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Description of a new species of the genus *Dendrelaphis* Boulenger, 1890 from Myanmar (Squamata: Serpentes: Colubridae)

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Abstract. The population systematics of the colubrid snake so far referred to as *Dendrelaphis gorei* (Wall, 1910) were investigated by carrying out a multivariate analysis of geographic variation. The results reveal the existence of two distinct and apparently disjunct phenotypes. These phenotypes are assumed to represent independent evolutionary lineages. The first lineage corresponds with *D. gorei* which inhabits the Assam Valley and adjoining Himalayan foothills. However, the name *Dendrophis gorei* Wall, 1910 is actually a junior synonym of *Dendrelaphis biloreatus* Wall, 1908. Consequently, the latter name is adopted for this lineage. The second lineage, described in this paper as a new species, inhabits the South Myanmar lowlands and neighbouring mountain chains. It is distinguished from *D. biloreatus* on the basis of its higher ventral count (203–212 versus 190–199), its undivided anal shield (divided in *D. biloreatus*) and its higher average number of anterior temporal shields (usually 2 versus usually 1).

Key words. *Dendrelaphis* sp. n., *Dendrelaphis gorei* syn. n., *Dendrelaphis biloreatus*, Myanmar, analysis of geographic variation.

INTRODUCTION

The colubrid snakes of the genus *Dendrelaphis* Boulenger, 1890 are widely distributed, ranging from Pakistan in the West to the northern and eastern coast of Australia in the East and South and to southern China in the North (Ziegler & Vogel 1999). Members of the genus *Dendrelaphis* are slender, diurnal species that are predominantly arboreal and feed mainly on lizards and amphibians.

Boulenger (1894), Wall (1921), Meise & Henning (1932), Mertens (1934) and Smith (1943) have in turn worked on the systematics of this genus. Nevertheless, their cumulative effort did not result in an unambiguous and complete taxonomy of this genus, a fact that was underlined by the recent descriptions and revalidations of several species (Vogel & Van Rooijen 2007, 2008, 2011; Van Rooijen & Vogel 2008a, 2008b, 2008c, 2009).

Dendrelaphis gorei (Wall, 1910) has been reported to occur in Northeast India and Myanmar. It is one of the least known members of its genus and is scarcely represented in museum collections. In recent years however, new material has become available through the Myanmar Herpetological Survey, a collaborative effort of the California Academy of Sciences, Smithsonian Institution and the Forest Department, Ministry of Forestry, Myanmar (e.g. Wogan et al. 2008). In this paper, we investigate the population systematics of *D. gorei* by performing a multivariate analysis of geographic variation based on morphological data. Furthermore, the name *Dendrelaphis biloreatus* Wall, 1908 is evaluated. Smith (1943) synonymized *D. biloreatus* with *D. gorei* (Wall 1910) as he could not find any differences between the two species apart from the divided loreal shield in *D. biloreatus*. However, according to the rule of priority (Art. 23, ICZN, 1999), the name *D. biloreatus* should be adopted for this species.

MATERIALS AND METHODS

Eleven museum specimens were examined for this study. In addition, data on three additional specimens were taken from Wall (1908, 1910). For each examined specimen, 23 characters including aspects of colour pattern, body proportions and scalation were recorded (Table 1). Eye-diameter and distance eye-nostril were measured with a slide calliper to the nearest 0.1 mm. These measurements were made on the left and right side and were subsequently averaged. Snout-vent length was measured to the pos-

terior margin of the anal plate by marking the length on a piece of string and subsequently measuring the position of the mark to the nearest 0.5 cm. Tail-length was measured to the nearest 0.5 cm by straightening the tail against a ruler. The number of ventrals was counted using Dowling's method (1951). Subcaudals were counted on one side, the terminal scute was excluded. The first sublabial was defined as the scale that starts between the posterior chin shield and the infralabials and that borders the infralabials (see Peters 1964, fig. 7). The last infralabial was defined as the infralabial still covered completely by the last supralabial. The posterior most temporal scales were defined as the scales of which more than half of the area lies in front of an imaginary line that runs from the apex of the last supralabial to the posterolateral corner of the parietal.

Geographic coordinates were taken directly from the field notes or were obtained by translating locations to coordinates. Relevant variables were included in a Principal Components Analysis (PCA, e.g. Cramer 2003) in order to reduce the dimensions of the dataset. The resulting PCA-scores were then plotted against longitude and latitude in order to visualize the pattern of geographic variation. Confirmatory geographic analyses of the PCA-score were carried out by Analysis of Covariance (ANCOVA; Maxwell & Delaney 1990; Norusis & SPSS 1993) using longitude and latitude as covariates and phenotype as factor. Normality of the PC-scores was first tested by means of Kolmogorov-Smirnov tests.

All statistical analyses were carried out with the software SPSS (2006; SPSS for Windows. Release 14.0.2. Chicago: SPSS Inc.).

Table 1. List of morphometric, scalation and coloration characters used in this study and their abbreviations.

Abbreviation	Character
Morphometrics	
EYED	Horizontal diameter of the eye
EYEN	Distance from centre of the eye to posterior border of the nostril
TAIL	Tail-length
WSNOUT	Width of the snout measured at the position of the nostrils
LHEAD	Head-length measured from the tip of the snout to the rear of the jaw
SVL	Snout-vent length
Scalation	
VENT	Number of ventrals
SUBC	Number of subcaudals
DOR1	Number of dorsal scale rows 1 head-length behind the head
DOR2	Number of dorsal scale rows at the position of the middle ventral
DOR3	Number of dorsal scale rows 1 head-length before the tail
SUBL	Number of infralabials touched by the first sublabial (L+R)
SL1	Number of supralabials (L+R)
SL2	Number of supralabials touching the eyes (L+R)
LOR	Number of loreals (L+R)
INFR	Number of infralabials (L+R)
ATEMP	Number of anterior temporals (L+R)
TEMP	Number of temporals (L+R)
POC	Number of postoculars (L+R)
VERT	Vertebral scales smaller than (0) or larger than (1) scales of the first dorsal row
AN	Anal shield divided (0) or undivided (1)
Coloration	
TSTRIPE	Postocular stripe absent (0), rudimentary (1), present (2)
LSTRIPE	Ventrolateral stripe absent (0), present (1)

The collected data were used to carry out an analysis of geographic variation. The objective of this analysis was to enable differentiation between clinal variation and phenetic discontinuities, the latter being evidence for lineage separation (e.g. Lenk & Wüster 1999; De Queiroz 2007).

Material examined. S-037, Guwahati, Assam; BMNH 1940.3.4.24, Assam; BMNH 1940.3.4.25, Samagooting, Assam; BMNH 1946.1.10.30, Jaipur, Assam (syntype *Dendrophis gorei* Wall, 1910); CAS 208429, Myanmar, Bago Division, Bago Yoma, Sein Yay Camp, 18 51 21.636

N, 96 10 21.324 E; CAS 211939, Myanmar, Ayeyarwady Division, vic Mwe Hauk Village (16 16 39.2 N, 94 45 32.5 E); CAS 222114-222115, Myanmar: Bago Division, Aok Twin Township, Ka Baung Reserve, Sein Ye Camp, Block 120, 18 51 16.1 N, 96 10 23.6 E; CAS 222339, Myanmar: Chin State, Min Dat Township, Min Dat Township, Nat Ma Taung National Park, 21 21 14.9 N, 93 56 08.3 E; CAS 234880, Myanmar,: Chin State, Mindat Township, Mindat District, 21 26 43.5 N, 94 00 24.0 E; CAS 244037, Myanmar, Sagaing Division, Leha and Khante township boundary, Nana Sa Laing camp, 26 07 23.1 N, 95 32 24.6 E

Museum abbreviations. BMNH: Natural History Museum, London, Great Britain. CAS: Collection of the California Academy of Sciences, USA. S: Saibal Senguptas Collection, Guwahati, Assam

RESULTS

Statistics

Visual inspection of the data suggested a striking differentiation between specimens from Assam (NE India) and Northwest Myanmar on the one hand and specimens from the remainder of Myanmar on the other hand. One phenotype was characterized by a high number of ventral counts, an undivided anal shield and usually two anterior temporal shields whereas the other was characterized by a low number of ventrals, a divided anal shield and usually one anterior temporal shield. These characters were included in a PCA. The first component explained 92% of the total variance. This demonstrates that these characters covary strongly and thus form a suite of characters that sharply differentiates between the two phenotypes. The individual scores on this component were plotted

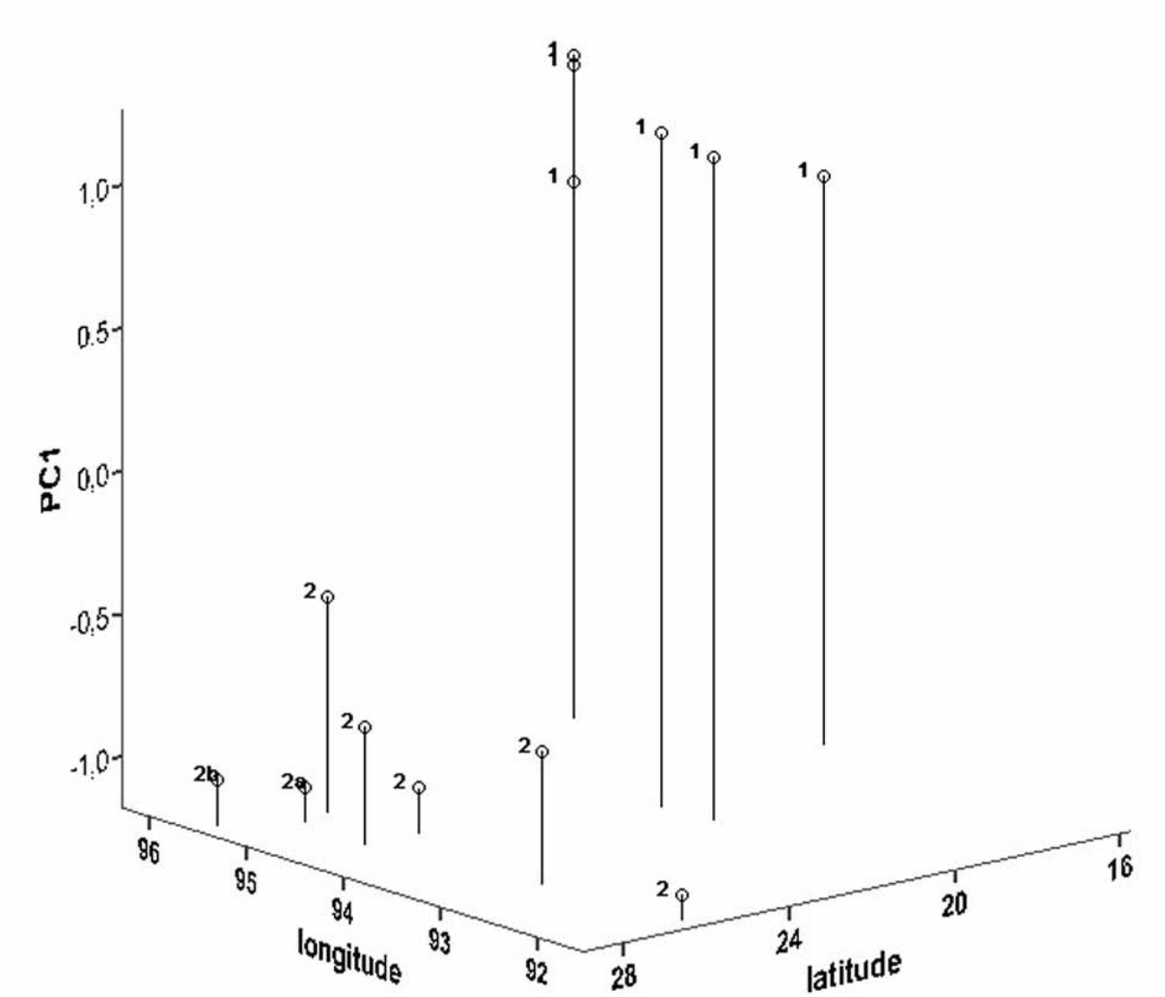

Fig. 1. PCA-scores based on a PCA of the characters VENT, AN and ATEMP against longitude and latitude. 1 Phenotype 1, 2 phenotype 2, 2b= type *D. biloreatus* Wall, 1908; 2a = syntype *D. gorei* Wall, 1910.

against latitude and longitude to visualize the pattern of geographic variation. In figure 1, data-points corresponding with the type of *Dendrelaphis biloreatus* and one of the two syntypes of *Dendrophis gorei* are indicated for a later discussion of the appropriate nomenclature. A phenetic discontinuity is in evidence, the difference in PCA-scores between the phenotypes being highly significant (ANCOVA, df=1,11; P<0.0001). Subsequent inclusion in the model of longitude and latitude in the form of covariates demonstrated that geographic coordinates had no added explanatory power (ANCOVA, df=1,9; P=0.9 and df=1,9; P=0.4 respectively). Thus, there is no evidence of clinal variation, the transition from one phenotype to the other apparently being sudden rather than gradual.

The sudden phenetic transition represents strong evidence for lineage separation. Thus, the two distinguished phenotypes are here interpreted as representing distinct evolutionary sister-lineages. An evaluation of the characters separating the two phenotypes supports this view. First, one phenotype exhibits an undivided anal shield whereas the other has a divided anal shield. An undivided anal shield is an exceptional character in the genus *Dendrelaphis*. The only congeneric species that exhibits this character (in roughly 40% of the specimens) is *Dendrelaphis proarchos* (Wall, 1909) (Vogel & van Rooijen 2011). We examined more than 600 museum specimens of this genus, representing 24 species and subspecies. Only a single specimen (beside those identified as *D. proarchos* and the material presented in this study) was found to have an undivided anal shield. Second, the two phenotypes differ substantially in the number of ventral scales, the difference being 19 on average (211 in phenotype 1, 192 in phenotype 2). This is a relatively large difference when compared to established interspecific differences. For instance, the difference in ventral count between *D. formosus* on the one hand and *D. kopsteini* and *D. cyanochloris* on the other hand is 5 and 19 respectively (Vogel & Van Rooijen 2007). The difference between *D. haasi* and *D. pictus*, *D. pictus andamanensis*, *D. humayuni*, *D. tristis* is 3, 20, 10 and 14 respectively (Van Rooijen & Vogel, 2008a). Finally, the difference between *D. chairecacos* on the one hand and *D. tristis* and *D. schokari* on the other is 10 and 12 respectively (Van Rooijen & Vogel 2009). The third difference between the two phenotypes is the number of anterior temporal scales. Phenotype 1 usually has two anterior temporal scales whereas phenotype 2 has a single anterior temporal in the majority of cases. This character alone already leads to a correct identification in 85% of the cases.

Table 2. Comparison between the type of *Dendrelaphis biloreatus* and six specimens of the species so far referred to as *Dendrelaphis gorei*.

	type *Dendrelaphis biloreatus*	*Dendrelaphis gorei* (n=6)
Ventrals	192	190–199
Subcaudals	147	144–152
Relative tail-length	0.34	0.34–0.35
Supralabials	9	8–9
Supralabials touching the eye	3	2–3
Anterior temporals	1	1–2
Total number of temporals	8	7–12
Poctoculars	2	1–2
Loreals	2	1
Dorsal rows at midbody	13	13
Divided anal shield	yes	yes
Faint ventrolateral line, not bordered by black lines	yes	yes
Postocular stripe that covers the whole temporal region and extends onto the neck	yes	yes
Total length	70.0	53.5–90.0
vertebrals strongly enlarged	yes	yes
Ground color brown	yes	yes
Maxillary teeth	21	20 (n=1)

Fig. 2. *Dendrelaphis walli* sp. n., holotype (CAS 234880).

Nomenclature

Two available names, *Dendrophis gorei* Wall, 1910 and *Dendrelaphis biloreatus* Wall, 1908 are relevant in the context of this study. In figure 1, data pertaining to a syntype of *D. gorei* and the type of *D. biloreatus* are indicated. It is evident that neither of these types represents phenotype 1 (South Myanmar and neighbouring mountain chains). Thus, we here describe phenotype 1 as a new species. Phenotype 2 (Assam and Northwest Myanmar) is currently known as *D. gorei* (Wall, 1910), but we here adopt the older name *Dendrelaphis biloreatus* Wall, 1908 to represent this lineage. *Dendrelaphis biloreatus* was described by Wall on the basis of a single specimen. Smith (1943) synonymized *D. biloreatus* with *D. gorei* as he could not find any difference between the two species apart from the divided loreal shield in *D. biloreatus*. In table 2, a more detailed comparison is provided between the morphological characteristics of the type of *D. biloreatus* and six specimens of *D. gorei*. With the exception of the loreal shield, the values pertaining to the type of *D. biloreatus* all fall within the range of *D. gorei*. Thus, the results agree with Smith's view that the type of *D. biloreatus* represents an exceptional specimen with a split loreal shield within *D. gorei*. In the context of a revision of the taxonomy of this genus, the authors have come across several specimens of *Dendrelaphis* with either a double or an absent loreal shield. Furthermore *D. biloreatus* has a rather long and slender postnasal scale which looks like second loreal shield at the first glance. So indirectly the name makes some sense. Consequently, the two names indeed refer to the same species. According to the rule of priority (ICZN, 1999, art. 23.1), the name *Dendrelaphis biloreatus* should actually be adopted for this species.

Table 3. Morphological and coloration characters of the types of *Dendrelaphis walli* sp. n.

Collection N°	CAS 234880	CAS 208429	CAS 211939	CAS 222114	CAS 222339	CAS 222115
status	holotype	paratype	paratype	paratype	paratype	paratype
Sex	f	–	m	m	m	f
Snout-vent length (cm)	48.5	–	49.0	54.5	61.5	59.5
Tail-length (cm)	22.5	–	25.5	29.5	29.0	31.0
Head-length (mm)	13.5	–	15.5	15.5	17.0	17.0
Eye-diameter (mm)	3.1	–	3.5	3.5	3.9	3.5
Snout-width	2.8	–	3.2	3.4	3.7	3.3
Ventrals	213	211	203	210	212	212
Subcaudals	145	–	148	163	147	159
Dorsal formula	13-13-11	–	13-13-11	13-13-11	13-13-9	13-13-11
Temporal formula	22212/2122	222/222	222/212	212/112	2212/222	222/212
Supralabials	8/8	8/8	8/8	8/8	8/8	8/8
Supralabials touching the eye	4,5/4,5	4,5/4,5	4,5/4,5	4,5/4,5	4,5/4,5	4,5/4,5
Infralabials	10/10	–	10/10	?/9	10/10	11/10
Infralabials touched by first sublabial	6,7/6,7	–	6,7/6,7	6,7/5,6	6,7/6,7	6,7/6,7
Loreals	1/1	1/1	1/1	1/1	1/1	1/1
Postoculars	2/2	3/3	2/2	2/2	2/2	2/2
Number of scales bordering the parietal scales	4	–	5	5	6	5
Vertebrals larger than dorsals of the first row	yes	–	yes	yes	yes	yes
Anal shield entire	yes	yes	yes	yes	yes	yes
Light ventrolateral stripe which is faint and is not bordered by black lines	yes	–	yes	yes	yes	yes
Postocular stripe broad, covering the whole temporal region and extending onto the neck	yes	–	yes	yes	yes	yes

Taxonomy

***Dendrelaphis walli* sp. n.** (Fig. 2)
Dendrelaphis gorei (Wall, 1921) (part.)

Holotype. CAS 234880, adult female from Myanmar (Chin State: Mindat township, Mindat District, 21 26 43.5 N, 94 00 24.0 E, 3582 ft), collected by A.K. Shein and T. Nyo, 23 Aug 2005.

Paratypes. CAS 208429, CAS 211939, CAS 222114–222115, CAS 222339.

Diagnosis. A species of *Dendrelaphis*, characterized by the combination of: 1) 13 dorsal scale rows at midbody; 2) strongly enlarged vertebral scales; 3) 203–213 ventrals; 4) 145–163 subcaudals; 5) 8 supralabials; 6) supralabials 4 and 5 bordering the eye; 7) 2 anterior temporals in the majority of specimens; 8) a short sublabial that touches 2 infralabials; 9) an undivided anal shield; 10) a black postocular stripe that covers the majority of the temporal region and extends onto the neck; 11) black, oblique bars on the neck region; 12) a pale ventrolateral line, not bordered by black lines.

Table 4. Diagnostic differences between *Dendrelaphis walli* sp. n. and *Dendrelaphis biloreatus* Wall, 1908.

	Dendrelaphis walli n. sp. (n=7)	*Dendrelaphis biloreatus* (n=7)
Ventrals	211 (203–213)	192 (190–199)
Anterior temporals	usually 2 (92% of specimens)	usually 1 (86% of specimens)
anal shield	entire	divided

Description of the holotype. Adult female; body very slender; snout-vent length 48.5 cm; tail-length 22.5 cm;head distinct from neck; head-length 13.5 mm; snout-width 2.8 mm; pupil round; eye-diameter 3.1 mm; distance eye-nostril 3.1 mm; 213 ventrals; 145 subcaudals; dorsal scales in 13-13-11 rows; 8 supralabials, 4th and 5th border the eye; 10 infralabials, infralabials 1–5 touch the first chinshield, infralabials 5 and 6 touch the second chinshield; 1 preocular; 2 postoculars; 1 loreal; temporal formula 2:2:2:1:2 (L), 2:1:2:2 (R); first sublabial touches infralabials 6 and 7; vertebrals strongly enlarged, with straight posterior margin, width of the vertebral scale at the position of the middle ventral scale 2.4 mm; anal entire; parietal scales bordered posteriorly by 4 scales; ground color brownish; supralabials and throat white; some black spots on supralabials 2–4, the loreal and the preocular; a black postocular stripe starts behind the eye, covers the majority of the temporal region, and extends onto the neck where it breaks up into narrow, black oblique bars which fade away further posteriorly; a faint ventrolateral line is present, covering the first dorsal row and lower half of the second dorsal row; the ventrolateral line is not bordered by black lines; belly whitish.

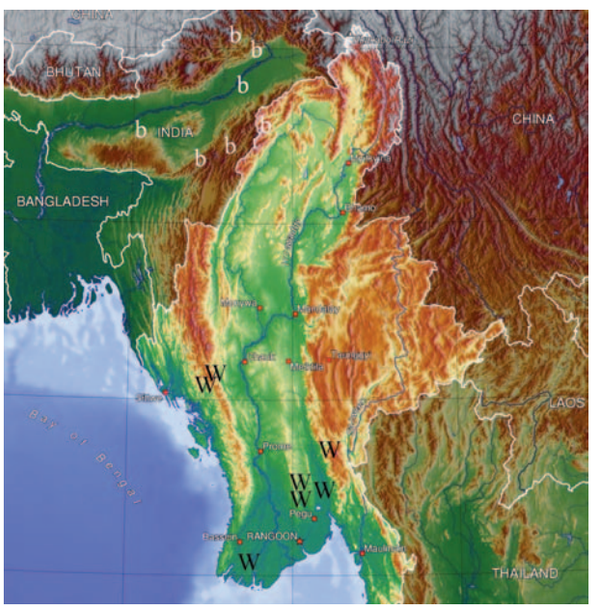

Fig. 3. Currently known distribution of *D. biloreatus* (white b) and *D. walli* sp. n. (black W).

Variation. Table 3 provides data regarding the types of *D. walli* sp. n.

Comparison with congeneric species. *Dendrelaphis walli* sp. n. differs from all congeners, except *Dendrelaphis biloreatus*, *Dendrelaphis caudolineatus* and *Dendrelaphis caudolineolatus*, by its dorsal formula of 13-13-11/9. It differs from *Dendrelaphis caudolineatus* in its strongly enlarged vertebral scales (not enlarged in *D. caudolineatus*), its much more slender body (stout in *D. caudolineatus*), its undivided anal shield, the number of supralabials (9 vs. 8 in *D. walli* sp. n.) and in its coloration. It differs from *Dendrelaphis caudolineolatus* in the number of ventral scales (149–175 vs. 203–213 in *D. walli* sp. n.) and subcaudal scales (111–129 vs. 145–163 in *D. walli* sp. n.) and its undivided anal shield. Differences between *D. walli* sp. n. and *D. biloreatus* are given in Table 4.

Sexual dimorphism. Females have a wider snout than males (ANCOVA, df=1,5, P=0.004). In addition, there is some evidence that females have a larger eye than males (ANCOVA, df=1,5, P=0.08). No evidence of other sexual dimorphisms was found though this may be due to lack of statistical power (e.g. Streiner 1990).

Distribution. According to currently known locality records, *D. biloreatus* inhabits the Assam Valley and adjoining Himalayan foothills whereas *D. walli* sp. n. inhabits the South Myanmar lowlands and neighbouring mountain chains. Thus, the two species appear to exhibit a disjunct distribution (figure 3). However, this may be due to collecting gaps. In reality, one or both of these species may inhabit the intermediate area. On the other hand, the Myanmar Herpetological Survey did collect in the central and northern parts of Myanmar, which did not yield a specimen of either species, with the exception of one *D. biloreatus* (CAS 244037) near the border with Assam, within the known range of this species. If these species indeed occur allopatrically, the central dry zone of Myanmar and adjoining mountain ranges may be the geographic barrier that separates these species and that may have enabled the independent evolution of the two.

Etymology. This species is dedicated to Major Frank Wall (1868–1950), in recognition of his outstanding work on the genus *Dendrelaphis*.

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