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A new species of *Amphisbaena* (Squamata: Amphisbaenidae) from the Orinoquian region of Colombia

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Abstract

In northern South America, amphisbaenians are rarely seen among the herpetofauna.Thus, general knowledge about them is very poor. During a herpetological survey in 2012 at Casanare, Colombia, we found two specimens of an unusual *Amphisbaena*. A third specimen sharing the same morphotype labeled *Amphisbaena* sp. from Vichada department was found deposided in an Colombian reptile collection. Based on morphological analyses together with phylogenetic analyses of 1029 base pairs of the mitochondrial DNA (mtDNA), we describe a new species of *Amphisbaena* that inhabits in the Orinoquian region of Colombia. The new species is part of a phylogenetic clade together with *A. mertensii* and *A. cunhai* (central-southern Brazil), exhibiting a great genetic distance (26.1–28.9%) between the newly identified lineage versus those taxa, and versus the sympatric taxa *A. alba* and *A. fuliginosa*. Morphologically, this new *Amphisbaena* can be distinguished from their congeners by characters combination of number of preocloacal pores, absence of malar scale, postgenial scales and body and caudal annuli counts. *Amphisbaena gracilis* is on morphology grounds the most similar species. However, the new species can be distinguished from it by having higher body annuli counts, angulus ories aliegned with the edges of the ocular scales and center of frontal scales, less number of large middorsal segments of the first and second body annulus, and rostral scale visible from above. The description of this new *Amphisbaena* species points out the urgent need to increase the knowledge of worm lizards in Colombia

Keywords

burrowing habits, cryptic species, fossorial, integrative taxonomy, mtDNA, worm lizard, South America

Introduction

Amphisbaenians are one of the most enigmatic and unusual squamates. All species have burrowing habits, but some occasionally venture onto the surface or can be found under objects on the ground (Pough et al. 1998). Thus, due to its fossorial habit, cryptic behavior, secretive microhabitats and lower encounter rate, amphisbaenians are considered an elusive research objective. About 102 species of the genus *Amphisbaena* Linnaeus, 1758 have been described in South America (Gans 2005; Uetz et al. 2020), with Brazil being the country with the highest diversity with over 80 species (Gans 2005; Gomes and Maciel 2012; Teixeira et al. 2014; Uetz et al. 2020).

Since Gans and Mathers (1977) early efforts to establish species boundaries between *Amphisbaena* from northern South America (sensu Eva and Huber 2005), few researchers have focused on continuing studies on the zoogeography and systematics of these uncommon reptiles (Costa et al. 2018b). The Northern South American *Amphisbaena* currently comprise eight nominal species: *A. alba* Linnaeus, 1758; *A. fuliginosa* Linnaeus, 1758; *A. medemi* Gans & Mathers, 1977; *A. spurrelli* Boulenger, 1915; *A. gracilis* Strauch, 1881; *A. rozei* Lancini, 1963; *A. stejnegeri* Ruthven, 1922 and *A. vanzolinii* Gans, 1963; all inhabiting the tropical lowland ecosystems of Panama, Colombia, Venezuela, Guyana and Surinam.

Colombia is considered to be a megadiverse country in part due to its rich fauna of around 621 species of reptiles (Uetz et al. 2020). However, worm lizards remain poorly represented in the Colombian herpetofauna due to the lack of scientific knowledge. Currently, Colombian worm lizards comprise two genera (*Mesobaena* Mertens, 1925 and *Amphisbaena* Linnaeus, 1758) and five species: *Mesobaena huebneri* Mertens, 1925; *Amphisbaena alba*, *A. fuliginosa*, *A. medemi* and *A. spurrelli*. *Amphisbaena alba* and *A. fuliginosa* (sensu Vanzolini 2002) are the most widely distributed amphisbeanids in the country; *A. alba* is restricted to the Cis-Andean region while *A. fuliginosa* is present in both Cis and Trans-Andean regions, ranging from the sea level to 1300 m. a.s.l. *Amphisbaena spurrelli* was the first amphisbeanid described in Colombia. It is distributed across the Chocoan region to Panáma and its type locality corresponds to corregimiento of Andagoyá, Municipality of San Juan, department of Chocó (Boulenger 1915; Gans and Mathers 1977). *Mesobaena huebneri*, the second worm lizard species described, is only known from three disjunct and distant localities: Its type locality corresponds to department of Inirida (Amazonian basin, specific locality unknown); the Timbá community, municipality of Mitu, deparment of Vaupes; and Serranía de la Macarena, department of Meta [specific locality unknown (Gans 1971; Cole and Gans 1987)]. Finally, *Amphisbaena medemi* was erected by Gans and Mathers 33 years ago and is the most recently described worm lizard. This species is distributed across the Caribbean region of Colombia, having as type locality the old Inderena fishing facility at Ciénaga de Amajehuevo, municipality of San Cristobal, Atlántico.

After the early efforts made by Gans and collaborators during the 20th century, few attempts have been made to carry out a comprehensive taxonomic assessment of the *Amphisbaena* species distributed in Colombia, as well as in northern South America (Señaris 1999; Costa et al. 2018a). The most recent studies in Colombia have only provided a check list of the already known *Amphisbaena* species or distributional records obtained from fieldwork, ignoring the specimens housed in museums that are waiting for a detailed revision (Rangel-Ch et al. 2012; Angarita-Sierra et al. 2013; Aponte-Gutiérrez et al. 2019; Carvajal-Cogollo 2019).

During a herpetological inventory in the department of Casanare, Colombia (Pedroza-Banda et al. 2014), we found two specimens of an unusual *Amphisbaena* from the municipalities of Paz de Ariporo and Orocué. A third specimen sharing the same morphotype seen in the *Amphisbaena* specimens from Casanare was found in the reptile collection of the Pontificia Universidad Javeriana, labeled as *Amphisbaena* sp., from the municipality of Puerto Carreño, department of Vichada. These three specimens shared unique similarities between them and did not match previous descriptions of any recognized species of the genus (Gonzalez-Sponga and Gans 1971; Gans and Mathers 1977; Gans 2005). Hence, it has become clear that these specimens represent an undescribed evolutionary lineage of amphisbaenians. Therefore, the goal of this paper is to recognize this new species and describe it by integrating molecular and morphological analyses.

Methods

Ethics statement

Fieldwork was performed under the scientific research permit for collection of wild specimens of biological diversity for non-commercial purpose issued by CORPORINOQUIA (Research Auto: 500.5712.0380) and the Colombian Ministry of Environment and Sustainable development (MADS) by agreement 083 of 2012. This study was conducted following the Colombian animal welfare law and the collection of wild specimens of the biological diversity acts (Ley 1774, 2016; Decreto 1376, 2013), as well as considering the Universal Declaration on Animal Welfare (UDAW) endorsed by Colombia in 2007.

Fieldwork and sampling

Fieldwork was carried out in August 2012 in the municipalities of Paz de Ariporo and Orocué, department of Casanare, Colombia. Searches for amphisbaenians were conducted by three researchers from 8:00 to 11:30 and 14:00 to 17:00 for 15 days, with a sampling effort of 97.5 man/hours. We removed covered objects and leaf litter, digging up the ground from 5 to15 cm deep, during three to five minutes for each event. Particularly, we included piles of palm leaves of moriche palm (*Mauritia flexuosa* L.f., 1782), as part of the microhabitats sampled. Individuals collected were immediately placed into cloth bags for later general procedures of measurement and identification as described by Pedroza-Banda et al. (2014).

Molecular data collection and laboratory procedures

Molecular distinctiveness and phylogenetic relationships of the new species of *Amphisbaena* were assessed by analyzing molecular data corresponding to 1029 bp of the NADH dehydrogenase subunit 2 (ND2) gene, mtDNA. We assembled a data set by aligning the sequence from the new species and colombian individuals of *A. alba* and *A. fuliginosa*, with homologous sequences from the Antillean and South American amphisbaenian species published in Genbank (Table 1). The homologous ND2 sequence of the lizard species *Anolis auratus* DQ377355 was used as outgroup. Total genomic DNA was extracted using a standard phenol-chloroform method (Sambrook et al. 1989). We amplified the gene fragment using the primer pairs NADHF/NADH R and L4349/H5540 (Measey and Tolley 2013). We carried out PCRs in a total volume of 30 µl containing one-unit Taq polymerase (Bioline; Randolph, MA), 1 X of buffer (Bioline), a final concentration of 1.5 mM MgCl2 (Bioline), 0.5 µM of each primer, 0.2 mM of each dNTP (Bioline), 0.2 µg of bovine serum albumin (BSA) and approximately 50 ng of total DNA. We purified the PCR products using the ammonium acetate protocol (Bensch et al. 2000), and we sequenced them on an ABI 3130xl genetic analyzer (Applied Biosystems, Foster City, CA, USA) using the BigDye Terminator v3.1 Cycle Sequencing Kit (Applied Biosystems) at the Instituto de Genética, Universidad Nacional de Colombia. We stored the remaining DNA extractions at –80°C in the tissue collection of the Instituto de Genética (for voucher numbers see Table 1). We performed the thermocycling conditions as indicated by Measey and Tolley (2013). The GenBank accession numbers of the obtained sequences are: MT433762, MT433763, MT433764, MT433765, MT433766 (Table 1). The sequences were edited and aligned using Chromas 1.51 (http://www.technelysium.com.au/chromas.html) and BioEdit 7.0.5.2 (Hall 1999).

Phylogenetic analyses and genetic divergence

We analyzed the dataset using the unpartitioned and partitioned (i.e., we treated each codon of the protein-coding gene ND2 as distinct partitions) partition schemes. We assessed the optimal partitioning scheme and best-fit evolutionary models using Partitionfinder v1.1.1 and the Bayesian Information Criterion (Lanfear et al. 2012), resulting in the selection of the partitioned scheme. For this scheme we applied the resulting models in a Bayesian analysis with MrBayes v3.2.1 (Ronquist et al. 2012): ND2 1st and 3rd codons – GTR+I+G and ND2 2nd codon – TVM+G. We incorporated these models into a single tree search mixed model partitioning approach (Nylander et al. 2004). For this analysis, we carried out two parallel runs using four Markov chains, each starting from a random tree. We ran the Markov chains for 20 million generations. The burn-in was set to sample only the plateau of the most likely trees that were used for generating a 50% majority-rule consensus. We then used the software TRACER 1.5.4 (Rambaut and Drummond 2007) to assess an acceptable level of the MCMC chain mixing and to estimate effective sample sizes for all parameters. To assess the genetic differentiation between the new lineage and the other related *Amphisbaena* species (including the sympatric ones *A. fuliginosa* and *A. alba*), we calculated uncorrected *p* genetic distances for the ND2 gene fragment using MEGA 7.0.21 (Kumar et al. 2016).

Morphology

We compared the collected amphisbaenians and the individual found in the collection of the Pontificia Universidad Javeriana to other preserved specimens housed in the following colombian biological collections: reptile collection of the Instituto de Ciencias Naturales, Universidad Nacional de Colombia (ICN-R, Bogotá); Museo de Historia Natural, Universidad de Antioquia (MHUA, Medellin); Museo de la Universidad La Salle (MLS, Bogotá); Pontificia Universidad Javeriana (MUJ, Bogotá); Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH-R, Villa de Leyva) and the reptile collection of the Universidad Industrial de Santander (UIS-R, Bucaramanga).

We compared the pholidosis of the three specimens analyzed in this study to morphological data available in published references of the 50 nominal four pored *Amphisbaena* species, as well as to the *Amphisbaena* species that inhabit the Orinoquian region (Table 2). The definition and terminology used in the diagnosis, description and comparison sections are, as far as possible, in accordance with the broadly used descriptions of South American amphisbaenians according to Gans (1962, 1963, 1967); Gans and Mathers (1977); Vanzolini (1994); Vanzolini (2002); Teixeira et al. (2014) as follows: number of precloacal pores (P); supralabial scales (SS); infralabial scales (IS); temporal scales (TS); number of segments of the first postgenial scale row (FPG); number of segments of the second postgenial scale row (SPG); malar scales (M); number of segments of the postmalar scale row (PM); body annuli (BA); caudal annuli (CA); number of dorsal segments per annulus at midbody (DS); number of ventral segments per annulus at midbody (VS); number of segments per annulus at anterior edge of the cloaca (SAC); number of segments per annulus at posterior edge of the cloaca (SPC); number of cloacal annuli (CCA) [Cloaca annuli are those between the anterior and posterior edge of the cloaca]; autotomy sites on caudal annuli (AUC). Likewise, we followed the characters used by Gonzalez-Sponga and Gans (1971), particularly, we added to our analyses the angulus oris (i.e. the lateral limit of the oral fissure formed by junction of upper and lower lips), as well as the presence/absence or number of the large middorsal segments of the first and second body annulus.

Sex determinations were performed by direct dissections. Furthermore, we made measurements of the head scales on fixed specimens, taking digital pictures using a Zeiss Axiocam microscope camera installed on a stereo

Table 1. ND2 sequences of *Amphisbaena* species used in the present study.

Species	Locality	Accession number. ND2	Voucher	Source
A. alba	Brazil: Vilhena, Rondônia	FJ441943	CHUNB 12795	Mott and Vieites 2009
A. alba	Brazil: Jalapão, Tocantins	FJ441948	CHUNB 30678	Mott and Vieites 2009
A. alba	Brazil: Minaçu, Goiás	FJ441946	CHUNB 430	Mott and Vieites 2009
A. alba	Brazil: Minaçu, Goiás	FJ441947	CHUNB 435	Mott and Vieites 2009
A. alba	Brazil: Mariana, Minas Gerais	FJ441941	JC 795a	Mott and Vieites 2009
A. alba	Brazil: Uruçuí-Una, Piauí	FJ441942	MTR 5502a	Mott and Vieites 2009
A. alba	Brazil: Manso, Mato Grosso	FJ441940	MZUSP 88618	Mott and Vieites 2009
A. alba	Brazil: Lajeado, Tocantins	FJ441944	MZUSP 94813	Mott and Vieites 2009
A. alba	Brazil: Guarantã do Norte, Mato Grosso	FJ441949	UFMT 3468	Mott and Vieites 2009
A. alba	Brazil: Campo Novo dos Parecis, Mato Grosso	FJ441945	UFMT 3476	Mott and Vieites 2009
A. alba	Colombia: Paz de Ariporo, Casanare	MT433762	MLS 1904	This study
A. anaemariae	Brazil: Brasília, Distrito Federal	FJ441911	CHUNB 38647	Mott and Vieites 2009
A. angustifrons	Argentina: Tucuman	FJ441950	Monteiro 3	Mott and Vieites 2009
A. anomala	Brazil:Igarapé-Açú, Pará	FJ441955	MPEG 22139	Mott and Vieites 2009
A. anomala	Brazil: Sao Antônio de Tauá, Pará	FJ441956	MPEG 22141	Mott and Vieites 2009
A. arenaria	Brazil: Canudos, Bahía	KY018695	MTR23279	Teixeira et al. 2016
A. bahiana	Brazil: Campo Formoso, Bahía	MG028575	MZUSP106222	Dal Vechio et al. 2018
A. bahiana	Brazil: Campo Formoso, Bahía	MG028574	MZUSP106221	Dal Vechio et al. 2018
A. bolivica	Argentina: Tucuman	FJ441913	Monteiro 11	Mott and Vieites 2009
A. bolivica	Argentina: Salta	FJ441912	Monteiro 8	Mott and Vieites 2009
A. brasiliana	Brazil: Guarantã do Norte, Mato Grosso	FJ441951	UFMT3998	Mott and Vieites 2009
A. caeca	USA: Manati, Puerto Rico	FJ441914	MVZ 232753	Mott and Vieites 2009
A. caiari	Brazil: Porto Velho, Rondônia	KJ669333	MZUSP101602	Teixeira et al. 2014
A. caiari	Brazil: Porto Velho, Rondônia	KJ669334	MZUSP104237	Teixeira et al. 2014
A. camura	Brazil: Aquidauana, Mato Grosso do Sul	FJ441915	MPEG 21463	Mott and Vieites 2009
A. carli	Brazil: Sao Desiderio, Bahia	KY352335	MTR17848	Teixeira et al. 2016
A. cuiabana	Brazil: Campo Novo dos Parecis, Mato Grosso	FJ441938	UFMT 3545	Mott and Vieites 2009
A. cuiabana	Brazil: Campo Novo dos Parecis, Mato Grosso	FJ441939	UFMT 3546	Mott and Vieites 2009
A. cunhai	Brazil: Manaus, Amazonas	FJ441916	LSUMZH13969	Mott and Vieites 2009
A. darwinii	Brazil: São Jerônimo, Rio Grande do Sul	FJ441936	MCP 14723	Mott and Vieites 2009
***A. elbakyanae* sp. nov.**	Colombia: Paz de Ariporo, Casanare	MT433763	MLS 1901	This study
A. fuliginosa	Brazil	JN700169	BPN 988	Genbank
A. fuliginosa	Brazil: Manso, Mato Grosso	FJ441926	MTR 3177	Mott and Vieites 2009
A. fuliginosa	Brazil: Aripuanã, Mato Grosso	FJ441927	MZUSP 82798	Mott and Vieites 2009
A. fuliginosa	Peru: San Jacinto, Loreto	FJ441925	KU 222189	Mott and Vieites 2009
A. fuliginosa	Colombia: San Martín, Meta	MT433765	MLS 1903	This study
A. fuliginosa	Colombia: Bucaramanga, Santander	MT433764	UIS-R 3181	This study
A. fuliginosa	Colombia: Girón, Santander	MT433766	UIS-R 3724	This study
A. hastata	Brazil: Mocambo do Vento, Bahia	FJ441920	MTR 3555	Mott and Vieites 2009
A. hastata	Brazil: Mocambo do Vento, Bahia	FJ441921	MTR 3662	Mott and Vieites 2009
A. ignatiana	Brazil: Santo Inácio, Bahia	FJ441922	MTR 3538	Mott and Vieites 2009
A. ignatiana	Brazil: Santo Inácio, Bahia	FJ441923	MZUSP 93480	Mott and Vieites 2009
A. kingii	Brazil: São Jerônimo, Rio Grande Do Sul	FJ441969	MCP 14720	Mott and Vieites 2009
A. kingii	Brazil: São Jerônimo, Rio Grande Do Sul	FJ441968	MCP 14721	Mott and Vieites 2009
A. kraoh	Brazil: Jalapão, Tocantins	FJ441935	CHUNB 30676	Mott and Vieites 2009
A. leeseri	Brazil: Mateiros, Tocantins	FJ441937	CHUNB 41351	Mott and Vieites 2009
A. leucocephala	Brazil: Santa Maria Eterna, Bahia	KY352337	MTR33126	Teixeira et al. 2016
A. leucocephala	Brazil: Ilheus, Bahia	KY352336	MTR33467	Teixeira et al. 2016
A. mertensii	Paraguay: Itapua, Alto Vera	FJ441917	KU 290721	Mott and Vieites 2009
A. mertensii	Brazil: Marília, Sao Paulo	FJ441919	MPEG 21462	Mott and Vieites 2009
A. mertensii	Brazil: Campo Novo dos Parecis, Mato Grosso	FJ441918	UFMT 3469	Mott and Vieites 2009
A. mitchelli	Brazil: Belo Monte, Alagoas	KY018696	BM137	Teixeira et al. 2016
A. munoai	Brazil: São Jerônimo, Rio Grande Do Sul	FJ441930	MCP 14749	Mott and Vieites 2009
A. pretrei	Brazil: EEEWG, Bahia	KY352338	MTR22216	Teixeira et al. 2016
A. pretrei	Brazil: Salvador, Bahia	KY352339	TM262	Teixeira et al. 2016
A. roberti	Brazil: Lajeado, Tocantins	FJ441954	MTR 6770	Mott and Vieites 2009

Table 1 continued.

Species	Locality	Accession number. ND2	Voucher	Source
A. roberti	Brazil: Marilia	MG028576	TM16	Dal Vechio et al. 2018
A. saxosa	Brazil: Lajeado, Tocantins	FJ441952	MTR 8830	Mott and Vieites 2009
A. saxosa	Brazil: Lajeado, Tocantins	FJ441953	MTR 8831	Mott and Vieites 2009
A. schmidti	USA: Puerto Rico	AY605475	MVZ 232754	Macey et al. 2004
A. schmidti	USA: PuertoRico, Marchiquita	NC_006284	MVZ 232754	Macey et al. 2004
A. schmidti	USA, Manati, Puerto Rico	FJ441924	MVZ 232756	Mott and Vieites 2009
A. silvestrii	Brazil, Cuiabá, Mato Grosso	FJ441931	UFMT 3996	Mott and Vieites 2009
A. silvestrii	Brazil, Cuiabá, Mato Grosso	FJ441932	UFMT 3997	Mott and Vieites 2009
A. uroxena	Brazil, Mucuge, Bahia	MG028577	MZUSP95987	Dal Vechio et al., 2018
A. uroxena	Brazil, Mucuge, Bahia	MG028578	MZUSP95988	Dal Vechio et al., 2018
A. vermicularis	Brazil, Paranã, Tocantins	FJ441928	CHUNB 35348	Mott and Vieites 2009
A. vermicularis	Brazil, Paranã, Tocantins	FJ441929	CHUNB 35349	Mott and Vieites 2009
A. vermicularis	Brazil, Alagoado, Bahia	MG028579	MTR11246	Dal Vechio et al. 2018
A. vermicularis	Brazil, Santo Inacio, Bahia	MG028583	MTR11294	Dal Vechio et al. 2018
A. vermicularis	Brazil, Serra do Cipo, Minas Gerais	MG028580	MTR20286	Dal Vechio et al. 2018
A. vermicularis	Brazil, Lajeado, Tocantins	MG028582	LAJ403	Dal Vechio et al. 2018
A. xera	—	AY662541	—	Townsend et al. 2004
Amphisbaena sp.	Brazil, Pacoti, Ceara	FJ441933	MTR 169	Mott and Vieites 2009
Amphisbaena sp.	Brazil, Serra das Confusões, Piauí	FJ441934	SC 76	Mott and Vieites 2009

Table 2. Pholidosis comparisons between *Amphisbaena elbakyanae* **sp. nov.** and all the four-pored *Amphisbaena* species from South America.

Species	P	Head scales							Body and caudal scales								Source
		SS	IS	TS	FPG	SPG	M	PM	BA	CA	DS	VS	SAC	SPC	CCA	AUC	
***A. elbakyanae* sp. nov.**	4	3	3	2–3	4	0	0	6–7	245–257	20–24	13–15	16–18	6–7	11–12	4	6–8	*
A. alba Linnaeus, 1758	4–10	4	3	5	2	2–3	1	12–15	198–248	13–21	30–42	35–46	10			Absent	1, 2, 3, 4, 5, 6
A. albocingulata Boettger, 1885	4	3	3					0	183–204	23–27	12–14	15–18				7–9	4, 5, 7, 8
A. angustifrons Cope, 1861	3–6	4	3					P	190–253	12–18	20–31	21–30				Absent	4, 5, 9
A. arda Rodrigues, 2003	4	4	3				1	P	242	30	23	23				8	5, 10
A. arenaria Vanzolini, 1991	4	3	3		P	P		0	285–307	22–23	12–14	14–16				6–7	4, 5, 6, 11, 12
A. arenicola Perez & Borges-Martins, 2019	4	3–4	3	2	2	3	1	6	199–216	20–22	12–14	15–18	6	11		8–9	8
A. bahiana Vanzolini, 1964	4	3	3						204–223	14–16	12–16	14–20				4–5	5, 13
A. bedai Vanzolini, 1991	4	4	3					P	272–284	22–23	18–20	16–18				6	5, 14
A. bolivica Mertens, 1929	2–6	3	3						200–231	18–26	27–36	26–36				3–5	4, 5, 6, 15, 16
A. borelli Peracca, 1897	4	3	3						239–245	17–19	14–16	16–20				6–8	5, 17
A. brasiliana Gray, 1865	4	3	3						213–229	11–15	18–21	18–22				Absent	5, 6, 18, 52
A. camura Cope, 1862	3–6	4	3						188–207	14–19	28–42	29–46				3–5	4, 5, 6, 19,
A. carvalhoi Gans, 1965	4	3	3					0	231–245	19–22	12–14	16–18				7–8	4, 5, 20
A. cegei Montero, Sáfadez & Álvarez, 1997	4	3	3		3	4–5	1	0	179–199	22	17–22	17–23	6	13–15	3–4	6–8	4, 5, 21, 22
A. cuiabana Strussman & Carvalho, 2001	4	3	3						286–292	18–20	14	16				9–10	5, 23
A. cunhai Hoogmoed & Ávila-Pires, 1991	4	3	3	2	2–3	0	1	7–9	226–239	25–26	14–16	14–18	6	7–11		5–7	4, 5, 6, 24

Table 2 continued.

Species	P	Head scales							Body and caudal scales								Source
A. darwinii Duméril & Bibron, 1839	2–5	3	3					P	174–199	18–25	13–19	16–23				7–10	4, 5, 8, 25, 26
A. frontalis Vanzolini, 1991	4	3	3					0	252–272	23–24	14–16	14–16				6–7	4, 5, 11
A. fuliginosa Linnaeus, 1758	6–9	2–3	3–4	3–5	2–6	5–7	1–2	10–14	196–218	24–30	19–28	21–28	7–10	10–16	3–6	4–7	1, *
A. gracilis Strauch, 1881	4	3	3	2	4	0	0	7–8	224–248	21–24	13–16	14–17	6	12–13	5	6–7	4, 27, 28, 29, 30
A. hastata Vanzolini, 1991	4	3	3						266–273	40	18	16				12–16	4, 5, 31
A. heathi Schmidt, 1936	4	3	3					0	183–187	32	12	18–20				7–8	4, 5, 32
A. hogei Vanzolini, 1950	4	3	3					P	177–191	15–19	10–13	14–18				4–7	4, 5, 8, 33
A. ibijara Rodrigues, Andrade & Lima, 2003	4	3	3	1	6	6	1	0	239–250	23–25	14–16	14–16				8–11	5, 34,
A. kingii Bell, 1833	4	3	3		P	P		P	214–244	15–23	12–19	14–22				7	5, 35, 36
A. lumbricalis Vanzolini, 1996	2–6	3	3					0	225–247	20–26	12–16	16–20				6–10	4, 5, 26, 37
A. medemi Gans & Mathers, 1977	4	3	3	2	2–3	3–5	1	9	230–235	17–18	14–16	17–18	6–8	12–17		5–7	4, 5, 30, 38
A. munoai Klappenbach, 1960	4	3	3	2	3	0		9	194–221	18–25	10–15	13–20	6–8	7–14		5–9	4, 5, 8, 39
A. myersi Hoogmoed, 1989	4	3	3						221	28	16	16				8	4, 5, 40
A. nigricauda Gans, 1966	0/4–5	3	3					0	192–226	19–24	9–11	13–16				6–10	4, 5, 8, 41, 42
A. occidnetalis Cope, 1875	4	4	3					P	261–279	18–26	16–19	22–27				9	4, 5, 43
A. pericensis Noble, 1921	4	3	3					0	198–218	16–19	12–16	16–20				6–8	4, 5, 44
A. plumbea Gray, 1872	4	4	3					P	210–283	16–21	18–27	20–30				5–9	4, 5, 45
A. polygrammica Werner, 1901	4	3	3		P	0			270	22	18	16				–	4, 5, 36, 46
A. prunicolor Cope, 1885	4	3	3	2	2	0	1	8	180–215	18–27	10–17	14–20				7–11	4, 5, 8, 47
A. ridleyi Boulenger, 1890	4	4	3					P	172–192	14–17	16–18	20–28				Absent	4, 5, 48
A. rozei Lancini, 1963	4	4	3	2	3	0	1	7	205–209	20	15–16	14				6–7	4, 5, 30, 49, 50
A. sanctaeritae Vanzolini, 1994	4	3	3						269		12	12				6–7	5, 51
A. saxosa Castro-Mello, 2003	4	4	3	2	2	0	1	8	253–272	17–21	18–24	16–21	6		4	Absent	5, 6, 52
A. slateri Boulenger, 1907	4	3	3–4	2	2–3	2–4	1	0–7	176–213	20–24	10–14	14–16	6–8	10–12		7–10	4, 5, 36, 53, 54
A. slevini Schmidt, 1936	4	2	2					0	204–211	23–25	10–14	10–12				5–6	4, 5, 32
A. spurrelli Boulenger, 1915	4	4	4	2	2	0	1	7	213–222	18–23	16–18	16–18	6			7	4, 5, 30, 56
A. steindachneri Strauch, 1881	4	3	3						256–266	17–18	14–16	16				7	5, 57
A. stejnegeri Ruthven, 1922	6	4	2						243–247	13	17–19	16–20	6			9	4, 30, 58
A. supernumeraria Mott, Rodrigues & Dos Santos, 2009	4	3	3	0	2	3	1	0	333–337	22–23	14	17–18				10–12	5, 59
A. talisiae Vanzolini, 1995	4	3	3	2	2	0	1	P	205–234	17–29	10–14	14–18	5–8	7–14		6–8	4, 5, 60, 61
A. townsendi Stejneger, 1911	4	4	3					P	261–279	22–26	16–19	22–27				7–8	5, 62

Table 2 continued.

Species	P	Head scales							Body and caudal scales								Source
A. trachura Cope, 1885	3–4	3	3					P	168–208	15–25	14–24	16–24	6–8	9–14		5–9	8, 25, 47, 63
A. tragorrhectes Vanzolini, 1971	4	4	3					P	169	31	12	12				12–14	4, 5, 64
A. vanzolinii Gans, 1963	4	2	2						200–231	28–31	12–16	12–18				7–14	4, 24, 30, 3
A. vermicularis Wagler, 1824	4								211–254	23–30	18–26	18–25				6	4, 6, 65
A. xera Thomas, 1966	4	3	3					0	225–234	12–16	12–16	14–16				5–7	5, 30, 55

Precloacal pores (P); supralabial scales (SS); infralabial scales (IS); temporal scales (TS); number of segments of the first postgenial scale row (FPG); number of segments of the second postgenial scale row (SPG); malar scales (M); number of segments of the postmalar scale row (PM); body annuli (BA); caudal annuli (CA); number of dorsal segments perannulus at midbody (DS); number of ventral segments per annulus at midbody (VS); number of segments per annulus at anterior edge of the cloaca (SAC); number of segments perannulus at posterior edge of the cloaca (SPC); number of cloacal annuli [(CCA) Cloaca annuli are those between anterior and posterior edge of the cloaca]; autotomy sites on caudal annuli (AUC). Source: * = This study, 1= (Linnaeus 1758), 2= (Gans 1962), 3= (Gans 1963), 4= (Vanzolini 2002), 5= (Maciel 2011), 6= (Dal Vechio et al. 2016), 7= (Boettger 1885), 8= (Perez and Borges-Martins 2019), 9= (Cope 1861), 10= (Rodrigues 2003), 11= (Vanzolini 1991b) , 12= (Teixeira et al. 2016), 13= (Vanzolini 1964), 14= (Vanzolini 1991a), 15= (Mertens 1929), 16= (Montero 2019), 17= (Peracca 1897), 18= (Gray 1865), 19= (Cope 1862), 20= (Gans 1965), 21= (Montero et al. 1997), 22= (Montero 2001), 23= (Strussman and Carvalho 2001), 24= (Hoogmoed & Ávila-Pires, 1991), 25= (Duméril and Bibron 1839), 26= (Teixeira et al. 2014), 27= (Gonzalez-Sponga and Gans 1971), 28= (Señaris 1999), 29= (Gans 1971), 30= (Gans and Mathers 1977), 31= (Vanzolini 1991c), 32= (Schmidt 1936), 33= (Vanzolini 1950), 34= (Rodrigues et al. 2003), 35= (Rojas et al. 2016), 36= (Costa et al. 2018b), 37= (Vanzolini 1996), 38= (Meza-Joya 2015), 39= (Klappenbach 1960), 40= (Hoogmoed 1989), 41= (Gans 1966), 42= (Souza e Lima et al. 2014), 43= (Cope 1875), 44= (Noble 1921), 45= (Gray 1872), 46= (Werner 1901), 47= (Cope 1885), 48= (Boulenger 1890), 49= (Lancini 1963), 50= (Costa et al. 2018a), 51= (Vanzolini 1994), 52= (Castro-Mello 2003), 53= (Boulenger 1907), 54= (Gans 1967), 55= (Thomas 1966), 56= (Boulenger 1915), 57= (Strauch 1881), 58 = (Ruthven 1922), 59= (Mott et al. 2009), 60= (Vanzolini 1995), 61= (Costa et al. 2019), 62= (Stejneger 1911), 63= (Ruiz-García et al. 2016), 64= (Vanzolini 1971), 65= (Wagler 1824).

microscope Carl Zeiss model stemi 2000c and the software Image-J version 1.52 (Schneider et al. 2012). We measured the following morphometric characters: head length (HL); head width (HW); prefrontal length (PFL); prefrontal width (PFW); frontal length (FL); frontal width (FW); parietal length (PL); parietal width (PW); ocular length (OL); ocular height (OH); postocular length (POL); postocular width (POW); first temporal length (TEL); first temporal height (TEH); mental length (ML); mental width (MW); post mental length (PML); post mental width (PMW). Additionally, we took the following body size measurements using a measuring tape (±1 mm): snout-vent length (SVL) and caudal length (TL). We also took body diameter (BD) at mid-body using a digital caliper (±0.01 mm).

Results

Phylogenetic analyses and genetic divergence

The tree-building methods revealed *Amphisbaena elbakyanae* **sp. nov.** with robust support (BA: 0.91) as a sister taxon of a highly supported clade (BA: 0.97), comprising a specimen of *A. cunhai* Hoogmoed & Ávila-Pires, 1991 FJ441916 and specimens of *A. mertensii* Strauch, 1881 FJ441917, FJ441919, and FJ44191 (Fig. 1). Furthermore, *A. elbakyanae* **sp. nov.** appeared evolutionarily distant from sequences belonging to individuals from the sympatric species *A. fuliginosa* and *A. alba* (Fig. 1). The uncorrected *p* distances for the ND2 gene showed that the sequence differentiation values between *Amphisbaena elbakyanae* **sp. nov.** versus *A. cunhai* and *A. mertensii* were 28.9 % and 26.1%, respectively. Furthermore, sequence differentiation values between the new species versus the individuals of the sympatric species *A. alba* and *A. fuliginosa* were 26.2% and 28.4%, respectively. The sequence divergence ranges of *A. elbakyanae* **sp. nov.** compared to other Antillean and South American taxa was 23.5–30.8% (Table 3).

New species description

Amphisbaena elbakyanae sp. nov.

http://zoobank.org/5E06051E-F7CC-4C62-8DCB-05738958-4A65

Figs 2–4.

Chresonymy: *Amphisbaena* sp. (ICN-TAS 700): Pedroza-Banda et al. (2014).

Holotype (Fig. 2). Specimen MLS 1901, a male from El Porvenir farm, Vereda La Colombina, municipality of Paz de Ariporo, department of Casanare, Colombia.

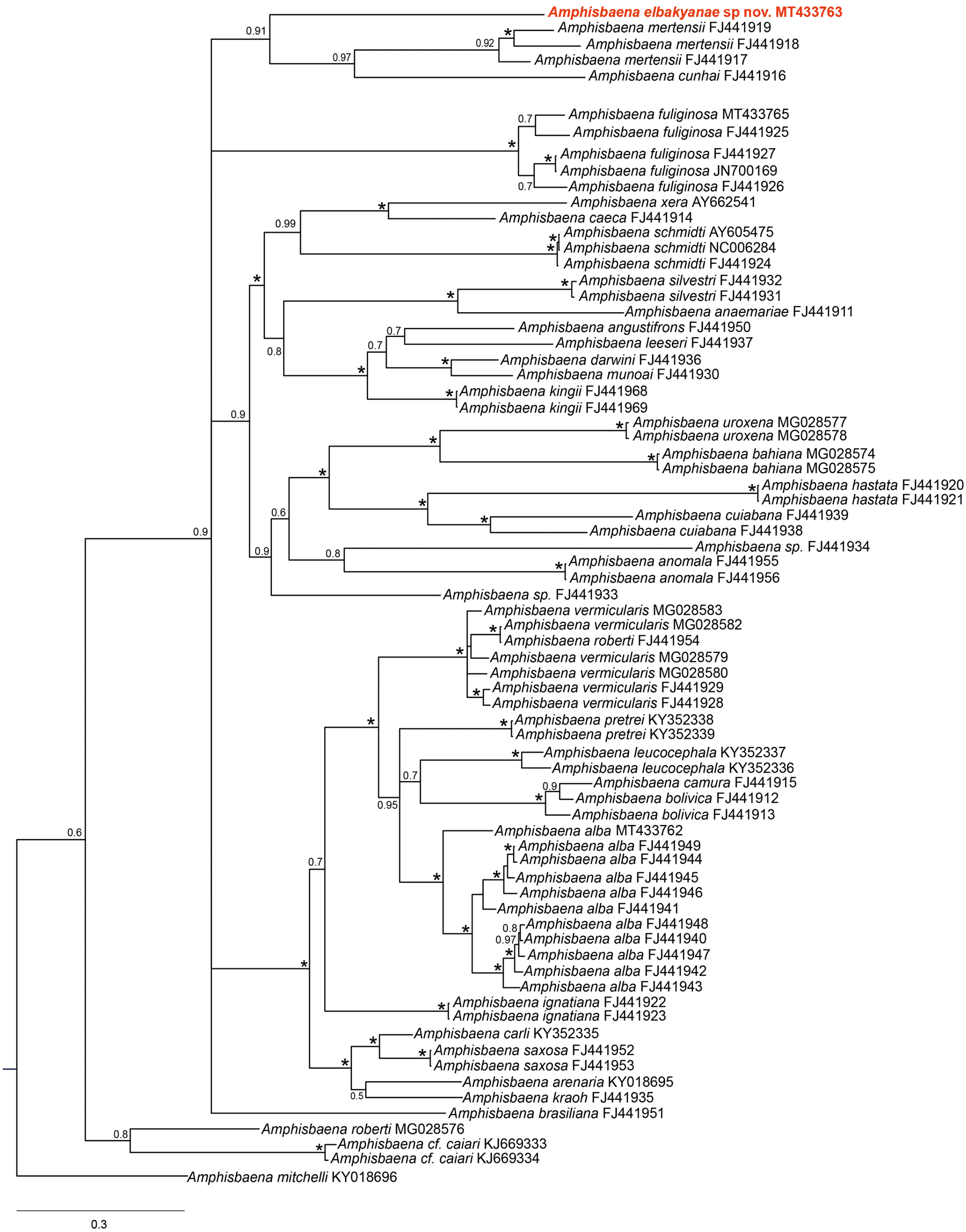

Figure 1. Bayesian inference tree showing the evolutionary relationships of *Amphisbaena elbakyanae* **sp. nov.** (red) based on 1029 bp of mitochondrial DNA. Numbers before nodes: posterior probability values. Asterisks indicate maximum support.

Coordinates: N 6.043472222, W –71.09283333; elevation 140 m. a.s.l. The specimen was collected by Teddy Angarita-Sierra, Marvin Anganoy-Criollo and John Jairo Ospina-Sarria, on 20th August 2012, in a riparian forest near the Ariporo River, under leaf litter of the moriche palm (*Mauritia flexuosa*). This specimen was found in sympatry with *A. alba*.

Paratypes. Two specimens: MUJ 806, a female from Bojonawi Natural Reserve, Fundación Omacha, municipality of Puerto Carreño, department of Vichada, Colom-

Table 3. Uncorrected *p* distances for the fragment of ND2 gene (763 bp) of the species of *Amphisbaena* expressed as percentages (averages). Values below the diagonal represent between lineage divergences. Bold values along the diagonal depict within lineage divergence.

Species	n	elb	alb	ful	ana	ang	ano	are	bah	bol	bra	cae	cam	car	cai	cui	cun	dar	has	ign	kin	kra	lee	leu	mer	mit	mun	pre	rob	sax	sil	sch	uro	ven
A. elbakyanae **sp. nov.**	1	—																																
A. alba	11	26.2	**7.2**																															
A. fuliginosa	5	28.4	28.1	**7.1**																														
A. anaemariae	1	27.5	27.1	29.3	—																													
A. angustifrons	1	28.1	25.7	29.1	24.8	—																												
A. anomala	2	28.7	26.6	30.1	29.2	26.2	**0.0**																											
A. arenaria	1	27.0	19.4	27.1	26.5	25.1	26.8	—																										
A. bahiana	2	30.8	30.0	30.9	29.9	29.5	28.6	30.2	**0.2**																									
A. bolivica	2	27.0	18.1	29.9	28.3	27.3	28.3	21.0	28.3	**5.8**																								
A. brasiliana	1	25.4	25.7	26.5	27.8	26.8	24.8	24.2	29.5	27.8	—																							
A. caeca	1	27.8	26.9	29.8	27.3	24.2	24.6	26.1	28.5	27.7	27.6	—																						
A. camura	1	28.7	19.1	30.1	29.7	28.7	27.9	21.8	29.1	6.8	27.9	28.7	—																					
A. carli	1	23.5	17.7	27.0	26.6	22.4	23.9	12.8	28.8	18.4	21.8	22.6	19.5	—																				
A. cf. *caiari*	2	29.2	28.6	29.1	29.8	27.4	31.9	28.2	30.7	27.3	28.1	28.8	28.1	25.2	**1.7**																			
A. cuiabana	2	25.8	26.4	28.4	26.0	26.3	26.8	26.2	26.5	26.8	24.9	24.5	28.7	23.0	28.3	**18.1**																		
A. cunhai	1	28.9	30.4	30.3	32.8	30.9	32.8	30.3	32.7	30.1	30.3	31.2	29.8	27.0	31.3	30.4	—																	
A. darwini	1	28.6	24.0	29.8	24.5	18.5	26.4	26.5	27.8	27.6	27.8	23.5	28.6	23.5	27.6	24.8	31.6	—																
A. hastata	2	32.7	32.7	30.8	33.4	31.1	32.3	30.9	29.8	32.3	30.8	31.2	33.1	28.7	30.8	27.2	32.8	29.7	**0.0**															
A. ignatiana	2	26.5	19.4	29.0	27.8	27.0	27.9	16.3	27.6	21.6	24.2	27.2	21.8	15.3	27.5	26.1	27.5	27.6	30.5	**0.0**														
A. kingii	2	27.5	24.7	29.6	23.7	17.3	25.4	25.0	28.3	26.1	24.6	23.1	27.9	21.6	27.9	24.2	30.6	16.8	29.8	27.2	0.0													
A. kraoh	1	25.1	19.8	28.8	27.0	25.9	25.4	14.6	29.1	22.0	25.4	25.3	21.7	13.2	28.7	25.9	28.3	25.7	30.5	19.3	24.6	—												
A. leeseri	1	28.7	27.2	29.4	27.0	19.2	25.1	26.4	29.0	28.0	26.5	25.3	29.4	25.2	28.2	25.6	33.0	20.6	30.8	28.4	18.7	25.9	—											
A. leucocephala	2	28.2	18.0	27.8	28.6	28.0	26.5	20.6	29.5	18.9	26.5	27.0	19.3	19.3	27.9	26.3	31.4	26.9	31.8	21.4	25.0	21.4	28.4	**6.1**										
A. mertensii	3	26.1	26.5	30.2	30.7	27.3	28.0	26.9	29.3	27.1	27.6	28.4	27.2	23.6	29.9	28.0	25.0	28.0	32.9	24.6	27.0	26.8	29.4	26.4	**11.4**									
A. mitchelli	1	27.5	26.9	31.2	30.3	27.6	30.0	29.7	31.2	26.8	27.2	28.6	27.9	25.6	27.3	27.3	32.0	27.2	30.3	26.5	27.5	27.2	27.6	26.0	28.0	—								
A. munoai	1	29.8	25.0	29.7	27.5	19.0	25.7	25.9	27.7	28.1	28.9	24.6	28.9	24.5	30.3	25.5	31.9	11.1	30.5	27.9	17.9	26.7	20.7	26.9	29.3	28.1	—							
A. pretrei	2	26.5	16.4	27.3	27.5	28.0	25.9	19.7	29.4	19.1	27.1	25.8	20.2	17.1	28.9	27.6	28.3	26.7	31.2	19.4	26.4	18.9	28.3	16.9	27.0	27.8	27.2	**0.0**						
A. roberti	2	27.9	22.1	29.1	28.6	27.0	28.3	22.5	30.1	23.0	25.9	28.0	24.1	22.0	24.0	26.6	30.5	26.3	31.9	21.9	25.9	22.9	27.9	21.9	27.1	25.5	27.2	21.8	28.3					
A. saxosa	2	25.6	19.2	27.2	25.7	22.9	25.0	14.1	28.1	20.3	23.4	22.4	20.7	8.4	26.5	24.6	29.0	25.1	29.2	16.0	21.8	13.3	23.7	20.2	25.1	27.5	23.9	18.2	21.6	**0.0**				
A. silvestrii	2	27.6	25.5	28.3	19.4	23.7	27.2	23.8	27.7	26.5	27.6	25.8	26.8	22.0	27.2	25.3	31.6	22.7	28.9	25.1	24.3	23.8	24.4	27.9	28.5	27.8	23.9	27.9	26.5	21.6	**0.8**			
A. schmidti	3	27.2	26.8	29.0	27.6	26.1	27.2	25.0	27.2	26.8	26.4	23.7	28.1	22.2	29.7	24.6	29.8	25.9	29.8	25.6	22.9	24.6	25.3	25.9	26.7	27.8	26.1	26.6	26.3	22.9	25.1	**0.0**		
A. uroxena	2	30.3	29.0	32.8	29.4	28.5	28.5	29.4	25.0	29.4	29.3	28.7	29.5	26.8	31.5	27.8	33.1	27.4	32.9	27.2	26.9	27.9	27.9	28.9	29.9	31.4	28.3	28.3	30.1	27.0	26.6	27.7	**0.5**	
A. ventrimacularis	6	27.1	16.1	27.4	26.9	26.3	27.2	17.7	29.8	18.8	25.2	27.4	19.9	17.2	27.2	24.5	30.5	25.2	31.6	16.9	25.0	19.7	27.0	18.2	25.2	26.7	26.6	18.2	16.3	18.3	24.6	24.8	28.3	**0.5**
A. xera	1	29.8	26.3	29.6	27.5	25.6	25.6	25.4	27.0	28.2	25.6	19.6	29.4	23.9	28.2	25.5	32.3	25.6	30.9	25.1	24.6	26.1	25.3	26.8	26.8	28.6	24.2	28.1	26.8	22.8	26.1	23.5	27.9	25.8

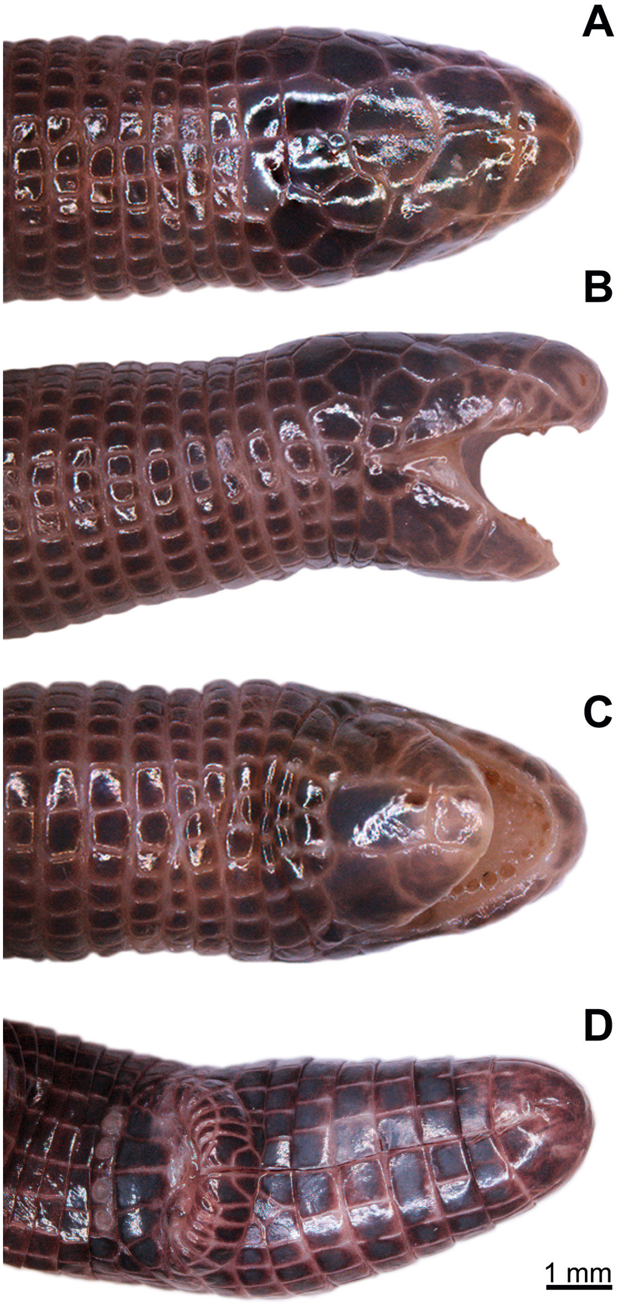

Figure 2. Holotype *Amphisbaena elbakyanae* **sp. nov.** in preservation (MLS 1901, male). (A) Doral view of the head; (B) Lateral view of the head; (C) Ventral view of the head; (D) Ventral view of the tail (tail is autotomized).

bia. Coordinates: N 6.097997222, W –67.48321667; elevation 54 m a.s.l., collected by Melissa Cuevas in July 2005. MLS 1902, a female from Caño El Socorro, between veredas Aguaverde and La Virgen, municipality of Orocué, department of Casanare, Colombia. Coordinates: N 5.02901, W –71.18037; elevation 128 m. a.s.l., collected by Marvin Anganoy-Criollo in December 2012, under a pile of palm leaves of moriche palm.

Generic placement. *Amphisbaena elbakyanae* **sp. nov.** belong to the genus *Amphisbaena* Linnaeus, 1758 (sensu Mertens 1925; Vanzolini 1951; Gans and Alexander 1962) by having the following characters: (1) Snout rounded, flattened or slightly convexed above; (2) upper head scales paired; (3) rostral scale short, subtriangular, ventrally expanded and posteriorly without contact with prefrontal scales; (4) nasal scales in broad contact; (5) six premaxillary teeth; (6) ten maxillary teeth.

Diagnosis. *Amphisbaena elbakyanae* **sp. nov.**, can be distinguished from all its congeners by the following combination of characters: (1) three supralabial scales; (2) three infralabial scales; (3) second supralabial scale longer than first and third supralabial scales, contacting first and third supralabial, temporal, ocular and prefrontal scales; (4) angulus oris lies in transverse plane passing through the posterior edges of the ocular scales and the center of the frontal scales; (5) second infralabial scale in contact with postmental scales; (6) six premaxillar teeth; (7) ten maxillar teeth; (8) one temporal scale; (9) absence of malar scale; (10) a single postgenial scale row with four segments; (11) postmalar scale rows with six to seven segments; (12) first body annulus includes one large segment on each side lying immediately posterior to inner parietal scales, abutting onto posterolateral edge of the outer parietal scales; (13) middorsal segments of second and third body annulus non-enlarged; (14) 245–257 body annuli; (15) 13–15 dorsal segments per annulus at midbody; (16) 16–18 ventral segments per annulus at midbody; (17) four precloacal pores; (18) autotomy sites located on sixth to eighth caudal annuli, (19) 20–24 caudal annuli, (20) rostral scale visible from above, (21) dorsal and ventral surfaces homogeneusly dark brown or dark brown-reddish, (22), and small body size 211–237 mm (Fig. 3).

Comparisons (Table 2)**.** Among all four-pored *Amphisbaena* species from South American, *Amphisbaena cunhai*, *A. frontalis*, *A. gracilis*, *A. medemi*, *A. talisiae* and *A. slateri* are the most similar species. Nonetheless, *A. elbakyanae* **sp. nov.** can be distinguished by having 245–257 body annuli (versus 226–239 in *A. cunhai*, 252–272 in *A. frontalis*, 224–248 in *A. gracilis*, 230–235 in *A. medemi*, 205–234 in *A. talisiae*, and 176–213 in *A. slateri*); 20–24 caudal annuli (versus 25–26 *A. cunhai*, 17–18 in *A. medemi*); a single postgenial scale row composed by four segments (versus two postgenial scale rows in *A. medemi* and *A. slateri*); absence of malar scales (versus a single malar scale in *A. cunhai*, *A. slateri* and *A. talisiae*); postmalar scale row composed by six to seven segments (versus nine segments in *A. medemi*); rostral scale visible from above (versus rostral scale non-visible from above in *A. gracilis*. Fig. 3A–B), first body annulus includes one large segment on each side lying immediately posterior to inner parietal scales, abutting onto posterolateral edge of the outer-parietal scales (versus first body annulus including two or three, large segments on each side lying immediately posterior to inner parietal scales, abutting onto posterolateral edge of the outer parietal scales in *A. gracilis*, Fig. 3A–B); middorsal segments of second and third body annuli non-enlarged (versus three or four middorsal segments of second and third body annuli enlarged in *A. gracilis*, Fig. 3A–B) and angulus oris lies in trans-

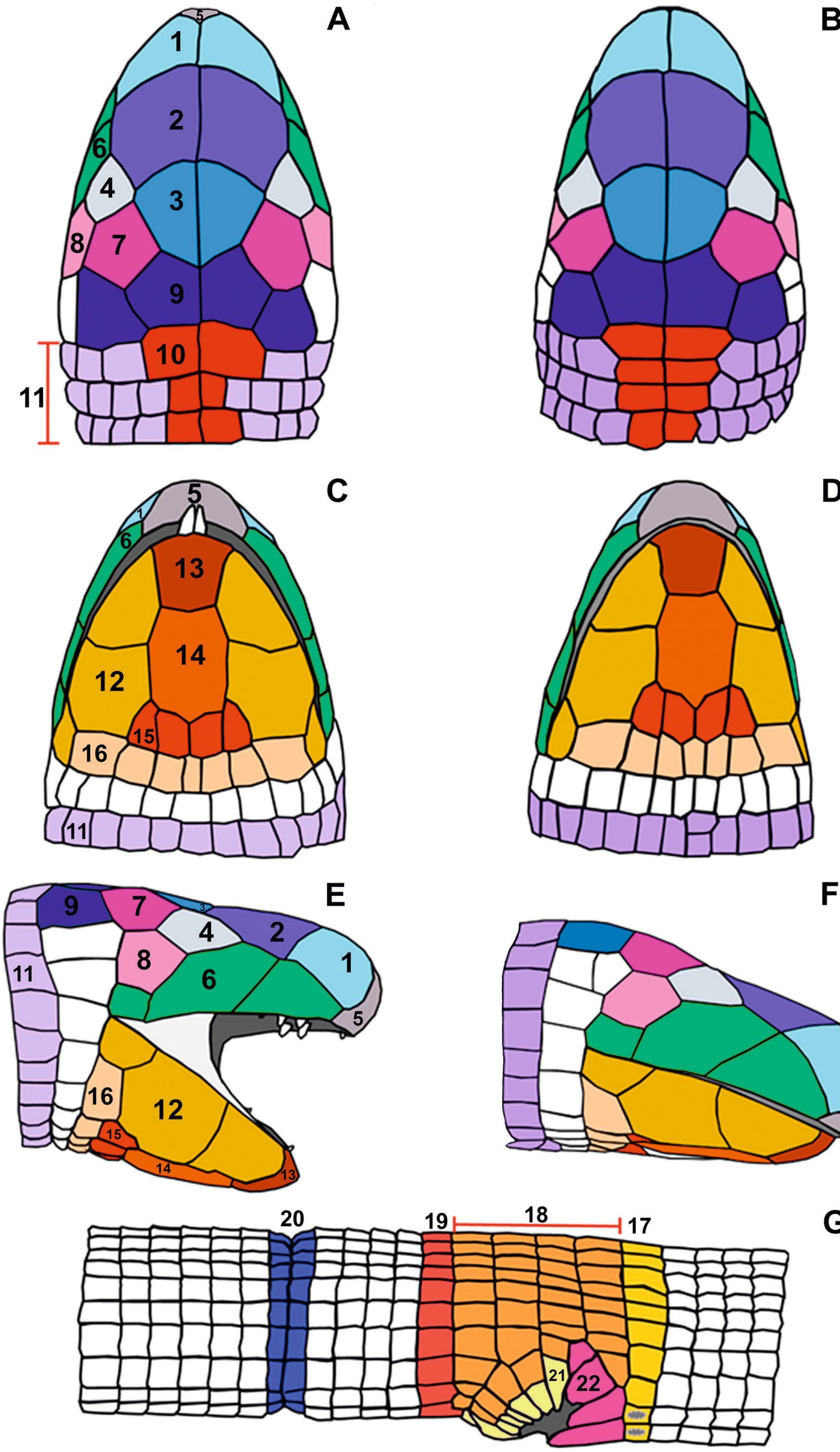

Figure 3. Comparison of the head scuttelation between the holotypes of *Amphisbaena elbakyanae* **sp. nov.** and *A. gracilis.* (A, C, E) Dorsal, lateral and ventral view of the head of *A. elbakyanae* **sp. nov.** (B, D, F) Dorsal, lateral and ventral view of the head of *A. gracilis*. (G) Lateral view of the caudal scuttelation of *A. elbakyanae* **sp. nov.** Scales: 1 = nasals, 2 = prefrontals, 3 = frontals, 4 = oculars, 5 = rostral, 6 = supralabials, 7 = posoclulars, 8 = temporals, 9 = parietals, 10 = middorsals segments of the body annulus, 11 = first, second and third body annulus, 12 = infralabials, 13 = mental, 14 = postmentals, 15 = postgenials, 16 = postmalars, 17 = precloacal annulus, 18 = cloacal annuli, 19 = postcloacal annulus, 20 = autotomus annulus, 21 = postclocal lip, 22 = precloacal lip.

Table 4. Measurements (in mm) of holotype and paratype series of *Amphisbaena elbakyanae* **sp. nov.**

Trait (mm)	**MLS 1901***	**MLS 1902**	**MUJ 806**
Sex	Male	Female	Female
SVL	211	237	224
TL	incomplete	27	20
BD	5.3	5.6	5.9
HL	7.1	7.0	6.4
HW	5.5	5.3	5.2
PFL	1.9	2.2	2.5
PFW	1.8	1.7	1.4
FL	1.8	2.0	1.8
FW	1.1	1.2	1.1
IPL	1.4	1.5	1.6
IPW	1.3	1.3	1.3
OPL	1.2	1.2	1.5
OPW	1.3	1.3	1.4
OL	1.6	1.3	1.2
OH	1.0	0.9	0.9
POL	1.4	1.6	1.6
POW	1.2	1.0	0.8
TEL	1.6	1.3	1.4
TEH	1.1	1.2	1.2
ML	1.2	1.4	1.3
MW	1.1	1.2	1.1
PML	2.0	1.9	1.9
PMW	1.4	1.4	1.5

Snout ventral length (SVL), caudal length (TL), head length (HL), head width (HW), prefrontal length (PFL), prefrontal width (PFW), frontal length (FL), frontal width (FW), inner parietal scales length (IPL), inner parietal scales width (IPW), outer parietal scales length (OPL), outer parietal scales width (OPW), ocular length (OL), ocular height (OH), postocular length (POL), postocular width (POW), first temporal length (TEL), first temporal height (TEH), mental length (ML), mental width (MW), postmental length (PML), postmental width (PMW). Asterisk (*) indicates the holotype.

Figure 4. Color in life of *Amphisbaena elbakyanae* **sp. nov.** (A) Holotype of *A. elbakyanae* **sp. nov.**, recently euthanized (MLS 1901, male). (B) Specimen in life of *A. elbakyanae* **sp. nov.** from paratype locality: Bojonawi Natural Reserve, Fundación Omacha, municipality of Puerto Carreño, Vichada Department, Colombia (N 6.097997222, W - 67.48321667; elevation 54 m. a.s.l.). Photo by Beiker Castañeda.

verse plane that passes through posterior edges of the ocular scales and center of frontal scales [versus angulus oris lies in transverse plane that passes through posterior edges of the postocular scales and center of parietal scales in *A. gracilis*, Fig. 3E–F (Gonzalez-Sponga and Gans 1971)]. Additionally, *Amphisbaena elbakyanae* **sp. nov.** can be distinguished from *A. mertensii* (one of phylogenetically closely related species, Fig. 1) by having four pre-cloacal pores and 245–257 body annuli (versus 6–8 and 210–250 in *A. mertensii*, respectively). Comparisons with the remaining four-pored *Amphisbaena* species are summarized in Table 2.

Description of holotype (Figs 2–4; Table 4)**.** Male, small body size (SVL = 211 mm; TL = Incomplete tail); slender body (BD = 5.3 mm); head and body slightly differentiated by a small nuchal constriction; head longer than wide (HW/HL 77.7%); snout rounded; six premaxillary teeth beginning with two large, anteromedian teeth that are flanked on either side by a posteriorly directed row of two slightly recurved teeth that gradually diminish in size; ten maxillary slightly recurved teeth that gradually diminish in size arrayed in an oblique row; rostral scale visible from above, subtriangular, ventrally expanded, wider and concave posteriorly, narrowly contacting first supralabial and broadly contacting with nasal scales; nasal, prefrontal, frontal and parietal scales from both sides contacting along the midline of the head forming a longitudinal suture (Figs 2A, 3A); nasal scale quadrangular, contacting the first supralabial, prefrontal and rostral scales; nostrils lateral in the anteroventral part of nasal scale; prefrontal scales roughly pentagonal, wider than long (PFW/PFL 92.9%), broadly contacting nasal, frontal, ocular, first and second supralabial scales, hav-

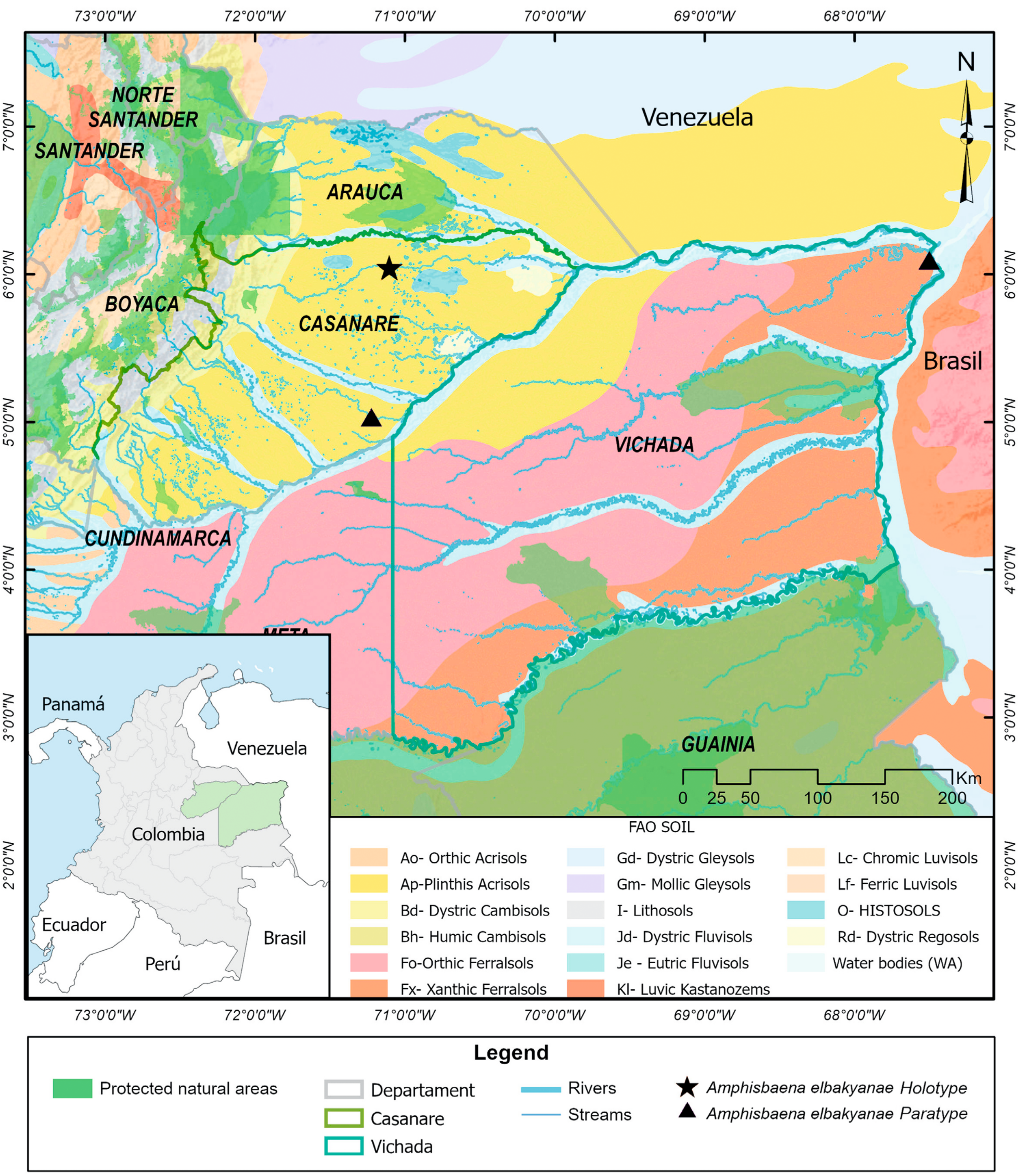

Figure 5. Geographic distribution of *Amphisbaena elbakyanae* **sp. nov.** detailing the soil type where each specimen was collected. The black star represents the holotype locality. The black triangles represent the localities of the paratypes. Background map was retrieved from the Esri open database accessing the following sources: DeLorme, USDS, NPS; USGS, NOAA.

ing a narrow contact with first supralabial scale and a broad contact with second supralabial scale (Figs 2A, 3A); frontal scales trapezoidal, longer than wide (FW/FL 63.0%), in broad contact with prefrontal, postocular and inner parietal scales and in narrow contact with ocular scale. Four parietal scales roughly pentagonal; inner parietal scales longer than wide (IPW/IPL 91.4%), in broad contact with frontal, postocular, and outer-parietal scales, as well as with the middorsal enlarged segments of the first body annulus; outer parietal scales wider than long (OPL/OPW 91.8%), in broad contact with inner-parietal and postocular scales; first body annular non-enlarged scales, but in narrow contact with middorsal enlarged segments of the first body annulus; angulus oris lies in transverse plane that passes through posterior edges of the ocular scales and center of frontal scales (Figs 2B, 3E); three supralabial scales, first subtriangular, longer than wide in broad contact with nasal and second supralabial scales, in narrow contact with prefrontal and rostral scales; the second supralabial larger than the first one and

Figure 6. Habitat of *Amphisbaena elbakyanae* **sp. nov.** (A) Panoramic view of savanna flood forest dominated by moriche palm at the Bita River, Department of Vichada, Colombia. (B) Microhabitats inside of moriche palm's forest. (C) Moriche palm (*Mauritia flexuosa*).

third supralabial scales, contacting first and third supralabial, temporal, ocular and prefrontal scales; third supralabial scale smaller than first and second supralabial scales, contacting second supralabial, temporal and in posterior contact with first body annulus; ocular scales rhomboidal, longer than high (OH/OL 62.4%), in broad contact with prefrontal, postocular, temporal and second supralabial scales, in narrow contact with frontal scales; eye slightly visible in the anterior corner of the ocular scale; postocular scales roughly hexagonal, longer than wide (POW/POL 84.8%), broadly contacting frontal, parietal, ocular, temporal and in posterior contact with first body annulus; one temporal scale roughly pentagonal longer than wide (THE/TEL 68.1%) broadly contacting second and third supralabial and ocular scales, as well as the first body annular scales.

Mental scales quadrate, smaller and narrower than rostral scale, longer than wide (MW/ML 94.8%), in broad contact with postmental and first infralabial scales; postmental scale oblong, longer than wide (PMW/PML 70.3%), visible longer than and in broad contact with mental scale, first and second infralabials and postgenial scale row; three infralabial scales, first trapezoidal, longer than wide and in broad contact with mental, postmental and second supralabial scales; second infralabial scale larger than first and third infralabial scales, broadly contacting first and third infralabial and postmalar scale rows; third infralabial scale smaller than first and second infralabial scales, in contact with second infralabial scale, postmalar scale row and in posterior contact with first body annulus; malar scales absent; postgenial scale row composed by four segments, in contact with second infralabial, postmental, and in posterior contact with postmalar row of scales; postmalar row of scales composed by seven segments (Figs 2C, 3C).

Body annuli demarcated; lateral and middorsal sulci present, beginning from 16th (left) or 18th (right) body annulus; 245 body annuli, 13 dorsal segments per annulus at midbody, 16 ventral segments per annulus at midbody; first body annulus with one enlarged middorsal segment on each side contacting with posterior edge of the inner parietals, abutting onto posterolateral edge of the outer parietal scales; middorsal segments of second and third body annulus non-enlarged (Figs 2A, 3A); four precloacal pores rounded; anal flap semicircular; four cloacal annuli, six caudal annuli (incomplete tail), caudal autotomy site between sixth to seventh caudal annuli (Figs 2D, 3G).

Color of the holotype in life (Fig. 4). Dorsal and ventral surfaces from dark brown to dark brown-reddish; occipital, parietal, frontal, temporal, third supralabial, third infralabial, postmental scales, as well as postgenial and postmalar scale rows dark brown highly pigmented; rostral, prefrontal, ocular, nasal, first and second supralabial, mental and first infralabial scales dark brown faded.

Color of the holotype in preservative (Fig. 2)**.** After seven years in preservative, dorsal and ventral surfaces, as well as head scales maintained dark brown coloration having slight differences with color in life, such as a faint grey coloration on dorsal and ventral surfaces, and a few unpigmented scales.

Etymology. We dedicate this species to the Kazakhstani scientist Alexandra Asanovna Elbakyan (Russian: Алекса́ндра Аса́новна Элбакя́н), creator of the web site Sci-Hub, for her colossal contributions for reducing the barriers in the way of science, as well as her reclamation that "everyone has the right to participate and share in scientific advancement and its benefits, freely and without economic constraints".

Distribution and natural history. The known localities of *Amphisbaena elbakyanae* **sp. nov.**, are distributed in the flooded savanna ecosystem of the Orocué and Ariporo River basin, as well as in the drained savanna ecosystem of the Bita River basin in the department of Vichada (Fig. 5). *Amphisbaena elbakyanae* **sp. nov.** seems to be highly associated with the leaf litter of the savanna flood forest dominated by moriche palm (*Mauritia flexuosa*), which are commonly known as "morichales" or "cananguchales" in Colombia (Fig. 6). The new species was found in sympatry with *A. alba* and *A. fuliginosa*.

Discussion

In this research, molecular and morphological evidence allowed us to confirm that *Amphisbaena elbakyanae* **sp. nov.** represents a new species of amphisbaenian from northern South America (sensu Eva and Huber 2005). Our phylogenetic analysis suggests that *Amphisbaena elbakyanae* **sp. nov.** together with *A. cunhai* and *A. mertensii* from central-southern Brazil, is part of the same monophyletic clade (Fig. 1). However, great genetic distances for the ND2 gene fragment were revealed between *Amphisbaena elbakyanae* **sp. nov.** versus *A. cunhai* and *A. mertensii* (28.9% and 26.1%, respectively). Currently, molecular data of several species from northern South America is lacking (e.g. *A. medemi*, *A. spurrelli*, *A. gracilis*, *A. vanzolinii*, and *A. steinegeri*), limiting the understanding of the evolutionary relations of northern-South American amphisbaenians. Therefore, it is crucial to include many more taxa, to formulate a complete phylogenetic hypothesis that may reduce spurious phylogenetic relationships, basal polytomies and poorly supported nodes (Teixeira et al. 2014). Despite the scarcity of the molecular data, our analyses revealed that the new taxon is not closely related to the sympatric species *A. alba* or *A. fuliginosa* (Fig. 1), confirmed by the great genetic distances between them (Table 3). The morphological evidence analyzed allowed us to clearly diagnose *Amphisbaena elbakyanae* **sp. nov.** as a different lineage compared to the 50 nominal four pored *Amphisbaena* species, demonstrating that it was an undescribed species of worm lizard from Colombia.

Furthermore, both molecular and morphological evidence agreed with Gans and Mathers (1977) group's division of the amphisbaenians from northern South America: The first group included two larger and wide-ranging species (*A. alba* and *A. fuliginosa*), and the second group comprised six smaller narrow-ranging species (*A. gracilis*, *A. medemi*, *A. rozei*, *A. spurrelli*, *A. stejnegeri* and *A. vanzolinii*). Based on the morphological characters of *Amphisbaena elbakyanae* **sp. nov.**, this taxon can be allocated into Gans and Mathers' second group. Interestingly, *Amphisbaena elbakyanae* **sp. nov.**, exhibited a close morphological similarity with both closely distributed taxon (e.g. *A. gracilis*) and geographically distant taxa (e.g. *A. cunhai*, *A. frontalis*, *A. talisiae* and *A. slateri*). Moreover, *Amphisbaena elbakyanae* **sp. nov.** and *A. gracilis* are the continental worm lizards that seem to have the greatest affinity with the Antillean *Amphisbaena* species by showing a lack of malar scales, four precloacal pores, relatively small size and uniform dorsal and ventral pigmentation. Aditionally, *A. elbakyanae* **sp. nov.** together with *A. gracilis* and *A. medemi* are the only forms of the northern mainland that have fewer dorsal rather than ventral segments to a midbody annulus closely resembling the Antillean *Amphisbaena* species (Gans and Alexander 1962; Gonzalez and Gans 1971; Gans and Mathers 1977).

This situation leaves open the question of whether such morphological similarities are due to evolutionary ancestry or could be due to convergent evolution of characters, a product of adaptation to similar habitats (Harmon et al. 2005; Edwards et al. 2012). Some authors have claimed that parallelism, understood as the independent evolution of similar traits, starting from a similar ancestral condition, could be another possibility for morphological similarities between *Amphisbaena* species (Mott and Vieites 2009). Vidal et al. (2008) dated the split between African and South American Amphisbaenidae at 40 Mya ago (Eocene), proposing that transatlantic dispersal from Africa to South America + West Indies could explain this divergence. According to Gonzalez and Gans (1971), the West Indies species may be the ancestors of the northern South American *Amphisbaena* species. Consequently, the similarities between some Antillean and South American species may have resulted from the retention of a primitive character pattern in a zone geographically peripheral to the range of the genus. Although we cannot assess directly Gonzalez-Sponga and Gan's hypothesis, the distant evolutionary relationship between *Amphisbaena elbakyanae* **sp. nov.** and the Antillean species *A. caeca* and *A. xera* revealed by our phylogenetic and genetic distance analyses (Fig. 1; Table 3), as well as the distant relationships showed by Pyron et al. (2013; Fig 12K) between *A. cunhai* and *A. mertensii* (species that form a monophyletic clade together with *Amphisbaena elbakyanae* **sp. nov.**) and the Antillean species (i.e. *A. bakeri*, *A. caeca*, *A. cubana*, *A. fenestrate*, *A. manni*, *A. schmidti* and *A. xera*), suggest that recent evolutionary ancestry may not be the cause of the morphological similarities. Those and many more questions concerning northern South American worm lizards remain open, evidence that the state of knowledge for many fields is still extremely fragmentary.

Conclusions

Amphisbaena elbakyanae **sp. nov.**, described as a new species from the Orinoquia savanna ecosystem of Colombia, seems to be related to *A. cunhai* and *A. mertensii* from central-southern Brazil. This species of *Amphisbaena* is one of the several still-unrecognized evolutionary lineages of worm lizards that are deposed in Colombian museum shelves waiting to be described. We think that the lack of worm lizard studies in Colombia is derived from three main factors. First, insufficient funding for field and museum research; second, large areas still lack intensive sampling and third, there are few investigators searching for worm lizards and few experts and trained personnel capable of describing species (Gascon et al. 2007; Ospina-Sarria and Angarita-Sierra 2020). Therefore, the description of this new *Amphisbaena* species points out the urgent need to generate a research grant program that could support field surveys and research on several disciplines to increase our knowledge of worm lizards, as well as help to train researchers to describe species including the known but yet-undescribed species currently housed in Colombian biological collections. Studies of taxonomy and species descriptions in a megadiverse country like Colombia play a substantial role in the conservation of our natural heritage. Thus, encouraging these activities will allow an evaluation of biodiversity loss and the development of systematic conservation planning and practices, as well as a scientific focus on value judgments that make up environmental policies and laws.

Key to the Colombian worm lizard species

(**1**) Snout prognathous; rostral scale large, elongate and coniform in broad contact with prefrontal scales, separating nasal scales .... (Genus *Mesobaena*) ***Mesobaena huebneri***

— Snout non-prognathous; rostral scale short, subtriangular, ventrally expanded and posteriorly without contact with prefrontal scales; nasal scales in broad contact (Genus *Amphisbaena*) **2**

(**2**) Robust body; 30–42 dorsal segments per annulus at midbody, 35–46 ventral segments per annulus at midbody, caudal autotomy absent .... ***Amphisbaena alba***

— Robust or thin body, less than 29 dorsal and ventral segments per annulus at midbody, caudal autotomy present ... **3**

(**3**) Robust body; 19–28 dorsal segments per annulus at midbody, 21–28 ventral segments per annulus at midbody; 6–9 precloacal pores, postmalar scale row composed by 10–14 segments .... ***Amphisbaena fuliginosa***

— Thin body, four precloacal pores, postmalar scale row composed by 6–9 segments **4**

(**4**) 245–257 body annuli, 13–15 dorsal segments per annulus at midbody, three supralabial and infralabial scales .... ***Amphisbaena elbakyanae*** **sp. nov.**

— Less than 244 body annuli **5**

(**5**) 230–235 body annuli, 14–16 dorsal segments per annulus at midbody, three supralabial and infralabial scales .... ***Amphisbaena medemi***

— 213–222 body annuli, 16–18 dorsal segments per annulus at midbody, four supralabial and infralabial scales .... ***Amphisbaena spurrelli***

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