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A new species of Parachute Gecko of the subgenus *Ptychozoon* (Sauria: Gekkonidae: *Gekko*) from the Indo-Burma region

Hmar Tlawmte Lalremsanga[1], Lal Muansanga[1], Mathipi Vabeiryureilai[1] & Zeeshan A. Mirza[2]

[1] Developmental Biology and Herpetology Laboratory, Department of Zoology, Mizoram University, 796004 Aizawl, Mizoram, India

[2] Max Planck Institute for Biology, Max-Planck-Ring 1, 72076 Tübingen, Germany

Corresponding author: Zeeshan A. Mirza, ORCID-ID: https://orcid.org/0000-0003-1685-9816, e-mail: snakeszeeshan@gmail.com, zeeshan.mirza@tuebingen.mpg.de

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Abstract. The Parachute Gecko *Gekko lionotum* (Annandale, 1905) has been reported to be distributed across parts of Mizoram state (India), Bangladesh, Myanmar, Thailand and Cambodia. A phylogeographic study revealed that the species is paraphyletic and comprises multiple cryptic species. Earlier studies included samples from most parts of the species range except for India, and the status of the Indian population remained unresolved. We conducted surveys in Mizoram and collected specimens, which allowed us to assess the systematic status of the Indian population. Morphology and molecular data suggest that the Indian population represents a distinct species and is here described as new. The new species is most similar to its sister species *Gekko popaensis,* from which it differs in having an uncorrected pairwise sequence divergence of 7–14% and by discrete differences in morphology and colour pattern. The discovery of the new species and several other reptiles from northeast India highlights the poor state of biodiversity documentation and the need for dedicated efforts to document this region's biota.

Key words. Squamata, new species, phylogeny, taxonomy, biodiversity hotspot, northeastern India.

Introduction

The gekkonid genus *Gekko* (Laurenti, 1768) contains morphologically diverse lizards represented by 86 species distributed across South and Southeast Asia (Uetz et al. 2022). The genus comprises members with fascinating adaptations like elaborate skin flaps to facilitate gliding flightin members of the subgenus *Ptychozoon* Kuhl & van Hasselt, 1822 (Smith 1935, Wood et al. 2020). *Ptychozoon*, commonly known as Parachute Geckos, are nocturnal, arboreal geckos with a lifestyle that revolves around crypsis and paragliding from one tree to another (Brown et al. 1997, Dudely et al. 2007, Grismer et al. 2019). The structure of dipterocarp forests has been hypothesized as a driver of paragliding among certain Southeast Asian geckos, agamas, snakes and other vertebrates (Heinicke et al. 2012). Despite their high degree of morphological adaptation, these geckos were found to be phylogenetically embedded within the genus *Gekko* and are currently treated as a subgenus (Wood et al. 2020), *Ptychozoon*. It contains 13 species, however, with further study more species are likely to be discovered throughout its range (Grismer et al. 2018, 2019). In nearly all species of this subgenus, camouflage is enhanced by enlarged skin flaps along the head, body, limbs and tail, preventing the casting of shadows outlining the body while perched motionlessly on the substrate (Grismer et al. 2018). *Gekko lionotum* was originally described from Pegu in southern Myanmar (Annandale 1905). Pawar & Biswas (2001) subsequently reported this species from southern Mizoram, extending its known range by ca. 700 km to the northwest. This record was based on twofinds, one being a female (BNHS 1445) and the other a photograph of another individual. The species was in the following reported to be distributed across parts of Bangladesh, Myanmar, Thailand, Cambodia and Laos (see Grismer et al. 2018, 2019, Bhuiyan et al. 2020, Wood et al. 2020). Phylogeographic studies revealed that *P. lionotum* is a species complex and is paraphyletic with respect to *G. popaensis* (Grismer et al. 2018, 2019). The systematic status of the populations of the species complex from most parts of the range was resolved except for the Indian population of *G. lionotum,* as fresh material for molecular data was unavailable to earlier authors. We conducted surveys throughout Mizoram state and procured specimens to elucidate the status of the Indian population of *G. lionotum*. The results of our studies suggest that this population is distinct from *G. lionotum* and it is herein described as a new species.

Materials and methods

Collection

Extensive field surveys were conducted throughout Mizoram to study the herpetofaunal diversity of the state (Permit no. A.33011/2/99-CWLW/225 issued by the Department of Environment, Forest and Climate Change, Government of Mizoram). Specimens were captured by hand in the field, photographed and euthanized following standard reptile euthanasia protocols (Underwood & Anthony, 2020). They were then fixed in 4% formaldehyde and later washed and transferred to 70% ethanol. Liver tissue for molecular work was taken from the holotype, the paratype and a non-type juvenile prior to fixation and stored in > 95% molecular-grade ethanol. All specimens were examined under a Leica™ CSM2 stereo microscope. The specimens examined in this study are deposited in the collections of Bombay Natural History Society, Mumbai (BNHS); the Museum of the Zoology Department, Mizoram University, Aizawl (MZMU); and in the National Research Collection of the National Centre for Biological Sciences, Bangalore (NCBS), respectively.

Morphology

Scale counts and measurements were taken on the right side of the body where appropriate. We took the following measurements with a dial caliper (Mitutoyo™) to the nearest 0.1 mm following the methodology of Grismer et al. (2018): SVL = snout–vent length, from the tip of snout to the vent; AG = axilla–groin distance, from the posterior margin of the forelimb insertion to the anterior margin of the hind limb insertion; TaL = tail length, from the vent to the tip of the tail; TFL = terminal skin flap length; HD = head depth, the maximum head height; HL = head length, from the posterior margin of the retroarticular process of the lower jaw to the tip of the snout; HW = head width, measured at the angle of the jaws; ED = eye diameter, the greatest horizontal diameter of the eyeball; EAO = eye to auricular opening distance, from the anterior margin of the auricular opening to the posterior margin of the eyeball; NE = distance between the posterior border of the nostrils to the anterior border of the eye; AOW = auricular opening width, the greatest horizontal distance across the auricular opening; SL = snout length, from the anteriormost margin of the eyeball to the tip of the snout; IND = internarial distance, measured between the nares across the rostrum; IOD = interorbital distance, measured between the anterior edges of the orbit; FL = forearm length, from the posterior margin of the elbow while flexed at 90° to the inflection of the flexed wrist; and TBL = tibia length, from the posterior face of the knee while flexed at 90° to the base of the heel. Morphological data for related species were taken from Grismer et al. (2018, 2019), and comparisons were limited to members of the subgenus *Ptychozoon;* see Grismer et al. (2018, 2019) for a detailed description of mensural data collection. Multivariate Principal Component Analyses (PCA) were performed on morphometric data taken from the type series from Mizoram and *G. popaensis*. The morphometric values were corrected for individual SVL and log-transformed to normalise the data. Species names were amended in accordance with the ICZN as proposed by Wood et al. (2021), and we herein follow their recommendations.

Molecular analysis

Genomic DNA was extracted from liver tissue of the types using the Qiagen™ DNAeasy extraction kit and following the protocol as directed by the manufacturers. We amplified a partial segment of the mitochondrial Nicotinamide Adenine Dinucleotide Dehydrogenase Subunit 2 (ND2) gene with the published primers L4437 5'-AAGCTTTCGGGCCCATACC-3' and H5540 5'-TTTAGGGCTTTGAAGGC-3' (Macey et al. 1997). A 23-µl reaction was set, containing 10 µl of ThermoFisher Scientific™ DreamTaq Green PCR Master Mix, 10 µl of water, 0.5 µl of each primer, and 2 µl template DNA, and carried out with an Eppendorf Mastercycler Nexus GSX1. The thermocycle profile used for amplification was as follows: 95°C for 3 minutes (denaturation temperature 95°C for 30 seconds, annealing temperature 58°C for 50 seconds, elongation temperature 72°C for 1 minute) × 35 cycles, 72°C for 12 minutes, hold at 4°C. The PCR product was cleaned with the QIAquick PCR Purification Kit and sequenced with a 3730 DNA Analyzer. Sequences for members of the subgenus *Ptychozoon* were downloaded from GenBank following Grismer et al. (2018, 2019). Downloaded sequences were aligned in Mega X (Kumar et al. 2018) using ClustalW (Thompson et al. 2002) with default settings. Representatives of the sister clade of *Ptychozoon* were selected as outgroup taxa for the phylogenetic analysis. The aligned dataset was analyzed in a maximum likelihood framework using the IQ-TREE (http://iqtree.cibiv.univie.ac.at/) online portal (Minh et al. 2020). The sequence substitution model was selected, using the auto parameter with provision for FreeRate heterogeneity. The analysis was run with an ultrafast bootstrap option for 1000 iterations to assess clade support. The tree was visualised and edited in FigTree (Rambaut 2012). Uncorrected pairwise sequence divergence (p-distance) was calculated in MegaX with pairwise deletion for missing data (Supplementary document S1).

Nomenclatural act

The electronic edition of this article conforms to the requirements of the amended International Code of Zoological Nomenclature, and hence the new names contained herein are available under that Code from the electronic edition of this article. This published work and the nomenclatural acts it contains have been registered in ZooBank, the online registration system for the ICZN. The LSID (Life Science Identifier) for this publication is: urn:lsid:zoobank.

org:pub:D7D1D04A-B8D7-4A01-BFDD-FEE7DBC7E20C. The electronic edition of this work was published in a journal with an ISSN, has been archived, and is available from the following digital repositories: www.salamandra-journal.com, www.zenodo.org.

Results

Molecular analysis

Molecular phylogenetic analysis based on the ND2 gene recovered the *Gekko* specimens from Mizoram as a member of the *lionotum* group (Grismer et al. 2018, 2019) and the sister lineage of *G. popaensis* with high support (BS=100; Fig. 1). The *Gekko* from Mizoram had an uncorrected p-distance from *G. popaensis* of 7–14% and 7–57% (Table 1, Supplementary document S1) from other members of the subgenus *Ptychozoon*. The intraspecific genetic divergence observed was 2–5% (n=2). The lowest genetic divergence between two species of the subgenus *Ptychozoon* is 5% (*G. lionotum* and *G. kabkaebin*); in this regard, a divergence of > 7% can be considered sufficient to call the population of the *Gekko* from Mizoram distinct from *G. popaensis*. For morphological comparison, see the section on systematics below.

Morphology

In the multivariate PCA, PC1 and PC2 explain 66.6 and 27.6% of the variance observed, respectively (Fig. 2, Appendices II and III) and the Mizoram specimens of *Gekko* are found to be distinct from *G. popaensis*; see the section below for a detailed comparison with congeners.

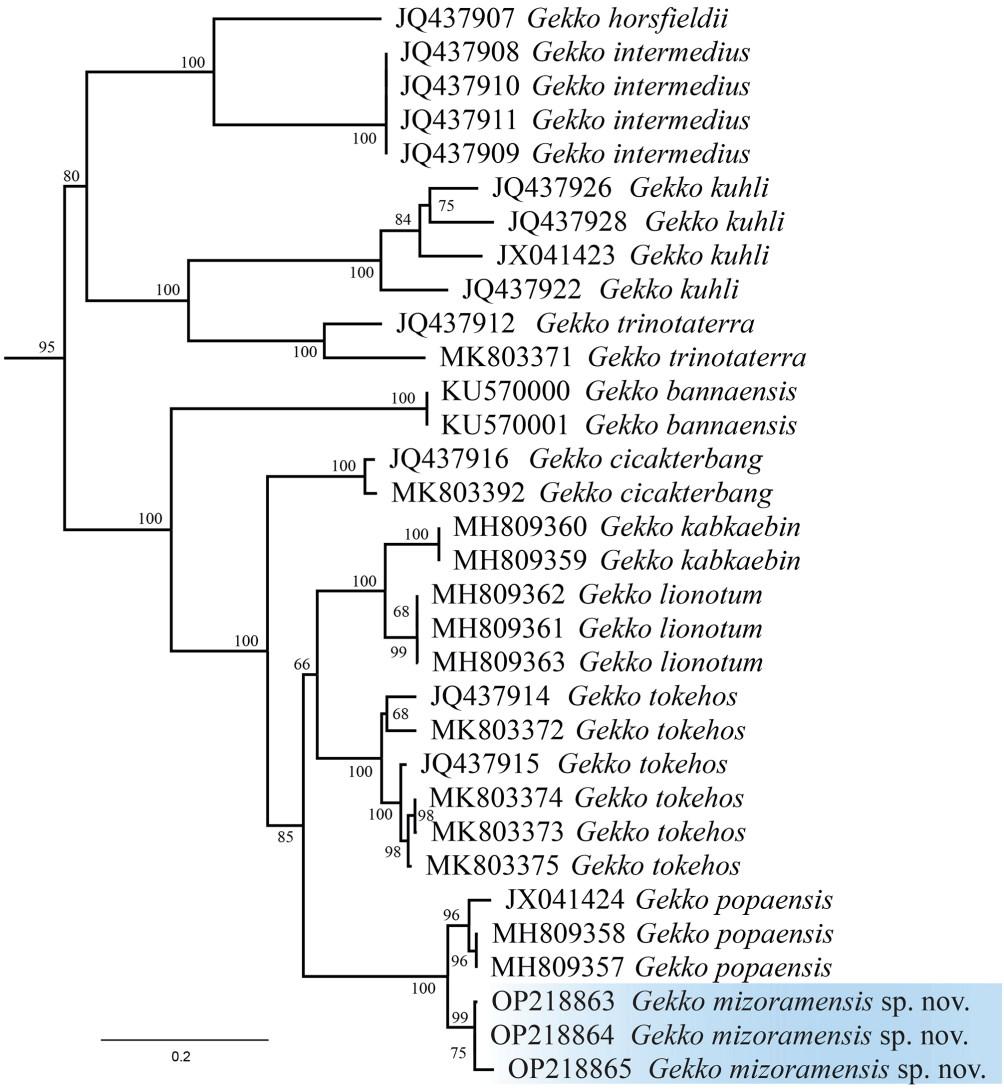

Figure 1. The ML phylogeny based on a fragment of the mitochondrial ND2 gene for members of the subgenus *Ptychozoon* shows the new species' phylogenetic position. Numbers at nodes indicate bootstrap support values (BS).

Systematics

Gekko mizoramensis sp. n.

Figs 3–5, Tables 1–3

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Ptychozoon lionotum Pawar & Biswas (2001): 101; Bhuiyan et al. (2020): 17161

Holotype. Adult female, NCBS NRC-AA-4514 (ex-MZMU-2879), collected from the partition wall inside the Circuit House (22.53502° N, 92.89177° E; 830 m a.s.l.), Electric veng, Lawngtlai town, Lawngtlai District, southern Mizoram, India, at around 09:30 h on 2 May 2022 by Laithang Liani.

Paratypes. Adult female, BNHS 1445, collected by Samraat Pawar on 21 April 1999, same collection locality as the holotype; another adult female (MZMU 2883) from the outside wall of a building at Chawnhu (22.50456° N, 92.89520° E; 1057 m a.s.l.), outskirts of Lawngtlai town, southern Mizoram, India, collected by Ro Tea on 17 May 2022 at around 20:00 h; MZMU 3031, female, from N. Hlimen, Kolasib District, northern Mizoram (24.230092° N, 92.806047° E; 684 m a.s.l.) by Alfred J. C. Ralte on 4 November 2022.

Referred material. MZMU 2880, juvenile, collected by Laithang Liani on 2 May 2022 at around 12:00 h with the same collection data as the holotype; adult female, NCBS NRC-AA-4515 (ex-MZMU-1609) collected from a partition wall of a residential house (22.53698° N, 92.89821° E; 894 m a.s.l.) near the Baptist Church of Mizoram (BCM), Vengpui, Lawngtlai town by Lal Ruatthara at 21:30 h on 19 October 2019.

Table 1. Uncorrected p-distances for members of the subgenus *Ptychozoon* for the ND2 gene.

	G. mizoramensis sp. nov. (n=3)
G. bannaensis (n=2)	35–39
G. cicakterbang (n=2)	24–29
G. horsfieldii (n=1)	41–47
G. intermedius (n=4)	38–44
G. kabkaebin (n=2)	20–23
G. kuhli (n=4)	40–44
G. lionotum (n=2)	21
G. mizoramensis sp. nov. (n=3)	0–3
G. popaensis (n=2)	7
G. rhacophorus (n=1)	48–57
G. tokehos (n=6)	15–26
G. trinotaterra (n=2)	34–42

Diagnosis. *Gekko mizoramensis* sp. n. differs from all other members of the genus *Gekko* (other than the subgenus *Ptychozoon*) in bearing patagia along the forelimbs, trunk and hind limbs. The new species differs from all mem-

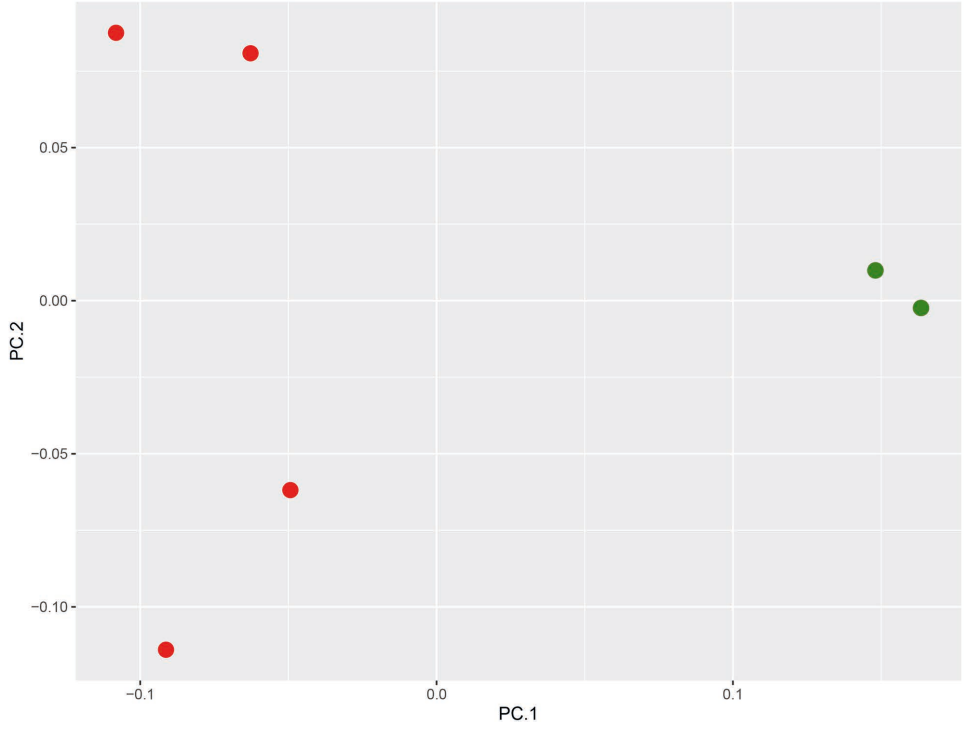

Figure 2. Multivariate PCA plot showing the separation of *Gekko mizoramensis* sp. n. (red) from *G. popaensis* (green).

bers of the subgenus *Ptychozoon* by exhibiting the following unique combination of characters: maximum SVL 100 mm; supranasals not in contact; 11–13 supralabials of which the 9th or 10th is situated at mid-orbit; 9–10 infralabials; caudal tubercles present; 32 ventral scales; no enlarged femoral scales; 12 enlarged non-pored (at least in females) precloacal scales in a transverse row; 5 rows of enlarged post-precloacal scales; 14–17 subdigital lamellae under the fourth toe; enlarged dorsal caudal scales form whorls.

Comparison. The new species differs from members of the subgenus *Ptychozoon* by exhibiting the following non-overlapping set of characters: supranasals not in contact (vs. supranasals in contact in *G. nicobarensis* [Das & Vijayakumar, 2009], *G. trinotaterra* [Brown, 1999], *G. kaengkrachanensis* [Sumontha, Pauwels, Kunya, Limlikhitaksorn, Ruksue, Taokratok, Ansermet & Chanhome, 2012]); infra-auricular cutaneous flap present (vs. absent in *G. rhacophorus* [Boulenger, 1899]); prominent infra-auricular cutaneous lobe absent (vs. present in *G. cicakterbang* [Grismer, Wood, Grismer, Quah, Thy, Phimmachak, Sivongxay, Seateun, Stuart, Siler, Mulcahy, Anamza & Brown, 2019]); tubercles on dorsum absent (vs. present in *G. intermedius* [Taylor, 1915]), *G. kuhli* [Stejneger, 1902], *G. rhacophorus*, *G. trinotaterra*); fourth toe lamellae 14–17 (vs. 13 or 14 in *G. popaensis* [Grismer, Wood, Thura, M Grismer, Brown & Stuart, 2018], 11–13 in *G. horsfieldii* [Gray, 1827], 9–14 in *G. intermedius*, 12–16 in *G. kuhli*, 12–14 in *G. linotus,* 11–13 in *G. rhacophorus*, 12–14 in *G. trinotaterra*). The new species is most similar to *G. popaensis* from which it differs as follows: mid-dorsal caudal tubercles present (vs. absent in *G. popaensis*); 15–16 caudal lobes (vs. 25); distal caudal lobes fused into a long caudal flap (vs. caudal lobes fairly distinct and not forming a long caudal flap); fourth toe lamellae 14–17 (vs. 13 or 14); 12–13 supralabials (vs. 9–11); a thick dark postorbital stripe absent (vs. present); see Table 3 for a summary of the comparison with members of the *G. lionotum* clade.

Etymology. The specific epithet refers to the state of Mizoram in which the new species was discovered. The suggested common English name is Mizoram Parachute Gecko.

Description of the holotype (Figs 3–4, 5a). The specimen is in a good state of preservation except for a longitudinal incision on the venter and is more depressed than in the paratypes, likely an artefact of preservation. Morphometric and meristic details are presented in Tables 2 and 3.

Adult female, SVL 100 mm; head long (HL/SVL 0.17), wide (HW/SVL 0.20), depressed (HD/HL 0.52), distinct from neck; snout rounded at the tip in dorsal view; interorbital region flat; lores rounded; rostral scale large, rectangular, with a dorsomedial groove visible in dorsal view, in contact posteriorly with two supranasals, the internasal, and laterally with nostrils and the first supralabials; supralabials (12R,13L), 10th supralabial in mid-orbital position; infralabials (9R,10L); nostrils round, each bordered anteriorly by the rostral, dorsally by the supranasal, posteriorly by two postnasals, and ventrally by the first supralabial; scales on rostrum granular, slightly larger than the granular scales on the top of the head and occiput; no ridges of tubercles along the mandibles; eyes large (ED/HL 0.27), but smaller than the snout length and EAO distance; pupil vertically elliptical, crenulated; supraciliaries elongate, posteriormost ones spinose; auricular opening rounded, lacking enlarged lobes; tympanum deeply sunk; infra-auricular flap broad, rounded, extending from the lower corner of the mouth to the base of the neck, measuring 3 mm at its widest point; dorsal scales of infra-auricular flap large, subimbricate proximally, small and juxtaposed distally, minute and granular ventrally; infra-auricular flap on the right side deeply notched; mental triangular, wider than deep, bordered laterally by the first infralabials and posteriorly by paired, rectangular postmentals, contacting medially for 100% of their lengths; posterior postmentals small, half the length of the anterior one; one row of enlarged sublabials bordering the infralabials, anteriormost ones largest; gular scales small, rounded, grading abruptly into larger imbricate scales on the throat and venter.

Body dorsoventrally depressed, relatively stout (AG/SVL 0.44); axilla-groin cutaneous expansion (flap) 6.6 mm at midpoint of body and bearing enlarged, juxtaposed, rectangular scales dorsally, and minute, juxtaposed, subrectangular scales ventrally; dorsal body scales minute, flat, rounded, juxtaposed, largest mid-dorsally; 32 transverse

Table 2. Morphological and meristic data from the type specimens of *Gekko mizoramensis* sp. n. All measurements in mm.

	Holotype	Paratypes		
	NCBS NRC-AA-4514	BNHS 1445	MZMU 2879	MZMU 3031
Sex	♀	♀	♀	♀
SVL	100	94.6	90.2	101.4
TailL	104	93	82.7	NA
TL	204	187.6	172.9	NA
AG	44.4	43	42.7	45.4
TBL	15.5	15.1	14.2	16.7
FL	11.2	11.5	9.6	11.6
HL	17.2	17.3	16.3	18.8
HD	8.9	10.7	8.7	11.7
HW	20.4	17.2	18.6	20.3
SL	11.3	11.7	10.2	11.9
NE	7.5	8.7	6.9	8.4
EE	7.4	7.2	6.8	8.3
IND	3.9	4.4	3.5	5.4
ED	4.7	5.2	4.6	5.2
IOD	9.2	9.9	8.45	10.1
SupraL	13/12	11/13	11/13	13/12
SupraL to mid-orbit	10L/10R	10L/10R	9L/10R	10L/10R
InfraL	10L/9R	10L/10R	10L/10R	10L/9R

Table 3. Character states for species of the *Gekko lionotum* clade (derived from Grismer et al. 2018, 2019)

Characters	*G. mizoramensis* sp. nov.	*G. popaensis*	*G. bannaensis*	*G. lionotum*	*G. cicakterbang*	*G. kabkaebin*	*G. tokehos*
Max SVL (mm)	100	86.2	87.5	98.6	93.4	89.1	97.5
Enlarged parachute support scales	present	present	present	absent	present	present	present
Supralabials to middle of eyeball	9 or 10	8	7 or 8?	7–9	9–13	8–10	8–11
Fourth toe lamellae	14–17	13 or 14	16 or 17	16 or 17	14–17	13–17	13–18
Scales across widest portion of caudal flap	32–35	28–29	15	24–31	25–34	27–30	28–34
Thick dark, postorbital stripe	absent	present	present	variable	absent	present	variable
Irregularly shaped, white vertebral markings	absent	present	absent	absent	absent	variable	variable
Caudal tubercles	present	absent	absent	absent	absent	absent	absent

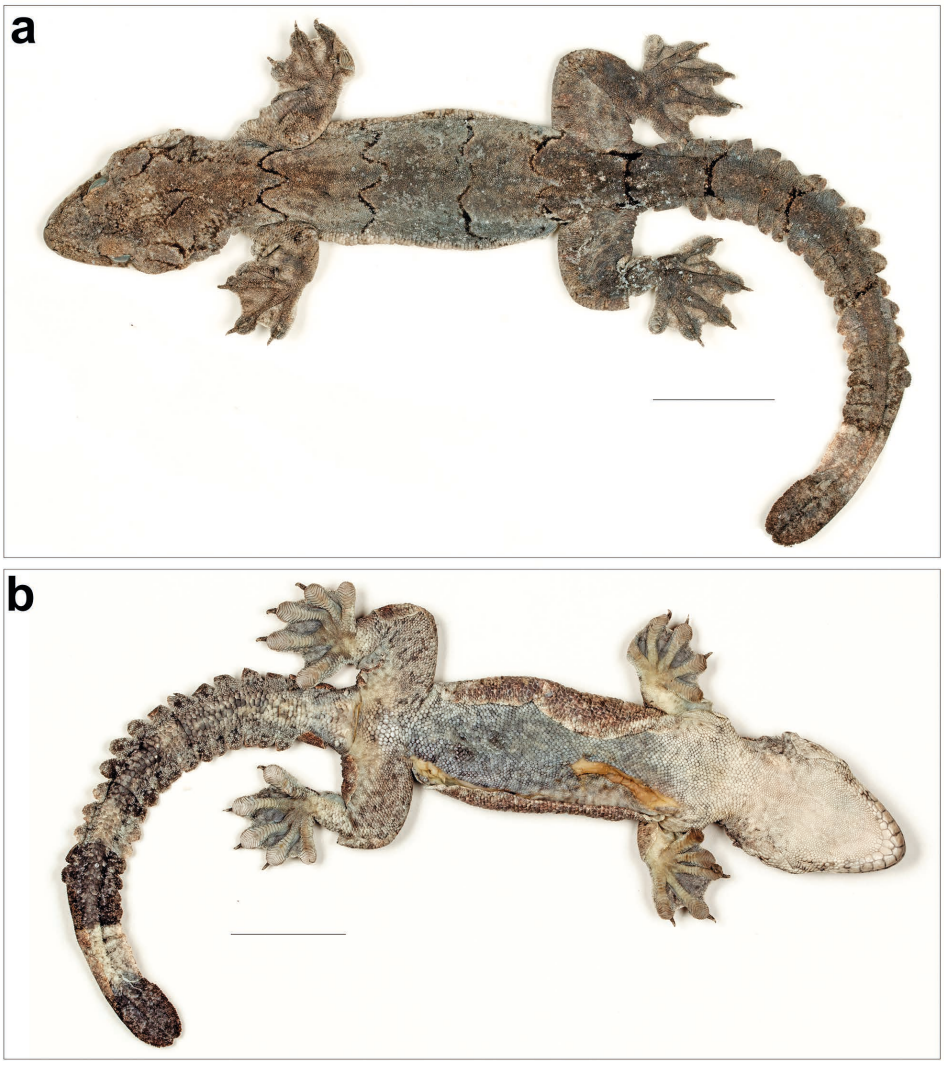

Figure 3. *Gekko mizoramensis* sp. n. holotye female NCBS NRC-AA-4514 showing habitus (a) dorsal view, (b) ventral view. Scale bar = 20 mm. Photos by Zeeshan A. Mirza.

rows of large, smooth, flat, subimbricate ventrals, much larger than dorsals, decreasing in size laterally; 12 enlarged non-pored precloacal scales; five rows of enlarged, post-precloacal scales; scales immediately anterior to vent granular. Limbs short, robust (FL/SVL 0.11; TBL/SVL 0.15); dorsal scales of forelimbs flat, juxtaposed, slightly larger than dorsal body scales, and juxtaposed ventral forelimb scales; anterior and posterior margins of forelimbs, posterior margins of hind limbs, and anterior margins of forelegs bearing wide, cutaneous flaps extending to the bases of digits I and V, bearing subimbricate, moderately larger scales dorsally and smaller, wide, imbricate scales ventrally; a wide predigital notch in the pre-antebrachial flap; palmar scales smooth, rounded; digits fully webbed, relatively short, dorsoventrally compressed; undivided transverse subdigital lamellae of left manus 11 (I), 15 (II), 15 (III), 16 (IV), 13 (V), distalmost lamellae V-shaped; claws II–V arise from within the dorsal surface of the digital pads; first digit lacks a claw; dorsal scales of hind limbs flat, juxtaposed, smaller than dorsal body scales, and flat, subimbricate scales on the thighs; posterior margins of thighs and forelegs, and anterior margins of forelegs have wide, cutaneous flaps bearing subimbricate, moderately large scales dorsally and much smaller, subimbricate scales ventrally; pretibial flap not contacting the base of digit V; post-tibial flap contacts base of digit I; plantar scales smooth, subimbricate; digits fully webbed; transverse subdigital lamellae of left pes 15 (I), 14 (II), 16 (III), 17 (IV), 15 (V), distalmost lamellae V-shaped; claws II–V arise from within the dorsal surface of digital pads; and first digit lacks a claw.

Tail original, flattened, moderate in length (TaL/SVL 1.04); 5–7 median rows of heterogeneous, transversely widened, smooth subcaudals; a single large postcloacal spur, domed, imbricate; dorsal caudals flat, juxtaposed, larger than dorsal body scales, arranged in whorls; 6–8 smaller scales between larger scales delimiting whorls; tail width and caudal lobes decrease slightly posteriorly; 17R/15L caudal lobes on each side, slightly angled posteriorly; lobes fused at their bases, prior to grading posteriorly into short, straight-edged appendages.

Coloration in life (Fig. 5). Grey with darker grey blotches edged with black and black reticulations on the head, and paired black bands on the trunk and the tail. The nape exhibits a sub-ovate mark, and the temporal region an undefined reticulate pattern, which becomes obsolete posteriorly as both join the first band on the trunk. The first black band is at the level of the forelimbs, followed by two on the trunk and a fourth at the level of the hindlimbs. The bark bands are 2–3 scales wide, and the paler interspaces span more than 70 scales. The tail is alternately banded with five dark- and light-coloured bands and has a dark tip. The legs are patterned with diffuse reticulations. The ventral side is cream coloured, but the underside of the tail exhibits the same banded pattern as the dorsal side.

Coloration in preservative (Figs 3 and 4): The coloration in preservation is more faded, with only the black markings evident. The overall background colour is grey to greyish brown.

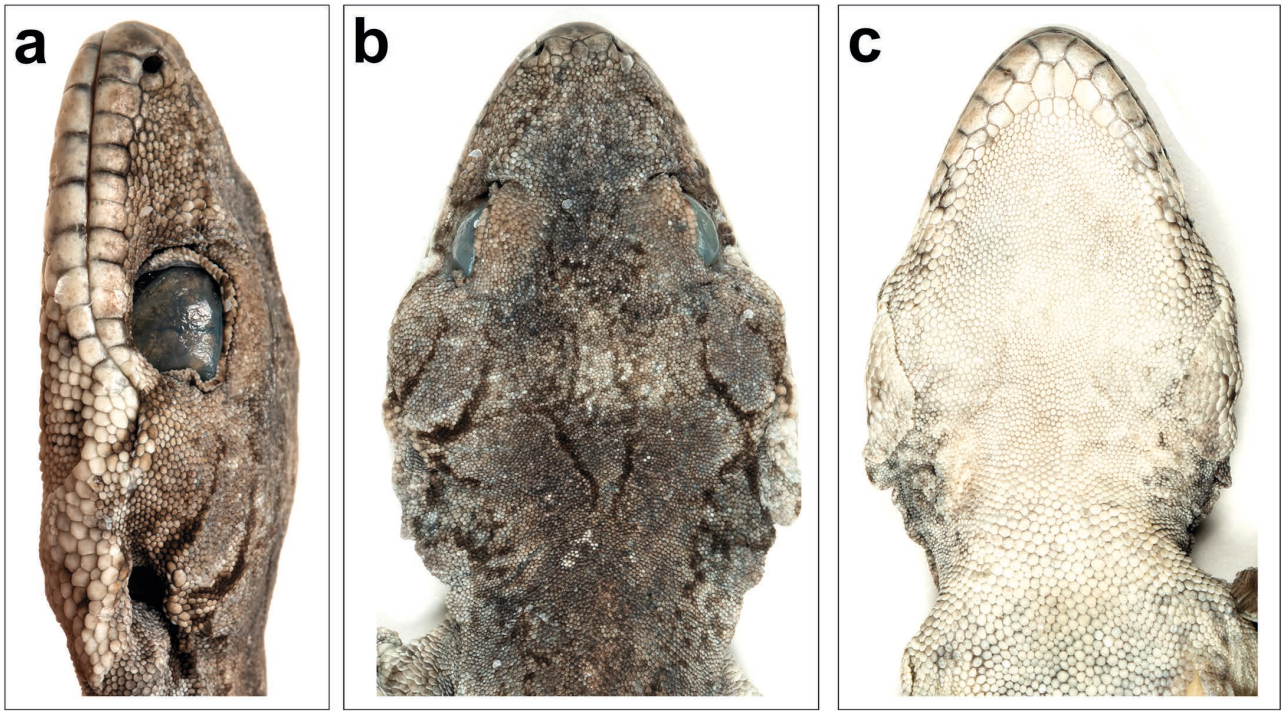

Figure 4. *Gekko mizoramensis* sp. n. holotype, female, NCBS NRC-AA-4514, head in (a) left lateral view, (b) dorsal view, (c) ventral view. Photos by Zeeshan A. Mirza.

Natural history and distribution. The type specimens were collected only from the Lawngtlai town area, particularly during the monsoon season (April to October) in the state. However, this species is not only known from the type locality, but was also encountered in various other areas in Mizoram during the survey period (Fig. 6). All individuals were discovered and collected at heights of approximately 150 to 360 cm above the ground or floor. Being nocturnal, they were observed active from the onset of dusk and hunted or ambushed their prey of beetles, roaches, moths and other insects attracted by light sources. All collected individuals remained motionless if not disturbed; however, they then responded aggressively, attempting to bite when handled. The habitat lies within a largely anthropogenic settlement with small scattered patches of homestead gardens, surrounded by moderately disturbed secondary tropical evergreen forest. The vegetation around the microhabitats where the new species has been collected includes tree species like *Crataegus monogyna, Ficus geniculata, Mangifera indica* and *Schima wallichi.* Other common sympatric lizard species found during the survey were *Calotes irawadi, Gekko gecko* and *Hemidactylus frenatus.*

Discussion

The phylogeographic studies by Grismer et al. (2018, 2019) revealed that *Gekko lionotum* is paraphyletic and comprises multiple cryptic species. These studies included samples

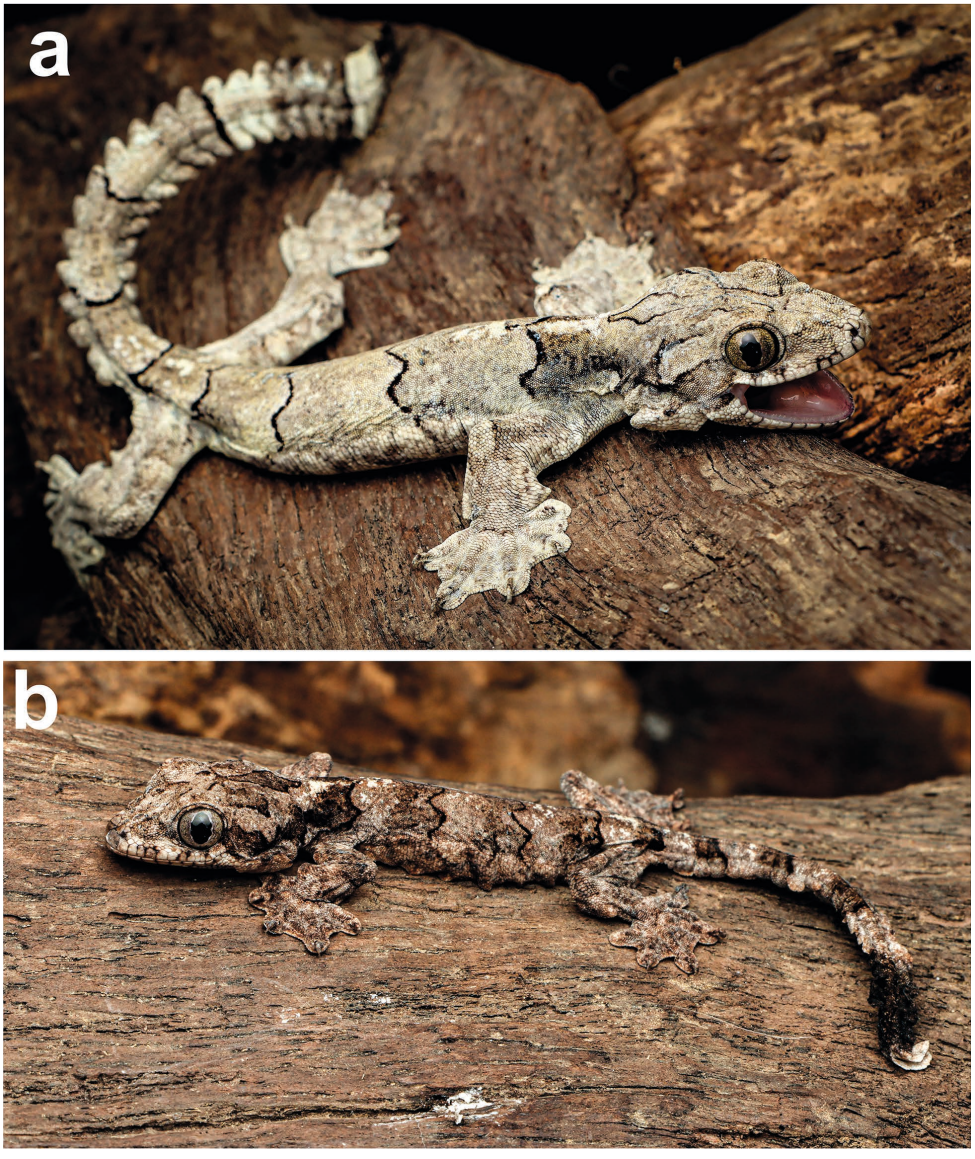

Fig. 5. *Gekko mizoramensis* sp. n., coloration in life, (a) holotype NCBS NRC-AA-4514, (b) juvenile MZMU-2880. Photos by Lal Muansanga.

from most parts of the range of *Gekko lionotum* sensu lato except for India, and the status of the Indian population thus remained unresolved. The present study fills this gap and adds another species to the biodiversity of the Indo-Burma region. The new species, *Gekko mizoramensis* sp. n., is genetically most similar to *G. popaensis* from which it differs by 7–14% sequence divergence in addition to a suite of distinct morphological characters. The new species is geographically separated from *G. popaensis* by the Arakan Hill range, which may be a biogeographic barrier for these species. The type locality, Lawngtlai town, is the capital of the Lawngtlai District and lies in southern Mi-

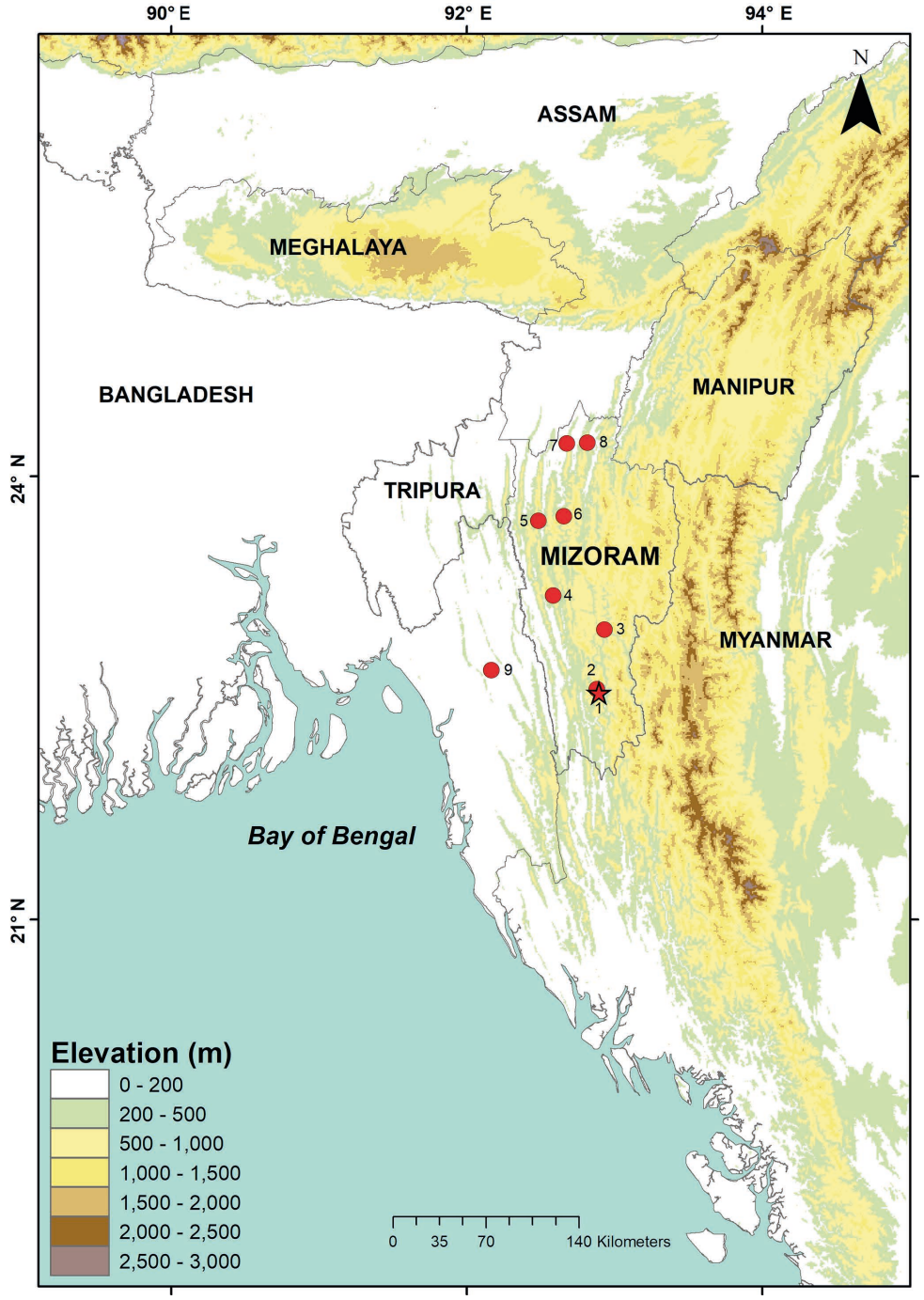

Figure 6. Map of the Indo-Burma region with the known distribution of *Gekko mizoramensis* sp. n. (1) Lawngtlai (type locality 'black star'), (2) Thingkah, (3) Hnahthial, (4) Thenhlum, (5) Dampa Tiger Reserve, (6) Mizoram University Campus, (7) Kolasib, (8) Pualreng Wildlife Sanctuary and (9) Sangu Wildlife Sanctuary (Bhuiyan et al 2020). Map generated with QGIS.

zoram, which forms part of the Indo-Burma biodiversity hotspot (Myers et al. 2000). It is located in the vicinity of the Ngengpui Wildlife Sanctuary in the west and ca. 10 km airline distance northwest of Siaha town, which is the type locality of the recently described Mizoram-endemic gecko *Cyrtodactylus siahaensis* Purkayastha, Lalremsanga, Litho, Rathee, Bohra, Mathipi, Biakzuala & Muansanga, 2022. This district has a moderate climate. In winter, the temperature ranges from 8 to 24°C, and in summer, between 18 and 32°C. The forest type at the type locality is tropical moist evergreen, corresponding to the Northern Tropical Evergreen Forest (Champion & Seth 1968). The average annual rainfall in the area amounts to 2428.7 mm (Gurathakurtha et al. 2020). The forest and the terrain are contiguous with the adjacent parts of Myanmar and Bangladesh, and the new species may likely be found in these neighbouring countries, too. In light of the description of the new species, a recent report on *Gekko lionotum* from Sangu Wildlife Sanctuary in Bangladesh by Bhuiyan et al. (2020) is here regarded as referring to *G. mizoramensis* sp. n. based on the geographic proximity of that locality and morphology.

Based on the present survey, *Gekko mizoramensis* sp. n. appears to be sparsely distributed throughout the state of Mizoram. Despite their wide distribution, Parachute Geckos were not commonly encountered during regular surveys. This may be attributed to their cryptic coloration and behaviour, as is also evident from the scarcity of specimens and records from most parts of their ranges, particularly from India. The discovery is not surprising as northeastern India is rich in herpetofaunal diversity but poorly explored. The discovery of several new reptile species from across northeastern India in the last five years (Giri et al. 2019, Bhosale et al. 2019, 2020, Mirza et al. 2020, 2021, Purkayastha et al. 2021, 2022, Lalremsanga et al. 2022a, 2022b; Rathee et al. 2022, Mahony & Kamei 2022, Kamei & Mahony 2021) warrants dedicated efforts to document the region's biodiversity.

We suggest that the new species described herein should also be considered Data Deficient (DD) according to the criteria of the International Union for Conservation of Nature due to the fact that it is rarely encountered and very little is known about its natural history. Our knowledge of many reptile species in northeastern India is limited. Further detailed research should be carried out to establish the limits of distribution and other data necessary to assess its threat status objectively.

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References

Annandale, N. (1905): Notes on some Oriental geckos in the Indian Museum, Calcutta, with descriptions of new forms. – Annal & Magazine of Natural History, **7**(15): 26–32.

Bhosale, H. S., G. G. Gowande & Z. A. Mirza (2019): A new species of fossorial natricid snakes of the genus *Trachischium* Günther, 1858 (Serpentes: Natricidae) from the Himalayas of northeastern India. – Comptes Rendus Biologies, **342**(9–10): 323–329.

Bhosale, H., P. Phansalkar, M. Sawant, G. Gowande, H. Patel & Z. A. Mirza (2020): A new species of snail-eating snakes of the genus *Pareas* Wagler, 1830 (Reptilia: Serpentes) from eastern Himalayas, India. – European Journal of Taxonomy, **729**: 54–73.

Bhuiyan, M. R. K., M. F. Rabbe, M. F. Jaman, A. K. Das & S. Mohsanin (2020): A new country record of Smooth-backed Gliding Gecko *Gekko lionotum* (Annandale, 1905) (Squamata: Gekkonidae) from Bangladesh. – Journal of Threatened Taxa, **12**(15): 17161–17164.

Brown, R. M., J. W. Ferner & A. C. Diesmos (1997): Definition of the Philippine parachute gecko, *Ptychozoon intermedium* Taylor 1915 (Reptilia: Squamata: Gekkonidae): redescription, designation of a neotype, and comparisons with related species. – Herpetologica, **53**(3): 357–373.

Champion, H. G. & S. K. Seth (1968): A revised survey of the forest types of India. – Manager of publications.

Dudley, R., G. Byrnes, S. P. Yanoviak, B. Borrell, R. M. Brown & J. A. McGuire (2007): Gliding and the functional origins of flight: biomechanical novelty or necessity? – Annual Review of Ecology, Evolution, and Systematics, **38**: 179–201.

Giri, V., D. J. Gower, A. Das, H. T. Lalremsanga, S. Lalronunga, A. Captain & V. Deepak (2019): A new genus and species of natricine snake from northeast India. – Zootaxa, **4603**(2): 241–264.

Grismer, L. L., P. J. Wood, M. K. Thura, M. S. Grismer, R. M. Brown & B. L. Stuart (2018): Geographically structured genetic variation in *Ptychozoon lionotum* (Squamata: Gekkonidae) and a new species from an isolated volcano in Myanmar. – Zootaxa, **4514**(2): 202–214.

Grismer, L. L., J. L. Grismer, E. S. Quah, N. Thy, S. Phimmachak, N. Sivongxay, S. Seateun, B. L. Stuart, C. B. Siler, D. G. Mulcahy, & T. Anamza (2019): Geographic structure of genetic variation in the Parachute Gecko *Ptychozoon lionotum* Annandale, 1905 across Indochina and Sundaland with descriptions of three new species. – Zootaxa, **4638**(2): 151–198.

Guhathakurta, P., A. Bandgar, P. Menon, A. K. Prasad, N. Sangwan & S. C. Advani (2020): Observed Rainfall Variability and Changes Over Mizoram State. Met Monograph No. ESSO/IMD/HS/Rainfall Variability/18 (2020)/42. – India Meteorological Department. Ministry of Earth Sciences, Government of India.

Heinicke, M. P., E. Greenbaum, T. R. Jackman & A. M. Bauer (2012): Evolution of gliding in Southeast Asian geckos and other vertebrates is temporally congruent with dipterocarp forest development. – Biology Letters, **8**(6): 994–997.

Kamei, R. G. & S. Mahony (2021): A new species of Bent-toed gecko (Squamata: Gekkonidae: *Cyrtodactylus* Gray, 1827) from the Garo Hills, Meghalaya State, north-east India, and discussion of morphological variation for *C. urbanus*. – Herpetological Journal, **31**(3): 177–196.

Kumar, S., G. Stecher, M. Li, C. Knyaz & K. Tamura (2018): MEGA X: molecular evolutionary genetics analysis across computing platforms. – Molecular Biology and Evolution, **35**(6): 1547.

Lalremsanga, H. T., A. K. Bal, G. Vogel & L. Biakzuala (2022): Molecular phylogenetic analyses of lesser known colubrid snakes reveal a new species of *Herpetoreas* (Squamata: Colubridae: Natricinae), and new insights into the systematics of *Gongylosoma scriptum* and its allies from northeastern India. – Salamandra, **58**(2): 101–115.

Lalremsanga, H. T., H. Chinliansiama, S. C. Bohra, L. Biakzuala, M. Vabeiryureilai, L. Muansanga, F. Malsawmdawngliana, G. Z. Hmar, H. T. Decemson, V. Siammawii & J. Purkayastha (2022): A new bent-toed gecko (*Cyrtodactylus* Gray: Squamata: Gekkonidae) from the state of Mizoram, India. – Zootaxa, **5093**(4): 465–482.

Mahony, S. & R. G. Kamei (2022): A new species of *Cyrtodactylus* Gray (Squamata: Gekkonidae) from Manipur State, northeast India, with a critical review highlighting extensive errors in literature covering bent-toed geckos of the Indo-Burma region. – Journal of Natural History, **55**(39–40): 2445–2480.

Macey, J. R., A. Larson, N. B. Ananjeva & T. J. Papenfuss (1997): Evolutionary shifts in three major structural features of the mitochondrial genome among iguanian lizards. – Journal of Molecular Evolution, **44**(6): 660–674.

Minh B. Q., H. A. Schmidt, O. Chernomo, D. Schrempf, M. D. Woodhams, A. Von Haeseler & R. Lanfear (2020): IQ-TREE 2: new models and efficient methods for phylogenetic inference in the genomic era. – Molecular Biology and Evolution, **37**(5): 1530–1534.

Mirza, Z. A., H. Bhosale, F. Ansari, P. Phansalkar, M. Sawant, G. Gowande & H. Patel (2021): A new species of geckos of the genus *Cyrtodactylus* Gray, 1827 from Arunachal Pradesh, India. – Evolutionary Systematics, **5**: 13–23.

Mirza, Z. A., H. Bhosale, P. Phansalkar, M. Sawant, G. Gowande & H. Patel (2020): A new species of green pit vipers of the genus *Trimeresurus* Lacépède, 1804 (Reptilia, Serpentes, Viperidae) from western Arunachal Pradesh, India. – Zoosystematics and Evolution, **96**(1): 123–138.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. Da Fonseca & J. Kent (2000): Biodiversity hotspots for conservation priorities. – Nature, **403**(6772): 853–858.

Pawar, S. S. & S. Biswas (2001): First record of the Smoothbacked Parachute Gecko *Ptychozoon lionotum* Annandale 1905 from the Indian Mainland. – Asiatic Herpetological Research, **9**: 101–106.

Purkayastha, J., H. T. Lalremsanga, S. C. Bohra, L. Biakzuala, H. T. Decemson, L. Muansanga, M. VabeiryureilaI, S. Chauhan & Y. Rathee (2021): Four new Bent-toed geckos (*Cyrtodactylus* Gray: Squamata: Gekkonidae) from northeast India. – Zootaxa, **4980**(1): 451–489.

Purkayastha, J., H. T. Lalremsanga, B. Litho, Y. Rathee, S. Bohra, V. Mathipi, L. Biakzuala & L. Muansanga (2022): Two new *Cyrtodactylus* (Squamata, Gekkonidae) from Northeast India. – European Journal of Taxonomy, **794**: 111–139.

Rambaut, A. (2012): FigTree v 1.3.1. [Online]. Available online at:http://tree.bio.ed.ac.uk/software/figtree/

Rathee, Y. S., J. Purkayastha, H. T. Lalremsanga, S. Dalal, L. Biakzuala, L. Muansanga & Z. A. Mirza (2022): A new cryptic species of green pit viper of the genus *Trimeresurus* Lacépède, 1804 (Serpentes, Viperidae) from northeast India. – PLoS ONE, **17**(5): p.e0268402.

Smith, M. A. (1935): The fauna of British India including Ceylon and Burma. – Taylor And Francis, London.

Thompson, J. D., T. J. Gibson & D. G. Higgins (2002): Multiple sequence alignment using ClustalW and ClustalX. – Current Protocols in Bioinformatics, **1**: 2–3.

Uetz, P., P. Freed & J. Hošek (2022): The Reptile Database. Available from: http://www.reptile-database.org, accessed 12 August 2022.

Underwood, W. & R. Anthony (2020): AVMA guidelines for the euthanasia of animals: 2020 edition. – Retrieved on March, 2013(30), 2020–1.

Wood, P. L. Jr, X. Guo, S. L. Travers, Y. Su, K. Olson, A. M. Bauer, L. L. Grismer, C. D. Siler, R. G. Moyle, M. J. Andersen & R. M. Brown (2020): Parachute geckos free fall into synonymy: *Gekko* phylogeny, and a new subgeneric classification, inferred from thousands of ultraconserved elements. – Molecular Phylogenetics and Evolution, **146**: 106731.

Wood, P. L. Jr, X. Guo, S. L. Travers, Y. Su, K. Olson, A. M. Bauer, L. L. Grismer, C. D. Siler, R. G. Moyle, M. J. Andersen & R. M. Brown (2021): Corrigendum to "Parachute geckos free fall into synonymy: *Gekko* phylogeny, and a new subgeneric classification, inferred from thousands of ultraconserved elements" – [Molecular Phylogenetics and Evolution 146 (2020) 106731], Molecular Phylogenetics and Evolution, **164**: 107255.

Supplementary data

The following data are available online:

Supplementary document S1. Uncorrected p-distance (sequence divergence) for selected members of the genus *Gekko*.