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A new species of *Dibamus* Duméril & Bibron, 1839 (Squamata: Dibamidae) from Pulau Manado Tua, Northern Sulawesi, Indonesia

THORE KOPPETSCH[1,2], WOLFGANG BÖHME[1] & ANDRÉ KOCH[1,2]

[1] *Zoologisches Forschungsmuseum Alexander Koenig, Adenauerallee 160, 53113 Bonn, Germany*
[2] *Corresponding authors. E-mails: t.koppetsch@leibniz-zfmk.de, andrepascalkoch@web.de*

Abstract

Based on three adult specimens, viz. two males and a female that form the type series, a new species of blind or worm-like lizards is described from Pulau (= Island) Manado Tua, a little volcanic island located off the northern tip of the Minahassa Peninsula of Sulawesi, Indonesia. *Dibamus manadotuaensis* **sp. nov.** differs from all congeneric species in the following unique combination of characters: maximum snout-vent length 135 mm; tail length up to 14.2 mm (i.e., 12–13% of SVL); labial and nasal sutures present and complete; four (three) postoculars; four to six scales on posterior edge of infralabial; 26–28 midbody scale rows; 30–33 transverse scale rows posterior to head; 25 transverse scale rows anterior to vent; 218–232 ventral scales; 39 subcaudal scales; relative size of frontal to frontonasal 0.68–0.73; relative size of interparietal to surrounding scales 0.67–1.43; 132–135 presacral and 21–24 postsacral vertebrae. Morphologically, *D. manadotuaensis* is most similar to *D. celebensis*, which occurs on mainland Sulawesi.

Dibamus manadotuaensis **sp. nov.** represents the twenty-fourth species of *Dibamus* and the third species of this genus recorded from the Sulawesi region. At the same time, it is the only squamate species considered endemic for the islands of the Bunaken Marine National Park, to which Manado Tua belongs.

Key words: *Dibamus manadotuaensis* **sp. nov.**, systematics, taxonomy, morphology, Bunaken Marine National Park, Wallacea, blind lizards

Introduction

Dibamidae, or blind lizards, are an ancient family of essentially limbless squamates characterized by a fossorial lifestyle accompanied by several special adaptations. This includes a worm-like appearance, reduction and degeneration of the eyes, which are covered by large scales, lack of external ear openings and enlarged plate-like scales covering the head. In addition, they exhibit sexual dimorphism in the reduction of the hind-limbs, with only male dibamids possessing rudimentary flap-like structures (Greer 1985). They represent the sister group to all remaining squamates in molecular phylogenetic studies (Townsend *et al.* 2004; Vidal & Hedges 2005; Pyron *et al.* 2013; Harrington *et al.* 2016). Morphological investigations, however, revealed little support for such a basal phylogenetic placement (Hallermann 1998; Conrad 2008; Gauthier *et al.* 2012). Within squamates, dibamids are characterized by the presence of a non-bifurcated tongue (only chameleons possess a secondarily specialized tongue, see Estes *et al*. 1988; Vidal & Hedges 2005) and the possession of paired egg teeth which they have in common with gekkonids (Greer 1985; Underwood & Lee 2000; Vidal & Hedges 2005).

Dibamidae are divided into the two genera *Anelytropsis* Cope 1885 and *Dibamus* Duméril & Bibron 1839 (Greer 1985), with the former genus being placed among the latter in recent molecular phylogenetic studies, thus rendering the genus *Dibamus* paraphyletic (Townsend *et al.* 2011; Pyron *et al.* 2013). In addition, biogeographic and phylogenetic analyses revealed two deeply divergent, geographically concordant and morphologically conserved clades of *Dibamus*, that are separated into a mainland and a peninsular/island Southeast-Asian clade (Townsend *et al.* 2011). The monotypic genus *Anelytropsis*, with its only species *A. papillosus* Cope 1885 from north-eastern Mexico, represents the sister group to the mainland *Dibamus* clade (Townsend *et al.* 2011; Pyron *et al.* 2013).

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The currently 23 recognized species of *Dibamus* are found from the Nicobar Islands of India (Steindachner 1867; Das 1996) to western New Guinea (De Rooij 1915; Smith 1935; Das & Lim 2009). Southeast Asia, with Borneo (Tan 1993; Das & Lim 2003), Cambodia (Neang *et al.* 2011), Indonesia (Duméril & Bibron 1839; Schlegel 1858; Bleeker 1860; Greer 1985; Das & Lim 2003, 2005, 2009), Peninsular Malaysia (Greer 1985; Das & Yaakob 2003; Diaz *et al.* 2004; Quah *et al.* 2017), Thailand (Taylor 1962; Honda *et al.* 1997) and Vietnam (Smith 1921; Angel 1935; Darevsky 1992; Ineich 1999; Honda *et al.* 2001), is the centre of dibamid diversity (Quah *et al.* 2017; Uetz & Stylianou 2018).

Due to their secretive life-style and small body size, dibamid diversity has only recently been uncovered, with the majority of species having been described within the last 35 years (Quah *et al.* 2017; Uetz & Stylianou 2018). From the Indonesian island of Sulawesi, which lies in the centre of the Wallacea biodiversity hotspot, two species of *Dibamus* have been recorded: These are the wide-spread *D. novaeguineae* Duméril & Bibron 1839, which is distributed from the southern Philippines across the Moluccan Islands and Sulawesi to the western part of New Guinea, and the endemic *D. celebensis* Schlegel 1858 (Greer 1985; Koch 2012).

Examination and recent inventory of so far unidentified specimens of the herpetological collection at the Zoologisches Forschungsmuseum Alexander Koenig revealed three dibamid specimens from the little island of Manado Tua off the coast of the northern peninsula of Sulawesi (Fig. 1), which could not be assigned to any of the known species. In the following, they are described as a new species.

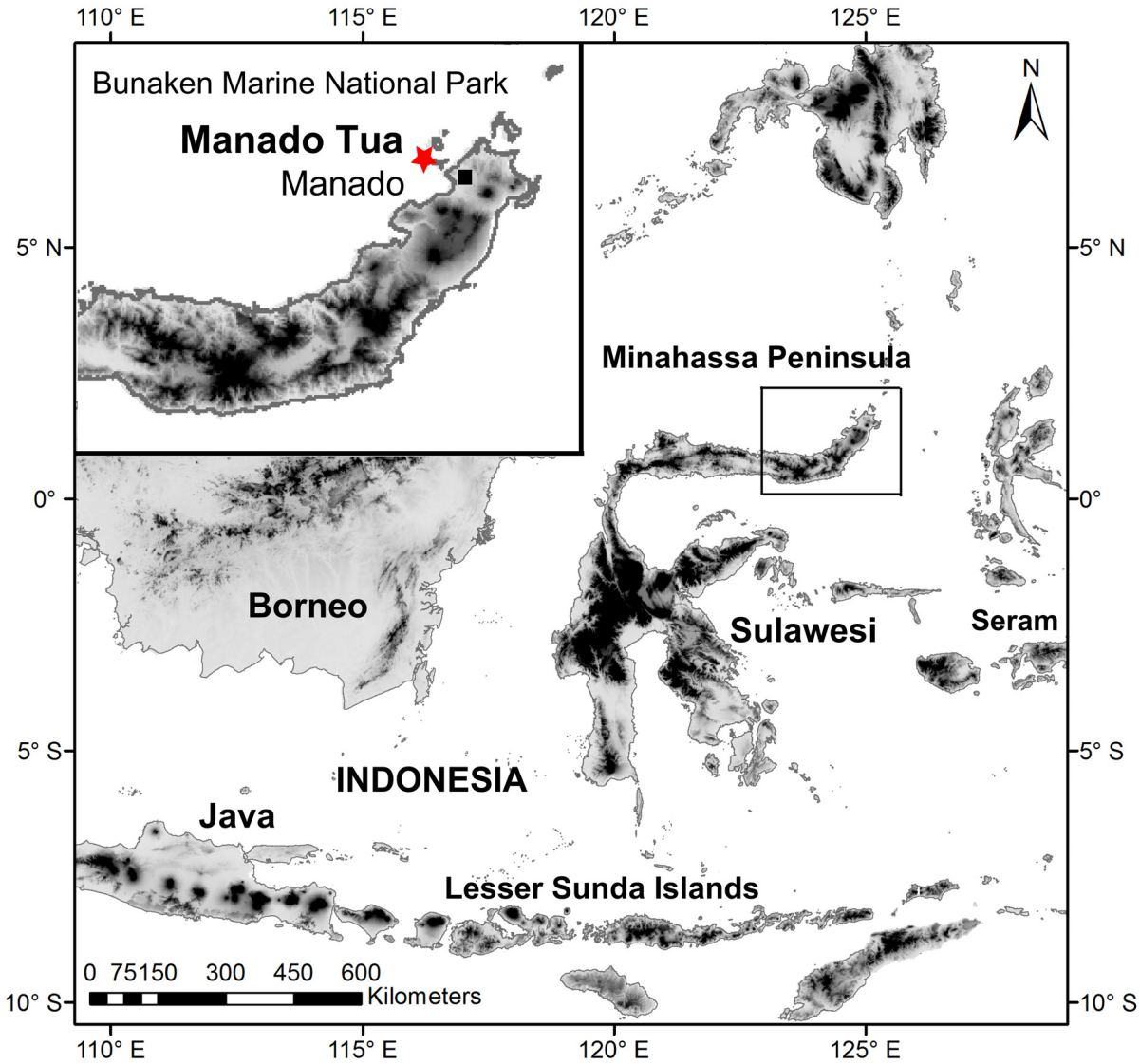

FIGURE 1. Map of Sulawesi showing the type locality of *Dibamus manadotuaensis* **sp. nov.**, which is restricted to Pulau (= island) Manado Tua off the coast of Manado, the capital of Sulawesi Utara Province on the northern Minahassa Peninsula.

Material and methods

The new species is described on the basis of three adult specimens, two males and one female. All individuals were sexed externally using a dissecting microscope. Males were identified by the presence of two small, flap-like structures near the tail base above the vent. The specimens are stored in 70% denatured ethanol and deposited at the Museum Zoologicum Bogoriense (MZB), Chibinong, Indonesia and the Zoologisches rschungsmuseum Alexander Koenig (ZFMK), Bonn, Germany.

Scale counts and external observations of morphology were made using a dissecting microscope and the following characters were measured with a caliper: snout to vent length (SVL: measured from tip of snout to vent); tail length (TL: measured from vent to tip of non-regenerated tail); head length (HL: measured from posterior edge of supralabial to tip of snout); head width (HW: measured at angle of jaws); eye to nostril distance (EN: distance between anterior most edge of eyes to posterior most edge of nostrils); eye to snout distance (ES: distance between anterior most edge of eyes and tip of snout); internasal distance (IN: distance between nostrils); interorbital distance (IO: shortest distance between orbits); frontal scale width (FSW: widest transverse distance of frontal scale); frontal scale length (FSL: longest longitudinal distance of frontal scale); frontonasal scale width (FNSW: widest transverse distance of frontonasal scale); frontonasal scale length (FNSL: longest longitudinal distance of frontonasal scale); interparietal scale width (IPW: widest transverse distance of interparietal scale); width of nuchal scale contacting posterior interparietal (NW: greatest width of any scale contacting interparietal); relative size of frontal scale (proportion of frontal scale width to width of frontonasal); relative size of the interparietal (proportion of interparietal scale width to width of nuchal scale contacting posterior interparietal); body width (BW: greatest width of body at midbody); midbody scale rows (MBSR: number of scales around midbody); anterior transverse scale rows (ATSR: number of scales just posterior to head); posterior transverse scale rows (PTSR: transverse scale row just anterior to vent); ventral scales; subcaudal scales; and vestigial hind limb length. Terminology for morphometric and meristic characters follows Greer (1985) and Quah *et al*. (2017).

For obtaining information on skeletal morphology, specimens were X-rayed in 3D using a micro-CT scanner (Bruker Skyscan 1173®). Entire specimens were scanned at a source voltage of 50kV and a source current of 160µA without the use of a filter in front of the x-ray detector. Micro-CT scanning resulted in image stacks of X-ray projections. Between each projection, the specimens were rotated by 0.2 degrees. From these X-ray projections, stacks of virtual cross sections through the specimens' skeletal structures were reconstructed with the software NRecon® (Bruker micro-CT, Kontich, Belgium). The reconstructed cross-sectional images had pixel resolutions of 34.75µm. The stacks of cross-sectional images were imported as volumetric data into the three-dimensional visualization software package CT Vox® for three-dimensional rendering.

Character states and information about geographical distributions for the various *Dibamus* species were obtained from Smith (1935), Taylor (1962, 1963), Greer (1985), Darevsky (1992), Das (1996), Manthey & Grossmann (1997), Honda *et al.* (1997, 2001), Ineich (1999), Diaz *et al.* (2004), Das & Lim (2003, 2005, 2009), and Das & Yaakob (2003).

Collection acronyms follow Sabaj Pérez (2012): MNHN: Muséum national d'Histoire naturelle, Paris, France; MZB: Museum Zoologicum Bogoriense, Chibinong, Indonesia; RMNH: Naturalis, Netherlands Centre of Biodiversity (formerly Rijksmuseum van Natuurlijke Historie), Leiden, the Netherlands; TNHC: Texas Natural History Collections, University of Texas at Austin, Austin, USA; ZFMK: Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany.

Results

Taxonomy

Dibamidae Boulenger, 1884

Dibamus Duméril & Bibron, 1839

***Dibamus manadotuaensis*, new species**
Figs. 2–7
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Holotype: MZB Lace. 14728 (ex-ZFMK 95558, Figs. 2–7), a male collected by N. Schneider on Pulau (= island) Manado Tua off the northern tip of the Minahassa Peninsula of Sulawesi, Indonesia, donated to the ZFMK in August 1991.

Paratypes: ZFMK 95559 (Figs. 4B, 7B), an adult female, and ZFMK 95560, an adult male, with the same locality and collecting data as the holotype.

Diagnosis: *Dibamus manadotuaensis* **sp. nov.** can be distinguished from all other congeners by the following combination of characters: maximum snout-vent length 135 mm; tail length up to 14.2 mm (i.e., 12–13% of SVL); labial and nasal sutures present and complete; no enlarged sublabial scale; four (three) postoculars; four to six scales on posterior edge of infralabial; 26–28 midbody scale rows; 30–33 transverse scale rows posterior to head; 25 transverse scale rows anterior to vent; 218–232 ventral scales; 39 subcaudal scales; relative size of frontal to frontonasal 0.68–0.73; relative size of interparietal to surrounding scales 0.67–1.43; 132–135 presacral vertebrae; and 21–24 postsacral vertebrae. Light bands on the body are missing (Table 1).

FIGURE 2. The preserved holotype of *Dibamus manadotuaensis* **sp. nov.** (MZB Lace. 14728, ex-ZFMK 95558) from Pulau (= island) Manado Tua, Northern Sulawesi, Indonesia. Photo by Morris Flecks.

Description of holotype: Snout-vent length (SVL) 109 mm; tail length (TL) 14 mm (13% of SVL); head nearly as long (HL 3.9 mm) as wide (HW 4.0 mm); eye to snout distance (ES) 2.3 mm; eye to nostril distance (EN) 1.8 mm; internasal distance (IN) 1.0 mm; interorbital distance (IO) 2.4 mm; snout bluntly rounded, distinctly conical (IN/IO ratio 0.42), projecting beyond lower jaw; nostril laterally oriented, oval, situated closer to tip of snout than to orbit (EN/ES ratio 0.78); rostral pad with a large number of evenly distributed sensory papillae; nasal sutures complete, extending from ocular to nostril; labial sutures complete, extending from anterior part of nasal suture to mouth; posterior border of rostral deeply curved; both frontonasal (FNSL/FNSW = 0.29) and frontal (FSL/FSW = 0.5) wider than long; frontonasal 1.42 times wider than frontal; frontonasal posteriorly bordered by

five scales including frontal; two ocular scales; interparietal single, not enlarged, narrower than frontonasal and frontal, posteriorly bordered by four slightly smaller nuchal scales; four postoculars, with one postocular scale contacting frontal on each side; supralabial single, elongated, bordering ocular ventrally; infralabials lanceolate, separated by a smaller, trapezoid mental; six scales bordering posterior edge of infralabial; ear opening absent; eyes dimly visible through ocular; ocular scale larger than anterior body scales (Fig. 3); tongue short, not bifurcated; fourteen teeth in the lower and upper jaw, respectively, each with a slightly curved tip (Fig. 6).

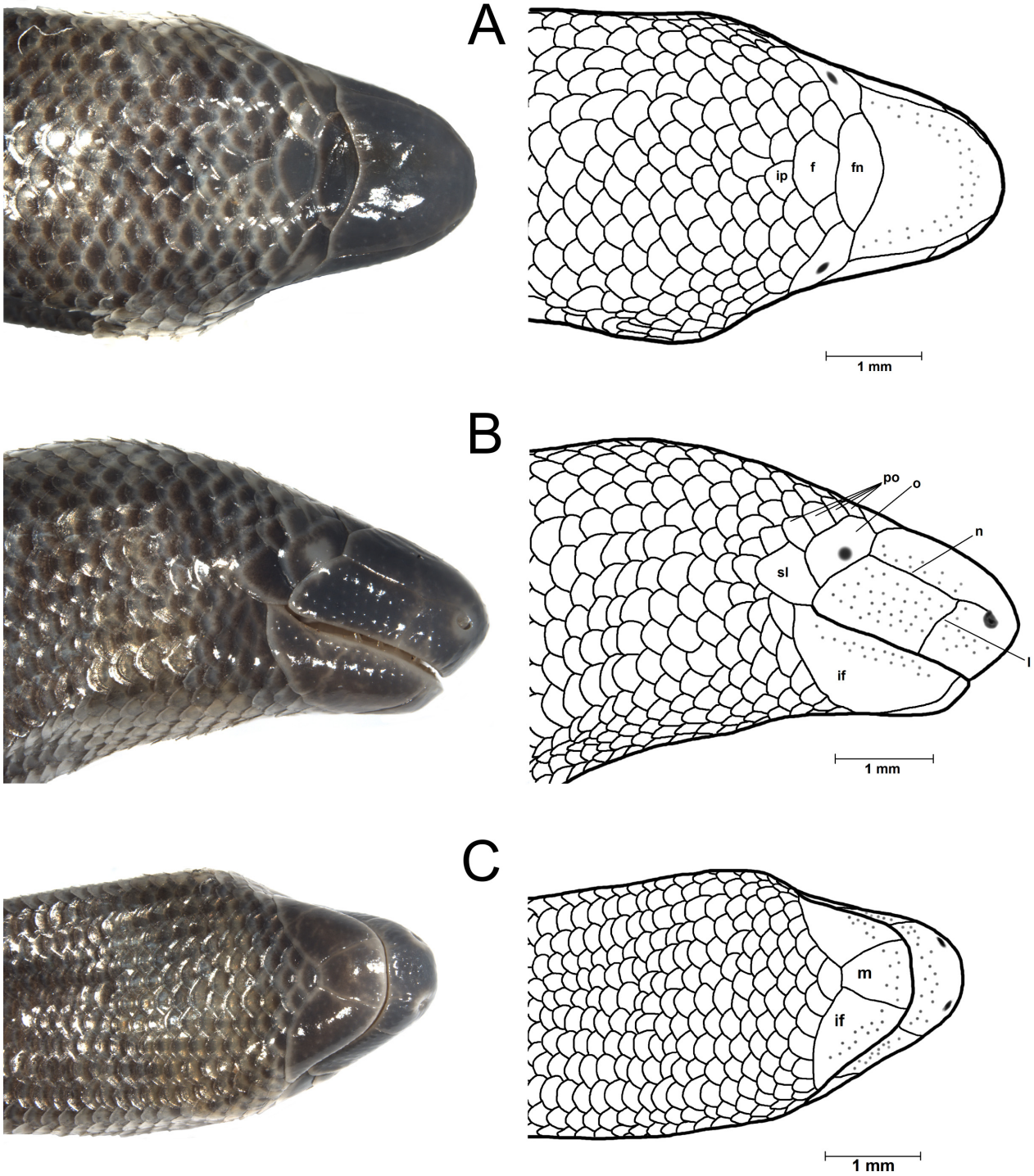

FIGURE 3. Head of the holotype of *Dibamus manadotuaensis* **sp. nov.** (MZB Lace. 14728, ex-ZFMK 95558) in dorsal (A), lateral (B) and ventral (C) views (f: frontal; fn: frontonasal; ip: interparietal; if: first infralabial; l: labial suture; m: mental; n: nasal suture; o: ocular; po: postocular; sl: supralabial). Drawings by Thore Koppetsch based on photos by André Koch.

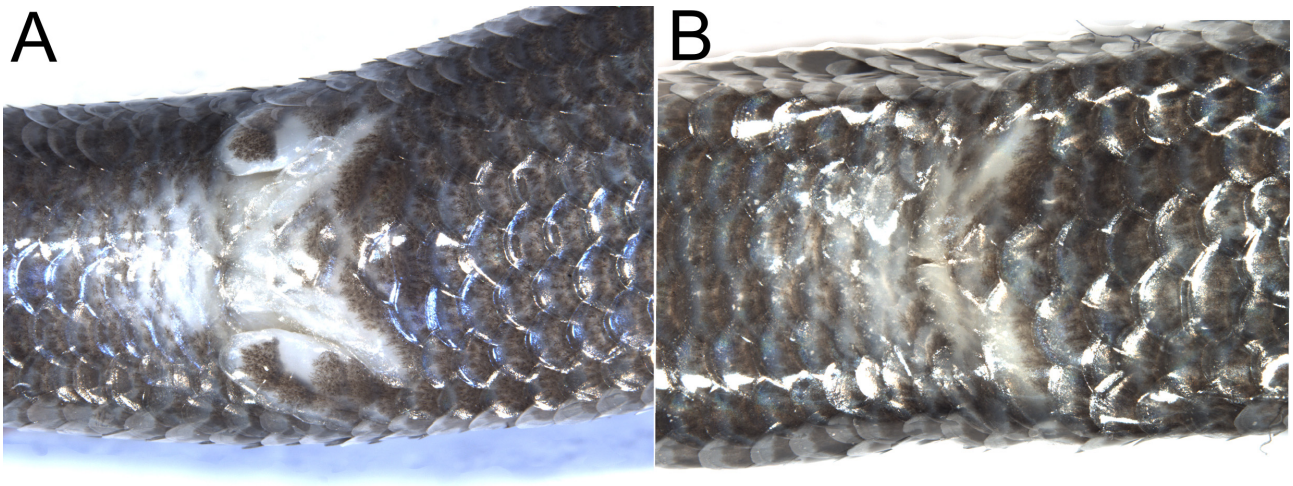

FIGURE 4. (A) Flap-like hind limbs of the male holotype of *Dibamus manadotuaensis* **sp. nov.** (MZB Lace. 14728, ex-ZFMK 95558). (B) Reduction of hind limbs in the female paratype of *Dibamus manadotuaensis* **sp. nov.** (ZFMK 95559).

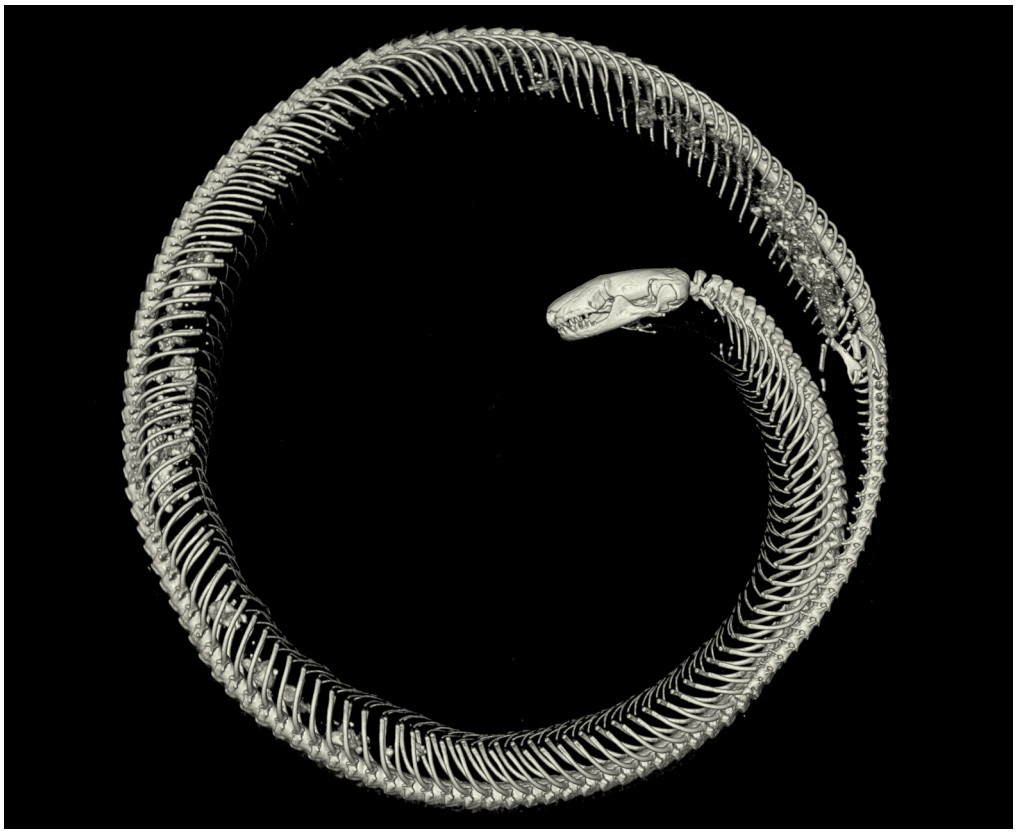

FIGURE 5. Skeleton structure of the male holotype of *Dibamus manadotuaensis* **sp. nov.** (MZB Lace. 14728, ex-ZFMK 95558).

Body worm-like, almost cylindrical, midbody width (BW) 4.4 mm (BW/SVL ratio 0.04); head slightly distinct from neck; tail short (TL/SVL ratio 0.13), tip rounded, not bulbous, wider than rest of the tail (Fig. 2); body scales smooth, subcycloid, including near preanal region; 27 midbody scale rows; 30 transverse scale rows posterior to head; 25 transverse scale rows anterior to vent; 218 ventral scales; 39 subcaudal scales; 134 presacral vertebrae; 24 postsacral vertebrae (Fig. 5); tail complete; rudimentary flap-like hind limbs present, measuring 1.6 mm in length, covered with four paired scales, and terminating in a single scale with a rounded tip (Fig. 4A); pair of enlarged scales on preanal region, separated by a median scale, overlapping those on sides; preanal pores absent; postanal scales not reduced, compared to body scales.

FIGURE 6. Skull of the holotype of *Dibamus manadotuaensis* **sp. nov.** (MZB Lace. 14728, ex-ZFMK 95558).

Colouration in life: Unknown.

Colouration in preservation: Dorsum dark brown to grey-brown, unpatterned (Fig. 2); venter slightly paler than dorsum; scales of head and neck dark brown, each edged by a brighter border; remaining body scales, particularly on the ventral side, light brown with darker marbling; nuchal and body bands absent; tip of snout, supralabials, throat, hind limbs and preanal region slightly lighter, cream coloured (Fig. 4A).

Variation. In the female paratype ZFMK 95559 the two flap-like hind limbs that are present in the two males, as is typical for dibamids, are lacking (Fig. 4B). The absence of hind limbs correlates with the reduction of osseous limb structures in the female specimen. Fibula and tibia are missing as is visible in the micro-CT images (Fig. 7B). In addition, this specimen shows a slightly higher number of transverse scale rows posterior to head (33 vs. 30), a lower number of scales bordering the posterior edge of the infralabial (5 vs. 6), a higher number of ventrals (232 vs. 218), and a greater snout-vent length (115 mm vs. 109 mm). The male paratype ZFMK 95560 is similar to the holotype in morphology except for the missing tail probably caused by damage during collecting or by a predator. The specimen exhibits a slightly higher number of ventrals (223 vs. 218), but shows a lower number of scales bordering the posterior edge of the infralabial (4 vs. 6) and possesses only three postoculars on the right side (see Table 1).

Comparisons. In possessing four postoculars, *Dibamus manadotuaensis* **sp. nov.** can be distinguished from the following congeners that possess three or fewer postoculars: *D. alfredi* Taylor 1962, *D. bogadeki* Darevsky 1992, *D. booliati* Das & Yaakob 2003, *D. bourreti* Angel 1935, *D. celebensis*, *D. dalaiensis* Neang *et al.* 2011, *D. deharvengi* Ineich 1999, *D. dezwaani* Das & Lim 2005, *D. floweri* Quah *et al.* 2017, *D. greeri* Darevsky 1992, *D. ingeri* Das & Lim 2003, *D. kondaoensis* Honda *et al.* 2001, *D. leucurus* (Bleeker 1860), *D. montanus* Smith 1921, *D. nicobaricum* (Steindachner 1867), *D. novaeguineae* Duméril & Bibron 1839, *D. smithi* Greer 1985, *D. somsaki* Honda *et al.* 1997, *D. tebal* Das & Lim 2009, *D. tiomanensis* Diaz *et al.* 2004 and *D. vorisi* Das & Lim 2003.
The lower maximum snout-vent length of *D. manadotuaensis* **sp. nov.** (135 mm) separates it from *D. seramensis* Greer 1985 (203 mm) and *D. taylori* Greer 1985 (169 mm). In addition, *D. manadotuaensis* **sp. nov.** can be distinguished from *D. seramensis* by its lower number of mid-body scale rows (26–28 vs. 33) and the lower number of subcaudal scales of the new species (39 in both sexes) separates it from *D. taylori* (males: 41–55; females: 41–52) (see Table 2).

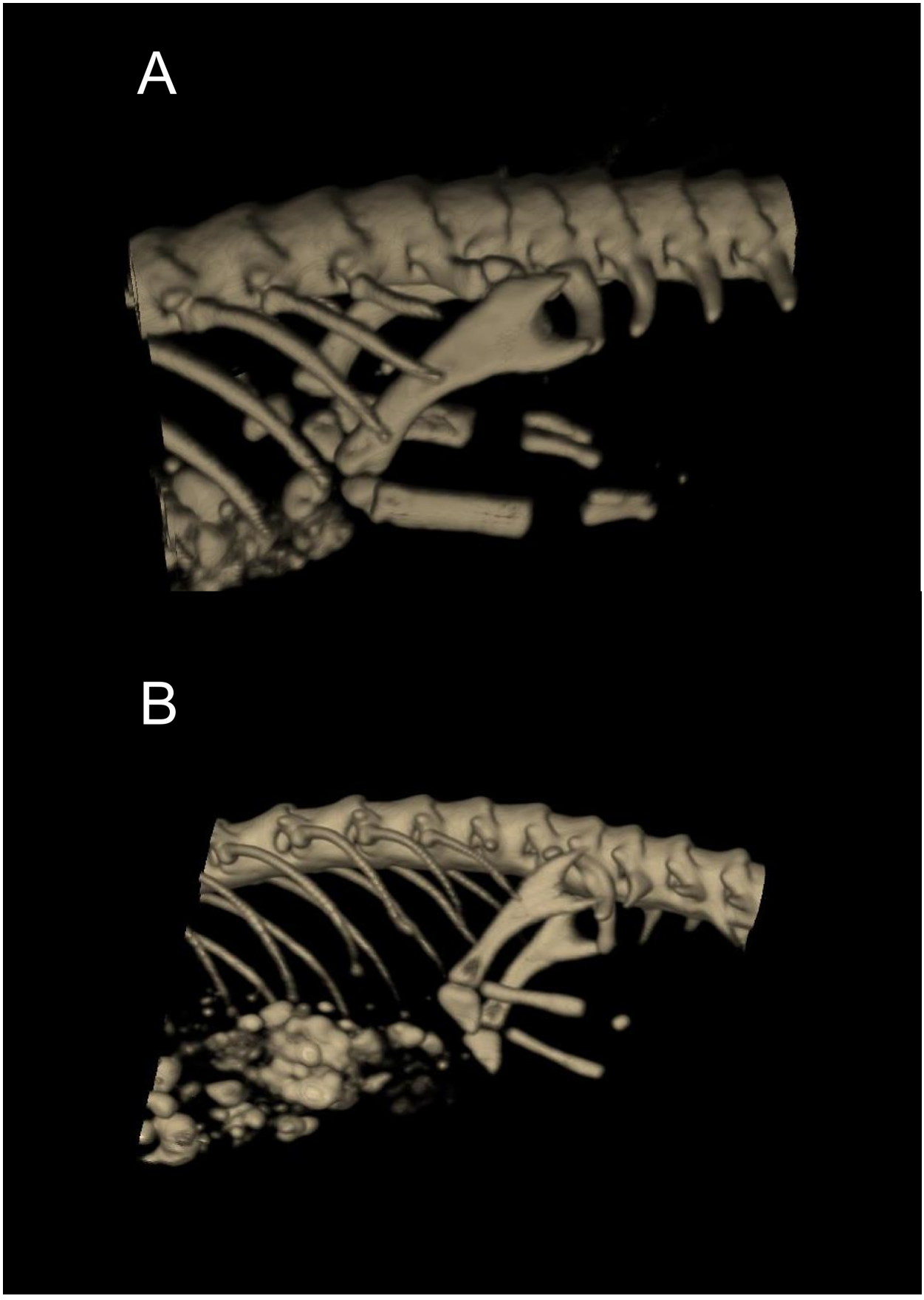

FIGURE 7. Skeleton structures present in the anal region of the male holotype of *Dibamus manadotuaensis* **sp. nov.** (MZB Lace. 14728, ex-ZFMK 95558) (A) and the female paratype (ZFMK 95559) (B).

TABLE 1. Measurements of the holotype (MZB Lace. 14728, ex-ZFMK 95558) and the two paratypes (ZFMK 95559, ZFMK 95560) of *Dibamus manadotuaensis* **sp. nov.** Remarks: * missing tail structures probably caused by damage during collecting. Paired characters presented in left/right order.

Dibamus manadotuaensis, **sp. nov.**	**Holotype** MZB Lace. 14728, ex-ZFMK 95558	**Paratype** ZFMK 95559	**Paratype** ZFMK 95560
Sex	male	female	male
Number of postoculars	4/4	4/4	4/3
Number of scales behind supralabial	3	3	3
Number of scales on posterior edge of infralabial	6	5	4
Number of scales posterior interparietal	3	3	3
Midbody scale rows (MBSR)	27	28	26
Anterior transverse scale rows (ATSR)	25	25	25
Posterior transverse scale rows (PTSR)	30	33	32
Body width (BW) (mm)	4.4	4.6	4.7
Number of subcaudal scales	39	39	12*
Number of ventral scales	218	232	223
Relative size of frontal	0.71	0.73	0.68
Relative size of interparietal	1.2	0.67	1.43
Snout-vent length (SVL) (mm)	109	115	135
BW/SVL ratio	0.04	0.04	0.03
Tail length (TL) (mm)	14	14.2	4.8*
Relative Tail length (% of SVL)	13	12	4*
Hind limb length (mm)	1.6	–	2.7
Head length (HL) (mm)	3.9	4	4.9
Head width (HW) (mm)	4	3.5	4.5
Eye to nostril distance (EN) (mm)	1.8	2	2.1
Eye to snout distance (ES) (mm)	2.3	2.7	2.8
EN/ES ratio	0.78	0.74	0.75
Internasal distance (IN) (mm)	1	1	1
Interorbital distance (IO) (mm)	2.4	2.5	2.5
IN/IO ratio	0.42	0.4	0.4
Frontal scale width (FSW) (mm)	1.2	1.1	1.3
Frontal scale length (FSL) (mm)	0.6	0.9	0.8
FSL/FSW	0.5	0.82	0.62
Frontonasal scale width (FNSW) (mm)	1.7	1.5	1.9
Frontonasal scale length (FNSL) (mm)	0.5	0.7	0.9
FNSL/FNSW	0.29	0.47	0.47
Interparietal scale width (IPW) (mm)	0.6	0.4	1
Width of scale contacting posterior interparietal (NW) (mm)	0.5	0.6	0.7
Enlarged median sublabial	–	–	–
Presence of light band: present (+), absent (–)	–	–	–
Labial suture (LS): complete (+), incomplete (–)	+	+	+
Nasal suture (NS): complete (+), incomplete (–)	+	+	+
Rostral suture (RS): present and complete or incomplete (+), absent (–)	+	+	+
Presacral vertebrae	134	135	132
Postsacral vertebrae	24	21	7*

TABLE 2. Comparison of several scale characters and measurements of all nominal species of *Dibamus* (modified from Greer 1985; Diaz *et al.* 2004; Das & Lim 2009; Quah *et al.* 2017). Numbers of specimens are given in parentheses. Entries for mid-body scale rows and subcaudal scales are as follows from top to bottom: range, mean and sample size.

Species of *Dibamus*	Number of postoculars	Number of scales on posterior edge of infralabial	Mid-body scale rows	Number of subcaudal scales		Relative size of		Max. SVL (mm)	Tail Length (% of SVL)
				Male	Female	Frontal	Interparietal		
manadotuaensis, **sp. nov.**	4(3)	4(1) 5(1) 6(1)	26–28 27 3	39 39 2	39 39 1	0.68–0.73	0.67–1.43	135	12–13
alfredi	2(4)	3(3) 4(1)	20–21 20.3 3	46–47 46.5 2	41–47 43.5 2	1.4–2.0	1.7–2.2	135	17–18
bogadeki	1(1)	2(1)	23 23 1	51 51 1	?	?	?	177	22.5
booliati	1(2)	4(2)	20 20 1	?	24–39 31.5 1	?	?	102.7	9.4–13.0
bourreti	1(1)	2(1)	24 24 1	?	52+ 52+ 1	2.3	4.5	151	23
celebensis	2(10) 3(3)	3(6) 4(7)	26–30 27.4 13	38–40 39.3 3	35–40 38 4	1.2–2.3	1.0–2.9	188	10–13
dalaiensis	1(4)	3(4)	20 20 4	50 50 1	48–52 49.3 3	1.4–1.5 1.4	1.3–1.8 1.5	127.6	18–22
deharvengi	1(1)	2(1)	16 16 1	57 57 1	?	1.3	1.4	92	22.4
dezwaani	2	4	22 22 1	?	37	?	?	123.1	12.75
floweri	1(2)	4(2)	21	46	23	1.1–1.5	1.3–1.8	112	11.4–15.2
greeri	1(3)	1 & 3 (2)	20 20 1	53 53 1	54 54 1	?	?	86	23–28
ingeri	2(3)	3(1)	20 20 1	36 36 1	?	1.5	1	96	14.8

.....continued on the next page

TABLE 2. (Continued)

Species of *Dibamus*	Number of postoculars	Number of scales on posterior edge of infralabial	Mid-body scale rows	Number of subcaudal scales		Relative size of		Max. SVL (mm)	Tail Length (% of SVL)
				Male	Female	Frontal	Interparietal		
kondaoensis	2(1)	3(1)	23 23 1	59 59 1	?	1.03	1	112.4	19.4
leucurus	1(23)	3(21) 4(2)	20–23 21 23	48–52 49.5 2	41–47 43.5 4	1.2–4.2	1.0–3.1	136	16–20
montanus	1(2)	2(2)	22 22 2	49 49 1	43 43 1	2	2.2	130	15–18
nicobaricum	1(6)	4(6)	23–25 24.6 6	34–38 35.6 3	31–36 34.3 3	?	?	134.7	8.7–18.3
novaeguineae	2(92) 3(2)	3(53) 4(41) 5(1)	22–26 24.5 107	42–45 43 6	37–42 39.6 9	1.0–3.0	0.7–2.4	158	10–19
seramensis	4(1)	4(1)	33 33 1	?	40 40 1	0.7	1.2	203	11
smithi	1(1) 2(4)	2(5)	18-19 18.8 5	59 59 1	59–61 60 3	1.5–2.3	1.3–2.0	108	21–24
somsaki	1(4)	2(4)	18–19 18.5 4	44–58 51 2	27–57 42 2	1.1–1.3	1.0–2.2	106	18–24
taylori	3(13) 4(6)	2(2) 3(14) 4(4)	22–28 23.4 22	41–55 48.4 5	41–52 48 7	0.2–1.3	1.0–1.2	169	14–19
tebal	2	4	24 24 1	42 42 1	?	1.4	0.1	133.5	18.65
tiomanensis	1(3)	4(3)	25–26 25.3 3	50 50 1	45–48 46.5 2	1.2	1.8	123	15–16
vorisi	2(2)	3(2)	20 20 2	33 33 1	11 11 1	1.2	1	90.1	6.1–16.8

Etymology. The specific epithet *manadotuaensis* refers to the little volcanic island of Manado Tua, the type locality and only known distribution of the new species.

Distribution. At present, *Dibamus manadotuaensis* **sp. nov.** is only known from the type locality Pulau (= island) Manado Tua, Northern Sulawesi, Indonesia, which belongs to the Bunaken Marine National Park (Fig. 1). It is likely that this species also inhabits the other surrounding islands off the coast of Manado, the capital of Sulawesi Utara Province.

Natural history. While nothing is known about behaviour or ecology of *D. manadotuaensis* **sp. nov**., it seems likely that it resembles those of other dibamids from insular Southeast Asia. All known species show a fossorial lifestyle and occur in rainforest leaf litter and soil (Das & Lim 2009). They feed on small arthropods and earth worms (Zug *et al.* 2001). When disturbed a defensive, anti-predator behaviour is reported for several species, such as *D. floweri* and *D. tiomanensis*. They flare up their body scales, so that the smooth surface appears to be covered with little bristles, resembling the epidermis of possibly non-palatable earthworms (Diaz *et al.* 2004; Quah *et al.* 2017).

Discussion

Dibamus manadotuaensis **sp. nov.** represents the twenty-fourth species of *Dibamus* discovered and the third species of this genus recorded from the Sulawesi region sensu Vane-Wright (1991). It is only known from three adult specimens, two males and a female.

In several morphological characters (i.e., the number of scales on posterior edge of infralabial, mid-body scale rows, subcaudal scales, and relative tail length) *D. manadotuaensis* **sp. nov.** is very similar to *D. celebensis* from neighbouring Sulawesi, which occurs from near sea level on the northern peninsula up to at least 1363 m in Central Sulawesi (Greer 1985). The highest morphological similarity, however, exists between our new species and *D. seramensis* from the Moluccas (Fig. 1). These assumptions need to be proved by a molecular approach, also providing a better understanding of their phylogenetic relationship.

Manado Tua, a small and young volcanic island, belongs to a double volcanic chain known as Sangihe volcanic arc (Zulkarnain 2001) and is famous for the discovery and subsequent records of the Indonesian coelacanth *Latimeria menadoensis* Pouyaud *et al.* 1999 (Erdmann 1999; Erdmann *et al.* 1999). While it is very likely that *D. manadotuaensis* **sp. nov.** will be recorded from other islands of the Bunaken Marine National Park in the future, it seems unlikely that it also occurs on mainland Sulawesi. Although both are separated by merely twelve kilometres of open sea, the average sea depth of Bunaken strait is 130 m (Rompas & Manongko 2016) emphasizing the probability of long-term absence of a land connection between Manado Tua and mainland Sulawesi. Thus, colonization and faunal exchange between Sulawesi and the Bunaken islands were severely hampered in the past despite periodic drops in global sea levels by up to 140 meters during the Pleistocene (Lambeck *et al.* 2002, Bintanja *et al.* 2005, Rabineau *et al.* 2006). Therefore, *D. manadotuaensis* **sp. nov.** probably evolved in spatial isolation from the two dibamid species occurring on mainland Sulawesi, viz. *D. celebensis* and *D. novaeguineae*.

Due to their cryptic lifestyle, dibamids have been poorly represented in collections and relatively low in species diversity, although inhabiting such a wide range in the Indo-Australian region (Greer 1985). Most species are still known from only few specimens. *D. seramensis*, for instance, is a very rare species from the Moluccan island of Seram, which until recently was known only from the female holotype MCZ R-7623 collected in 1906-1907 (Greer 1985). Townsend *et al.* (2011) published a phylogeography of the family Dibamidae including DNA sequences from another specimen of *D. seramensis* (TNHC 59521), that was collected by Jimmy McGuire near Desa (= village) Lohiatala, Kecamatan (= district) Kairatu, on Seram Island on 15th April 1998, more than 90 years after its original discovery.

Since several new species of *Dibamus* were described on the basis of material collected many years or even decades ago (Das & Lim 2003, 2005, 2009; Honda *et al.* 2001), it seems likely that even more undescribed dibamid species await discovery in natural history collections. The discovery of *D. manadotuaensis* **sp. nov.** together with the large number of other reptile species discoveries from Sulawesi in recent years (e.g., Kuch *et al.* 2007; Hayden *et al.* 2008; Linkem *et al*. 2008; Koch *et al.* 2009a; Riyanto *et al.* 2018) emphasises the need to enhance and intensify systematic taxonomic investigations in the region (Koch 2012). On a broader scale, a large number of

species still await discovery within the Wallacea region since it includes numerous isolated and remote islands which are not easily accessible or little explored (Setiadi & Hamidy 2006; Koch *et al.* 2009b; Kaiser *et al.* 2011). As a consequence, not only does the incredible marine biodiversity of Indonesia's coral reefs, such as in Bunaken Marine National Park, need protection, but also terrestrial species in that area which are under enormous human pressures by tourism and agriculture.

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References

Angel, F. (1935) Un lézard nouveau de la famille des dibamidés. *Bulletin Museum National d'Histoire Naturelle*, Series 2, 7 (6), 354–356.

Bintanja, R., van de Wal, R.S.W. & Oerlemans, J. (2005) Modelled atmospheric temperatures and global sea levels over the past million years. *Nature*, 437, 125–128.
https://doi.org/10.1038/nature03975

Bleeker, P. (1860) Reptilien van Agam angeboden door E.W.A. Ludeking. *Natuurkundig Tijdschrift voor Nederlandsch Indie*, 20, 325–329.

Boulenger, G.A. (1884) Synopsis of the families of existing Lacertilia. *The Annals and Magazine of Natural History*, Series 5, 14 (80), 117–122.
https://doi.org/10.1080/00222938409459779

Conrad, J.L. (2008) Phylogeny and Systematics of Squamata (Reptilia) based on Morphology. *Bulletin of the American Museum of Natural History*, 310, 1–182.
https://doi.org/10.1206/310.1

Cope, E.D. (1885) A contribution to the herpetology of Mexico. *Proceedings of the American Philosophical Society*, 22, 379–404.

Darevsky, I.S. (1992) Two new species of the worm-like lizard *Dibamus* (Sauria, Dibamidae), with remarks on the distribution and ecology of *Dibamus* in Vietnam. *Asiatic Herpetological Research*, 4 (1), 1–12.
https://doi.org/10.5962/bhl.part.6175

Das, I. (1996) The validity of *Dibamus nicobaricum* (Fitzinger in Steindachner, 1867) (Squamata: Sauria: Dibamidae). *Russian Journal of Herpetology*, 3 (2), 157–162.

Das, I. & Lim, K.K. (2003) Two new species of *Dibamus* (Squmata: Dibamidae) from Borneo. *Raffles Bulletin of Zoology*, 51 (1), 137–142.

Das, I. & Lim, K.K. (2005) New species of *Dibamus* (Squamata: Dibamidae) from Pulau Nias, Indonesia. *Journal of Herpetology*, 39 (1), 113–117.
https://doi.org/10.1670/0022-1511(2005)039[0113:NSODSD]2.0.CO;2

Das, I. & Lim, K.K. (2009) A new species of *Dibamus* (Squamata: Dibamidae) from Pulau Simeuleu, Mentawai Archipelago, Indonesia. *Zootaxa*, 2088 (1), 15–23.

Das, I. & Yaakob, N. (2003) A new species of *Dibamus* (Squamata: Dibamidae) from Peninsular Malaysia. *Raffles Bulletin of Zoology*, 51 (1), 143–148.

de Rooij, N. (1915) *The Reptiles of the Indo-Australian archipelago. I. Lacertilia, Chelonia, Emydosauria.* E. J. Brill, Leiden, xiv + 384 pp.

Diaz, R.E., Leong, T.M., Grismer, L.L. & Yaakob, N.S. (2004) A new species of *Dibamus* (Squamata: Dibamidae) from West Malaysia. *Asiatic Herpetological Research*, 10, 1–7.

Duméril, A.M.C. & Bibron, G. (1839) *Erpétologie Générale ou Histoire Naturelle Complète des Reptiles.* Tome 5, Librairie Encyclopédique de Roret, Paris, 871 pp.

Erdmann, M.V. (1999) An account of the first living coelacanth known to scientists from Indonesian waters. *Environmental Biology of Fishes*, 54 (4), 439–443.
https://doi.org/10.1023/A:1007584227315

Erdmann, M.V., Caldwell, R.L., Jewett, S.L. & Tjakrawidjaja, A. (1999) The second recorded living coelacanth from north

Sulawesi. *Environmental biology of fishes*, 54 (4), 445–451.
https://doi.org/10.1023/A:1007533629132
Estes, R., De Queiroz, K. & Gauthier, J. (1988) Phylogenetic relationships within Squamata. *In*: Estes, R. & Pregill, G. (Eds.), *Phylogenetic Relationships of the Lizard Families.* Stanford University Press, Palo Alto, CA, pp. 119–281.
Gauthier, J.A., Kearney, M., Maisano, J.A., Rieppel, O. & Behlke, A.D.B. (2012) Assembling the Squamate Tree of Life: Perspectives from the Phenotype and the Fossil Record. *Bulletin of the Peabody Museum of Natural History*, 53, 3–308.
https://doi.org/10.3374/014.053.0101
Greer, A.E. (1985) The relationships of the lizard genera *Anelytropsis* and *Dibamus*. *Journal of Herpetology*, 19, 116–156.
https://doi.org/10.2307/1564427
Grismer, L.L. (2011) *Lizards of Peninsular Malaysia, Singapore, and their adjacent archipelagos: their description, distribution, and natural history.* Edition Chimaira, Frankfurt am Main, 728 pp.
Hallermann, J. (1998) The ethmoidal region of *Dibamus taylori* (Squamata: Dibamidae), with a phylogenetic hypothesis on dibamid relationships within Squamata. *Zoological Journal of the Linnean Society*, 122 (3), 385–426.
https://doi.org/10.1111/j.1096-3642.1998.tb02157.x
Harrington, S.M., Leavitt, D.H. & Reeder, T.W. (2016) Squamate Phylogenetics, Molecular Branch Lengths, and Molecular Apomorphies: A Response to McMahan et al. *Copeia*, 104 (3), 702–707.
https://doi.org/10.1643/CG-16-391
Hayden, C.J., Brown, R.M., Gillespie, G., Setiadi, M.I., Linkem, C.W., Iskandar, D.T., Umilaela, Bickford, D.P., Riyanto, A., Mumpuni & McGuire, J.A. (2008) A new species of bent-toed gecko *Cyrtodactylus* Gray, 1827 (Squamata: Gekkonidae) from the island of Sulawesi, Indonesia. *Herpetologica*, 64, 109–120.
https://doi.org/10.1655/07-026.1
Honda, M., Nabhitabhata, J., Ota, H. & Hikida, T. (1997) A new species of *Dibamus* (Squamata: Dibamidae) from Thailand. *Raffles Bulletin of Zoology*, 45, 275–280.
Honda, M., Ota, H., Hikida, T. & Darevsky, I.S. (2001) A new species of the worm-like lizard, *Dibamus* Dumeril & Bibron 1839 (Squamata Dibamidae), from Vietnam. *Tropical Zoology*, 14 (1), 119–125.
https://doi.org/10.1080/03946975.2001.10531146
Ineich, I. (1999) Une nouvelle espèce de *Dibamus* (Reptilia, Squamata, Dibamidae) du Vietnam. *Bulletin de la Société zoologique de France*, 124 (3), 279–286.
Kaiser, H., Carvalho, V.L., Ceballos, J., Freed, P., Heacox, S., Lester, B., Richards, S.J., Trainor, C.R., Sanchez, C. & O'Shea, M. (2011) The herpetofauna of Timor-Leste: a first report. *ZooKeys*, 109, 19–86.
https://doi.org/10.3897/zookeys.109.1439
Koch, A., Arida, E., McGuire, J.A., Iskandar, D.T. & W. Böhme (2009a) A new species of *Calamaria* (Squamata: Colubridae) similar to *C. ceramensis* de Rooij, 1913, from the Banggai Islands, east of Sulawesi, Indonesia. *Zootaxa*, 2196, 19–30.
Koch, A, Arida, E., Riyanto, A. & Böhme, W. (2009b) Islands between the realms: a revised checklist of the herpetofauna of the Talaud Archipelago, Indonesia, with a discussion about its biogeographic affinities. *Bonner Zoologische Beiträge*, 56 (1/2), 107–129.
Koch, A. (2012) *Discovery, diversity, and distribution of the amphibians and reptiles of Sulawesi and its offshore islands.* Edition Chimaira, Frankfurt am Main, 374 pp.
Kuch, U., Gumprecht, A. & Melaun, C. (2007) A new species of Temple Pitviper (*Tropidolaemus* Wagler, 1830) from Sulawesi, Indonesia (Squamata: Viperidae: Crotalinae). *Zootaxa*, 1446 (1), 1–20.
https://doi.org/10.11646/zootaxa.1426.1.1
Lambeck, K., Esat, T.M. & Potter, E.-K. (2002) Links between climate and sea levels for the past three million years. *Nature*, 419, 199–206.
https://doi.org/10.1038/nature01089
Linkem, C.W., McGuire, J.A., Hayden, C.J., Setiadi, M.I., Bickford, D.P. & Brown, R.M. (2008) A new species of bent-toe gecko (Gekkonidae: *Cyrtodactylus*) from Sulawesi Island, Eastern Indonesia. *Herpetologica*, 64 (2), 224–234.
https://doi.org/10.1655/07-040.1
Manthey, U. & Grossmann, W. (1997) *Amphibien und Reptilien Südostasiens.* Natur und Tier Verlag, Münster, 512 pp.
Neang, T., Holden, J., Eastoe, T., Seng, R., Ith, S. & Grismer, L.L. (2011) A new species of *Dibamus* (Squamata: Dibamidae) from Phnom Samkos Wildlife Sanctuary, southwestern Cardamom Mountains, Cambodia. *Zootaxa*, 2828 (1), 58–68.
Pouyaud, L., Wirjoatmodjo, S., Rachmatika, I., Tjakrawidjaja, A., Hadiaty, R. & Hadie, W. (1999) Une nouvelle espèce de coelacanthe. Preuves génétiques et morphologiques. *Comptes Rendus de l'Académie des Sciences*, 322 (4), 261–267.
https://doi.org/10.1016/S0764-4469(99)80061-4
Pyron, R.A., Burbrink, F.T. & Wiens, J.J. (2013) A phylogeny and revised classification of Squamata, including 4161 species of lizards and snakes. *BMC Evolutionary Biology*, 13 (1), 93.
https://doi.org/10.1186/1471-2148-13-93
Quah, E.S., Anuar, S., Grismer, L.L. & Grassby-Lewis, R. (2017) A new species of *Dibamus* Duméril & Bibron 1839 (Squamata: Dibamidae) from a hill station in Peninsular Malaysia. *Raffles Bulletin of Zoology*, 65, 681–690.
Rabineau, M., Berné, S., Olivet, J.-L., Aslanian, D., Guillocheau, F. & Joseph P. (2006) Paleo sea levels reconsidered from direct observation of paleoshoreline position during Glacial Maxima (for the last 500,000 yr). *Earth and Planetary Science Letters*, 252, 119–137.

https://doi.org/10.1016/j.epsl.2006.09.033
Riyanto, A., Arida, E. & Koch, A. (2018) *Cyrtodactylus tahuna* sp. nov., a new bent-toed gecko (Reptilia: Squamata: Gekkonidae) from Sangihe Island, North Sulawesi, Indonesia. *Zootaxa*, 4399 (2), 220–232. https://doi.org/10.11646/zootaxa.4399.2.6
Rompas, P.T.D. & Manongko, J.D.I. (2016) Numerical simulation of marine currents in the Bunaken Strait, North Sulawesi, Indonesia. *In*: *IOP Conference Series: Materials Science and Engineering. Vol. 128. No. 1*. IOP Publishing, Bristol, pp. 012003 https://doi.org/10.1088/1757-899X/128/1/012003
Sabaj Pérez, M.H. (2012) *Standard symbolic Codes for institutional Resource Collections in Herpetology and Ichthyology: an Online Reference. Version 3.0 (23 February 2012)*. American Society of Ichthyologists and Herpetologists, Washington, D.C.
Setiadi, M.I. & Hamidy, A. (2006) *Jenis-jenis herpetofauna di Pulau Halmahera*. Museum Zoologicum Bogoriense, Puslit Biologi Lembaga Ilmu Pengetahuan Indonesia (LIPI), Bogor. Available from: http://biologi.lipi.go.id/zoologi/images/file_download/herpet/laporan/herpetofauna_halmahera.pdf (accessed 29 January 2018)
Schlegel, H. (1858) *Handleiding Tot de Beoefening der Dierkunde 2.* Natuurkundige Leercursus, Koninlijke Militarie Akademie, Nys, Breda, 628 pp.
Smith, M.A. (1921) New or little known Reptiles and Batrachians from Southern Annam (Indo-China). *Journal of Zoology*, 91 (2), 423–440.
Smith, M.A. (1935) *The fauna of British India, including Ceylon and Burma*. Taylor and Francis, London, 440 pp.
Steindachner, F. (1867) Reptilien. *In*: *Reise der Österreichischen Fregatte Novara um die Erde in den Jahren 1857, 1858, 1859 unter den Befehlen des Commodore B. von Wüllerstorf-Urbair. Zoologie. 1 (3)*. K. Gerold's Sohn/Kaiserlich-Königl. Hof- und Staatsdruckerei, Wien, pp. 1–98.
Tan, F.L. (1993) *Checklist of lizards of Sabah.* Sabah Parks Trustees, Kota Kinabalu, 18 pp.
Taylor, E.H. (1962) New oriental reptiles. *University of Kansas Science Bulletin*, 43, 209–263. https://doi.org/10.5962/bhl.part.13346
Townsend, T.M., Larson, A., Louis, E. & Macey, J.R. (2004) Molecular phylogenetics of Squamata: the position of snakes, amphisbaenians, and dibamids, and the root of the squamate tree. *Systematic biology*, 53 (5), 735–757. https://doi.org/10.1080/10635150490522340
Townsend, T.M., Leavitt, D.H. & Reeder, T.W. (2011) Intercontinental dispersal by a microendemic burrowing reptile (Dibamidae). *Proceedings of the Royal Society of London B: Biological Sciences*, 278 (1718), 2568–2574.
Uetz, P. & Stylianou, A. (2018) The original descriptions of reptiles and their subspecies. *Zootaxa*, 4375 (2), 257–264. https://doi.org/10.11646/zootaxa.4375.2.5
Underwood, G. & Lee, M.S.Y. (2000) The egg tooth of *Dibamus* and their bearing on possible relationships with gekkotan lizards. *Amphibia-Reptilia*, 21, 507–511.
Vane-Wright, R.I. (1991) Transcending the Wallace Line: Do the western edges of the Australian Region and the Australian Plate coincide? *Australian Systematic Botany*, 4, 183–197. https://doi.org/10.1071/SB9910183
Vidal, N. & Hedges, S.B. (2005) The phylogeny of squamate reptiles (lizards, snakes, and amphisbaenians) inferred from nine nuclear protein-coding genes. *Comptes rendus biologies*, 328 (10-11), 1000–1008. https://doi.org/10.1016/j.crvi.2005.10.001
Zug, G.R., Vitt, L.J. & Caldwell, J.P. (2001) *Herpetology, an Introductory Biology of Reptiles and Amphibians. Second Edition.* Academic Press, San Diego, 630 pp.
Zulkarnain, I. (2001) Rock chemistry of quaternary volcanics around Manado and Siau island, North Sulawesi. *Jurnal Teknologi Mineral*, 8 (1), 37–52.

Comparative material examined

Dibamus celebensis Schlegel, 1858: RMNH 3638 (lectotype), male, “Celebes”, Indonesia, coll. E. A. Forsten; RMNH 3637, (paralectotype), female, “Celebes”, coll. E. A. Forsten.

Dibamus novaeguineae Duméril & Bibron, 1839: MNHN 7156 (paralectotype), female, New Guinea (?), without collecting data.