513$). The optimal ML tree had a log-likelihood of $-\ln L = 1766.91104$.

The resulting tree shows three clearly separated groups with the two specimens of *L. lineolatum* genetically well separated from the rest of the included species; this was true even when these two OTUs were included as ingroup taxa and a different outgroup was used. The newly described *Lygosoma boehmei* sp. n. is consistently placed

TABLE 4. Summary of the uncorrected p-distances for the 16S data set.

Taxa	1	2	3	4	5	6	7	8	9	10	11
1 <i>Lygosoma lineolatum</i> (Rakhine State)	-										
2 <i>Lygosoma lineolatum</i> (Mandalay Div.)	0.0204	-									
3 <i>Lygosoma albopunctatum</i> India	0.0987	0.0947	-								
4 <i>Lygosoma quadrupes</i> Thailand	0.0988	0.0988	0.0944	-							
5 <i>Lygosoma boehmei</i> sp. n. Vietnam	0.0744	0.0705	0.0892	0.0684	-						
6 <i>Lygosoma koratense</i> Thailand	0.1170	0.1108	0.1174	0.0847	0.0767	-					
7 <i>Lygosoma koratense</i> Malaysia	0.1101	0.1025	0.1131	0.0845	0.0726	0.0000	-				
8 <i>Lygosoma</i> sp. India	0.0993	0.1006	0.0955	0.1013	0.0923	0.1176	0.1107	-			
9 <i>Lygosoma bowringii</i> (I) Thailand	0.1006	0.0984	0.0942	0.1125	0.0861	0.1169	0.1166	0.0962	-		
10 <i>Lygosoma bowringii</i> Indonesia (Bali)	0.0675	0.0691	0.0875	0.0949	0.0805	0.1106	0.1027	0.0817	0.0741	-	
11 <i>Lygosoma bowringii</i> (II) Thailand	0.0786	0.0824	0.0836	0.0931	0.0826	0.1191	0.1130	0.0808	0.0640	0.0211	-

into a second clade, which also includes the type species of the genus *Lygosoma* (*L. quadrupes*), as well as the two *L. koratense* specimens from Thailand and Malaysia (whose sequences showed a 100% identity despite coming from two different countries). This whole clade is strongly supported in all used analyses methods (MP: 86 / NJ: 84 / ML: 94 / PP: 1.00) and shows that *L. boehmei* sp. n. is a true member of the genus *Lygosoma*, regardless of the ongoing discussion on the validity of the genus *Riopa* (see Introduction). *Lygosoma boehmei* sp. n. stands basal to the other OTUs of this clade, but a definitive polarity decision cannot be made with our data set. The genetic differences between the different species of this clade varied from 6.8%-8.5%. *L. boehmei* sp. n. is also well separated from the members of the third recovered clade, which includes all three specimens of the *L. bowringii* species complex as well as *Lygosoma* sp. and *L. albopunctatum* (both from India). The genetic differences between the taxa of this third clade were similar to those found in the second clade and varied from 6.4%-9.5%. Regarding the distances between the two clades one finds that they are normally slightly higher than the distances within the two clades (9.4%-11.7%), but this is not completely consistent since the genetic distance of one of these species (*L. boehmei* sp. n.) towards the taxa of the third clade is in the range of or even slightly lower (8.1%-9.2%) than the maximum inter-clade differences mentioned above. Also we found that in some cases the genetic differences between geographically close taxa are not necessary lower than those living in far-away habitats (e.g. *L. boehmei* sp. n.-*L. lineolatum* and *L. boehmei* sp. n.-*L. koratense*; Table. 4). This shows that a subdivision of the genus *Lygosoma* would need to be based on a rather complete taxon sampling, since our preliminary molecular data already indicate a rather complicated intrageneric structure within *Lygosoma*. One further notable result is that (equal as shown in our key to the Vietnamese *Lygosoma* species where the *L. bowringii* species complex is found on two different positions in the key) the genetic analyses also strongly support that *L. bowringii* is a species-complex which comprises at least 2 different taxa. The recovered genetic difference between the two different specimens from Thailand is 6.4% and therefore has about same amount of genetic divergence as between other *Lygosoma* species, and the new *L. boehmei* sp. n. is about equidistant with all three included *L. bowringii* taxa (8.1%-8.6%).

KEY TO THE VIETNAMESE *LYGOSOMA* SPECIES

1a	Dorsal scales appearing smooth	2
1b	Dorsal scales with keels or pseudo-keels	7
2a	5 lamellae beneath fourth toe	3
2b	10-15 lamellae beneath fourth toe	4
3a	24-26 midbody scale rows	<i>quadrupes</i>
3b	30 midbody scale rows	<i>angeli</i>
4a	36-38 midbody scale rows, six supralabials	<i>corpulentum</i>
4b	24-32 midbody scale rows, seven supralabials	5
5a	52-58 middorsal scales	<i>bowringii</i> (species complex)
5b	62-76 middorsal scales	6
6a	lower eyelid scaly (central scales may be enlarged)	<i>albopunctatum</i>

6b	lower eyelid with undivided semitransparent disc	<i>punctatum</i>
7a	26-32 midbody scale rows, 52-66 middorsal scales	8
7b	38-40 midbody scale rows, 80-85 middorsal scales	<i>carinatum</i>
8a	52-58 middorsal scales	<i>bowringii</i> (species complex)
8b	66 middorsal scales	<i>boehmei</i> sp. n.

ACKNOWLEDGEMENTS

We thank Dr V. T. Hoang (Centre for Natural Resources and Environmental Studies, Vietnam National University, Hanoi), the People's Committee of Quang Binh, and the Phong Nha – Ke Bang National Park directorate (T. H. Nguyen, X. C. Cao, and M. T. Luu) for their continuous support as well as for issuing respective permits. The National Park staff, especially Dang Ngoc Kien helped again to make fieldwork successful. For their support we further would like to express our thanks to Dr Martina Vogt (Cologne Zoo nature conservation project, Phong Nha - Ke Bang) and Bernhard Forster (Frankfurt Zoological Society / Cologne Zoo nature conservation project, Phong Nha - Ke Bang). We are further grateful to Dr Natalia B. Ananjeva (ZIN, Zoological Institute, Russian Academy of Sciences, St. Petersburg) for enabling us to examine the holotype of *Lygosoma carinatum*. We thank Philipp Wagner and Thomas Wilms (ZFMK, Bonn) for critically reviewing the manuscript. For the translation of the scientific description of *Lygosoma carinatum* in Russian language we would like to express our thanks to our friend and colleague Ho Thu Cuc (Institute of Ecology and Biological Resources, Vietnamese Academy of Science and Technology). Philipp Wagner (ZFMK, Bonn) kindly prepared the SEM pictures. Our field work was funded in large by the Zoological Garden Cologne, the Kölner Kulturstiftung der Kreissparkasse Köln, and BIOPAT (www.biopat.de). Current lizard research in the Phong Nha - Ke Bang region is supported as well by the Alexander-Koenig-Gesellschaft (AKG), the Alexander Koenig Stiftung (AKS), the Deutsche Gesellschaft für Herpetologie und Terrarienkunde (DGHT), and by the European Union of Aquarium Curators (E.U.A.C.).

REFERENCES

- BOURRET, R. unpubl. Les lézards de l'Indochine. Hanoi, unpublished manuscript.
- DAREVSKY, I. S. & ORLOV, N. L. 1994. *Vietnascincus rugosus*, a new genus and species of the *Dasia*-like arboreal skinks (Sauria: Scincidae) from Vietnam. *Russian Journal of Herpetology* 1(1): 37-41.
- DAREVSKY, I. S. & ORLOV, N. L. 1997. A new genus and species of scincid lizards from Vietnam: The first Asiatic skink with double rows of basal subdigital pads. *Journal of Herpetology* 31(3): 323-326.
- DAREVSKY, I. S. & ORLOV, N. L. 2005. New species of limb-reduced lygosomine skink genus *Leptoseps* Greer, 1997 (Sauria, Scincidae) from Vietnam. *Russian Journal of Herpetology* 12(1): 65-68.
- DAREVSKY, I. S. & ORLOVA, V. F. 1996. A new species of slender skinks *Lygosoma carinatum* (Sauria, Scincidae) from South Vietnam. *Zoologicheskyy Zhurnal*, Moscow 75(5): 791-795.
- HALL, T. A. 1999. BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. *Nucleic Acids Symposium Series* 41: 95-98.

- HONDA, M., OTA, H., KÖHLER, G., INEICH, I., CHIRIO, L., CHEN, S.-L. & HIKIDA, T. 2003. Phylogeny of the lizard subfamily Lygosominae (Reptilia: Scincidae), with special reference to the origin of the new world taxa. *Genes and Genetic Systems* 78: 71-80.
- HUELSENBECK, J. P. & RONQUIST, F. 2001. MRBAYES: Bayesian inference of phylogenetic trees. *Bioinformatics* 17: 754-755.
- MANTHEY, U. & GROSSMANN, W. 1997. Amphibien und Reptilien Südostasiens. Münster, Natur und Tier - Verlag.
- MAUSFELD, P. & SCHMITZ A. 2003. Molecular phylogeography, intraspecific variation and speciation of the Asian scincid lizard genus *Eutropis* Fitzinger, 1843, (Squamata: Reptilia: Scincidae): taxonomic and biogeographic implications. *Organisms, Diversity and Evolution* 3(3): 161-171.
- MAUSFELD, P., SCHMITZ, A., BÖHME, W., MISOF, B., VRCIBRADIC, D. & ROCHA, C.F.D. 2002. Phylogenetic affinities of *Mabuya atlantica* Schmidt, 1945, endemic to the Atlantic Ocean Archipelago of Fernando de Noronha (Brazil): necessity of partitioning the genus *Mabuya* Fitzinger, 1826 (Scincidae: Lygosominae). *Zoologischer Anzeiger* 241: 281-293.
- MITTLEMAN M. B. 1952. A generic synopsis of the lizards of the subfamily Lygosominae. *Smithsonian miscellaneous Collections* 117: 1-35.
- NGUYEN, V. S., HO, T. C. & NGUYEN, Q. T. 2005. A checklist of amphibians and reptiles of Vietnam. Hanoi, Nha xuất bản nông nghiệp.
- NYLANDER, J. A. A. 2005. MrModeltest 1.1b, Uppsala, Sweden.
- PALUMBI, S. R., MARTIN, A., ROMANO, S., McMILLAN, W. O., STICE, L. & GRABOWSKI, G. 1991. The simple fool's guide to PCR. Department of Zoology and Kewalo Marine Laboratory, Hawaii: 47 pp.
- POSADA, D. & CRANDALL, K. A. 1998. MODELTEST: testing the model of DNA substitution. *Bioinformatics* 14: 817-818.
- REEDER, T. W. 2003. A phylogeny of the Australian *Sphenomorphus* group (Scincidae: Squamata) and the phylogenetic placement of the crocodile skinks (*Tribolonotus*): Bayesian approaches to assessing congruence and obtaining confidence in maximum likelihood inferred relationships. *Molecular Phylogenetics and Evolution* 27: 384-397.
- SCHMITZ, A. 2003. Taxonomic and phylogenetic studies on scincid lizards (Reptilia: Scincidae). Unpubl. PhD thesis. University of Bonn, 262 pp.
- SCHMITZ, A., INEICH, I. & CHIRIO, L. 2005. Molecular review of the genus *Panaspis* sensu lato in Cameroon, with special reference to the status of the proposed subgenera. *Zootaxa* 863: 1-28.
- SMITH, M. A. 1935. The fauna of British India, including Ceylon and Burma. Reptilia and Amphibia. Vol. II. Sauria. London, Taylor & Francis Ltd.
- SMITH, M. A. 1937. A review of the genus *Lygosoma* (Scincidae: Reptilia) and its allies. *Records of the Indian Museum* 39(3): 213-234.
- SWOFFORD, D. L. 2002. PAUP*. Phylogenetic Analysis Using Parsimony (*and Other Methods). Version 4.0b10. Sinauer Associates, Sunderland, Massachusetts, USA.
- TAMURA, K. & NEI, M. 1993. Estimation of the number of nucleotide substitutions in the control region of mitochondrial DNA in humans and chimpanzees. *Molecular Biology and Evolution* 10: 512-526.
- TAYLOR, E. H. 1963. Lizards of Thailand. *University of Kansas Science Bulletin* 44(14): 687-1077.
- THOMPSON, J. D., GIBSON, T. J., PLEWNIAK, F., JEANMOUGIN F. & HIGGINS, D. G. 1997. The ClustalX windows interface: flexible strategies for multiple sequence alignment aided by quality analysis tools. *Nucleic Acids Research* 24: 4876-4882.
- WALSH, P. S., METZGER, D. A. & HIGUCHI, R. 1991. Chelex 100 as a medium for simple extraction of DNA for PCR-based typing from forensic material. *BioTechniques* 10(4): 506-513.

- WERNER, F. 1909. Über neue oder seltene Reptilien des Naturhistorischen Museums in Hamburg. 2 Eidechsen. *Jahrbuch der Hamburger wissenschaftlichen Anstalten* 27; 2. Beiheft, Mitteilungen aus dem Naturhistorischen Museum: 334 pp.
- ZIEGLER, T. & HERRMANN, H.-W. 2000. Preliminary list of the herpetofauna of the Phong Nha - Ke Bang area in Quang Binh province, Vietnam. *Biogeographica*, Paris 76(2): 49-62.
- ZIEGLER, T., HERRMANN, H.-W., VU, N. T., LE, K. Q., NGUYEN, T. H., CAO, X. C., LUU, M. T. & DINH, H. T. 2004. The amphibians and reptiles of the Phong Nha - Ke Bang National Park, Quang Binh Province, Vietnam. *Hamadryad* 28(1-2): 19-42.
- ZIEGLER, T. & LE, K. Q. 2005. A new species of reed snake, *Calamaria* (Squamata: Colubridae), from the central Truong Son (Annamite mountain range), Vietnam. *Zootaxa* 1042: 27-38.
- ZIEGLER, T. & LE, K. Q. 2006. A new natricine snake of the genus *Amphiesma* (Squamata: Colubridae: Natricinae) from the central Truong Son, Vietnam. *Zootaxa* 1225: 39-56.
- ZIEGLER, T., OHLER, A., VU NGOC THANH, LE KHAC QUYET, NGUYEN XUAN THUAN, DINH HUY TRI & BUI NGOC THANH. 2006. Review of the amphibian and reptile diversity of Phong Nha - Ke Bang National Park and adjacent areas, central Truong Son, Vietnam. In: VENCES, M., KÖHLER, J., ZIEGLER, T. & W. BÖHME (Hrsg.): *Herpetologia Bonnensis II*: 247-262. – Proceedings of the 13th Ordinary General Meeting of the Societas Europaea Herpetologica, Bonn: 262 pp.
- ZIEGLER, T., VU, N. T., BUI, N. T. 2005. A new water skink of the genus *Tropidophorus* from the Phong Nha - Ke Bang National Park, central Vietnam (Squamata: Sauria: Scincidae). *Salamandra* 41(3): 137-146.