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A new species of the *Gekko japonicus* group (Squamata: Sauria: Gekkonidae) from the border region between China and Vietnam

TRUONG QUANG NGUYEN[1,2,9], YING-YONG WANG[3], JIAN-HUAN YANG[4], TANJA LEHMANN[5], MINH DUC LE[6,7,8], THOMAS ZIEGLER[5] & MICHAEL BONKOWSKI[2]

[1]*Institute of Ecology and Biological Resources, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Hanoi, Vietnam. E-mail: nqt2@yahoo.com*

[2]*Department of Terrestrial Ecology, Zoological Institute, University of Cologne, Zülpicher Strasse 47b, D-50674 Cologne, Germany. Email: m.bonkowski@uni-koeln.de*

[3]*The Museum of Biology, Sun Yat-sen University, 135 Xingangxi Road, Guangzhou 510275, P. R. China. Email: wangyy@mail.sysu.edu.cn*

[4]*Kadoorie Conservation China, Kadoorie Farm and Botanic Garden, Lam Kam Road, Tai Po, Hong Kong SAR, P. R. China. E-mail: philautus@yahoo.com*

[5]*AG Zoologischer Garten Köln, Riehler Straße 173, D-50735 Köln, Germany. E-mail: lehmanntanja82@googlemail.com and ziegler@koelnerzoo.de*

[6]*Faculty of Environmental Sciences, Hanoi University of Science, Vietnam National University, 334 Nguyen Trai Road, Hanoi, Vietnam. Email: le.duc.minh@hus.edu.vn*

[7]*Centre for Natural Resources and Environmental Studies, Hanoi National University, 19 Le Thanh Tong, Hanoi, Vietnam*

[8]*Department of Herpetology, American Museum of Natural History, Central Park West at 79th Street, New York, New York 10024*

[9]*Corresponding author*

Abstract

We describe a new species of the genus *Gekko* on the basis of 25 specimens from southern China and northern Vietnam. *Gekko adleri* **sp. nov.** is distinguished from the remaining congeners by a combination of the following characters: size moderate (SVL<80 mm); nares in contact with rostral; internasal single, smaller than supranasal; postmentals enlarged; interorbital scales between anterior corners of the eyes 27–36; dorsal tubercle rows 7–11; ventral scales between mental and cloacal slit 168–190; midbody scale rows 123–144; ventral scale rows 35–44; subdigital lamellae on first toe 11–14, on fourth toe 11–15; finger and toe webbing present at base; tubercles absent on upper surface of fore limbs; tubercles on tibia 0–8; precloacal pores 17–21 in males; postcloacal tubercle single; tubercles present on dorsal surface of tail base; subcaudals enlarged; dorsal surface of body with four or five narrow light bands between shoulder and sacrum.

Key words: *Gekko*, phylogeny, taxonomy, Cao Bang Province, Guangxi Zhuang Autonomous Region

Introduction

The *Gekko japonicus* group is the most diverse group in the genus *Gekko* with a total of 19 recognized species, which have distributions in eastern Asia, from Japan throughout eastern China southward to Vietnam (Rösler *et al*. 2011). The members of this group are characterized by a moderate size; nare usually in contact with rostral; two or three nasals; 0–21 rows of dorsal tubercles; 0–32 precloacal pores; 1–4 postcloacal tubercles; the webbing between fingers and toes weakly to extensively developed; lateral folds without tubercles; enlarged subcaudals; and vertebral region with large, light flecks, blotches or bands (Rösler *et al.* 2011).

During recent field work in the karst forests of Guangxi Zhuang Autonomous Region, southern China and of Cao Bang Province, northern Vietnam, we collected a number of specimens of an unnamed gekkonid species, which can be assigned to the *Gekko japonicus* group based on morphological features and phylogenetic analysis. Herein, we describe it as a new species.

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Material and methods

Sampling. Field surveys were conducted in August 2011 in Jingxi County, Guangxi Zhuang Autonomous Region, China; and in May and in October 2011, and from April to May 2012 in Ha Lang and Trung Khanh districts, Cao Bang Province, Vietnam. Tissue samples were preserved separately in 95% ethanol and voucher specimens were fixed in approximately 85% ethanol, then later transferred to 70% ethanol for permanent storage. Specimens referred to in this paper are deposited in the collections of the Sun Yat-sen University (SYS), Guangzhou, China; the Institute of Ecology and Biological Resources (IEBR), Hanoi, Vietnam; the Vietnam National Museum of Nature (VNMN), Hanoi, Vietnam; and the Zoologisches Forschungsmuseum Alexander Koenig (ZFMK), Bonn, Germany.

Molecular data and phylogenetic analyses. We used the protocols of Le *et al.* (2006) for DNA extraction, amplification, and sequencing. A fragment of the mitochondrial gene 16S was amplified using the primer pair 16Sar + 16Sbr (Palumbi *et al.* 1991). After sequences were aligned by Clustal X v2 (Thompson *et al.* 1997), data were analyzed using maximum parsimony (MP) and Bayesian analysis (BA), as implemented in PAUP*4.0b10 (Swofford 2001) and MrBayes v3.2 (Huelsenbeck & Ronquist 2001), respectively. Settings for these analyses followed Le *et al.* (2006), except that the number of generations in the Bayesian analysis was increased to 1×10^7. The optimal model for nucleotide evolution was set to GTR+G as selected by Modeltest v3.7 (Posada & Crandall 1998). Nodal support was evaluated using Bootstrap replication (BP) as calculated in PAUP and posterior probability (PP) in MrBayes v3.2. Uncorrected pairwise divergences were calculated in PAUP*4.0b10. Nucleotide sequences from the new material were analyzed with those from morphologically similar species of the *Gekko japonicus* group (Rösler *et al.* 2011; Table 1). We selected *Gekko gecko* as the outgroup for our phylogenetic analyses (Table 1).

TABLE 1. Samples used in molecular analyses.

Species	Genbank No	Locality	Voucher information
Gekko gecko	AY282753	China	-
G. swinhonis	JQ906550	China	-
G. melli	JX624321	China, Guangdong Province	SYS r000437
G. subpalmatus	JX624320	China, Guangdong Province	SYS r000469
G. chinensis	KC710232	China, Guangdong Province	SYS r000464
Gekko **sp. nov.**	KC700622	China, Guangxi Province	SYS r000457
Gekko **sp. nov.**	KC700623	Vietnam, Cao Bang Province	IEBR A.2012.24
Gekko **sp. nov.**	KC700624	Vietnam, Cao Bang Province	IEBR A.2012.25
G. palmatus	KC710235-710237	Vietnam, Vinh Phuc Province	IEBR 3224a, 3224b, 3224c
G. palmatus	KC710234, 710238-710240	Vietnam, Lang Son Province	IEBR 2474, 3620, 3622, 3623
G. palmatus	KC710233	Vietnam, Bac Giang Province	IEBR 3672
G. palmatus	KC710241	Vietnam, Quang Ninh Province	IEBR A.0807

Morphological characters. Measurements were taken with digital calipers to the nearest 0.1 mm. The following abbreviations were used: Measurements: SVL = snout vent length (from tip of snout to anterior margin of cloaca), TaL = tail length (from posterior margin of cloaca to tip of tail), AG = distance between axilla and groin, HL = maximum head length (from tip of snout to posterior margin of auricular opening), HW = maximum head width, HH = maximum head height, SE = distance from snout tip to anterior corner of eye, EE = distance between posterior margin of eye to posterior margin of ear opening, RW = maximum rostral width, RH = maximum rostral height, MW = maximum mental width, ML = maximum mental length. Scalation: CS = ciliary spines, N = nasals (nasorostrals, supranasals, postnasals), I = intersupranasals (scales between supranasals, in contact with rostral), SPL = supralabials, IFL = infralabials, IO = interorbitals (number of scales in a line between anterior corners of eyes), PO = preorbitals (number of scales in a line from nostril to anterior corner of the eye), PM = postmentals, GP = gulars bordering the postmentals, DTR = dorsal tubercle rows at midbody, GSDT = granules surrounding dorsal tubercles, SMC = scales in a line from mental to the front of cloacal slit, SR = scale rows at midbody (includung

ventral scales), V = ventral scale rows at midbody, LF1 = subdigital lamellae under first finger, LF4 = subdigital lamellae under fourth finger, LT1 = subdigital lamellae under first toe, LT4 = subdigital lamellae under fourth toe, PP = precloacal pores (in males), PAT = postcloacal tubercles. Bilateral scale counts were given as left/right.

Multivariate analysis was conducted for examining overall morphological variation among species of the *Gekko japonicus* group, including the new species. We selected 25 of the 27 morphological characters, that were used by Rösler et al. (2011), for correspondence analysis (CA). All statistical analyses were performed with the PAST Statistics software version 2.17 (Hammer *et al.*, 2001).

Stomach content analysis. The stomachs of six preserved specimens were investigated for prey items. Remains of prey items were photographed with a digital microscope (Keyence VHX-500F). We followed Borror *et al.* (1992) for taxonomic identification of insects.

Results

Phylogenetic analyses. The final matrix consists of 593 aligned base pairs, of which 96 were parsimony informative. The genetic differences between species of some representatives of the *Gekko palmatus* group range from ca. 2.3% (between *Gekko* **sp. nov.** and *G. palmatus* Boulenger) to a maximum of ca. 16.8% (between *Gekko* **sp. nov.** and *G. swinhonis* Günther) (Table 2). MP analysis of the dataset recovered two most parsimonious trees with 266 steps (CI = 0.75; RI = 0.79; Fig. 1). In the Bayesian analysis, -ln*L* scores reached stasis after 7,000 generations in both runs. Most nodes were strongly supported by both the maximum parsimony and Bayesian analyses (Bootstrap value ≥ 70%, Bayesian posterior probability ≥ 95%), except for two nodes, one receiving a BP value of 63% and becoming unresolved in the Bayesian analysis, and the other receiving a strong BP value of 77%, but only a weak PP value of 88%.

TABLE 2. Uncorrected ("p") distance matrix showing pairwise genetic divergence (16S) between species of the genus *Gekko* in the analysis.

species name	1	2	3	4	5	6	7
1. *G. palmatus*	-						
2. *Gekko* **sp. nov.**	2.3–3.2	-					
3. *G. chinensis*	4.6–5.2	4.8–5.3	-				
4. *G. gecko*	15.7–16.3	15.4–16.4	18.0	-			
5. *G. melli*	14.2–14.7	14.4–14.8	13.9	19.2	-		
6. *G. subpalmatus*	13.9–14.6	14.1–14.8	14.7	19.4	6.6	-	
7. *G. swinhonis*	16.2–16.6	16.0–16.8	16.7	16.7	13.9	14.7	-

Morphological comparisons. We compared the undescribed gecko species from China and Vietnam with all other members of the *Gekko japonicus* group based on examination of specimens (see Appendix) and data obtained from the literature (Boulenger 1907; Ota *et al.* 1995; Rösler *et al*. 2005, 2010, 2011; Yang *et al*. 2012).

Both correspondence and cluster analyses revealed that the new *Gekko* species is closely related to *G. palmatus* and *G. chinensis* Gray (Figs. 2−3). The correspondence analysis also showed eigenvalues of 0.0115 (x-axis) and 0.008 (y-axis), respectively. The distance index (1-*r* of Pearson's correlation) among the species of the *G. japonicus* group varies from 0.0006 (between *G. hokouensis* Pope and *G. japonicus* (Schlegel)) to 0.1206 (between *G. palmatus* and *G. tawaensis* Okada). The new species is separated from *G. chinensis* and *G. palmatus* by a distance index of 0.0037 and 0.0018, respectively, which is lower than between *G. chinensis* and *G. palmatus* (0.0052), but significantly higher than between *G. hokouensis* and *G. japonicus* (0.0006) as well as between *G. shibatai* Toda, Sengoku, Hikida & Ota and *G. vertebralis* Toda, Sengoku, Hikida & Ota (0.0010) (see Table 3).

Morphologically, the new *Gekko* species differs from the previously named species of the *G. japonicus* group as follows: from *G. auriverrucosus* Zhou & Liu by having a nostril touching rostral (not touching in *G. auriverrucosus*), postmentals enlarged (not enlarged in *G. auriverrucosus*), fewer dorsal tubercle rows (7–11 vs. 16–20 in *G. auriverrucosus*), more lamellae under first and fourth toes (11−14 vs. 6−8 and 11–15 vs. 6–8,

respectively, in *G. auriverrucosus*), more precloacal pores in males (17–21 vs. 8–11 in *G. auriverrucosus*), and fewer postcloacal tubercles (one vs. two or three in *G. auriverrucosus*), and tubercles on dorsal surface of fore limbs absent (present in *G. auriverrucosus*); from *G. canhi* Rösler, Nguyen, Doan, Ho & Ziegler by having fewer interorbitals (27–36 vs. 49–50 in *G. canhi*), fewer scale rows around midbody (123–144 vs. 205–227 in *G. canhi*), fewer ventral scale rows (35–44 vs. 49–51 in *G. canhi*), more precloacal pores in males (17–21 vs. five in *G. canhi*), and fewer postcloacal tubercles (one vs. two or three in *G. canhi*); from *G. chinensis* Gray by having an internasal smaller than supranasals (vs. as large as or larger in *G. chinensis*) and more lamellae under first toe (11–14 vs. 8–10 in *G. chinensis*); from *G. hokouensis* Pope by having postmentals enlarged (vs. not enlarged in *G. hokouensis*), fewer dorsal tubercle rows (7–11 vs. 12–18 in *G. hokouensis*), fewer subdigital lamellae under fourth toe (11–15 vs. 15–18), and more precloacal pores in males (17–21 vs. 5–9 in *G. hokouensis*); from *G. japonicus* (Schlegel) by having postmentals enlarged (vs. not enlarged in *G. japonicus*), more precloacal pores in males (17–21 vs. 6–9 in *G. japonicus*), and fewer postcloacal tubercles (one vs. 2–4 in *G. japonicus*); from *G. liboensis* Zhao & Li by having an internasal present (vs. absent in *G. liboensis*), postmentals enlarged (vs. not enlarged in *G. liboensis*), fewer interorbitals (27–36 vs. 40 in *G. liboensis*), and more subdigital lamellae under first and fourth toes (11–14 vs. eight and 11–15 vs. nine, respectively, in *G. liboensis*); from *G. melli* Vogt by having postmentals distinctly enlarged (vs. not enlarged in *G. melli*), dorsal tubercles present (vs. absent in *G. melli*), fewer scales around midbody (123−144 vs. 147−160 in *G. melli*), and fewer preclocal pores (17−21 vs. 9−11 in *G. melli*); from *G. palmatus* Boulenger by having fewer precloacal pores in males (17–21 vs. 23–30 in *G. palmatus*) and a dorsum with narrow light crossbands instead of large vertebral blotches in *G. palmatus*; from *G. scabridus* Liu & Zhou by having postmentals enlarged (vs. not enlarged in *G. scabridus*), fewer dorsal tubercles (7–11 vs. 17–21 in *G. scabridus*), more subdigital lamellae under first and fourth toes (11–14 vs. 6–9 and 11–15 vs. 7–9, respectively, in *G. scabridus*), more precloacal pores in males (17–21 vs. 10–15 in *G. scabridus*), and tubercles on dorsal surface of fore limbs absent (vs. present in *G. scabridus*); from *G. scientiadventura* Rösler, Ziegler, Vu, Hermann & Böhme by having an internasal present (vs. absent in *G. scientiadventura*), fewer interorbitals (27–36 vs. 41–51 in *G. scientiadventura*), dorsal tubercles present (vs. absent in *G. scientiadventura*), more scales from mental to cloacal slit (168–190 vs. 118–140 in *G. scientiadventura*), more precloacal pores in males (17–21 vs. 5–8 in *G. scientiadventura*), and fewer postcloacal tubercles (one vs. two or three in *G. scientiadventura*); from *G. shibatai* Toda, Sengoku, Hikida & Ota by having fewer interorbitals (27–36 vs. 37–52 in *G. shibatai*), postmentals enlarged (vs. not enlarged in *G. shibatai*), and more precloacal pores in males (17–21 vs. 0–3 in *G. shibatai*); from *G. similignum* Smith by having postmentals enlarged (vs. not enlarged in *G. similignum*), fewer interorbitals (27–36 vs. 46–48 in *G. similignum*), and fewer midbody scale rows (123−144 vs. 144−153); from *G. subpalmatus* Günther by having postmentals enlarged (vs. not enlarged in *G. subpalmatus*), dorsal tubercles present (vs. absent in *G. subpalmatus*), fewer ventral scale rows (35–44 vs. 48 in *G. subpalmatus*), more subdigital lamellae under first and fourth toes (11–14 vs. 7–9 and 11–15 vs. 7–10, respectively, in *G. subpalmatus*), and more precloacal pores in males (17–21 vs. 5–11 in *G. subpalmatus*); from *G. swinhonis* Günther by having postmentals enlarged (vs. not enlarged in *G. swinhonis*), more interorbitals (27–36 vs. 23–24 in *G. swinhonis*), more subdigital lamellae under first and fourth toes (11–14 vs. 6–9 and 11−15 vs. 6−9 in *G. swinhonis*), more precloacal pores in males (17–21 vs. 7–9 in *G. swinhonis*), and fewer postcloacal tubercles (one vs. two or three in *G. swinhonis*); from *G. taibaiensis* Song by having more subdigital lamellae under first and fourth toes (11–14 vs. six or seven and 11–15 vs. seven or eight, respectively, in *G. taibaiensis*) and more precloacal pores in males (17–21 vs. 4–6 in *G. taibaiensis*); from *G. tawaensis* Okada by having postmentals enlarged (vs. not enlarged in *G. tawaensis*), a single internasal (vs. two in *G. tawaensis*), dorsal tubercles present (absent in *G. tawaensis*), and precloacal pores present in males (absent in *G. tawaensis*); from *G. vertebralis* Toda, Sengoku, Hikida & Ota by having postmentals enlarged (vs. not enlarged in *G. vertebralis*) and more precloacal pores in males (17–21 vs. absent or one in *G. vertebralis*); from *G. wenxianensis* Zhou & Wang by having more subdigital lamellae under first and fourth toes (11–14 vs. six and 11–15 vs. nine, respectively, in *G. wenxianensis*), more precloacal pores in males (17–21 vs. 6–8 in *G. taibaiensis*), and fewer postcloacal tubercles (one vs. two or three in *G. wenxianensis*); and from *G. yakuensis* Matsui & Okada by having postmentals enlarged (vs. not enlarged in *G. yakuensis*), more subdigital lamellae under first toe (11–14 vs. 10 in *G. yakuensis*), and more precloacal pores in males (17–21 vs. 6–8 in *G. yakuensis*) (see Table 4).

Based on the results of molecular analyses and morphological comparisons, we argue that the gekkonid collection from Guangxi Zhuang Autonomous Region and from Cao Bang Province represents a new species, which is described below.

TABLE 3. The distance index (1-*r* of pearson's correlation) among the species of the *G. japonicus* group based on morphological comparisons.

Gekko	sp. nov.	*canhi*	*chinensis*	*japonicus*	*palmatus*	*auriverrucosus*	*hokouensis*	*liboensis*	*melli*	*scabridus*	*scientiadventura*	*shibatai*	*similignum*	*subpalmatus*	*swinhonis*	*taibaiensis*	*tawaensis*	*vertebralis*	*wenxianensis*	*yakuensis*
sp. nov.	0																			
canhi	0.0458	0																		
chinensis	0.0037	0.0367	0																	
japonicus	0.0023	0.0385	0.0059	0																
palmatus	0.0018	0.0518	0.0052	0.0068	0															
auriverrucosus	0.0417	0.0442	0.0663	0.0281	0.0626	0														
hokouensis	0.0031	0.0407	0.0069	0.0006	0.0072	0.0255	0													
liboensis	0.0156	0.0049	0.0138	0.0125	0.0179	0.0291	0.0226	0												
melli	0.0033	0.0323	0.0053	0.0022	0.0072	0.0668	0.0040	0.0171	0											
scabridus	0.0333	0.0391	0.0503	0.0252	0.0507	0.0023	0.0236	0.0212	0.0582	0										
scientiadventura	0.0308	0.0104	0.0231	0.0257	0.0345	0.1126	0.0270	0.0374	0.0186	0.1010	0									
shibatai	0.0159	0.0127	0.0137	0.0091	0.0252	0.0775	0.0095	0.0260	0.0123	0.0713	0.0076	0								
similignum	0.0127	0.0086	0.0104	0.0108	0.0219	0.1047	0.0132	0.0455	0.0122	0.0880	0.0096	0.0163	0							
subpalmatus	0.0363	0.0292	0.0532	0.0250	0.0534	0.0645	0.0410	0.0148	0.0094	0.0556	0.0320	0.0459	0.0722	0						
swinhonis	0.0264	0.0288	0.0567	0.0153	0.0442	0.0230	0.0257	0.0149	0.0182	0.0213	0.0573	0.0611	0.0979	0.0124	0					
taibaiensis	0.0343	0.0111	0.0607	0.0103	0.0652	0.0069	0.0154	0.0038	0.0056	0.0089	0.0388	0.0442	0.0901	0.0039	0.0071	0				
tawaensis	0.0793	0.0290	0.1130	0.0438	0.1206	0.0990	0.0644	0.0283	0.0256	0.1032	0.0180	0.0288	0.0965	0.0278	0.0421	0.0197	0			
vertebralis	0.0158	0.0121	0.0154	0.0094	0.0246	0.0881	0.0108	0.0296	0.0118	0.0829	0.0084	0.0010	0.0177	0.0448	0.0628	0.0473	0.0227	0		
wenxianensis	0.0450	0.0291	0.0519	0.0211	0.0694	0.0194	0.0268	0.0068	0.0333	0.0220	0.0379	0.0187	0.0367	0.0206	0.0124	0.0075	0.0432	0.0280	0	
yakuensis	0.0268	0.0074	0.0492	0.0031	0.0563	0.0166	0.0028	0.0113	0.0065	0.0206	0.0039	0.0092	0.0336	0.0114	0.01402	0.0104	0.0158	0.0137	0.0092	0

TABLE 4. Morphological comparisons among the species of the *Gekko japonicus* group (modified after Rösler *et al*. 2011, abbreviations defined in text, - = data unavailable).

Character	*Gekko* **sp. nov.**	*auriverrucosus*	*canhi*	*chinensis*	*japonicus*	*hokouensis*	*liboensis*
Maximum SVL (mm)	75.3	69	99.2	72	74	70	85
SPL (min)	10	9	14	10	9	10	12
SPL (max)	15	11	14	14	13	14	12
IFL (min)	9	9	10	9	8	8	11
IFL (max)	13	11	12	13	13	11	11
Nostril touching rostral	1	0	1	1	1	1	1
N (min)	3	3	3	2	3	3	3
N (max)	3	3	3	3	3	3	3
I (min)	1	0	1	1	0	1	0
I (max)	1	1	1	1	1	2	0
IO (min)	27	25	49	35	32	30	40
IO (max)	36	25	50	48	35	33	40
Postmentals (enlarged = 1, not enlarged = 0)	1	0	1	1	0	0	0
DTR (min)	7	16	11	10	9	12	10
DTR (max)	11	20	12	10	14	18	10
SMC (min)	168	-	168	156	169	153	-
SMC (max)	190	-	170	167	188	174	-
SR (min)	123	-	205	118	130	119	-
SR (max)	144	-	227	140	144	130	-
V (min)	35	-	49	37	39	36	-
V (max)	44	-	51	39	44	43	-
LT 1 (min)	11	6	13	8	10	8	8
LT1 (max)	14	8	16	10	12	11	8
LT 4 (min)	11	6	14	9	14	15	9
LT4 (max)	15	8	17	12	16	18	9
Toes webbed	1	0	0	1	0	0	0
Tubercles on fore-limbs (present = 1, absent = 0)	0	1	0	0	1	0	0
Tubercles on hind limbs (present = 1, absent = 0)	1	1	1	1	1	0	0
PP (in males, min)	17	8	5	17	6	5	-
PP (in males, max)	21	11	5	27	9	9	-
PAT (min)	1	2	2	1	2	1	1
PAT (max)	1	3	3	1	4	1	1
Tubercles on dorsal surface of tail (present = 1, absent = 0)	1	1	0	1	1	1	-
Subcaudals enlarged	1	1	1	1	1	1	-
Marking on upper side of head	1	0	0	0	0	0	0
Back flecked or blotched	0	0	1	1	0	1	0
Back banded	1	1	1	0	1	0	1
Tail banded	1	1	1	1	1	1	-

continued.

Character	*melli*	*palmatus*	*scabridus*	*scientiadventura*	*shibatai*	*similignum*
Maximum SVL (mm)	84.6	79.7	77	73	70.9	58.9
SPL (min)	10	11	9	12	10	12
SPL (max)	13	15	11	14	13	14
IFL (min)	9	9	9	9	10	11
IFL (max)	12	13	11	13	14	11
Nostril touching rostral	1	1	1	1	1	1
N (min)	3	3	3	3	3	3
N (max)	3	3	3	3	3	3
I (min)	1	0	1	0	0	1
I (max)	1	3	2	0	1	1
IO (min)	34	27	30	41	37	46
IO (max)	40	36	30	51	52	48
Postmentals (enlarged = 1, not enlarged = 0)	0	1	0	1	0	0
DTR (min)	0	4	17	0	5	11
DTR (max)	0	12	21	0	14	11
SMC (min)	181	160	-	118	-	-
SMC (max)	200	194	-	140	-	-
SR (min)	147	116	-	139	114	144
SR (max)	160	147	-	143	134	153
V (min)	43	36	-	38	-	-
V (max)	49	47	-	48	-	-
LT 1 (min)	10	10	6	12	-	11
LT1 (max)	12	13	9	15	-	13
LT 4 (min)	11	10	7	14	9	12
LT4 (max)	14	16	9	17	16	14
Toes webbed	1	1	0	1	0	1
Tubercles on fore-limbs (present = 1, absent = 0)	0	0	1	0	0	0
Tubercles on hind limbs (present = 1, absent = 0)	0	0	1	0	0	0
PP (in males, min)	9	23	10	5	0	17
PP (in males, max)	11	30	15	8	3	17
PAT (min)	1	1	1	2	1	1
PAT (max)	1	1	3	3	1	1
Tubercles on dorsal surface of tail (present = 1, absent = 0)	0	1	1	0	1	1
Subcaudals enlarged	1	1	1	1	1	1
Marking on upper side of head	1	0	0	1	0	0
Back flecked or blotched	0	1	1	1	1	1
Back banded	1	1	1	0	0	0
Tail banded	1	1	1	1	1	1

continued.

Character	*subpalmatus*	*swinhonis*	*taibaiensis*	*tawaensis*	*vertebralis*	*wenxianensis*	*yakuensis*
Maximum SVL (mm)	72	66	69	71	69.2	59	72
SPL (min)	8	7	9	13	10	12	12
SPL (max)	12	12	10	13	15	12	13
IFL (min)	7	7	8	15	10	11	9
IFL (max)	12	11	10	15	15	11	13
Nostril touching rostral	1	1	1	1	1	1	1
N (min)	3	-	-	-	3	-	3
N (max)	3	-	-	-	3	-	3
I (min)	1	-	-	2	0	1	1
I (max)	1	-	-	2	2	1	1
IO (min)	32	23	28	-	35	-	-
IO (max)	32	24	28	-	50	-	-
Postmentals (enlarged = 1, not enlarged = 0)	0	0	-	0	0	-	0
DTR (min)	0	6	-	0	2	10	-
DTR (max)	0	8	-	0	12	10	-
SMC (min)	-	-	-	-	-	-	-
SMC (max)	-	-	-	-	-	-	-
SR (min)	-	-	-	-	112	-	-
SR (max)	-	-	-	-	139	-	-
V (min)	48	40	-	-	-	42	-
V (max)	48	40	-	-	-	44	-
LT 1 (min)	7	6	6	10	-	6	10
LT1 (max)	9	9	7	10	-	6	10
LT 4 (min)	7	6	7	12	9	9	15
LT4 (max)	10	9	8	12	17	9	15
Toes webbed	1	0	-	0	0	0	0
Tubercles on fore-limbs (present = 1, absent = 0)	0	1	-	0	0	0	0
Tubercles on hind limbs (present = 1, absent = 0)	0	1	-	0	0	1	0
PP (in males, min)	5	7	4	0	0	6	6
PP (in males, max)	11	9	6	0	1	8	8
PAT (min)	1	2	-	1	1	2	1
PAT (max)	1	3	-	1	2	3	1
Tubercles on dorsal surface of tail (present = 1, absent = 0)	0	-	-	0	0	-	1
Subcaudals enlarged	1	1	-	1	1	-	1
Marking on upper side of head	0	0	0	0	0	0	0
Back flecked or blotched	1	1	1	1	1	1	1
Back banded	1	0	1	1	0	0	0
Tail banded	1	1	1	1	-	1	1

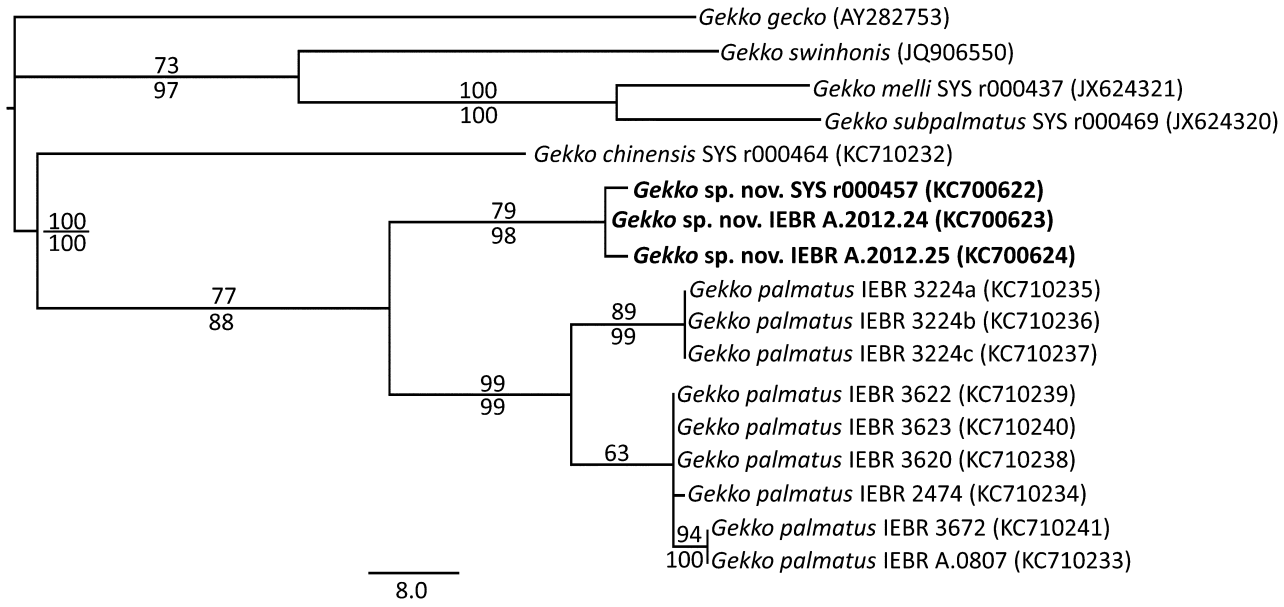

FIGURE 1. One of the two most parsimonious maximum parsimony trees based on the partial 16S gene. Number above and below branches are bootstrap values (>50%) and Bayesian posterior probabilities, respectively.

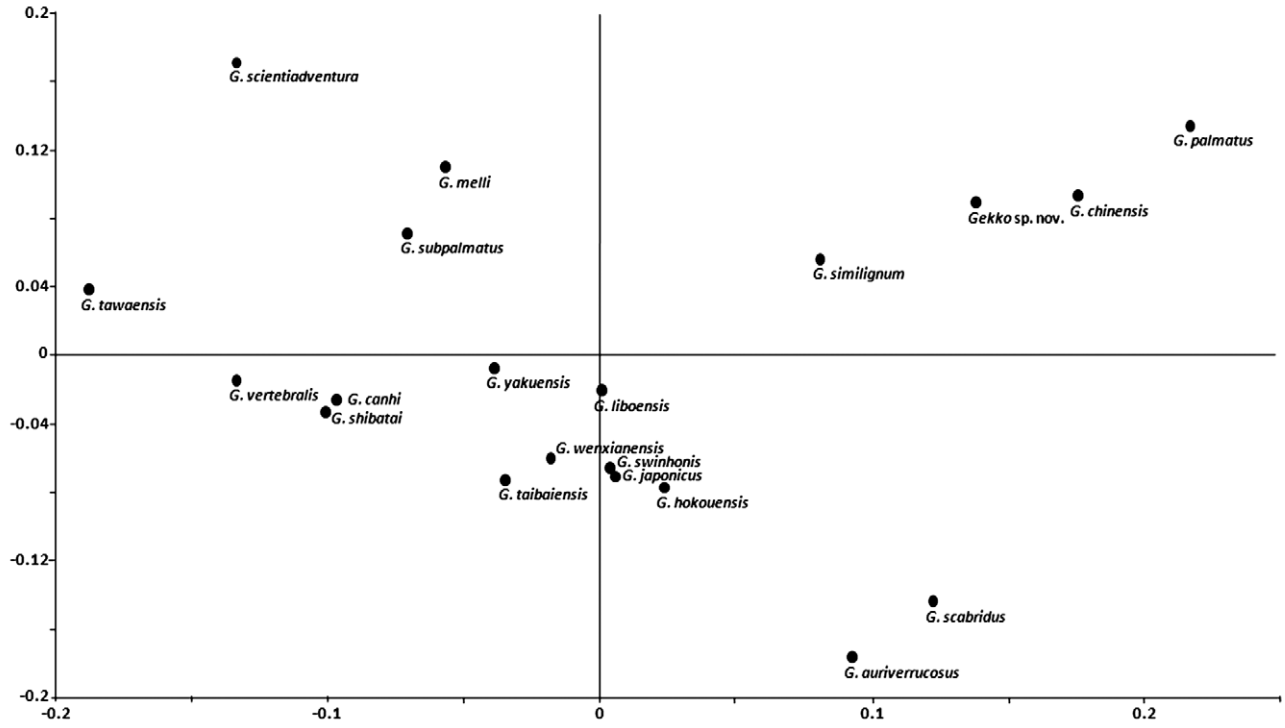

FIGURE 2. Correspondence analysis showing species association of the *Gekko japonicus* group based on morphological comparison.

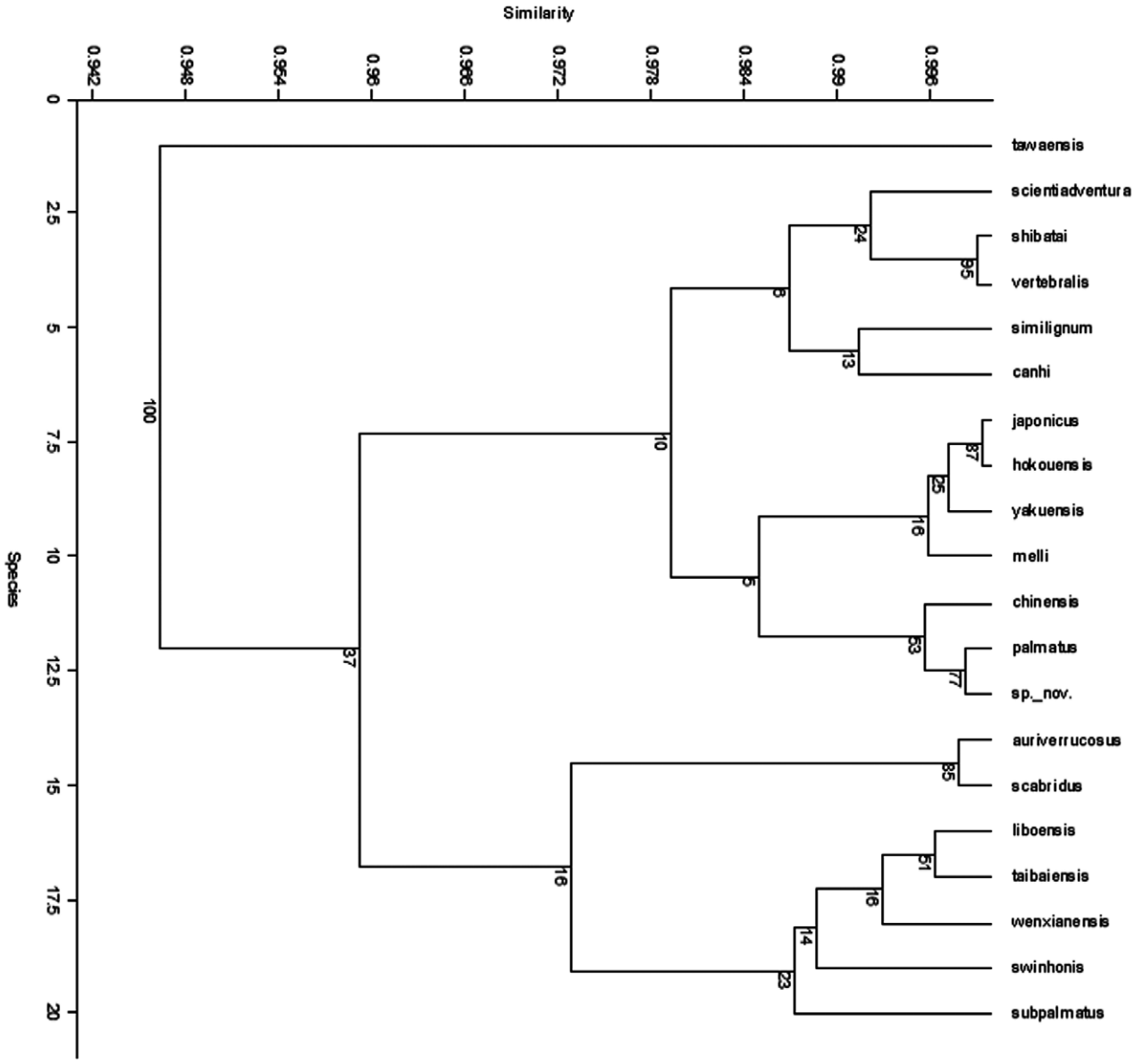

FIGURE 3. Cluster analysis showing species correlation of the *Gekko japonicus* group based on morphological comparison (Bootstrap replication: 1000).

***Gekko adleri* sp. nov.**
(Figs. 4 and 5)

Holotype: IEBR A.2012.24, adult male, from karst forest near Ban Coong Village (22º43.666'N, 106º39.054'E, at an elevation of 588 m a.s.l.), in Duc Quang Commune, Ha Lang District, Cao Bang Province, northern Vietnam, collected on 15 October 2011 by T. Q. Nguyen and C. T. Pham.

Paratypes (13 adult males, 7 adult females, 4 subadults): Seven specimens from Tongling Canyon, Qingzhou City, Guangxi Zhuang Autonomous Region, China (23º00.185'N, 106º40.037'E, at elevations between 450−550 m): SYS r000457, adult male, collected by Jian-Huan Yang (JHY hereafter), Run-Lin Li (RLL hereafter) at 2:35 on 20 August 2011; SYS r000263, adult male, collected by JHY at 17:30 on 6 August 2010; SYS r000458, adult female, collected by JHY and RLL at 1:32 on 20 August 2010; SYS r000456, adult male, collected by JHY and RLL at 1:44 on 20 August 2011; SYS r000459, SYS r000460−r0000461, subadult males, collected by JHY and RLL between 1:21−3:00 on 20 August 2011.

FIGURE 4. Dorsal view of the male holotype of *Gekko adleri* **sp. nov.** (IEBR A.2012.24) from Cao Bang Province, Vietnam (A) and the male paratype (SYS r000457) from Guangxi Zhuang Autonomous Region, China (B). Photos by T. Q. Nguyen and J. H. Yang.

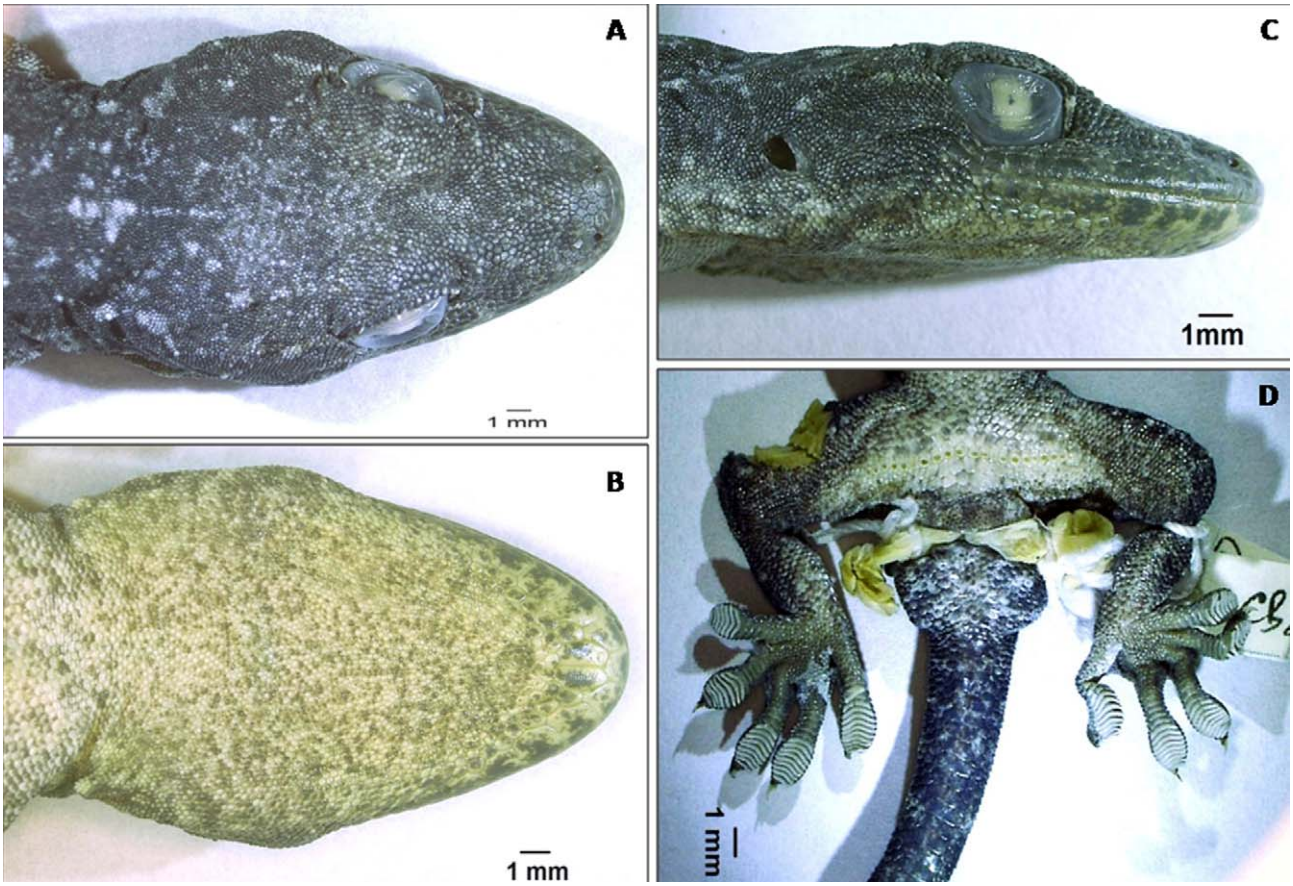

FIGURE 5. Dorsal view (A), ventral view (B) and lateral view (C) of the head, and precloacal region and ventral view of tail (D) of the holotype of *Gekko adleri* **sp. nov.** (IEBR A.2012.24). Photos T. Q. Nguyen.

Seventeen specimens from Cao Bang Province, Vietnam: In Ha Lang District: one subadult ZFMK 93993 collected on 18 May 2011 by T. Ziegler and T. Q. Nguyen in Thanh Nhat Commune (22º41.267'N, 106º40.275'E, at an elevation of 380 m); three males IEBR A.2012.25–2012.27 and one female IEBR A.2012.28 collected on 13, 15, and 16 October 2011 by T. Q. Nguyen, C. T. Pham, and D. T. Le near Ban Coong Village, Duc Quang Commune (22º43.153'N, 106º39.540'E, at elevations between 420–480 m); one male VNMN A.2012.4 collected on 17 October 2011 by T. Q. Nguyen, C. T. Pham, and D. T. Le near Ban Man Village, Duc Quang Commune (22º44.146'N, 106º39.044'E, at an elevation of 520 m); two males VNMN A.2012.5–2012.6 collected on 7 and 9 April 2012 by TQN, H.T. An, T. Lehmann, and S. Herbst (TQN *et al.* hereafter) near Ban Tao Village and Lung Tung Village, Kim Loan Commune (22°43.908'N, 106°36.779'E, at an elevation of 473 m); one female ZFMK 93994 collected on 10 April 2012 by TQN *et al*. near Ban Chao Village, An Lac Commune (22°43.272'N, 106°36.875'E, at an elevation of 446 m); one male ZFMK 93995 and one female ZFMK 93996 collected on 13 April 2012, and two males ZFMK 93997–93998 and one female ZFMK 93999 collected on 5, 22 and 24 May 2012, all by TQN *et al.* near Ban Coong Village, Duc Quang Commune (22°43.342'N, 106°39.962'E, at an elevation of 454 m). In Trung Khanh District: one male IEBR A.2012.29 collected on 19 April 2012 by TQN *et al*. near Lung Chuong Village, Ngoc Chung Commune (22°52.647'N, 106°28.116'E, at an elevation of 694 m a.s.l.), one female IEBR A.2012.30 and one male IEBR A.2012.31 collected on 20 and 21 April 2012 by TQN *et al*. near Ban Hau, Cao Thang Commune (22°47.989'N, 106°34.265'E, at an elevation of 576 m).

Description of holotype. Size moderate, SVL 74.5 mm, TaL 81.6 mm, AG 34.6 mm; head longer than wide (HL 20.8 mm, HW 15.6 mm); rostral rectangular, wider than high (RW 3.4 mm, RH 1.7 mm) and wider than mental (MW 1.7 mm), without suture; supralabials 13/13; nares in contact with rostral, first supralabial, supranasal, and two nasals posteriorly; upper nasal smaller than lower nasal; internasal single, rectangular, half as large as supranasal; snout medially with flat, elongate cavity; lateral snout scales oval, somewhat convex, juxtaposed, two times larger than those in rostral and interorbital region; preorbitals 17 or 18; interorbitals 30; pupil vertical; upper

ciliar scales 2 times as large as medial snout scales, 28/29 in number, 4/5 spinous tubercles posteriorly; a skin fold running from the last supralabial, backward about half way to tympanum; ear opening oblique, oval, about 35% of the eye diameter (maximum tympanum diameter 1.7 mm, horizontal eye diameter 4.8 mm), with a skin fold above; nuchal scales granular, as large as those in interorbital region; temporal region with several tubercles above tympanum; mental pentagonal, as wide as long (MW 1.7 mm, ML 1.6), smaller than first infralabials; infralabials 10/10; postmentals 2, trapezoidal, twice longer than wide, and longer than length of mental, in contact with mental and first infralabials anteriorly, medial suture between postmentals longer than the length of mental; postmental in contact with 6 gular scales posteriorly, outer gular scales larger than inner scales; dorsal tubercles 2–3 times as large as adjoining dorsal scales, round to oval, convex, smooth, surrounded by 8–9 dorsal scales, in 10 semiregular longitudinal rows at midbody; lateral fold weakly developed, without tubercles; ventrals between lateral folds 37; scales around midbody in 136 rows; ventral scales in a line between mental and cloacal slit 185; scales on upper and lower arm slightly enlarged; tubercles absent on dorsal surface of forelimbs; scales on anterior and ventral parts of thigh larger than those on dorsal and posterior parts; enlarged femoral scales absent; dorsal surface of tibia covered by granular scales, with 6 conical tubercles on each side; fingers and toes webbed basally (about 1/5); claws sheathed by 3 scales; subdigital lamellae under first finger 12/12, under fourth finger 15/13, under first toe 12/12, under fourth toe 13/13; precloacal pores 20, in an angular series; enlarged scales posterior to precloacal pores in 3 rows; postcloacal tubercle 1/1, blunt; tail not thickened at base, with some tubercles on dorsal surface of tail base; dorsal caudal scales as approximately twice the size of dorsal scales, squarish, flat, in regular transverse rows; third whorl in width of 8 dorsal scales; subcaudals flat, enlarged.

TABLE 5. Measurements (in mm) of the type series of *Gekko adleri* **sp. nov.** (Abbreviations defined in text, STDEV: standard deviation).

	Holotype IEBR A.2012.24	Males (holotype and paratypes, n = 14)				Females (paratypes, n = 7)				Subadults (paratypes, n = 4)			
		Min	Max	Average	STDEV	Min	Max	Average	STDEV	Min	Max	Average	STDEV
SVL	74.5	58.4	75.0	69.0	5.62	61.4	75.3	69.0	5.72	29.5	48.2	35.2	8.75
TaL	81.6	62.5	82.6	74.0 (n = 8)	8.23	70.0	72.4	71.2 (n = 2)	1.65	28.0	51.1	36.7 (n =3)	12.57
AG	34.6	26.8	34.75	31.5	3.07	27.1	34.4	30.1	3.08	11.6	19.8	15.2	3.38
HL	20.8	16.0	20.8	18.9	1.50	17.0	19.9	18.7	1.20	8.4	13.3	10.3	2.11
HW	15.6	12.1	15.6	14.2	1.22	12.9	14.9	13.9	0.69	6.2	9.4	7.3	1.41
HH	8	6.1	8.5	7.3	0.73	6.0	7.6	7.0	0.61	3.7	4.8	4.0	0.52
SE	9.5	7.3	9.5	8.6	0.78	7.2	8.9	8.4	0.72	4.5	5.8	4.9	0.66
EE	7.2	5.0	7.2	6.2	0.69	5.1	6.6	6.1	0.65	2.7	4.0	3.2	0.58
RW	3.4	2.8	3.6	3.2	0.29	2.9	3.3	3.1	0.18	1.6	2.2	1.8	0.26
RH	1.7	1.1	1.7	1.4	0.20	1.1	1.5	1.3	0.17	0.7	0.9	0.8	0.10
MW	1.7	1.5	2.0	1.7	0.17	1.6	2.1	1.8	0.19	0.9	1.1	1.0	0.09
ML	1.2	1	1.6	1.3	0.21	1.1	1.5	1.3	0.17	0.8	1.1	0.9	0.14

Coloration in life: Dorsal surface of head, body, limbs, and tail blackish grey; snout and interorbital region vermiculate; some small light spots present in temporal region and lateral sides of neck; lower jaw with some light bars; dorsal neck with a light grey blotch; dorsum without vertebral stripe, with five narrow light bands between shoulder and sacrum; some light spots present along lateral sides between limb insertions; a row of light spots present along lateral folds; limbs with small light spots and bars; dorsal tail with 9 light bands; throat, venter, and precloacal region yellowish cream with dark marbling; under surface of tail dark grey, posterior part with two narrow light bands. Coloration in preserved specimens is similar to coloration in life but with a paler venter.

Variation. Measurements and scalation characters of the paratypes are given in Tables 5 and 6. The scale counts vary among the type series: supralabials from 10–14, infralabials from 9–13, interobitals from 27–36, and scale rows around midbody from 123–144. Tubercles on dorsal surface of the tibiae are absent in three specimens (IEBR A.2012.26, A.2012.29, and ZFMK 93998). Ground color on upper surface of head, body and tail is also different among each individual from yellowish grey to blackish grey.

Etymology. We name the new species in honor of Professor Dr Kraig Adler, Cornell University (New York, USA), in recognition of his contribution to herpetological research in China and Vietnam. As common names we suggest Adler's Gecko (English), Adlers Gecko (German), and Tắc kè ad-lơ (Vietnamese).

Natural history. *Gekko adleri* **sp. nov.** inhabits secondary limestone forests, with mixed small hardwoods, shrubs and vines at elevations between 380–694 m (Fig. 6). Most specimens were found at night, however some individuals were sighted on the rock in the shade during the day. The new gecko species is a rock-dwelling specialist. Specimens of this species were found on walls in cave entrances, limestone cliffs and crevices, as well as on isolated limestone boulders in the valley near forest edges, about 0.5–6 m above the ground, but often at 1–3 m. The temperature during the field surveys ranged from 19.1–27.8°C and the relative humidity varied between 63 and 90%.

Most common prey of *Gekko adleri* **sp. nov.** were spiders (50% of the prey items). Remains of crickets (Orthoptera) were found in two stomachs (IEBR A.2012.26 –A.2012.27), remains of a wasp (Hymenoptera) were found in one stomach (IEBR A.2012.28), and remains of a moth (Lepidoptera) were found in one stomach (VNMN A.2012.4). One of the six dissected stomachs was empty (IEBR 2012.25).

TABLE 6. Scalation of the type series of *Gekko adleri* **sp. nov.** (Abbreviations defined in text).

	Holotype	Males		Females		Subadults	
	IEBR	(holotype and paratypes, n = 14)		(paratypes, n = 7)		(paratypes, n = 4)	
	A.2012.24	Min	Max	Min	Max	Min	Max
CS	4/5	3	5	3	6	4	4
N	3	3	4	3	4	3	3
I	1	1	1	1	1	1	1
SPL	13/13	10	13	11	13	12	14
IFL	10/10	9	13	9	13	10	12
IO	30	27	36	29	35	27	36
PM	2	2	2	2	2	2	2
GP	6	4	7	4	6	4	5
DTR	10	8	11	8	11	7	9
GSDT	8−9	7	11	7	11	8	11
SMC	185	169	187	168	190	176	186
SR	136	123	144	126	144	136	142
V	37	36	44	35	44	36	43
LF1	12/12	10	13	10	13	10	12
LF4	15/13	11	15	11	15	13	15
LT 1	11/12	11	14	11	14	11	12
LT4	13/13	11	15	12	15	12	15
PP	20	17	21	0	0	19	20
PAT	1/1	1	1	1	1	1	1

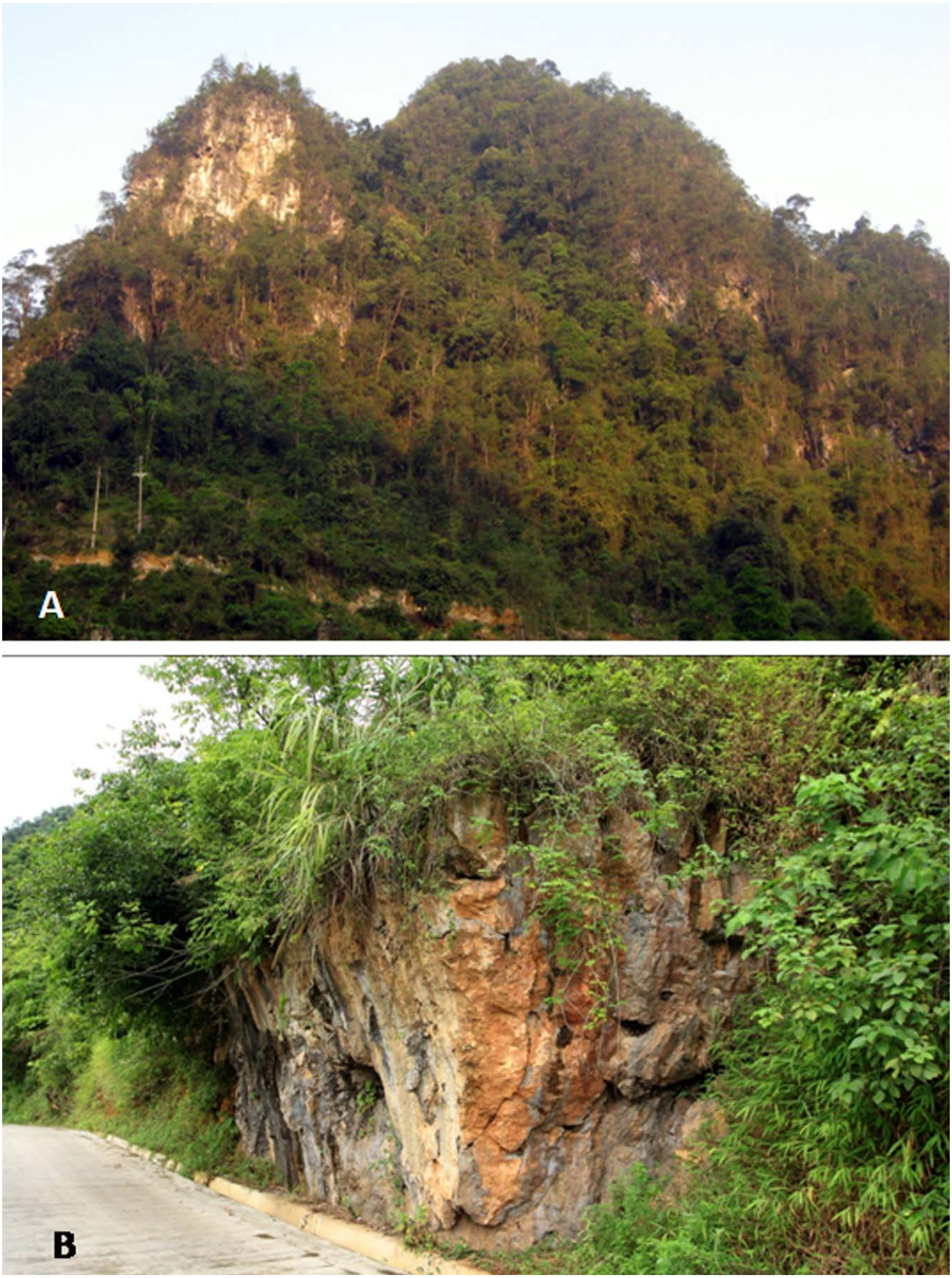

FIGURE 6. Habitat of *Gekko adleri* **sp. nov.** in Cao Bang Province, Vietnam (A) and in Guangxi Zhuang Autonomous Region, China (B). Photos by T. Q. Nguyen and J. H. Yang.

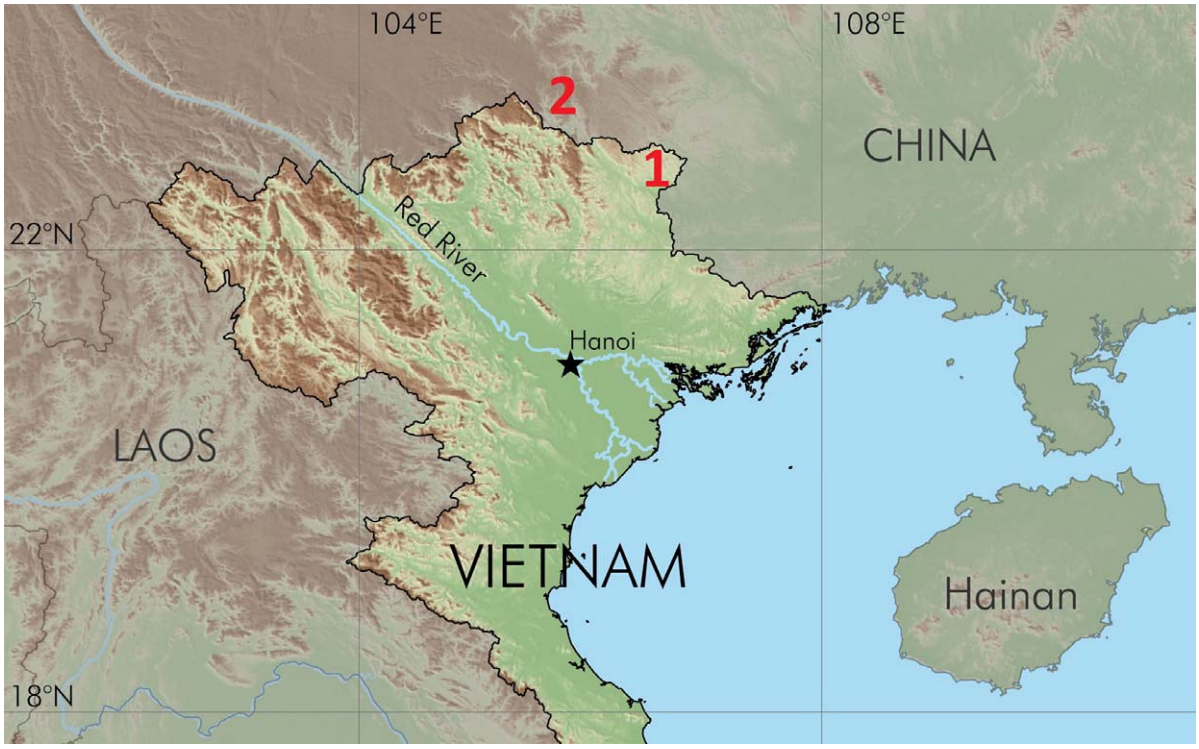

FIGURE 7. Distribution of *Gekko adleri* **sp. nov.**: 1) Ha Lang and Trung Khanh, Cao Bang Province in Vietnam and 2) Jingxi, Guangxi Zhuang Autonomous Region in China.

During the survey in Guangxi, China, in August 2011, we saw two gecko eggs, most likely of *Gekko adleri* **sp. nov.**, in a rock crevice. At the same time, three adults (SYS r000456–000458) and three juveniles (SYS r000459–000461) were found approximately 5–20 m away from the rock crevice and one juvenile was collected on the same rock.

Distribution. The species is currently known only from Tongling Canyon, Jingxi County, Guangxi Zhuang Autonomous Region in southern China and from Cao Bang Province in northern Vietnam (Fig. 7).

Discussion

Species within the *Gekko japonicus* group have not been well covered in previous phylogenetic analyses. The most recent study, Rösler *et al*. (2011), only included six species, all of which occur in China. In their study, the *G. japonicus* species group, consisting of *G. chinensis*, *G. subpalmatus*, and *G. swinhonis*, was strongly supported by the Bayesian, maximum likelihood, and maximum parsimony analyses. This group is not corroborated in our study, probably due to the low quantity of informative characters available in the 16S fragment. However, our study recovers a similar close relationship between *G. swinhonis* and *G. subpalmatus* with strong support values provided by both analyses. The phylogenetic results also indicate that the new species is most closely related to *G. palmatus*, and this species pair forms a sister relationship with *G. chinensis*. The discovery of *G. adleri* brings the species number of the genus *Gekko* to 16 in China and to 12 in Vietnam and this is the 20th species of the *G. japonicus* group (Nguyen *et al.* 2009; Rösler *et al.* 2011).

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APPENDIX. Specimens examined.

Gekko chinensis (13): China: Guangdong Province: Zhuhai City: Tangjia Town: SYS r000621, 000782–000784; Shenzhen City: Wutong Mountain: SYS r000613–000614, 000630, 000779–000780; Guangzhou, Sun Yat-sen University: SYS r000272; Shaoguan City: Renhua County: SYS r000730–000732.

G. canhi (4): Vietnam: Lang Son Province: Huu Lien: IEBR A.0910 (holotype), VNMN 1001–1002 (paratypes); Lao Cai Province: Sa Pa: ZFMK 88879 (paratype).

Gekko melli (9): China: Guangdong Province: Jiexi County: Liangtian Village: SYS r000095; Dongguan City: Yinpingshan Forest Park: SYS r000437–000440, 000451–000453, 000479; Jiangxi Province: Liannan County: Jiulianshan Nature Reserve: SYS r000267.

G. palmatus (30): Vietnam: Lao Cai Province: Sa Pa: IEBR FN.29174; Tuyen Quang Province: Na Hang: IEBR A.0948; Bac Kan Province: Ba Be: IEBR 2301, IEBR A.0950−A.0951; Lang Son Province: Mau Son Mountain: Cao Loc: IEBR 2474, Loc Binh: IEBR 3619–3623, Huu Lien: IEBR A.0949, A.0952; Quang Ninh Province: Uong Bi: Yen Tu Mountain: IEBR A.0807; Bac Giang Province: Yen Tu Mountain: IEBR 3638, 3672; Vinh Phuc Province: Tam Dao: IEBR 3223–3224a-c, ZFMK 44210, 59214−59215, 66517, 74552−74553; Hanoi: Huong Son: IEBR LQV3−LQV4; Thanh Hoa Province: IEBR TH.2011.1; Nghe An Province: Quy Hop: IEBR A.0953−A.0955; Quang Binh Province: Phong Nha – Ke Bang: ZFMK 82888, 86434.

G. scientiadventura (9): Vietnam: Quang Binh Province: Phong Nha – Ke Bang: ZFMK 76198 (holotype), ZFMK 76174–76179 (paratypes); ZFMK 80651–80652.

G. subpalmatus (2): China: Guangdong: Yingde: SYS r000469, 000546.