



Morphological variation of the rare psammophilous species *Apostolepis gaboi* (Serpentes, Dipsadidae, Elapomorhini)

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Abstract

Apostolepis gaboi was described based only on the holotype found in the Queimadas, state of Bahia, northeastern Brazil. Since its original description, no additional specimens were reported in literature and the species was considered to be rare and poorly known. Here, we provide a detailed description for the species based on the examination of the holotype and 34 additional specimens from the type locality and adjacent areas. Additional information is also provided on intraspecific color variation and hemipenial morphology.

Key words: Caatinga, color pattern, endemism, hemipenial morphology, intraspecific variation

Resumo

Apostolepis gaboi foi descrita com base apenas no holótipo, encontrado em Queimadas, estado da Bahia, nordeste do Brasil. Desde sua descrição, nenhum espécime adicional foi relatado na literatura e a espécie era considerada rara e pouco conhecida. Fornecemos aqui uma descrição detalhada para a espécie com base no exame do holótipo e de 34 espécimes adicionais oriundos da localidade-tipo e áreas adjacentes. Fornecemos também informações sobre a variação de coloração intraespecífica e morfologia hemipeniana.

Palavras-chave: Caatinga, endemismo, morfologia hemipeniana, padrão de coloração, variação intra-específica

Introduction

The dipsadid snake genus *Apostolepis* Cope 1862 includes 35 species distributed throughout cis-Andean South America (Uetz *et al.* 2018). The genus is considered to be monophyletic within the tribe Elapomorhini (Grazziotin *et al.* 2012), being characterized by fused internasal and prefrontal shields, and by the presence of a black band on the tip of the tail (Boulenger 1896; Ferrarezzi 1993; Lema 2001).

The lack of a taxonomically comprehensive review of the group since Strauch (1885) makes it difficult to assess the taxonomic identity of most populations of *Apostolepis* (Rodrigues 1992). As result, available keys for species identification (e.g., Peters & Orejas-Miranda 1970; Lema 2001; Ferrarezzi *et al.* 2005) have proven to be of limited accuracy or restricted value, forcing taxonomists to undergo tenuous, geographically restricted comparisons each time a new specimen needs identification (Vanzolini 1986). Furthermore, there are limitations imposed by the homogeneous scale pattern known to occur throughout the group and the paucity of available samples in collections for several currently recognized species (see below).

The last few years witnessed an unusually high number of species descriptions based on a single specimen that are ultimately recognized solely by their color pattern (e.g., *A. gaboi* Rodrigues 1992; *A. phillipsi* Harvey 1999; *A.*

christineae Lema 2002; *A. cerradoensis* Lema 2003; *A. striata* Lema 2004a; *A. tertulianobeui* Lema 2004b; *A. freitasi* Lema 2004c; *A. serrana* Lema & Renner 2006; and *A. roncadori* Lema 2016). Along with these, a number of older descriptions based on single specimens [e.g., *A. longicaudata* Gomes in Amaral 1921; *A. vittata* (Cope 1887)] help increase substantially the apparent state of chaos that characterizes the taxonomy of the genus. However, recent efforts that clarified the identity of some of these species were welcome (e.g., Lema *et al.* 2005; Lema & Renner 2005a,b; Curcio *et al.* 2011).

As for most species in the genus, *Apostolepis gaboi* was described based only in the holotype. Its secretive psammophilous habits and apparently restricted distribution to the quaternary sand dunes of the left bank of the São Francisco River (Rodrigues 1992; Guedes *et al.* 2014) reinforced the status of rare species. According to IUCN's definitions, *A. gaboi* was ultimately ranked in the Brazilian Red List of Threatened Species as Endangered (EN), under the criteria B1ab(iii) (ICMBio 2016). However, during a survey in the zoological collections of Brazil, we found a large number of specimens of *A. gaboi* that were collected at the type locality or close to it, within the sand dunes region. Here, we provide additional information on meristic variation, color pattern, and hemipenial morphology to the species.

Materials and methods

We examined a total of 35 specimens of *Apostolepis gaboi*, including its holotype, housed in the following Brazilian collections: Museu de Zoologia, Universidade de São Paulo (MZUSP), São Paulo; Museu de Zoologia, Universidade Federal da Bahia (MZUFBA), Salvador; and Museu de Zoologia, Universidade Estadual Feira de Santana (MZUEFS), Feira de Santana. The specimens and localities are listed in the Appendix.

We analyzed characters from external quantitative (meristic and morphometric data) and qualitative traits (pholidosis and color pattern) and hemipenial morphology. We took measurements to the nearest 0.01 mm with a digital caliper, except for the total length (snout-vent length plus tail length), which were taken with a flexible ruler. We converted most measurements to proportions for purpose of descriptions. The biometric information of intraspecific variation comprises minimum, maximum and average \pm single standard deviation, based on the 35 specimens examined (15 females and 20 males, including the holotype; Table 1). We performed a non-parametric Kruskal-Wallis analysis to test for secondary sexual dimorphism in the sample (Zar 1999). We followed Dowling (1951) method for the counting segmental scales. We prepared hemipenis following procedures described by Pesantes (1994) for retracted or semi-everted organs from preserved specimens. We colored the calcified structures of the hemipenis with red dye Alizarine S. We followed the terminology for the hemipenial morphology from Dowling & Savage (1960), Zaher (1999), and Zaher & Prudente (2003). We obtained the images with a digital camera or layer-by-layer camera and mounted in plates using Photoshop CS6 version 13.0. We retrieved coordinates of localities based on direct visual inspection of layers (municipality, São Francisco river, and villages) in the software QGIS version 2.14.10 (QGIS Development Team 2017) and Google Earth. We produced a geographical distribution map in QGIS on the basis of refined coordinates.

Results

Redescription of the holotype of *Apostolepis gaboi* Rodrigues 1992 (Figs. 1–2, Table 1). Described based on a single specimen (MZUSP 10290) from Queimadas (10° 23' S, 42° 30' W; 295 m a.s.l.), municipality of Pilão Arcado, state of Bahia, Brazil. A slim juvenile female 215 mm SVL, 20 mm TL (8.5% of total length); body diameter 2.5 mm (1.2% SVL); head length 5.64 mm (2.4% SVL), head width 2.26 mm at broadest point (40.1% head length); head not distinct from neck; dorsal scales rows 15/15/15; ventrals 229, divided cloacal plate; paired subcaudals 31; rostral plate slightly wider (0.84 mm) than long (0.66 mm), visible in dorsal view; prefrontals large, slightly wider (0.98 mm) than long (0.89 mm), in broad median contact, shorter than frontal scale; frontal longer (1.31 mm) than wide (1.01 mm), anteriorly exceeding anterior border of supraoculars; parietals very long (2.77 mm), almost two times longer than frontal scale; parietal laterally contacting 5th and 6th supralabials, in contact anteriorly with frontal, supraocular and postocular, posteriorly with first rows of dorsals slightly increased;

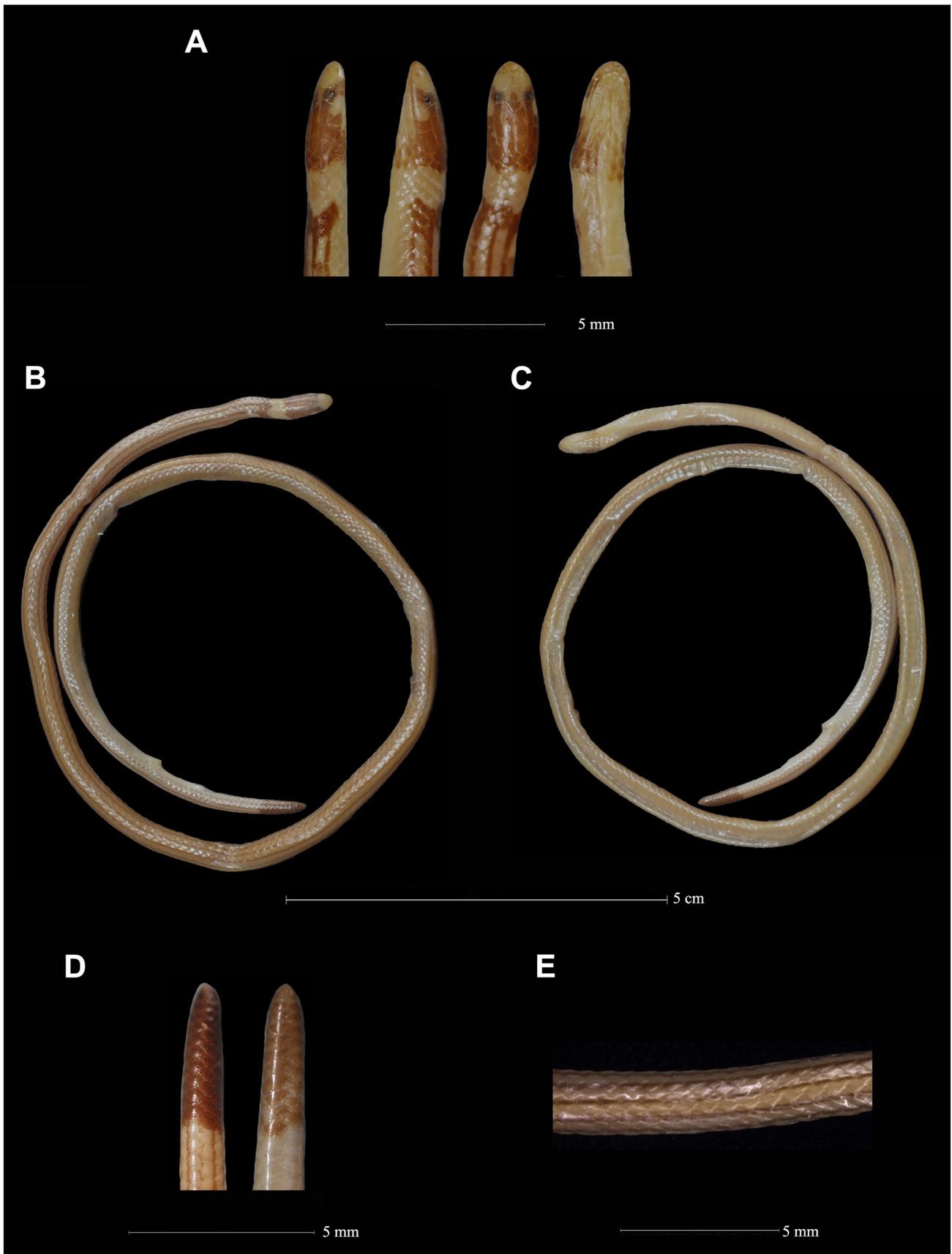


FIGURE 1. Head views (left, right, dorsal and ventral, respectively) (A), dorsal (B) and ventral body views (C), tail views (dorsal and ventral, respectively), and dorsal midbody view (E) of the holotype of *Apostolepis gaboi* (MZUSP 10290) from Queimadas, municipality of Pilão Arcado, state of Bahia, Brazil.



FIGURE 2. General view of the holotype of *Apostolepis gaboi* (MZUSP 10290) in life from Queimadas, municipality of Pilão Arcado, state of Bahia, Brazil. Photo by Miguel Rodrigues.

supraoculars smaller than frontal, with their anterior margin very straight; nasal plate entire, longer than high, thinner posteriorly, in contact with rostral, prefrontal, 1st and 2nd supralabials; nostril centralized in nasal plate; preocular one, very small; postocular one; supralabials six, 2nd and 3rd contact the eye, 5th and 6th increased in length; temporal scales indistinct, parietal in contact with 5th and 6th supralabials; mental triangular, as long as high, separated from chinshields by first pair of infralabials; chinshields in two pairs, second being longer (1.05 mm) than first (0.68 mm); first pair of chinshields in contact with first four infralabials, second pair with 4th and 5th infralabials.

Coloration of holotype faded after preservation in 70% ethanol. Head dark brown, except for the snout light cream; one cream blotch extending from 3rd to 5th supralabial scales; nostrils cream (Fig. 1A); neck with complete white collar (three scales long) in dorsal and lateral views followed by dark brown collar (two to three scales long); gular region cream anteriorly with incomplete dark brown band after chinshields (Fig. 1A); dorsum of body pale brown or beige with five narrow longitudinal brown stripes (one vertebral and four dorsolateral lines on the 4th and 6th rows) extending until the tip of the tail (Fig. 1B and E); ventral surface of body immaculate cream from the neck to subcaudals, except for the tip of the tail (Fig. 1C); tip of the tail dark brown in dorsal (12 scales long) and ventral (11 scales long) views; terminal spine dark brown (Fig. 1D).

Pictures of *Apostolepis gaboi* in life (Fig. 2), show it has dorsum of the head dark brown; snout pale brown; distinct oval blotch pale brown covering the 3rd to 5th supralabials; nuchal collar white, followed by dark brown to black cervical collar; five black stripes arising in the black collar following to up the tail; vertebral and paraventral stripes are narrowest while paravertebrals are widest; dorsal background is rust-colored; tip of the tail is black and terminal spine is also black.

Intraspecific variation in continuous characters (Table 1). Largest female 517 mm total length (TL), 31 mm of tail length; largest male has 424 mm and 38 mm. Total length 236–517 mm (mean = 349.3 ± 95.95 mm; $n = 15$) in females, 234–424 mm (mean = 299.7 ± 37.08 mm; $n = 20$) in males. Tail length 18–35 mm (mean = 25.33 ± 5.44 mm; 12.13–21.25% TL) in females, 16–40 mm (mean = 29.3 ± 5.52 mm; 7.63–18.50% TL) in males; ventral scales 200–239 (mean = 221.6 ± 11.32) in females, 190–230 (mean = 208.7 ± 9.18) in males; subcaudals 27–34 (mean = 30.95 ± 4.2) in males, 24–31 (mean = 27.4 ± 2.35) in females. We found a significant secondary sexual dimorphism in the number of ventrals ($H = 9.21$; $p < 0.001$; $n = 35$) and subcaudals ($H = 16.07$, $p < 0.001$; $n = 35$); supralabials six (2nd and 3rd contacting the eye). Preocular absent ($n = 9$), 1/1 ($n = 23$) or 1/0 ($n = 2$). Preocular usually fused to prefrontals, except for the MZUFBA 1693 where it seems to be fused with the 2nd supralabial. Second pair of

chinshields contacting 4–5 infralabials, except for the MZUFBA 1697 in which the first pair of chinshields contact first three infralabials and the secondary chinshields 3–4 infralabials.

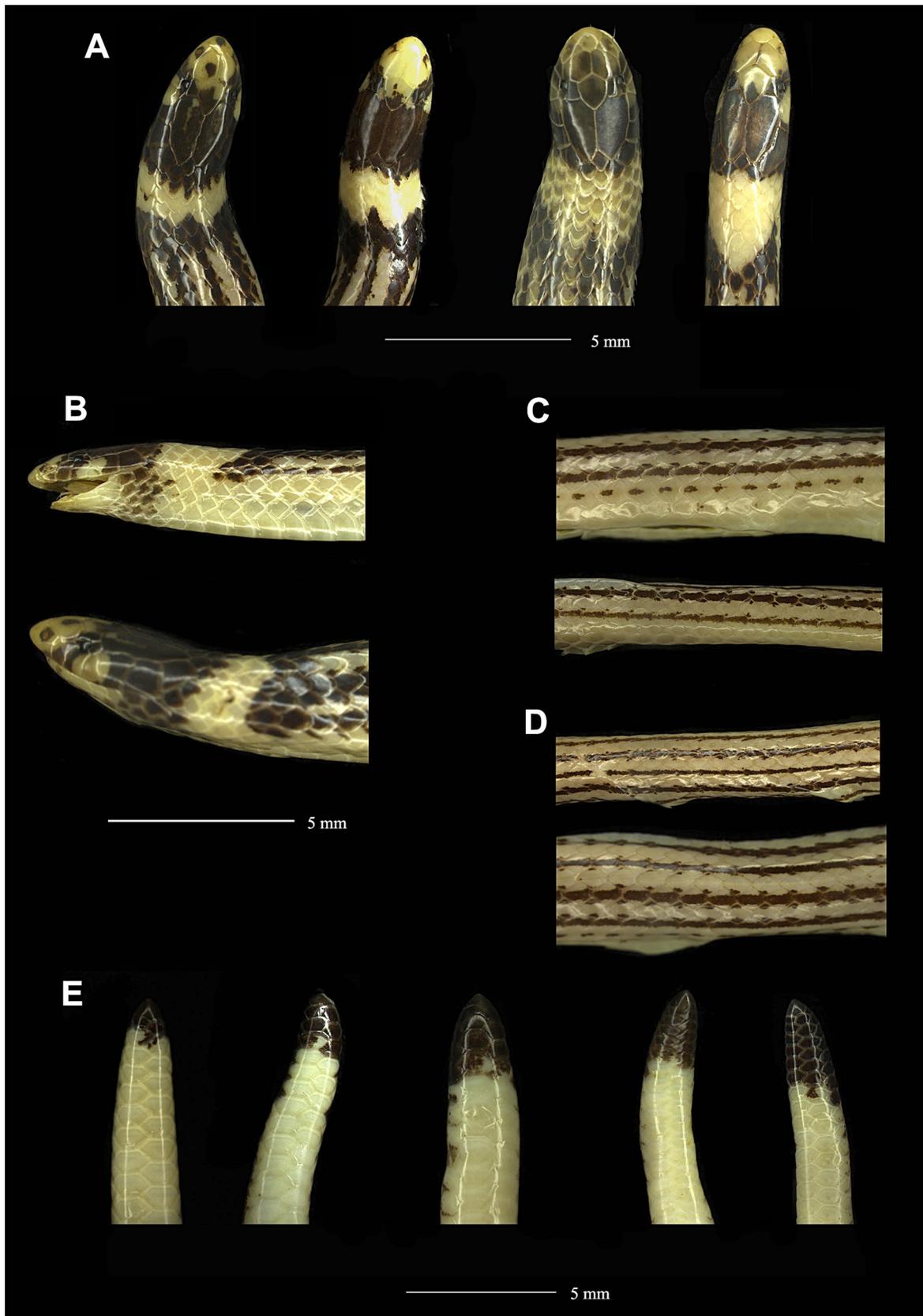


FIGURE 3. Color pattern variation of the preserved specimens of *Apostolepis gaboi*. Dorsal (A) and lateral (B) views of the head, lateral (C) and dorsal (D) views of the midbody, and ventral view of the tail (E).

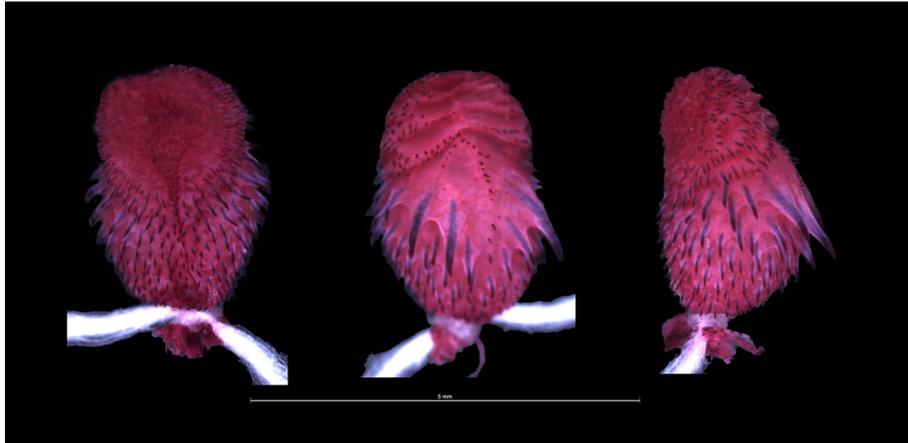


FIGURE 4. Sulcate (left), asulcate (center), and lateral (right) views of the fully everted and maximally expanded hemipenis of *Apostolepis gaboi* (MZUFBA 1683).

Intraspecific variation in coloration. White nuchal collar cover two (MZUFBA 1674, 1676, 1680–81, 1685, 1689, 1694, 1702–03) to five scales long (MZUFBA 1673, 1680, 1690, and 1697), most specimens with three scales long (MZUFBA 1675, 1677–79, 1682, 1684, 1686–88, 1691–93, 1695–96, 1698–1701, 1704) (Fig. 2A); dark brown collar one and half (MZUFBA 1690, 1693, 1703) to three scales long (MZUFBA 1673–76, 1678, 1680–81, 1683–85, 1687, 1691, 1694, 1699) (Fig. 3A), contacting ventrals or starts on third dorsal scale row (Fig. 3B); dorsal coloration usually with vertebral stripe and two dorsolateral stripes each; dorsal stripes continuous, dark brown, speckled with small dots and arranged between the 4th and 5th dorsal rows (Fig. 3C and D); eight individuals with five stripes along the body (MZUFBA 1675, 1678, 1683, 1688, 1692, 1696–97, 1701, and 1703) and 12 with five stripes plus a pair of faint dashed brownish lines at the level of the 3rd dorsal row (MZUFBA 1679, 1689, 1691, 1695, and 1700); six specimens presented vestigial additional stripes (MZUFBA 1673, 1677, 1682, 1684, 1694, 1699, and 1702) (Fig. 3C and D); tail tip surrounded by dark brown band, including terminal spine; caudal band varies in its extent, covering ventral region of two (MZUFBA 1704), four (MZUFBA 1687, 1689, and 1696), five (MZUFBA 1679), six (MZUFBA 1982), seven (MZUFBA 1684) or eight subcaudals (MZUFBA 1695) (Fig. 3E).

Hemipenial morphology. Organ of adult specimen (MZUFBA 1683) fully everted and maximally expanded (Fig. 4); hemipenis short, stout and unilobed, unicaliculate and unicapitate; lobe extends for about one third of the hemipenis; capitulum restricted to sulcate and lateral surfaces of the organ, covering half of the organ's length at the level of the sulcus spermaticus; capitulum formed by small papillate calyces disposed concentrically on sulcate and lateral surfaces of the lobe, except for two outermost rows of calyces that are clearly larger in size and spinulate; on asulcate surface, lobes ornamented with two parallel rows of three to four deep, mediolaterally enlarged and papillate body calyces; body of hemipenis covered by spinules on sulcate surface and proximal region of asulcate surface; spinules reduce in number and increase gradually in size towards lateral surface and distal region of asulcate surface of the body, where they form one outer and distal row of greatly enlarged spines; the enlarged spines disposed asymmetrically on each side of asulcate or lateral surfaces; distally to the last row of enlarged lateral spines, hemipenial body is completely nude, except for a median row of spinules arranged along midline of asulcate surface; sulcus spermaticus forks within the base of the capitulum where it continues in almost parallel portions to reach distal surface of lobe on its sulcate side.

Distribution and natural history notes. *Apostolepis gaboi* is a psammophilous species endemic of the Caatinga ecoregion (Rodrigues 1992, 2003; Guedes *et al.* 2014) with a restricted distribution known to encompass only the municipalities of Barra and Pilão Arcado, in the eastern sandy bank of the São Francisco River, state of Bahia, Brazil (Fig. 5). The vegetation of the area is bushy and herbaceous Caatinga that grows on sandy soil and dunes (Rodrigues 1992; Guedes *et al.* 2014). *Apostolepis gaboi* is both diurnal and nocturnal (Rodrigues 1992; Guedes *et al.* 2014), with a probable feeding preference for elongated preys, as suggested by the only prey item registered so far and identified as *Amphisbaena hastata* (Damasceno 2002).

TABLE 1. Morphometric and meristic variation for the known specimens of *Apostolepis gaboi*. Abbreviations are as following: DEOM= distance of eye to oral margin; DEST= distance of eye to snout tip (rostral); F= Female; FRL= frontal shield length; HEH= largest head height; HEW= largest head width; HEW= largest head width; IL= infralabial shields; M= Male; OCL= Ocular scales; ORH= orbit height; PRTL= Parietal; SC= subcaudal scales count; SVL= snout-vent length; TL= tail length; VE= ventral scales count. The bold text represents the data of the holotype. Asterisks mean amputated tail.

	Sex	SVL	TL	HEL	HEH	HEW	DEOM	DEST	FRL	PRTL	ORH	VE	SC	IL	OCL
MZUSP 10290	F	215	20	5.64	1.87	2.26	0.56	1.54	1.31	2.77	0.34	229	31	8	1+1
MZUEFS 981	F	270	24	6.43	2.06	2.39	0.75	2.11	1.64	3.01	0.54	212	30	7	1+1
MZUFBA 1682	F	350	39	7.69	2.72	3.20	0.79	2.68	1.77	3.67	0.43	228	28	7	1+1
MZUFBA 1687	F	340	36	6.84	2.90	3.28	0.90	2.48	1.61	3.18	0.37	223	28	7	0+1
MZUFBA 1676	F	356	32	8.64	2.79	4.11	0.86	2.85	2.26	3.83	0.52	224	31	7	1+1
MZUFBA 1700	F	242	21	6.26	1.80	2.77	0.63	1.52	1.31	2.77	0.34	204	29	7	0+1
MZUFBA 1693	F	281	24	5.38	2.11	2.35	0.45	2.36	1.39	2.62	0.31	227	25	7	0+1
MZUFBA 1696	F	258	22	6.29	1.88	2.80	0.63	2.30	1.77	3.12	0.44	200	25	7	1+1
MZUFBA 1674	F	286	24	6.35	1.85	2.90	0.82	2.07	1.41	3.04	0.32	214	24	7	1+1
MZUFBA 1675	F	303	24	6.41	2.09	2.86	0.78	2.21	1.81	2.85	0.40	239	29	7	1+1
MZUFBA 1691	F	269	21	6.05	1.86	2.15	0.39	1.89	1.50	2.69	0.32	223	28	7	1+1
MZUFBA 1699	F	231	18	5.76	1.93	2.43	0.62	1.97	1.19	2.53	0.36	212	26	7	1+1
MZUFBA 1679	F	453	34	9.68	3.81	5.00	1.33	3.38	2.59	4.52	0.37	221	27	7	1+1
MZUFBA 1689	F	494	35	10.14	3.96	5.63	1.31	3.80	2.59	5.01	0.50	238	26	7	0+1
MZUFBA 1704	F	486	31	10.88	4.11	5.45	1.52	4.03	2.65	4.89	0.42	230	24	7	1+1
MZUFBA 1681	M	280	16*	6.86	1.99	2.87	0.70	2.48	1.68	3.05	0.35	219	16*	7	1+1
MZUFBA 1698	M	265	40	6.25	2.34	2.94	0.67	1.75	1.76	3.11	0.38	205	30	7	1+1
MZUFBA 1692	M	246	36	5.98	2.00	2.45	0.60	2.16	1.33	2.66	0.38	209	33	7	1+1
MZUFBA 1684	M	290	35	6.90	2.40	3.30	0.75	2.52	1.41	3.03	0.41	211	33	7	1+1
MZUFBA 1686	M	269	32	6.36	2.02	2.70	0.55	2.13	1.46	2.91	0.36	207	33	7	1+1

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TABLE 1. (Continued)

	Sex	SVL	TL	HEL	HEH	HEW	DEOM	DEST	FRL	PRTL	ORH	VE	SC	IL	OCL
MZUFBA 1690	M	272	32	6.54	2.36	2.97	0.80	2.41	1.73	3.10	0.45	195	34	7	0+1
MZUFBA 1694	M	252	29	6.43	2.21	2.76	0.75	2.47	1.32	2.85	0.42	194	33	7	1+1
MZUFBA 1688	M	210	24	5.36	1.47	2.41	0.53	1.81	1.29	2.38	0.32	208	33	7	1+1
MZUFBA 1703	M	267	29	5.81	1.94	2.45	0.67	2.19	1.42	2.65	0.35	204	34	7	0+1
MZUFBA 1677	M	287	31	6.80	2.47	3.24	0.84	2.31	1.71	3.18	0.43	216	29	7	1+1
MZUFBA 1695	M	247	26	5.97	2.03	2.65	0.65	2.19	1.62	2.70	0.31	213	32	7	1+1
MZUFBA 1680	M	277	29	6.31	1.87	2.70	0.70	2.17	3.06	2.75	0.36	212	29	7	1+1
MZUFBA 1683	M	277	29	6.54	2.50	2.95	0.63	2.30	1.73	3.06	0.34	217	31	7	0+1
MZUFBA 1678	M	277	29	7.19	2.25	3.03	0.72	2.28	1.46	3.08	0.41	205	32	7	1+1
MZUFBA 1673	M	289	30	6.63	2.45	2.97	0.73	2.26	1.45	2.84	0.37	190	27	7	0+1
MZUFBA 1701	M	223	23	5.80	1.91	2.42	0.72	2.14	1.45	2.67	0.36	217	29	7	1+1
MZUFBA 1697	M	277	28	5.47	1.97	2.48	0.61	2.49	1.31	2.78	0.40	209	31	7	1+1
MZUFBA 1685	M	257	25	6.35	1.88	2.75	0.64	2.42	1.20	2.72	0.47	206	32	7	1+1
MZUFBA 1702	M	260	25	5.67	1.77	2.35	0.65	1.96	1.49	2.58	0.32	207	30	7	0+1
MZUSP 10547	M	386	38	9.24	4.13	4.78	1.41	2.51	2.43	3.71	0.53	230	38	7	1+1

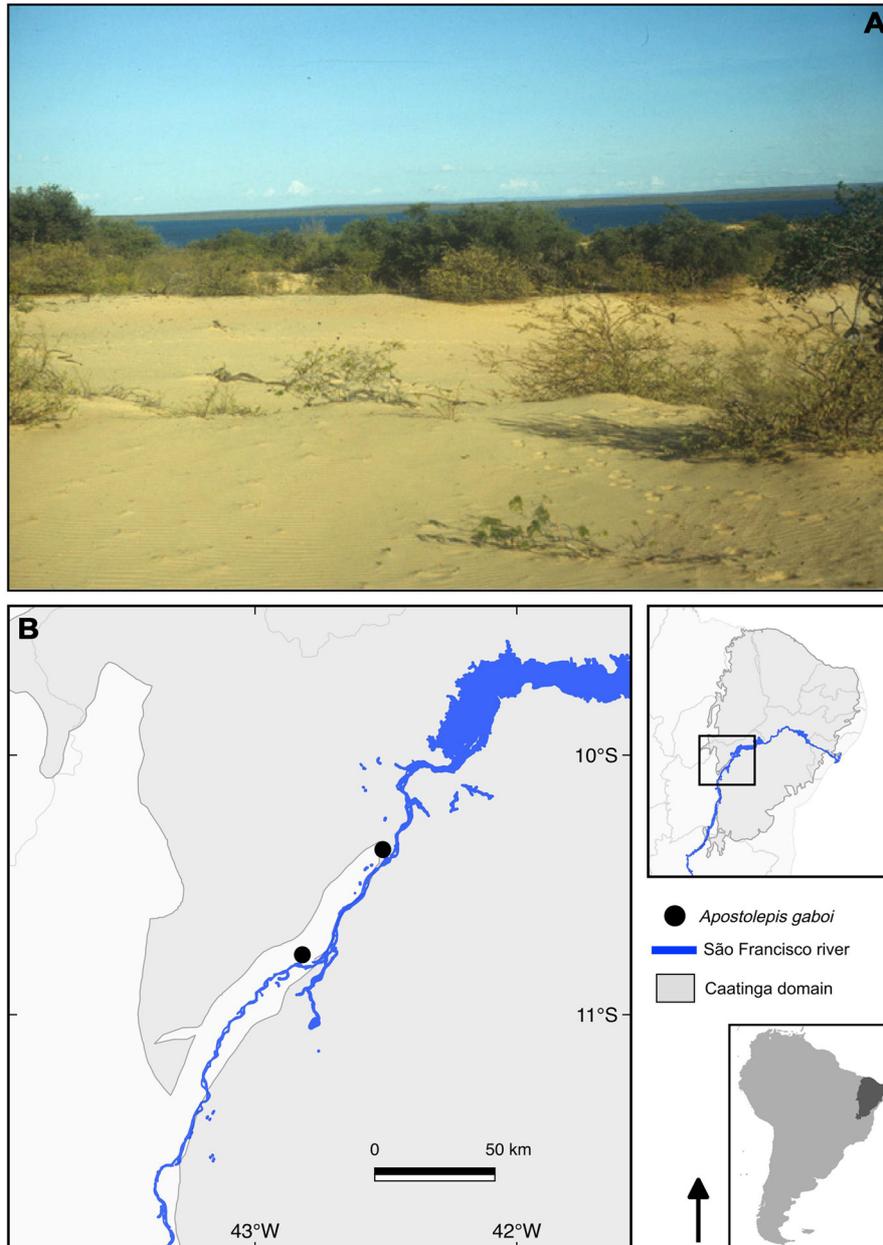


FIGURE 5. Landscape view from the Quaternary sandy dunes in the São Francisco River, state of Bahia, northeastern Brazil (A) and the map showing the distribution of *Apostolepis gaboi* in the left side of the São Francisco River (B). Photo A by Miguel Rodrigues.

Discussion

Rodrigues (1992) described *Apostolepis gaboi* on the basis of a single specimen from Queimadas, in the Caatinga biome of the state of Bahia, northeastern Brazil. Ferrarezzi *et al.* (2005) included *Apostolepis gaboi* in the *Apostolepis assimilis* species group along with *A. ammodites*, *A. assimilis*, *A. cearensis* and *A. arenaria*. All these species share external similarities such as the presence of white cervical collar followed by a black nuchal collar and entirely black terminal spine. Most species of the *A. assimilis* group present dorsal color pattern uniformly red (as in *A. flavotorquata*), while only *A. arenaria* and *A. gaboi* show dorsal color pattern with stripes (as in *A. longicaudata* and *A. nigrolineata*). Among the species of the *A. assimilis* group, two of them (*A. gaboi* and *A. cearensis*) show a higher degree of rostral prominence, which is a putative synapomorphy also shared with several

species referred to *A. dimidiata* group (e.g., *A. dimidiata*, *A. ambiniger*, *A. vittata*, *A. goiasensis*) (see Ferrarezzi *et al.* 2005).

The hemipenes of the species from the *A. assimilis* group are similar (Fig. 6). All of them are short, stout and unilobed, being unicaliculate and unicapitate and with a narrower base. The capitulum reaches the sulcate and lateral surface of the organs, covering almost half of its length until the level of the sulcus spermaticus. On its asulcate surface, the lobe is ornamented with two parallel rows of three to four deep, midlaterally enlarged and papillate body calyces. The hemipenial body is covered by spinules on the sulcate surface and the proximal region of the asulcate surface. Spinules reduce in number and increase gradually in size towards the lateral surface and distal region of the asulcate surface of the body, where they form one outer and distal row of greatly enlarged spines. However, the hemipenis of *A. gaboi* seems to share more similarities with the organs from the *A. assimilis*. These hemipenial conditions refereed above for the *A. assimilis* group are also present in the *A. longicaudata* (Curcio *et al.* 2011) and, at least partially, in the *A. quinquelineata* (T. Guedes pers. observ.); suggesting that these might have evolved independently in both groups or may be more widespread in the genus. Nevertheless, no definitive evidence supports a close phylogenetic affinity of *A. gaboi* with species of the *A. assimilis* group, except for the geographical proximity and overall morphological similarities pointed out by Ferrarezzi *et al.* (2005).

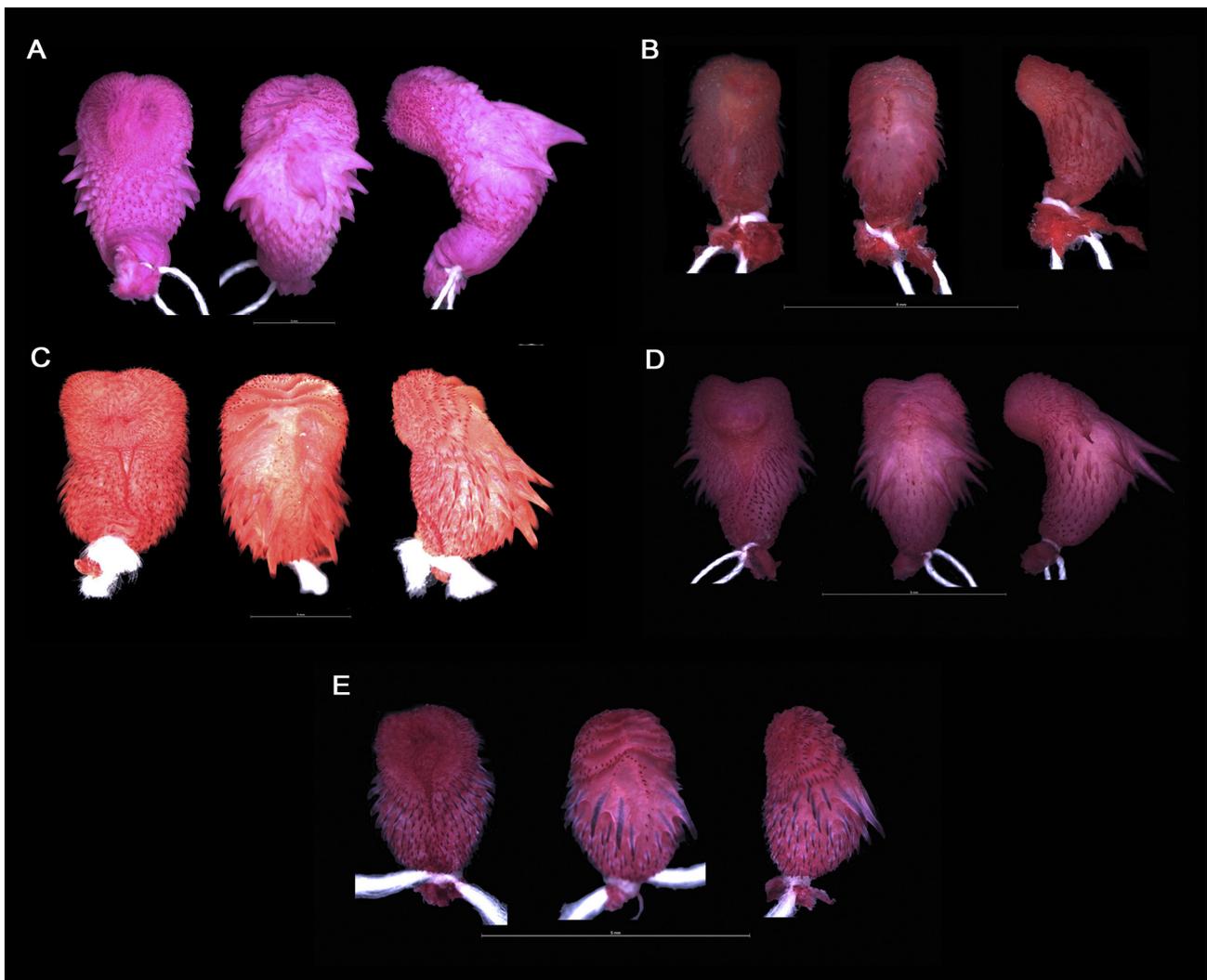


FIGURE 6. Sulcate (left), asulcate (center), and lateral (right) views of the fully everted and maximally expanded hemipenis of *Apostolepis ammodites* (MZUSP 12069-A), *A. arenaria* (MZUSP 15573-B), *A. assimilis* (IB 52754-C), *A. cearensis* (MZUSP 19549-D), and *A. gaboi* (MZUFBA 1683-E).

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APPENDIX. Material examined.

Country is given in bold capital, state in upper capital, municipalities in italics, and localities in plain text.

Apostolepis gaboii (*n* = 35). **BRAZIL**: BAHIA: Ibiraba, *Barra* (MZUFBA 1673–1704), Icatú, *Barra* (MZUEFS 981), Queimadas, *Pilão Arcado* (MZUSP 10290, holotype; MZUSP 10547, topotype).