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New Records, Morphological Variation, and Description of the Skull of *Liophis dorsocorallinus* Esqueda, Natera, La Marca and Ilija-Fistar, 2005 (Serpentes: Dipsadidae)

Based on molecular phylogenies, Zaher et al. (2009) and Grazziotin et al. (2012) proposed the synonymization of the genus *Liophis* Wagler, 1830 with *Erythrolamprus* Boie, 1826. However, this change was considered premature by some taxonomists (e.g., Curcio et al. 2009; Wallach et al. 2014), mainly because these genera are poorly sampled and the type species of *Liophis*—*L. cobella* (Linnaeus, 1758)—was not included in either of those phylogenetic studies. Therefore, we follow the generic arrangement proposed by Wallach et al. (2014) in continuing to recognize *Liophis*. The genus *Liophis* comprises about 40 species, including *L. dorsocorallinus* Esqueda, Natera, La Marca and Ilija-Fistar, 2005, described from Reserva Florestal de Caparo, state of Barinas, western Venezuela (Esqueda et al. 2005).

The second record of the species was from the Reserva Extrativista Riozinho da Liberdade, state of Acre, in the western region of the Brazilian Amazon, about 1700 km from the type locality (Bernarde et al. 2011). These authors also referred the specimen treated as "*Liophis* sp." by França and Venâncio (2010) to *L. dorsocorallinus*, thereby providing a third locality record for the species, in the Municipality of Boca do Acre, southwestern state of Amazonas, Brazil. Additionally, Araújo et al. (2012) presented data on five female specimens of *L. dorsocorallinus* collected in the municipalities of Sena Madureira, Bujari, and Rio Branco, also in the state of Acre, about 140 km from the nearest previously known record of the species and 1960 km from the type locality.

Liophis dorsocorallinus is morphologically similar to representatives of the *L. reginae* (Linnaeus, 1758) complex, being distinguished from their congeners by a combination of some pholidosis characters and a color pattern consisting of red dorsal scales with black posterior tips (Esqueda et al. 2005). No data on the skull morphology of *L. dorsocorallinus* has been published yet, and the hemipenis in this species has only been described from the holotype (Esqueda et al. 2005).

Herein we present meristic, morphometric, and coloration data on 18 specimens of *L. dorsocorallinus* from six localities, including two new records for Colombia (first country records) and two new records for Brazil. We also provide detailed descriptions of the skull and hemipenis of the species, comparing our results with data in the literature.

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Materials and Methods

Specimens examined (Table 1) are housed in four collections: Instituto de Ciencias Naturales, Universidad Nacional de Colombia (ICN), Bogotá, Colombia; Museu Nacional, Universidade Federal do Rio de Janeiro (MNRJ), Rio de Janeiro, Brazil; Museu de Zoologia "Adão José Cardoso," Universidade Estadual de Campinas (ZUEC), São Paulo, Brazil; Universidade Federal do Acre, Campus Floresta (UFAC-F), Acre, Brazil.

Snout–vent length (SVL) and tail length (TL) were measured with a flexible ruler to the nearest 1 mm. Head length (HL) and head width (HW) were measured with analogical calipers to the nearest 0.1 mm. Techniques for hemipenis preparation followed Manzani and Abe (1988) as modified by Pesantes (1994). Hemipenes were immersed in an alcoholic solution of Alizarin Red until the spines and other calcified structures became stained, as suggested by Nunes et al. (2012) in an adaptation of the procedures described by Uzzell (1973). Hemipenis terminology follows Zaher (1999). The skull was described based on X-ray computed microtomography (microCT) images, a non-destructive and relatively fast technique. The microCT images were obtained with a high energy Skyscan/Bruker system. After acquisition, the images were reconstructed using the FDK algorithm (Feldkamp et al. 1984) and analyzed with the software CTVox® version 2.7.0. Skull terminology follows Cundall and Irish (2008).

Results

Pholidosis and morphometrics.—Data obtained from 18 examined specimens are given in Table 1. Comparisons of data presented herein with those available in the literature are shown in Table 2. Specimens here examined extend the variation observed in *Liophis dorsocorallinus*: largest female SVL 664 mm; largest male SVL 639 mm; largest TL 230 and 183 mm for females and males, respectively; 142–156 ventrals and 61–77 subcaudals in females; 143–153 ventrals and 62–80 subcaudals in males; largest HL 23.6 mm and HW 15 mm; 8–9 supralabials (usually 8); 8–10 infralabials; 1–2 preoculars (usually 1); 1–2 postoculars (usually 2).

Adult color pattern in preservative.—Specimens analyzed showed the same dorsal color pattern described by Esqueda et al. (2005) (Fig. 1). However, it was possible to observe a ventral color pattern different from that given in the original description of the species. None of the 18 specimens analyzed here (nine males and

Table 1. Locality, sex, morphometric and meristic variation for the analyzed specimens of *Liophis dorsocorallinus*. Specimens marked with "S" and "H" indicate those whose skull or hemipenis were analyzed. Features marked with a dash were not observed due to poor conditions of the specimens. The symbol "*" indicates that the tail is broken but apparently complete, while "**" indicates specimens missing pieces of the tail.

Specimen	Locality	Sex	SVL	TL	HL (mm)	HW (mm)	Ventrals (mm)	Subcaudals (mm)	Supralabials (left | right)	Infralabials (left | right)	Postoculars (left | right)
ICN 1526	Arauca River, Arauquita,	Male	533	183	23.6	12.1	151	69	8 | 8	9 | 9	2 | 2
ICN 1527	Arauca, Colombia	Female	445	167	—	—	150	74	8 | —	10 | 10	2 | 2
ICN 6776	Caño Limón, Arauquita,	Female	516	186	22.5	11.6	150	75	8 | 8	10 | 10	2 | 2
ICN 6891	Arauca, Colombia	Female	522	191	—	—	155	77	8 | 8	—	2 | 2
ICN 6943		Female	—	—	—	—	156	37 **	8 | 8	10 | 10	2 | 2
MNRJ 189	"Mato Grosso"	Female	569	—	23.6	13.3	146	42 **	8 | 8	10 | 10	2 | 2
MNRJ 320	(current states of	Female	387	—	17.5	9.8	142	68 *	8 | 9	10 | 10	2 | 2
MNRJ 322	Rondônia, Mato Grosso,	Male	506	—	22.0	13.2	149	69 *	8 | 8	10 | 10	2 | 2
MNRJ 323[H]	Mato Grosso do Sul),	Male	470	—	19.1	9.2	148	64 *	8 | 8	10 | 10	2 | 2
MNRJ 324	Brazil	Female	413	—	18.1	9.4	147	35 **	8 | 8	10 | 10	2 | 1
MNRJ 26154	Boca do Acre, Amazonas, Brazil	Male	442	153	20.1	9.2	150	66	8 | 8	10 | 10	2 | 2
UFAC-F 405[S]	Reserva Extrativista	Female	423	135	19.4	10.1	150	67	8 | 8	10 | 10	2 | 2
UFAC-F 664[H]	Rioninho de Liberdade,	Male	419	137	18.4	9.1	148	62	8 | 8	10 | 9	2 | 2
UFAC-F 918[H]	Tarauacá, Acre, Brazil	Male	447	143	20.5	10.8	151	63	8 | 8	10 | 10	2 | 2
ZUEC 1587	Tejo River, Marechal	Female	350	120	17.4	11.0	148	66	8 | 8	10 | 10	2 | 2
ZUEC 1971	Thaumaturgo, Acre,	Male	328	117	15.0	8.8	144	69	8 | 8	10 | 10	2 | 2
ZUEC 1972	Brazil	Male	409	146	18.0	9.3	143	67	8 | 8	10 | 10	2 | 2
ZUEC 1973[H]		Male	309	—	13.6	7.9	145	23 **	8 | 8	10 | 10	2 | 2

Table 2. Comparison of analyzed specimens of *Liophis dorsocorallinus* and from literature. Entries marked with a dash indicate data not available.

Study	Esqueda et al. (2005)		Araújo et al. (2012)	This study		Total variation	
Sex	Female (N = 1)	Males (N = 4)	Females (N = 5)	Females (N = 9)	Males (N = 9)	Females (N = 15)	Males (N = 13)
SVL (mm)	664	200–639	390–520	350–569	309–533	350–664	200–639
TL (mm)	174	46.6–165	140–230	120–191	117–183	120–230	46.6–183
Ventrals	151	147–153	145–153	142–156	143–151	142–156	143–153
Subcaudals	69	69–80	61–68	66–77	62–69	61–77	62–80
HL (mm)	9.1–19.5		—	13.6–23.6		9.1–23.6	
HW (mm)	6.0–15		—	7.9–13.3		6.0–15	
Supralabials	8		8	8–9		8–9	
Infralabials	8–9		9	9–10		8–10	
Preoculars	1–2		1–2	1		1–2	
Postoculars	2		2	1–2		1–2	
Temporals	1+2		1+2	1+2		1+2	

nine females) have an immaculate venter. Relative size of black spots on the ventral surface is variable, ranging from very small black spots limited to the lateroanterior border of ventral scales to large black spots occupying about one third of the surface of each ventral scale. The most recently preserved specimen (MNRJ 26154) presented a reddish pigmentation on the medial region of ventral scales (Fig. 1F). This pigmentation was probably lost in the other specimens (assuming it existed) due to the interaction with preservative.

Hemipenial morphology.—Based on everted organs (N = 4; Fig. 2), hemipenes are bilobed (lobes correspond to approximately one third of hemipenial length), non-capitate, non-calyculate, with three inflated areas at their basal portion: one medially located on the sulcate side, and two laterally located on the asulcate side. Sulcus spermaticus bifurcates at about the proximal one-fourth to one-third of hemipenial body, with branches reaching the lateral portion of the organ in a centrifugal orientation, ending in the medial region of an apical disk positioned at the apex of each lobe. Apical disks slightly pleated without spinules. **Sulcate side** (Fig. 2A): mostly covered with several small spinules (including the surface of intrasulcar region and lobes); large spines restricted to basal and lateral regions. Distal half of intrasulcal region with two longitudinal rows of spinules, each extending throughout the lobe until the apex and becoming gradually smaller towards the

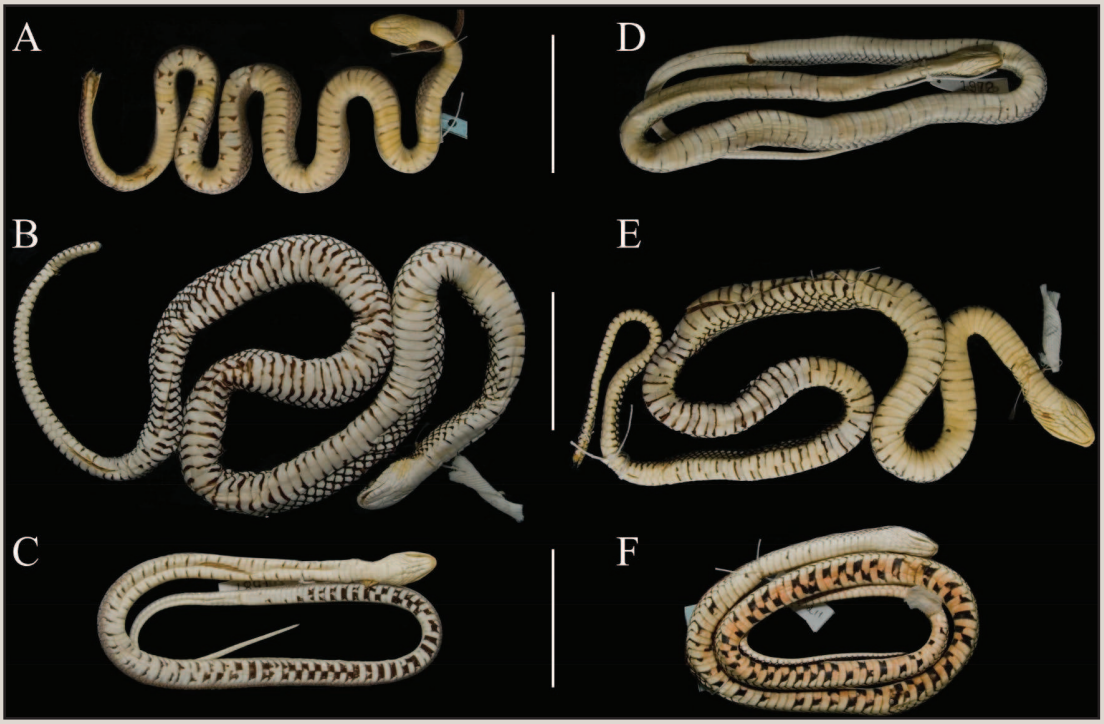

Fig. 1. Variation of ventral color pattern in females (A = MNRJ 320; B = MNRJ 189; C = ZUEC 1587) and males (D = ZUEC 1972; E = MNRJ 322; F = MNRJ 26154) of *Liophis dorsocorallinus*. Scale bars = 5 cm.

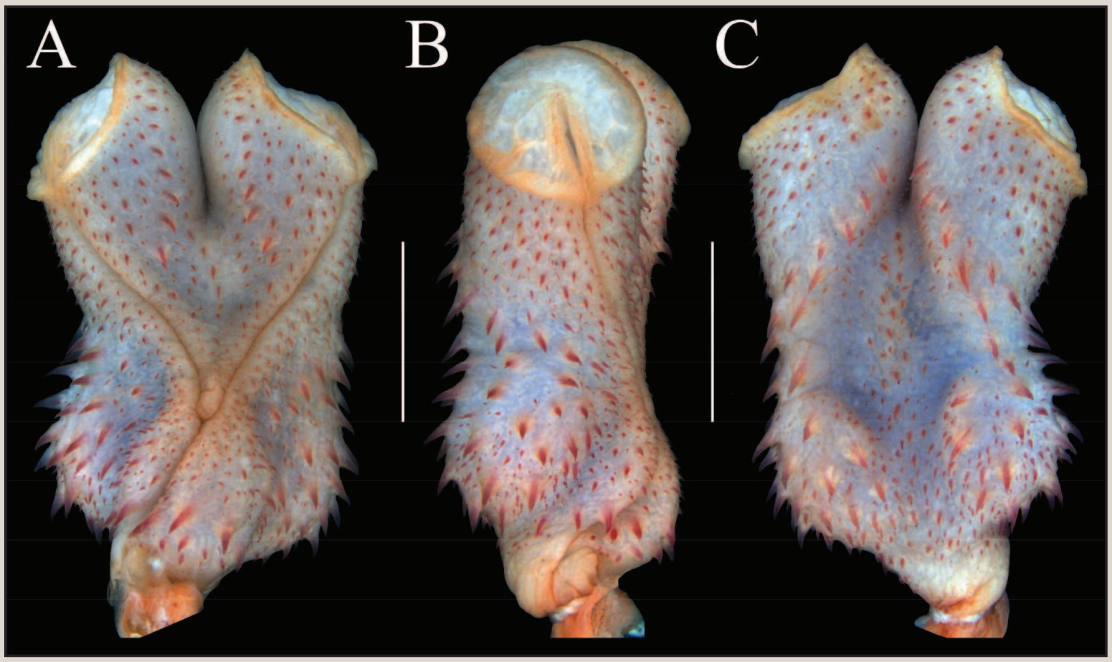

Fig. 2. Sulcate (A), lateral (B), and asulcate (C) sides of the hemipenis of *Liophis dorsocorallinus* (UFAC-F 664). Scale bars = 5 mm.

tips of the lobes, with basalmost spinules being enlarged and easily differentiated from the rest of the spinules on the lobes, while those near the apex are small and indistinct from surrounding spinules. **Lateral sides** (Fig. 2B): hemipenial body with large spines; lobes covered by small spinules. **Asulcate side** (Fig. 2C): mostly covered with several small spinules, except for a central region on hemipenial body where spinules are concentrated in a medial longitudinal stripe. Areas adjacent to that stripe may be smooth or show fewer and smaller spinules (when compared to medial stripe). Large spines covering the two laterobasal inflated areas and lateral regions of hemipenial body. Two oblique rows of large spines extend from each lateral of hemipenial body, extending throughout the basal portion of lobes and reaching the medial side of each lobe. These two rows may merge or not. Lobes covered by small spinules, except for a smooth stripe adjacent to the two oblique rows of large spines.

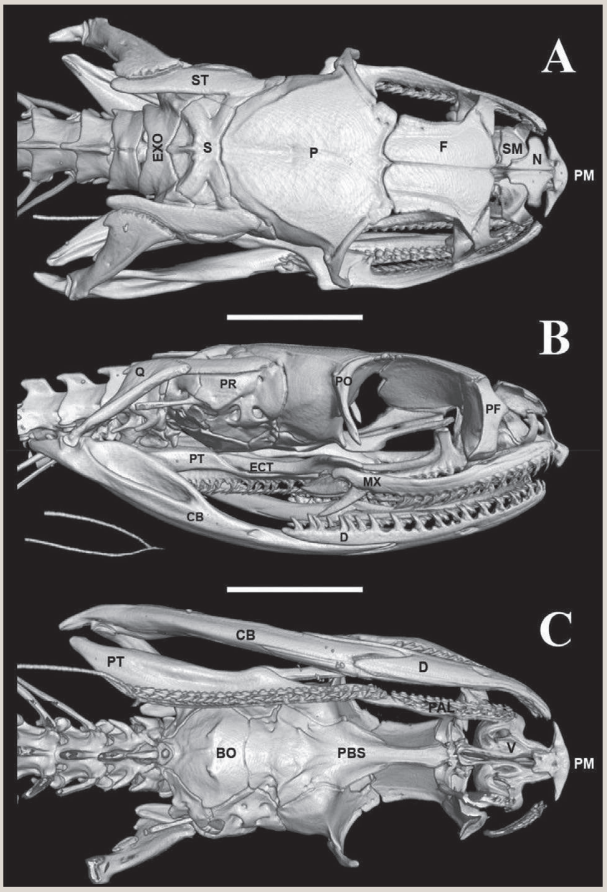

Fig. 3. Dorsal (A), lateral (B), and ventral (C) views of the skull of *Liophis dorsocorallinus* (UFAC-F 405) as accessed by micro tomography scanning. Scale bars = 5 mm. BO = basioccipital; CB = compound bone; D = dentary; ECT = ectopterygoid; EXO = exoccipital; F = frontal; MX = maxilla; N = nasal; P = parietal; PAL = palatine; PBS = parabasisphenoid; PF = prefrontal; PM = premaxilla; PO = postorbital; PR = prootic; PT = pterygoid; Q = quadrate; S = supraoccipital; SM = septomaxilla; ST = supratemporal; V = vomer.

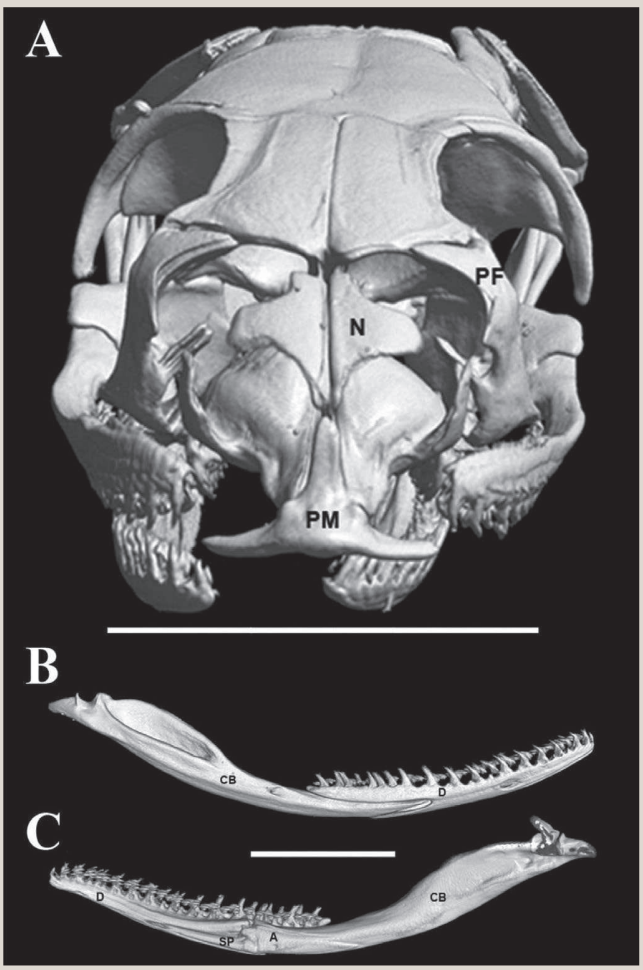

Fig. 4. Frontal view of the skull (A), lateral (B), and medial (C) views of the mandible of *Liophis dorsocorallinus* (UFAC-F 405) as accessed by micro tomography scanning. Scale bars = 5 mm. A = angular; CB = compound bone; D = dentary; N = nasal; PF = prefrontal; PM = premaxilla; SP = splenial.

Skull.—Based on a single example (Figs. 3–4). SNOUT: **Premaxilla** (Fig. 4A): triangular in frontal view with slender transverse process slightly oblique ventrally, not reaching anterior portion of maxilla; basal portion of ascending process narrow and apical portion blunt, almost the same width of the base; ascending process slightly touches nasals; vomerine processes divergent in ventral view overlapping vomer. **Septomaxillae** (Figs. 3A and 4A): anterior edge simple embedded in the angle formed by ascending and vomerine processes of premaxilla; anterolateral process oblique dorsally, with rounded edge, overlapping anterior portion of maxilla and transverse process of premaxilla; septomaxilla contacts nasals laterally. **Vomers** (Fig. 3C): anterior process overlapped by vomerine process of premaxilla; posterior edge of vomer with straight vertical lamina. **Nasals** (Fig. 3A and 4A): joined medially with diamond shape; frontal process of nasal contacting vertical lamina of frontals.

BRAINCASE: **Frontals** (Fig. 3A) joined medially, longer than wide with anterior margin wider than posterior margin in dorsal view; orbital foramen inserted in the region of contact between frontal and parietal; most of the foramen inserted in the parietal. **Prefrontals** (Fig. 3B and 4A): in lateral view prefrontals not reaching maxilla ventrally; anterior portion with acuminate projection; in frontal view, lacrimal foramen crosses the bone as far as its posterior portion; dorsal to this foramen, posterior ventromedial process developed and posteroventral lateral process present. **Parietal** (Fig. 3A): subtriangular in dorsal view; slightly touching supratemporals; two convergent well-developed dorsolateral crests emerge at the level of postorbital process up to region of contact with supraoccipital; dorsolateral crests with no contact. **Postorbitals** (Fig. 3B): with tapered and curved shape, not reaching maxilla. **Supraoccipital** (Fig. 3A): with irregular shape; two anterior and two posterior oblique crests converge at mesoanterior portion of supraoccipitals forming an "×" shape; longitudinal mesodorsal crest in posterior portion of supraoccipitals. **Exoccipitals** (Fig. 3A): with irregular shape; posterior oblique crests of supraoccipitals extending through exoccipitals, and laterally until the level of fenestra ovalis. **Prootics** (Fig. 3B): supratemporals overlap most of dorsal portion of prootics; next to region of contact with parabasisphenoid, prootics with multiple smaller foramina. **Columella auris** (Fig. 3B): small discoid footplate inserted in fenestra ovalis with elongated shaft extending toward quadrate. **Basioccipital** (Fig. 3C): subtrapezoidal shape; medial portion with two dentigerous processes and slight longitudinal mesial

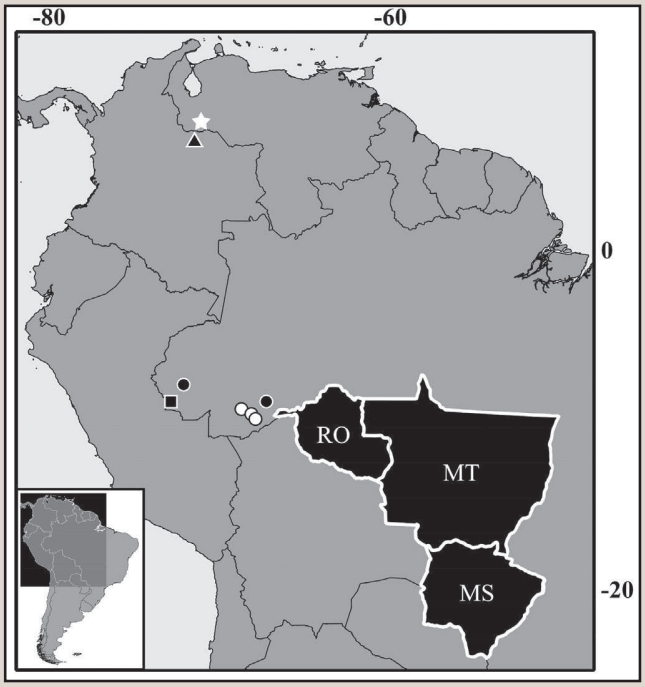

Fig. 5. Distribution of *Liophis dorsocorallinus*. Black symbols represent localities from analyzed specimens and white symbols represent localities recorded only from literature. Star – Reserva Florestal de Caparo, type locality (Esqueda et al. 2005). Circles represent previously known records for the species (from left to right): Reserva Extrativista Riozinho da Liberdade (Bernarde et al. 2011); Sena Madureira; Bujari; Rio Branco (Araújo et al. 2012); Boca do Acre (França and Venâncio 2010). Triangle and square represent new records: Triangle = surroundings of the Arauca river and Caño Limón; Square = Marechal Thaumaturgo. Dark shaded areas indicate the three current Brazilian states whose areas used to constitute the state of Mato Grosso at the time of the Rondon commission.

crest. **Parabasisphenoid complex** (Fig. 3C): spear shaped, anterior portion tapering approximately on the level of posterior edge of palatines; posterior opening of Vidian canal situated posterolaterally.

PALATOMAXILLARY APPARATUS: **Maxillae** (Fig. 3B): elongated and arched shape extending to the level of postorbitals; posterior portion of palatine process with broad base, extending from sixth up to ninth teeth, with medial edge narrowing at the level of eighth tooth; each maxilla bears twenty curved prediastemal and two enlarged and ungrooved postdiastemal teeth; diastema with the same size of one alveolus; anterior maxillary teeth smaller. **Palatines** (Fig. 3C): elongated and narrow, lateral maxillary process overlapped by prefrontal, slightly anterior to choanal process, extending from fourth to seventh teeth; maxillary process with wide base and tapered edge; choanal process extending from twelfth to thirteenth teeth, close to parabasisphenoid, but not reaching it; posterior portion single (without bifurcation); each palatine bears 10 or 11 curved teeth of nearly equal size. **Pterygoids** (Fig. 3C): elongated, tapered anteriorly, with length more than 50% of skull length; anterolateral portion of pterygoid articulates with ectopterygoid at the level of eighth to tenth teeth; pterygoid becomes broader anteroposteriorly, up to the end of the row of teeth, where the bone tapers, directing laterally on the posterior portion; mesoposterior portion with dorsolateral longitudinal crest emerging just after joint with ectopterygoid and extending to posterior edge of pterygoids; each pterygoid has twenty five curved teeth of nearly equal size. **Ectopterygoids** (Fig. 3B and 3C): elongated, with anterior edge bifurcated contacting posterior portion of maxilla.

SUSPENSORIUM AND MANDIBLE: **Supratemporals** (Fig. 3A): elongated, overlapping much of dorsal portion of prootic; posterior end extends beyond braincase, reaching the level of rear end of atlas. **Quadrates** (Fig. 3A and 3B): about the same length of supratemporals, elongated shape, dorsal portion wider than ventral portion. **Dentaries** (Fig. 3B and 4B): elongated, posterior edge bifurcated in lateral view; dorsal process approximately two times the length of ventral process; dentary with twenty eight teeth with nearly equal size distributed from anterior edge to the end of dorsal process. **Splenials** (Fig. 4C): triangular with anterior edge tapered and posterior end vertical; mylohyoid anterior foramen close to posterior joint with angular. **Angulars** (Fig. 4C): triangular, anterior edge vertical and posterior end tapered, exceeding the level of posterior edge of dorsal process of dentary; anterior portion bears mylohyoid posterior foramen; angular completely overlapped by anteroventral portion of compound bone dorsally. **Compound Bones** (Fig. 3B and 4B): anterior portion narrow fitting between dorsal and ventral processes of dentary; articular and surangular crests well developed (first higher than second), lying anterior to glenoid cavity.

Distribution.—Two specimens (ICN 1526; 1527) were collected in the surroundings of the Arauca River and three specimens (ICN 6776; 6891; 6943) were collected at Caño Limón, municipality of Arauquita, both localities in the department of Arauca, Colombia, representing the first records of *L. dorsocorallinus* to the country (Fig. 5). Four specimens (ZUEC 1587, 1971, 1972, 1973) were collected in the surroundings of the Tejo River, municipality of Marechal Thaumaturgo, state of Acre, Brazil, extending the distribution of the species by about 130 km to the southwest from the nearest previously known record of the species (Reserva Extrativista Riozinho da Liberdade). Furthermore, five specimens (MNRJ 189, 320, 322–324) were found in the herpetological collection of Museu Nacional, Universidade Federal do Rio de Janeiro, previously identified as *Leimadophis reginae* by Amaral (1948). According to the museum records, these specimens were collected between 1908 and 1914 in the state of Mato Grosso, central Brazil, by members of the Rondon Commission, a series of expeditions led by Marshall Cândido Mariano da Silva Rondon aiming to install telegraph lines to integrate the isolated central region of Brazil with the rest of the country. The Commission also intended to perform a scientific inventory of the territory and, for this reason, many naturalists (mainly from Museu Nacional) accompanied the expeditions (Sá et al. 2008). At that time, the state of Mato Grosso comprised an area that now corresponds to three states: Rondônia, Mato Grosso, and Mato Grosso do Sul. Therefore, it is not possible to know exactly where the specimens were collected. However, when analyzing these specimens, Amaral (1948) stated that they were collected in the central/northern region of Mato Grosso, which would probably be equivalent to the current states of Rondônia and Mato Grosso. These specimens represent the easternmost records of this species and, probably also its southernmost records. Furthermore, they also represent a historical record for an area that is currently being deforested at an extremely fast rate, mainly due to cattle ranching and soy plantations.

Discussion

Analyses of new specimens increased our knowledge of morphological variation of *Liophis dorsocorallinus* for most meristic and morphometric traits of this species. In particular, the amplitude of variation increased for the following variables (see Table 2): snout–vent length, tail length, number of ventrals, subcaudals, head length, supralabials, infralabials, and postoculars.

Additionally, we can reject the hypothesis that the variation observed in ventral color pattern represents a case of sexual dimorphism, as implied by Esqueda et al. (2005). Those authors stated that females, despite the fact that they examined only a single female specimen, have a completely immaculate ventral surface, whereas males have the first third of the venter immaculate and the posterior two-thirds with an alternate pattern of black and red spots (commonly described as a checkered pattern). However, as mentioned above, none of the specimens analyzed here (nine males and nine females) have an immaculate venter, but show black spots of variable sizes in both females and males. Therefore, this variation is not sex-related.

Our description of the hemipenial morphology included the presence of the hemipenial apical disks, a synapomorphy of the tribe Xenodontini (Zaher 1999), that according to Esqueda et al. (2005) would be absent in *L. dorsocorallinus*. In the original description the authors were unable to observe the apical disks in the hemipenis of the holotype, probably because the organ was not fully everted (see fig. 2A in Esqueda et al. 2005).

The two Colombian records confirm the occurrence of the species in that country, as would be expected considering the previously known records in Venezuela and Brazil. We expect that new records of *L. dorsocorallinus* will improve our knowledge of the distribution of this species, particularly regarding the apparent isolation between the northern records (in Colombia and Venezuela) and southern records (in the western region of the Brazilian Amazon), and whether this species is present in the Brazilian states of Rondônia and Mato Grosso.

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