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Research paper

The tadpoles of the neotropical *Scinax catharinae* group (Anura, Hylidae): Ecomorphology and descriptions of two new forms

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A B S T R A C T

Herein we provide novel data on the external morphological features and natural history of the tadpoles of *Scinax canastrensis* and *Scinax carnevallii*, two poorly known tree frog species occurring in southeastern Brazil. Both species share characteristics with all other species of the *Scinax catharinae* group, including oral discs not emarginated with the posterior margin concave when closed, many submarginal papillae laterally, circular nostrils, and vent tubes reaching the ventral fin margin. Landmark-based geometric morphometrics applied to 16 species of the *S. catharinae* group indicate that their tadpoles have substantial variation in body shape, yet with some overlap among species. Although the lentic/lotic habitat categorization was not sufficient for explaining the complex patterns of morphospace occupancy by tadpoles of *S. catharinae* group, some well-established ecomorphological relationships were recovered, such as that for suctorial and pond-type guilds. Moreover, the morphological diversity in shape may also reflect interspecific variation in microhabitat use, other contemporary factors (e.g., other abiotic habitat components and/or biological interactions) and evolutionary relationships.

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1. Introduction

Hylid tree frogs of the genus *Scinax* Wagler, 1830, are common constituents of Neotropical anurofauna, occurring from eastern and southern Mexico, Trinidad and Tobago, and St. Lucia to Argentina and Uruguay (Frost, 2015). Faivovich et al. (2005) recognized two monophyletic groups within the genus: the *Scinax catharinae* and the *Scinax ruber* clades. The *S. catharinae* clade comprises two monophyletic species groups, the *S. catharinae* and the *Scinax perpusillus* groups. Thirty-three species are recognized as belonging to the former (Lourenço et al., 2014), occurring predominantly in the Brazilian Atlantic Forest, from northeastern to southern Brazil.

Some species occupy gallery forests and open areas of the Cerrado domain (e.g., Lourenço et al., 2013; Pombal and Bastos, 1996; Pombal et al., 2010), and two species reach temperate areas of Uruguay and central-eastern Argentina (Faivovich, 2002, 2005; Pereyra et al., 2012). In general, species of the *S. catharinae* group are nocturnal and breed in a wide variety of habitats, from streams to ponds inside the forest, and more rarely in open formations (e.g., Carvalho-e-Silva and Carvalho-e-Silva, 2008; De-Sá et al., 1997; Faivovich, 2002; Hartmann et al., 2010; Kolenc et al., 2007; Lourenço et al., 2013; Rico et al., 2004; Teixeira and Röder, 2007).

Studies on the morphological and ecological diversity of tadpoles of the *S. catharinae* group are scarce. Despite advances in the taxonomy of the group (e.g., six new species described from 2005 to 2014; Frost, 2015) accurate and complete descriptions of the external morphology of the tadpoles of many species are still lacking, and tadpoles of nine species remain completely unknown (Abreu et al., 2015; Lourenço et al., 2013). This lack of information notwithstanding, larval characters of the *S. catharinae* clade have been included in phylogenetic studies of the genus (Faivovich, 2002), and are potentially informative regarding phylogenetic relation-

ships and taxonomy (e.g., Carvalho-e-Silva and Carvalho-e-Silva, 1994; Conte et al., 2007; Kolenc et al., 2007). Putative larval morphological synapomorphies have already been suggested for some groups of *Scinax* (Alcalde et al., 2011; Faivovich, 2002; Faivovich et al., 2005; Kolenc et al., 2003[2004]).

Most of the available information on the natural history and ecology of *Scinax* tadpoles comes from natural history notes included in original species and/or tadpole descriptions (e.g., Carvalho-e-Silva and Carvalho-e-Silva, 1994, 1998; Haddad and Pombal, 1987; Kolenc et al., 2007). Other studies addressing more general ecological issues have included tadpoles of the *S. catharinae* group (e.g., Eterovick and Barros, 2003; Eterovick et al., 2008).

At first glance, larvae of the *S. catharinae* group exhibit extensive variation in body shape, oral disc size and configuration, color, and behavior, which are poorly understood from adaptive and phylogenetic perspectives, mainly due to gaps in the basic information available and the absence of a comprehensive phylogenetic framework. Two species, *Scinax ariadne* (Bokermann, 1967) and *Scinax pombali* Lourenço et al., 2013; possess features presumably evolved to live in fast flowing water, such as large ventral oral discs with adherent structures (Bokermann, 1967; Lourenço et al., 2013). Some tadpoles, such as *Scinax aromothyella* Faivovich, 2005; *Scinax machadoi* (Bokermann and Sazima, 1973) and *Scinax berthae* (Barrio, 1962), have higher tail fins and globular bodies (Bokermann and Sazima, 1973; De-Sá et al., 1997; Kolenc et al., 2007), whereas other species such as *Scinax littoralis* (Pombal and Gordo, 1991) and *Scinax luizotavioi* (Caramaschi and Kisteumacher, 1989), possess a generalized benthic/lentic morphology (Bertoluci et al., 2007; Pombal and Gordo, 1991). An exploratory analysis suggested that the similarity of some external characters (i.e., position of nostrils, number of rows marginal papillae, presence of an anterior gap, jaw sheath width, LTRF, and presence of a tail flagellum) among the tadpoles of this group could be related to habitat use and/or vegetation (Conte et al., 2007). However, variation in external shape and its relationship to ecological factors and phylogenetic relationships have yet to be investigated.

Geometric morphometrics has been shown to be a valuable approach to exploring variation in the morphological shape of tadpoles of many anuran lineages (e.g., Baldo et al., 2014; Haad et al., 2011; Vera Candioti, 2007, 2008). Because these methods can document precise shape differences among species, the evolutionary relationships between morphology and ecology can be explored at many phylogenetic levels (Baldo et al., 2014; Haad et al., 2011; Marques and Nomura, 2015; Van Buskirk, 2009; Vera Candioti, 2008).

The present paper has two primary goals. The first goal is to fill-in gaps in knowledge of larval morphology of the *S. catharinae* group by describing the tadpoles of *Scinax canastrensis* (Cardoso and Haddad, 1982) and *Scinax carnevallii* (Caramaschi and Kisteumacher, 1989), including data on their natural history, and performing a qualitative comparison of the morphology of all 24 known tadpoles of the group. The second goal is to analyze the diversity in external shape among the majority of described tadpoles of the *S. catharinae* group. We were interested determining the extent to which these tadpoles differ morphologically from one another, and if this morphological variation is related to the environment in which they develop. Since the tadpole morphology of several anuran lineages is recurrently related to lentic and lotic water bodies (e.g., Baldo et al., 2014; Haad et al., 2011; Van Buskirk, 2009), we expect to find a similar ecomorphological pattern for the tadpoles of the *S. catharinae* group. In spite of the absence of an understanding of the phylogenetic relationships among species of the group and refined environmental data on the habitat used by tadpoles of all species, this inaugural approach aims to shed light on their morphological variation.

2. Material and methods

2.1. Tadpole collection and description

Tadpoles of *S. canastrensis* were collected in the municipalities of São Roque de Minas (type locality; 46°28′21″W, 20°19′50″S, 807 m a.s.l; collected on October 09, 2012–DZSJRP1353.1), Sacramento (about 80 km west of the type locality; 47°10′36″W, 19°51′25″S, 991 m a.s.l; collected on October 15, 2014–UFMG1668-9), and Tapiraí (about 55 km northeast of the type locality; 46°07′07″W, 19°55′02″S, 801 m a.s.l; collected on October 17, 2014–UFMG1670), all localities were in the region of Serra da Canastra in the state of Minas Gerais in southeastern Brazil. Tadpoles of *S. carnevallii* were collected in the southeastern portion of the Serra do Espinhaço in the municipality of Conceição do Mato Dentro in the state of Minas Gerais in southeastern Brazil (about 100 km east of the type locality; 43°26′02″W, 18°56′23″S, 671 m a. s. l; collected on July 28, 2008–UFMG604). Adults of these species were the only anurans reproducing in the environments where the larvae were found. Moreover, in the Serra da Canastra region, another species of *S. catharinae* group (*S. machadoi*) was also recorded, but not syntopic with *S. canastrensis*. Furthermore, the tadpoles of *S. machadoi* are quite different from those of *S. canastrensis* (Bokermann and Sazima, 1973; TLP personal observation).

Tadpoles were euthanized in 5% lidocaine solution and preserved in 10% formalin. For *S. canastrensis*, the description of the external morphology was based on two tadpoles from the type locality in stages 38-39 (Gosner, 1960; lot DZSJRP1353.1), whereas measurements were taken from 18 specimens between stages 30 and 39 (lots DZSJRP1353.1, UFMG1668-9, UFMG1670; Table 1). For *S. carnevallii,* the description of the external morphology was based on five tadpoles in stages 29-32 (lot UFMG 604a), and the measurements were taken from 12 specimens between stages 27 and 32 (lots UFMG 604a,b; Table 1). Throughout the descriptions the ratios between measurements are expressed as ranges.

Measurements and terminology follow Altig and McDiarmid (1999) for total length (TL), body length (BL), tail length (TAL), maximum tail height (MTH), internarial distance (IND), interorbital distance (IOD), tail muscle width (TMW), and tail muscle height (TMH); Lavilla and Scrocchi (1986) for body width (BW), body width at narial level (BWN), body width at eye level (BWE), body height (BH), eye-snout distance (ESD), eye-nostril distance (END), nostril-snout distance (NSD), eye diameter (ED), narial diameter (ND), snout-spiracular distance (SSD), and oral disc width (ODW); and Grosjean (2005) for dorsal fin height (DFH) and ventral fin height (VFH). Additional measurements taken were spiracle length (distance between the anterior insertion of the spiracle and its distal margin; SL), and spiracular-venter distance (perpendicular distance between the distal margin of the spiracle and the ventral surface of the tadpole; SVD). Classes of nostril, eye and oral disc size, height of the dorsal fin, and tail muscle robustness were determined using the following ratios, respectively: ND/BL (small $\leq 0.025 <$ middle $< 0.035 \leq$ large; Conte et al., 2007), ED/BWE (small $< 0.23 \leq$ large), ODW/BW (small $\leq 0.45 <$ middle $< 0.70 \leq$ large), DFH/TMH (low $\leq 1.0 <$ high; Conte et al., 2007), and TMH/BH (slender $\leq 0.45 <$ slightly robust $< 0.50 \leq$ robust). All measurements were taken to the nearest 0.1 mm with the aid of ImageTool version 3.00 (Wilcox et al., 1996). To obtain high quality photos we used an adjustable platform to support tadpoles immersed in water (Schacht and McBrayer, 2009). Lateral line descriptions and terminology is that of Lannoo (1987). For detailed morphological examination, especially characters of the oral disc, lateral line system, spiracle, narial opening and vent tube, preserved tadpoles were stained with methylene blue and analyzed using multifocal photographs, which were taken with a Leica M205 stereomicroscope.

Table 1

Measurements (in mm) of *Scinax canastrensis* from São Roque de Minas (DZSJRP1353.1), Sacramento (UFMG1668-9), and Tapiraí (UFMG1670), and *Scinax carnevallii* from Conceição do Mato Dentro (UFMG604a,b), state of Minas Gerais, Brazil, for some groups of Gosner (1960) stages. Data presented as mean ± standard deviation (range). For abbreviations, see text.

	Scinax canastrensis				*Scinax carnevallii*
Lot	DZSJRP 1353.1	UFMG 1668, 1669		UFMG 1670	UFMG 604a,b
Stage (*n*)	38–39 (2)	30 (3)	34–37 (10)	35–36 (3)	27–32 (12)
TL	(39.0–37.0)	40.9 ± 2.4 (42.6–38.2)	41.9 ± 1.3 (44.2–40.7)	40.4 ± 2.2 (42.6–38.2)	26.1 ± 2.5 (28.6–22.5)
BL	(11.1–10.7)	12.9 ± 0.8 (13.8–12.3)	12.9 ± 0.5 (13.6–12.3)	12.2 ± 0.4 (12.6–12.0)	8.4 ± 0.4 (9.0–7.8)
TAL	(28.0–26.3)	28.0 ± 1.8 (29.2–25.9)	29.0 ± 1.0 (30.6–28.1)	28.2 ± 2.0 (30.0–26.0)	17.7 ± 2.1 (19.8–14.6)
MTH	(8.0–7.9)	11.5 ± 0.7 (12.3–11.0)	11.4 ± 0.5 (12.2–10.8)	9.9 ± 0.2 (10.1–9.7)	5.5 ± 0.1 (5.7–5.3)
DFH	(3.1–2.8)	4.1 ± 0.2 (4.4–3.9)	4.0 ± 0.3 (4.5–3.6)	3.6 ± 0.1 (3.7–3.5)	1.9 ± 0.2 (2.1–1.7)
VFH	(2.1–2.2)	3.3 ± 0.2 (3.5–3.1)	3.3 ± 0.2 (3.6–3.1)	2.9 ± 0.1 (3.1–2.8)	1.5 ± 0.0 (1.5–1.4)
TMH	(3.5–3.5)	4.7 ± 0.3 (5.0–4.4)	4.9 ± 0.2 (5.1–4.4)	4.5 ± 0.2 (4.7–4.4)	2.8 ± 0.2 (3.2–2.6)
BH	(7.0–6.6)	7.9 ± 0.3 (8.2–7.7)	8.8 ± 0.5 (9.5–8.2)	7.9 ± 0.2 (8.0–7.7)	5.6 ± 0.3 (5.9–5.0)
SL	(1.7–1.6)	1.7 ± 0.1 (1.8–1.6)	1.6 ± 0.2 (1.9–1.4)	1.6 ± 0.1 (1.7–1.6)	0.8 ± 0.3 (1.0–0.6)
SDH	(2.9–2.2)	3.5 ± 0.3 (3.8–3.3)	3.3 ± 0.5 (4.1–2.7)	3.0 ± 0.7 (3.5–2.2)	2.3 ± 0.3 (2.7–1.9)
SSD	(7.9–7.7)	9.2 ± 0.7 (10.0–8.8)	8.9 ± 0.4 (9.6–8.5)	8.7 ± 0.4 (9.0–8.2)	6.0 ± 0.3 (6.4–5.7)
ED	(1.7–1.6)	1.8 ± 0.1 (1.9–1.8)	2.0 ± 0.1 (2.1–1.8)	1.8 ± 0.1 (1.9–1.7)	1.5 ± 0.1 (1.6–1.4)
BW	(8.5–8.1)	8.8 ± 0.5 (9.4–8.5)	9.3 ± 0.3 (9.7–8.9)	8.6 ± 0.3 (8.9–8.5)	6.5 ± 0.3 (6.8–6.0)
BWN	(5.2–4.9)	6.2 ± 0.4 (6.6–5.8)	6.6 ± 0.4 (7.1–6.2)	5.8 ± 0.2 (6.0–5.7)	4.4 ± 0.3 (4.7–4.0)
BWE	(6.8–6.7)	7.7 ± 0.3 (7.9–7.4)	8.2 ± 0.2 (8.4–7.9)	7.4 ± 0.1 (7.5–7.3)	5.4 ± 0.3 (5.8–5.0)
TMW	(3.5–3.2)	4.1 ± 0.5 (4.7–3.7)	4.4 ± 0.2 (4.8–4.1)	4.1 ± 0.2 (4.3–3.9)	2.5 ± 0.2 (2.9–2.4)
END	(2.2–2.1)	2.5 ± 0.2 (2.7–2.3)	2.7 ± 0.1 (2.9–2.5)	2.4 ± 0.1 (2.5–2.3)	1.7 ± 0.1 (1.9–1.5)
ESD	(4.7–4.1)	5.0 ± 0.2 (5.2–4.9)	5.3 ± 0.3 (5.7–4.8)	5.1 ± 0.2 (5.3–4.9)	3.5 ± 0.1 (3.7–3.3)
NSD	(2.3–1.9)	2.5 ± 0.1 (2.7–2.4)	2.6 ± 0.2 (3.0–2.3)	2.5 ± 0.3 (2.8–2.30)	1.8 ± 0.1 (1.9–1.8)
ND	(0.2–0.2)	0.3 ± 0.1 (0.4–0.2)	0.3 ± 0.1 (0.4–0.3)	0.2 ± 0.0 (0.2–0.2)	0.3 ± 0.0 (0.3–0.3)
IND	(3.1–3.0)	3.1 ± 0.1 (3.2–3.1)	3.4 ± 0.1 (3.6–3.2)	3.5 ± 0.2 (3.8–3.4)	2.1 ± 0.1 (2.3–2.0)
IOD	(5.4–5.2)	6.4 ± 0.3 (6.6–6.1)	6.8 ± 0.3 (7.1–6.3)	6.1 ± 0.2 (6.3–6.0)	4.6 ± 0.3 (4.9–4.2)
ODW	(3.3–3.0)	3.8 ± 0.1 (3.9–3.8)	4.0 ± 0.2 (4.3–3.8)	4.1 ± 0.1 (4.2–4.0)	2.5 ± 0.1 (2.6–2.4)

Data on the morphological features of tadpoles of the *S. catharinae* group were obtained from the review in Conte et al. (2007), and from their original descriptions, as follows: *Scinax albicans* (Bokermann, 1967) – Carvalho-e-Silva and Carvalho-e-Silva (1994); *Scinax angrensis* (Lutz, 1973a) – Carvalho-e-Silva et al. (1995); *Scinax argyreornatus* (de Miranda-Ribeiro, 1926) – Carvalho-e-Silva and Carvalho-e-Silva (1998); *S. ariadne* – Bokermann (1967); *S. aromothyella* – Kolenc et al. (2007); *S. berthae* – De-Sá et al. (1997); *S. catharinae* (Boulenger, 1888) – Conte et al. (2007); *Scinax flavoguttatus* (Lutz and Lutz, 1939) – Carvalho-e-Silva and Carnaval (1997); *Scinax heyeri* (Peixoto and Weygoldt, 1986) – Peixoto and Weygoldt (1987); *Scinax hiemalis* (Haddad and Pombal, 1987) – Haddad and Pombal (1987); *Scinax humilis* (Lutz and Lutz, 1954) – Carvalho-e-Silva and Carvalho-e-Silva (1998); *Scinax kautskyi* (Carvalho-e-Silva and Peixoto, 1991) – Carvalho-e-Silva et al. (1995); *S. littoralis* – Pombal and Gordo (1991); *Scinax longilineus* (Lutz, 1968) – Andrade and Cardoso (1991); *S. luizotavioi* – Bertoluci et al. (2007); *S. machadoi* – Bokermann and Sazima (1973); *Scinax melanodactylus* Lourenço, Luna and Pombal, 2014 – Abreu et al. (2015); *Scinax obtriangulatus* (Lutz, 1973b) – Heyer et al. (1990); *S. pombali* – Lourenço et al. (2013); *Scinax ranki* (Andrade and Cardoso, 1987) – Andrade and Cardoso (1987); *Scinax rizibilis* (Bokermann, 1964) – Bokermann (1964); *Scinax strigilatus* (Spix, 1824) – Camurugi et al. (2013), *Scinax trapicheiroi* (Lutz and Lutz, 1954) – Carvalho-e-Silva and Carvalho-e-Silva (1994); and *Scinax tripui* – Lourenço et al. (2009).

2.2. Comparative analyses of the body shape

We analyzed body shape variation using geometric morphometrics (Relative warp analysis; Zelditch et al., 2004). We selected and photographed 3–14 tadpoles of 16 of the species of *S. catharinae* group at stages 35–38: *S. argyreornatus* (*N* = 8); *S. ariadne* (*N* = 14); *S. aromothyella* (*N* = 9); *S. berthae* (*N* = 3); *Scinax brieni* (*N* = 9); *S. canastrensis* (*N* = 14); *S. carnevallii* (*N* = 6); *S. catharinae* (*N* = 6); *S. littoralis* (*N* = 3); *S. longilineus* (*N* = 10); *S. luizotavioi* (*N* = 13); *S. machadoi* (*N* = 11); *S. pombali* (*N* = 13); *S. tripui* (*N* = 8), *Scinax* sp. 1 (*N* = 8);

Scinax sp. 2 (*N* = 8). *Scinax* sp. 1 tadpoles are from Picinguaba, northern state of São Paulo, and are morphologically similar to tadpoles of *S. angrensis* and *S. littoralis* described by Carvalho-e-Silva et al. (1995) and Pombal and Gordo (1991), respectively. *Scinax* sp. 2 tadpoles are from Campos do Jordão and Serra da Bocaina, state of São Paulo, and are morphologically similar to *S. obtriangulatus* tadpoles described by Heyer et al. (1990) from Boracéia. A set of landmarks and semilandmarks was digitized on left lateral view images using the software tpsDig (Rohlf, 2008).

Fourteen landmarks were used [the first 12 adapted from Van Buskirk (2009)]: (1) most anterior point of the body; (2) most anterior point of the oral disc–body junction; (3) most posterior point of the oral disc–body junction; (4) naris; (5) pupil; (6) bottom edge of the body at the anterior gut margin; (7) spiracle aperture; (8) dorsal fin origin; (9) maximum ventral curvature of the body; (10) most dorsal point of the caudal musculature–body junction; (11) most anterior point of the axis of the tail myotomes; (12) most ventral point of the caudal musculature–body junction; (13) ventral fin origin; and (14) tip of the tail. Six semilandmarks were included in the tail, between landmarks 8 and 14, 13 and 14, 10 and 14, and 12 and 14. The "option" unbend of the software tpsUtil (Rohlf, 2012) was used to straighten the longitudinal axis of some bent specimens. Landmark configurations were then rotated, translated, and scaled before being submitted to the software tpsRelw (Rohlf, 2010) to perform a relative warp analysis. Thin-plate splines were used to illustrate shape variation using a consensus (average) configuration. For comparative purposes, shape averages for each species were also generated using the overall consensus as the reference.

Data on habitat use were compiled from the literature and authors field observations. The habitat types were classified as lotic if the tadpoles were found in any kind of stream habitat, and lentic if the tadpoles were found in lentic habitats such as swamps, puddles, and ponds. Voucher specimens are housed in the scientific tadpole collections of the Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, Minas Gerais, Brazil and the Departamento de Zoologia e Botânica da Universidade Estadual Paulista, São José do Rio Preto (DZSJRP), São Paulo, Brazil (see Appendix A).

3. Results

3.1. Tadpole descriptions

3.1.1. S. canastrensis

3.1.1.1. External morphology. Maximum total length 39.0 mm (at stage 39; Table 1). Body depressed (BH/BW = 0.81–0.82) (Fig. 1A, B); about one third of total length (BL/TL = 0.29); oval in dorsal view. In lateral view, ventral contour of body flat in peribranchial region, convex in abdominal region. Snout rounded in dorsal (BWN/BWE = 0.72–0.76) and lateral views. Nostrils rounded, small (ND/BL = 0.018–0.021), dorsally located (IND/BWN = 0.59–0.62), dorsolaterally directed, with a continuous and elevated marginal rim (Fig. 1E); distance to snout 47–48% of eye-snout distance. Eyes large (ED/BWE = 0.23–0.25), dorsally located (IOD/BWE = 0.77–0.80), dorsolaterally directed. Spiracle
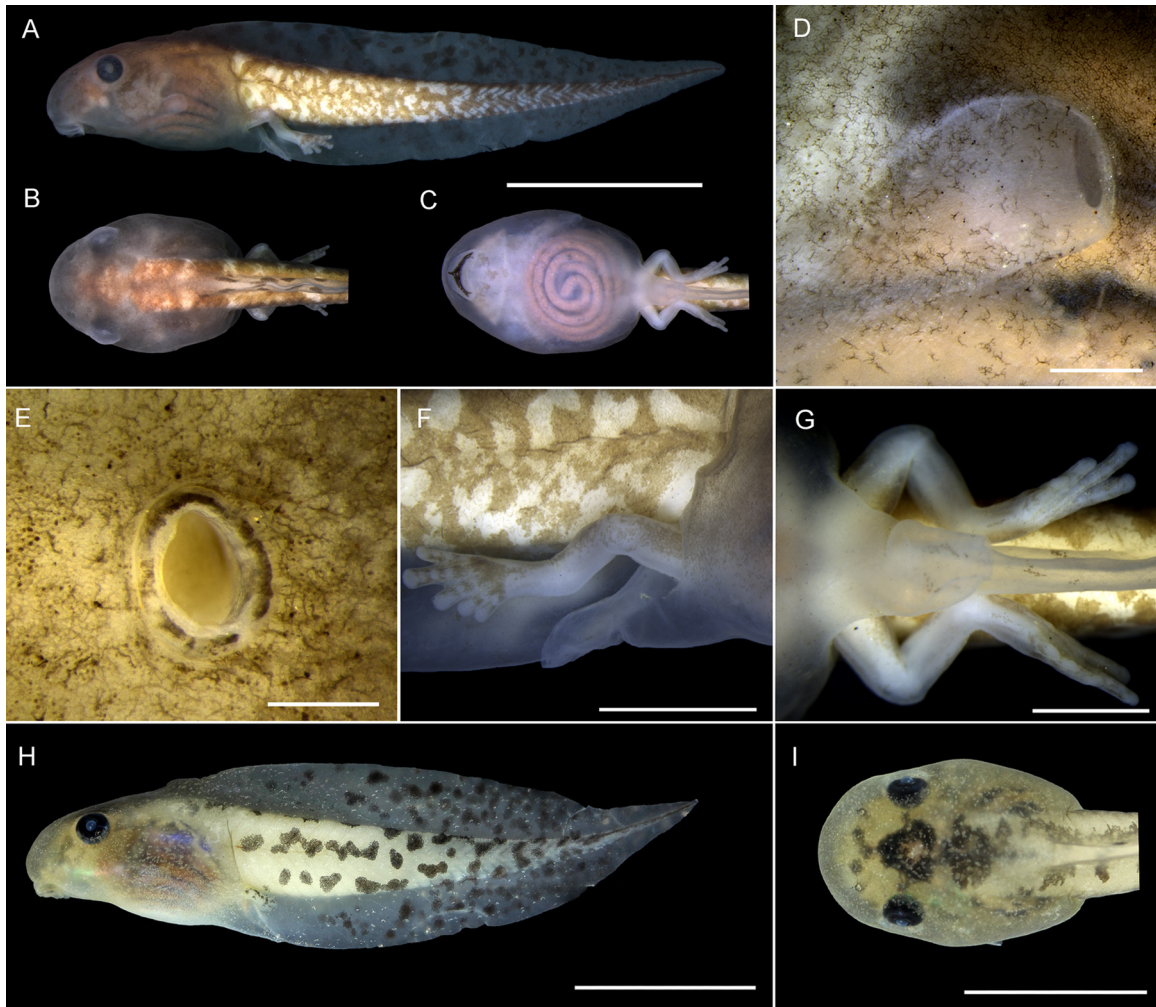

Fig. 1. *Scinax canastrensis* (DZSJRP1353.1) at stage 39: (A) lateral, (B) dorsal, and (C) ventral views (scale bar = 10 mm). Details of (D) spiracular aperture (scale bar = 0.5 mm), (E) margin of right nostrils with a continuous and elevated marginal rim (scale bar = 0.2 mm), (F, G) vent tube (scale bar = 2 mm). A specimen from Tapiraí (UFMG1670) at stage 35 with (H) a more globular body, higher tail, distinct tail color pattern, and (I) a triangular brownish inter-orbital spot (scale bar = 10 mm).
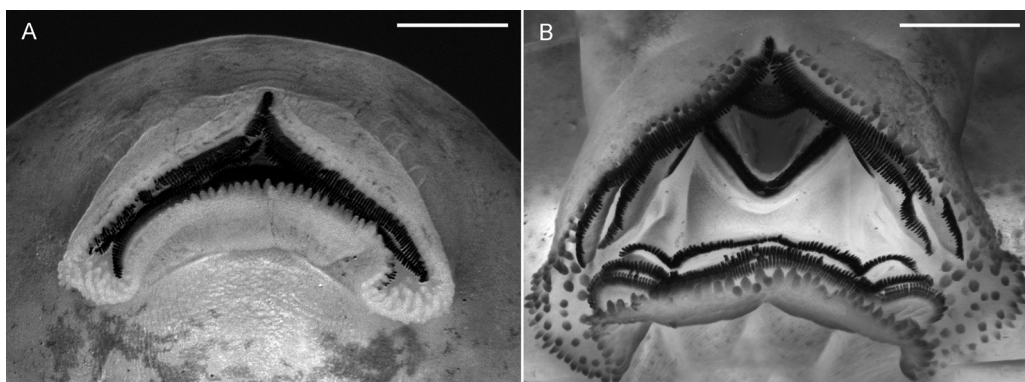

Fig. 2. Oral discs of *Scinax canastrensis* (DZSJRP1353.1): closed (A) and opened (B) oral discs of specimens at stages 38 and 39, respectively (scale bars = 1 mm).
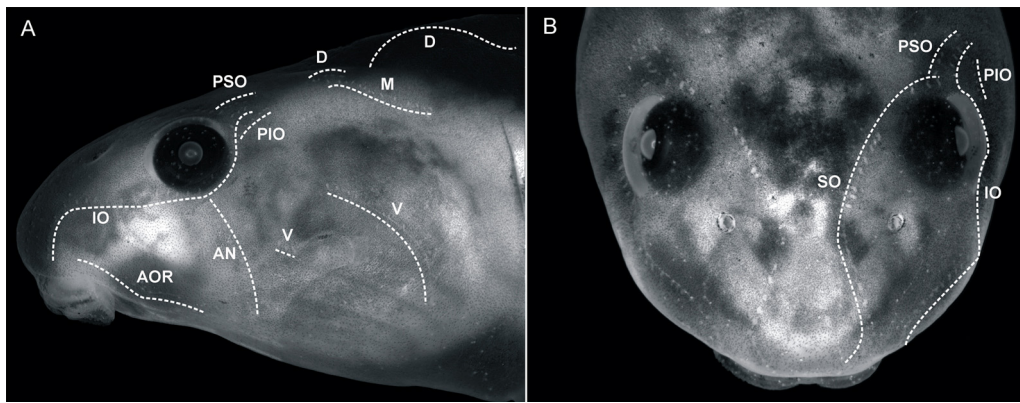
Fig. 3. The lateral line system of *Scinax canastrensis* (DZSJRP1353.1) represented in a stage 38 specimen. (A) Lateral and (B) dorsal views of the body indicating the angular (AN), anterior oral (AOR), infraorbital (IO), posterior supraorbital (PSO), posterior infraorbital (PIO), ventral (V), dorsal (D), middle (M), and supraorbital (SO) lines.
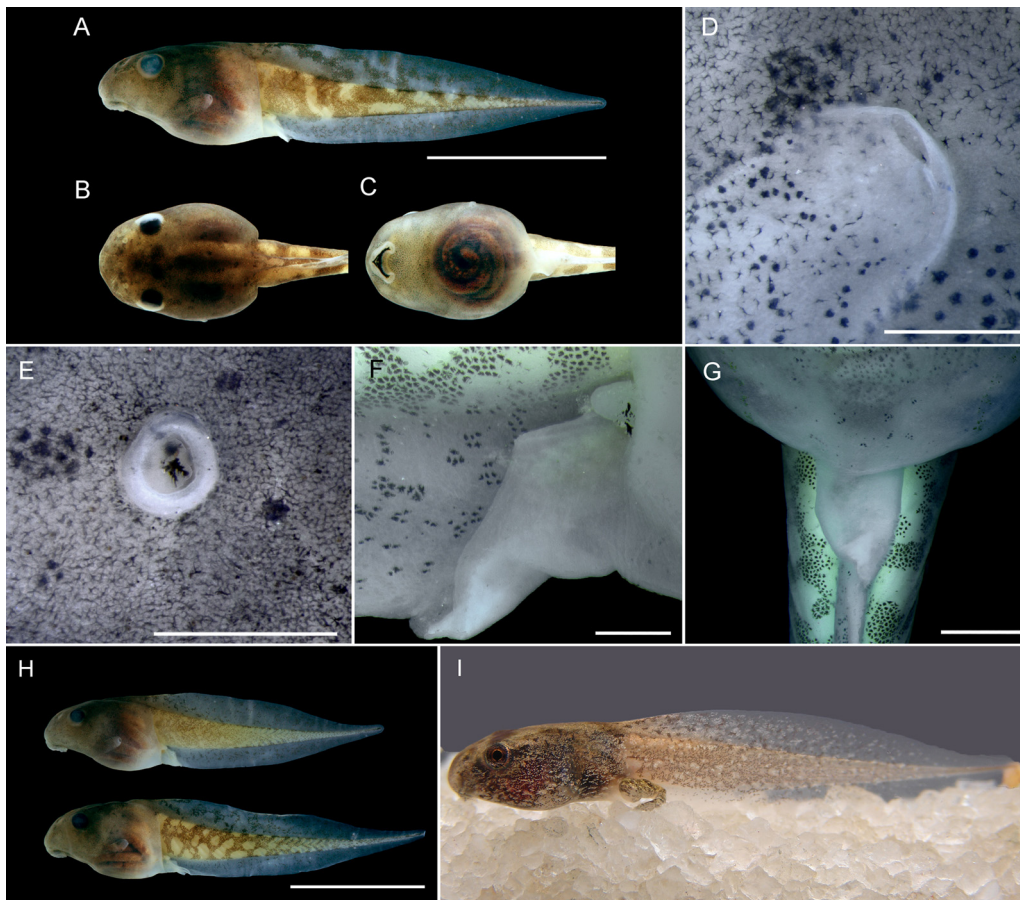

Fig. 4. *Scinax carnevallii* (UFMG 604a) at stage 32: (A) lateral, (B) dorsal, and (C) ventral views (scale bar = 10 mm). Details of (D) spiracular aperture (scale bar = 1 mm), (E) margin of right nostrils with a continuous and elevated marginal rim (scale bar = 0.5 mm), (F, G) vent tube (scale bars = 0.5, and 1 mm). Specimens (UFMG 604a) at stages 29 and 30 with variable caudal musculature color patterns (scale bar = 10 mm). (I) Tadpole photographed in life at stage 39 (unvouchered specimen).

sinistral, lateral (SVD/BH = 0.32–0.44); posterodorsally projected, visible in dorsal and ventral views; inner wall fused to the body, with distal portion free and longer than the external wall (Fig. 1D); opening located at the posterior third of the body (SSD/BL = 0.71–0.72). Intestinal tube circularly coiled, switchback point located at center of abdominal region (Fig. 1C). Vent tube large with dextral opening (Fig. 1G), entirely fused to ventral fin and positioned at its ventral margin (Fig. 1F). Tail 0.71 times total length; higher than body (MTH/BH = 1.15–1.20), tapering continuously from the middle third of its length; musculature robust

(TMH/BH = 0.50–0.52), does not reach the tip of the tail. Dorsal fin low (DFH/TMH = 0.35–0.38) with a convex external margin; maximum height at the anterior third of the tail; emerges at middle third of the body with a high slope. Ventral fin with a slightly convex external margin; origin concealed by vent tube; lower than dorsal fin (DFH/VFH = 1.31–1.41). Oral disc (Fig. 2A, B) ventrally positioned; posterior margin concave when closed; of small size (ODW/BW = 0.37–0.39, measured with oral disc folded); not emarginated; a single row of marginal papillae with a narrow anterior gap; several (15–19) submarginal papillae located later-
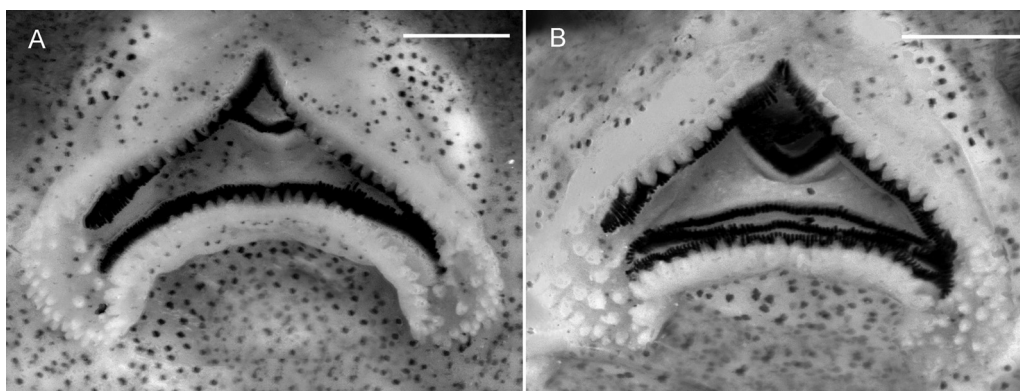
Fig. 5. Oral discs of *Scinax carnevallii* (UFMG 604a): closed (A) and opened (B) oral discs of specimens at stage 32 (scale bars = 1 mm).

ally. Labial tooth row formula (LTRF) 2(2)/3. A-1 and A-2 of the same length; P-1, P-2 and P3 of the same length; jaw-sheaths narrow, darkly colored and finely serrated on the margins; upper jaw sheath slightly M-shaped and lower sheath V-shaped. Lateral line system with 10 distinct lines (Fig. 3A, B). Most lines possess whitish elliptical stitches, except the dorsal, middle and ventral lines in which the stitches are more elongated. Supraorbital lines with 24–27 stitches converging anteriorly on head medial to nostrils and continuing anteroventrally approaching their respective infraorbital series of 29–36 stitches. Infraorbital lines begin behind the eyes, extend anteriorly and are slightly curved in lateral profile. Posterior infraorbital lines consist of a small series of four to six aligned stitches. Posterior supraorbital lines are composed of five to six stitches located near the posterior portion of their respective supraorbital lines. Angular lines with eight to twelve sparse stitches extend obliquely from below the eyes to the venter. Anterior oral lines discrete with about 10 small stitches. Dorsal lines located medially, beginning with four to five stitches near their respective middle lines. After a large gap, dorsal lines reappear posteriorly with four to five stitches converging prior to the body-tail junction and continuing posteriorly with 18–20 discrete stitches along the base of the dorsal fin until mid-length of tail. Middle lines located dorsolaterally with 10–12 stitches. Middle caudal series with about 10 sparse, small stitches along the approximate first third of tail. Ventral body lines of eight to 14 stitches extend anterodorsally from the venter to above the spiracle, and in the corresponding location on the other side of the tadpole; a small series of stitches is also present anteriorly to spiracle.

3.1.1.2. Coloration in preservative. In 10% formalin, the body is light brown with irregular dark brown spots scattered mainly ventrolaterally to eyes (Fig. 1A). Some dark brown spots present in the peribranchial region. Intestinal region translucent. Tail musculature pale, homogeneously and densely marbled along its length by irregular dark brown rounded spots. Fins translucent with irregular brown blotches, especially on the dorsal fin.

3.1.1.3. Variation. Tadpoles from Sacramento (UFMG1668-9) and Tapiraí (UFMG1670) are similar to those from the type locality (DZSJRP1353.1). However, in general they are larger (maximum total length 44.2 mm at stage 37–UFMG1668-9; 42.6 mm at stage 36–UFMG1670), have more globular bodies (BH/BW = 0.88–0.89–UFMG1668-9; 0.90–0.89–UFMG1670) and higher tails (MTH/BH = 1.24–1.50–UFMG1668-9; 1.22–1.28–UFMG1670—Fig. 1H). Dark spots on the tail may be less densely distributed (Fig. 1H). Some individuals have a brownish triangular inter-orbital spot (Fig. 1I).

3.1.1.4. Natural history notes. In all the localities, tadpoles of *S. canastrensis* were found on the bottom of backwaters of permanent streams surrounded by gallery forests in a Cerrado vegetation matrix. During the day tadpoles were grazing on dead leaves and detritus at the slow-flowing margins of the water bodies. Despite the collecting exclusively in the beginning of the rainy and hot season (October), individuals in several developmental stages (32–40) were found, suggesting that the pattern of reproduction is not restricted to the rainy season.

3.1.2. S. carnevallii

3.1.2.1. External morphology. Maximum total length 28.6 mm (at stage 32; Table 1). Body depressed (BH/BW = 0.83–0.88) (Fig. 4A, B); about one third of total length (BL/TL = 0.31–0.33); oval in dorsal view. In lateral view, ventral contour of body concave in peribranchial region, convex in abdominal region. Snout rounded in dorsal (BWN/BWE = 0.80–0.84) and lateral views. Nostrils rounded, mid-sized to large (ND/BL = 0.03–0.04), dorsally located (IND/BWN = 0.48–0.51), dorsolaterally directed, with a continuous and elevated marginal rim (Fig. 4E); distance to snout 49–54% of eye-snout distance. Eyes large (ED/BWE = 0.25–0.30), dorsally located (IOD/BWE = 0.83–0.88), dorsolaterally directed. Spiracle sinistral, lateral (SVD/BH = 0.38–0.46); posterodorsally projected, visible in dorsal and ventral views; inner wall fused to the body, with distal portion free and longer than the external wall (Fig. 4D); opening located at the posterior third of the body (SSD/BL = 0.69–0.72). Intestinal tube circularly coiled, switchback point located at center of abdominal region (Fig. 4C). Vent tube large with dextral opening (Fig. 4G), entirely fused to ventral fin and positioned at its ventral margin (Fig. 4F). Tail 0.65–0.69 times total length; equivalent to the body height (MTH/BH = 0.94–1.07), tapering continuously from the middle third of its length; musculature slightly robust to robust (TMH/BH = 0.49–0.54), does not reach the tip of the tail. Dorsal fin low (DFH/TMH = 0.52–0.74) with a slightly convex external margin; maximum height at the middle third of the tail; emerges at posterior third of the body with a low slope. Ventral fin with a slightly convex external margin; origin concealed by vent tube; lower than dorsal fin (DFH/VFH = 1.15–1.34). Oral disc (Fig. 5A, B) ventrally positioned; posterior margin concave when closed; of small size (ODW/BW = 0.36–0.41, measured with oral disc folded); not emarginated; a single row of alternated marginal papillae with a narrow anterior gap; several (10–12) submarginal papillae located laterally. Labial tooth row formula (LTRF) 2(2)/3, A-1 of the same length than A-2; P-1, P-2 and P3 of the same length; jaw-sheaths narrow, darkly colored and finely serrated on the margins; upper jaw sheath M-shaped and lower sheath V-shaped. Lateral line system with eight distinct lines. Most lines possess whitish elliptical stitches, except the dorsal, middle and ventral
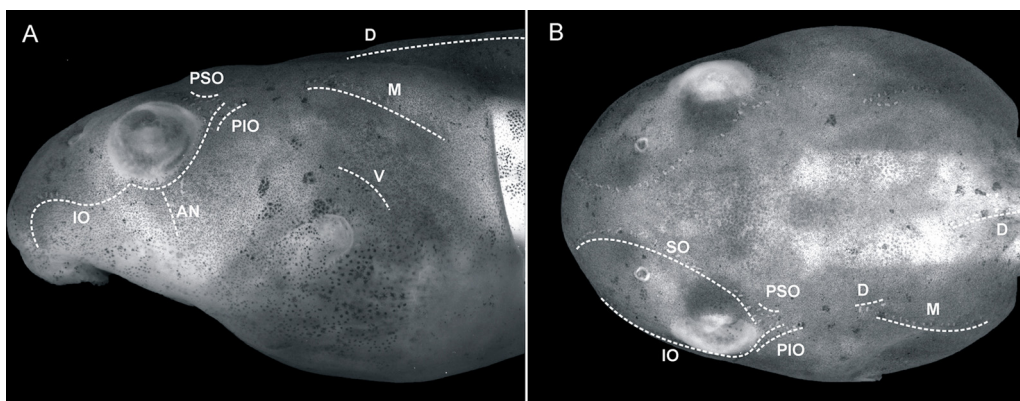
Fig. 6. The lateral line system of *Scinax carnevallii* (UFMG 604a) represented in a stage 32 specimen. (A) Lateral and (B) dorsal views of body indicating the angular (AN), infraorbital (IO), posterior supraorbital (PSO), posterior infraorbital (PIO), ventral (V), dorsal (D), middle (M), and supraorbital (SO) lines.

lines in which the stitches are more elongated. Supraorbital lines with 23–28 stitches converging anteriorly on head medial to nostrils and continuing anteroventrally approaching their respective infraorbital series of 33–37 stitches (Fig. 6A, B). Infraorbital lines begin behind the eyes, extend anteriorly and are slightly curved in lateral profile. Posterior infraorbital lines consist of six to eight aligned stitches. Posterior supraorbital lines are composed of three to four stitches located near the posterior portion of their respective supraorbital lines. Angular lines poorly defined with three to five stitches distributed mainly below the eyes. Oral lines indistinct. Dorsal lines located medially, beginning with three stitches near their respective middle lines. After a large gap, dorsal lines reappear posteriorly with six to seven stitches converging prior to the body-tail junction. Middle lines located dorsolaterally with 11–12 stitches. Small ventral body lines of six to eight stitches are present posterodorsal to the spiracle region, and in the corresponding location on the other side of the tadpole. Dorsal and middle series indistinct on the tail.

3.1.2.2. Coloration in life. Body uniformly yellowish light brown with tiny scattered golden iridophores and black dots (Fig. 4I); a triangular brownish inter-orbital spot is present; distal margin of spiracle lightly pigmented; belly region translucent with visible intestinal tube; iris black with irregularly scattered golden dots and a golden ring around the pupil. Tail musculature pale brown with agglomeration of dark brown melanophores forming irregularly rounded spots giving a marbled appearance; this pattern is also present on the fins, mainly dorsally.

3.1.2.3. Coloration in preservative. In 10% formalin, the coloration is very similar to that of living tadpoles but fades, loosing the golden tones and becoming more translucent (Fig. 1H). Iris also looses its golden tones, becoming black.

3.1.2.4. Variation. Six specimens in less developed stages (50% of the analyzed specimens) have a less pronounced marbled pattern on the tail musculature with only finely scattered dark brown dots in the tail. Moreover, two individuals have a more distinct pattern with more apparent rounded spots (Fig. 4H).

3.1.2.5. Natural history notes. Adult calling males and females were found on marginal vegetation of the backwaters of permanent streams or, more rarely, in slow-flowing swamps surrounded by semi-deciduous forest. Tadpoles were found on the bottom of large backwaters of permanent streams, grazing preferentially in slow-flowing marginal and shallow areas. The tadpoles occurred in high density in several development stages in the middle of the cold dry season (July) and hot rainy season (October, November and December). Although we did not sampled in other months, this may suggest a prolonged reproductive period.

3.2. External shape

Geometric morphometrics showed that the tadpoles vary substantially in body shape, but with some overlap among species with only two (i.e., *S. catharinae* and *Scinax* sp. 2) being completely discriminated from the others (Relative warp analysis–Fig. 7). The first two warps explained 59% of the total variation. In the first warp, species were distributed along a continuum with the extreme opposite deformation grids differing in body and tail height and length, tail musculature robustness, oral disc position and size, and region of dorsal fin origin.

Positive scores in first warp were associated with the lotic tadpoles of *S. tripui*, *S. ariadne*, and *Scinax* sp. 1 but also with some lentic species (i.e., *S. argyreornatus*, *S. littoralis*, and *S. luizotavioi*). These species possess more depressed bodies, lower and more robust tails (i.e., larger TMH), larger and more ventral oral discs, dorsal fins originating more posteriorly, and smaller bodies in relation to tail length. The negative scores were also related to both lotic (i.e., *S. machadoi*, *Scinax* sp. 2) and lentic species (i.e., *S. aromothyella*), which possess more globular bodies, higher and more slender tails (i.e., slender TMH), smaller and anteroventral oral discs, and larger bodies in relation to tail length. The second warp also corresponded to shape changes in body/tail proportion, region of dorsal fin origin, and rostrum proportion. Lotic tadpoles of *S. catharinae* and *Scinax* sp. 2 were discriminated from all other species mainly by possessing longer bodies in relation to tail length, more elongated rostrums, and slender tail musculatures. Conversely, the lotic tadpoles of *S. canastrensis, S. longilineus, and S. pombali* were distributed to the opposite extreme of the second warp because of their shorter bodies in relation to tail length, shorter rostrums, and more robust tail musculatures. The remaining species (i.e., *S. berthae*, *S. brieni*, *S. carnevalli*) had a shape similar to the consensus.

4. Discussion

4.1. Comparison with other tadpoles of the *S.* catharinae *group*

Tadpoles of *S. canastrensis* and *S. carnevallii* share the following characteristics with the species of *S. catharinae* group: oral discs not emarginated, with posterior margin concave when closed; many submarginal papillae laterally (but see the variation reported for *S. aromothyella* and *S. berthae*; De-Sá et al., 1997; Kolenc et al., 2007); labial tooth row formula 2(2)/3 or 2(2)/3(1) (except for LTRF 2/3,
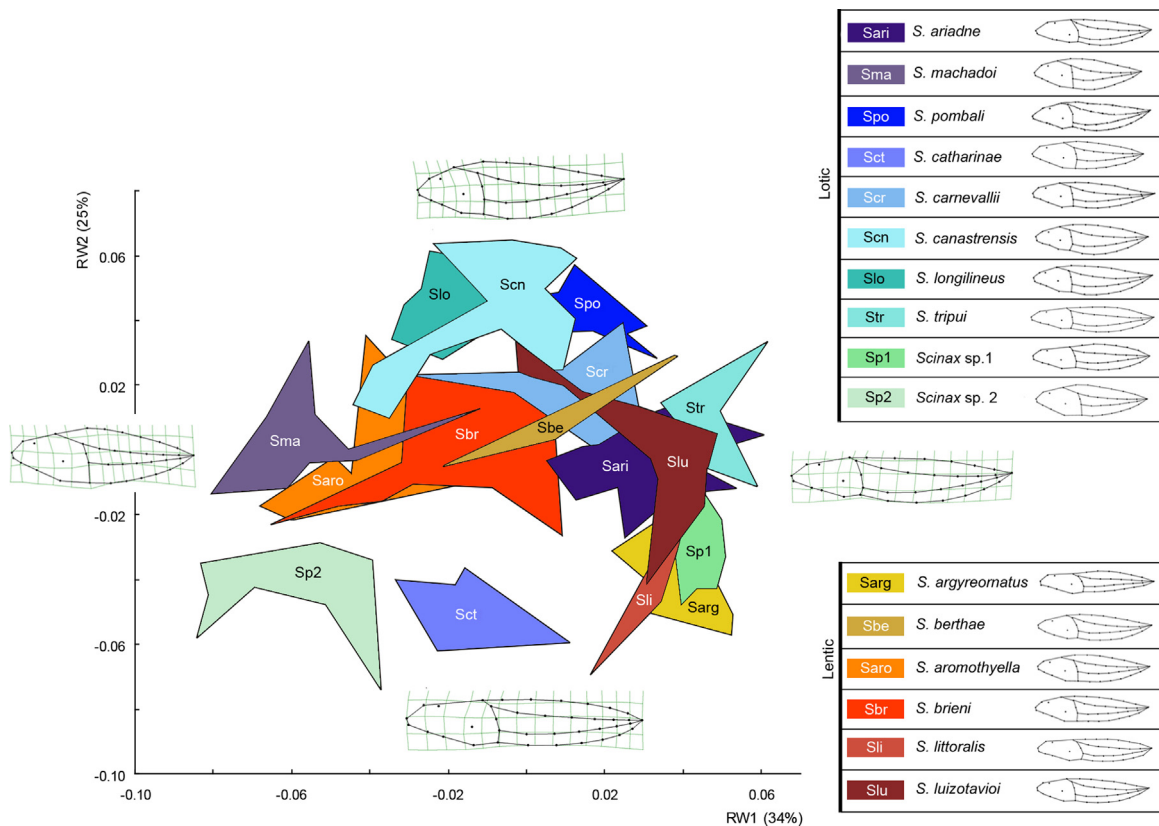
Fig. 7. Relative warp analysis of tadpoles of the *S. catharinae* species group in lateral view. Species are shaded according to habitat: warmer and cooler colors represent lentic and lotic species, respectively. Thin-plate splines depict shapes with minimum and maximum values along relative warps. Shape averages of each species are presented alongside each species name.

2(2)/3(3) reported for *S. ariadne* and *S. rizibilis*); circular nostrils; and vent tubes reaching the free margin of the ventral fin. The concave posterior margin of oral disc, and the vent tube reaching the ventral fin margin have been treated as features exclusive to the *S. catharinae* group since the tadpoles of other taxa in the *S. ruber* clade possess oral discs with a straight posterior margin, and vent tubes above the free margin of the ventral fin (Faivovich, 2002).

Tadpoles of *S. canastrensis* and *S. carnevallii* differ in body shape in lateral view (ventral contour in peribranchial region concave in *S. carnevallii* and slightly flat in *S. canastrensis*), relative size of the body (smaller in *S. canastrensis*), tail height (higher in *S. canastrensis*), slope of the dorsal fin origin (higher in *S. canastrensis*), and the marbled pattern of the tail. Like most species of the group, *S. canastrensis* and *S. carnevallii* have dextral vent tubes, which differs from *S. kautskyi,* which has a medially positioned vent tube. The low height of dorsal fins differentiates *S. canastrensis* and *S. carnevallii* from *S. argyreornatus*, *S. berthae*, *S. flavoguttatus*, *S. humilis*, *S. obtriangulatus* (which have relative higher dorsal fins DFH/TMH > 1.0). Further, *S. berthae* is the only species of the group to possess a tail flagellum.

S. canastrensis and *S. carnevallii* tadpoles differ from those of *S. ariadne*, *S. rizibilis*, and *S. machadoi* in LTRF [2/3, 2(2)/3(3) and 2(2)/3(1) in these species, respectively], and from those of *S. aromothyella* by having M-shaped upper jaw sheaths (arch-shaped upper jaw in this species). They are distinguished from the tadpoles of *S. ariadne* and *S. pombali* by their small-sized oral discs and the presence of uniseriate marginal papillae on anterior and posterior labia of their oral discs (large-sized oral discs and multiseriate rows of marginal papillae in these species). They also differ from the tadpoles of *S. albicans*, *S. angrensis*, *S. ariadne*, *S. flavoguttatus*, *S. heyeri*, *S. pombali*, *S. rizibilis*, and *S. strigilatus* in having the presence of a narrow anterior gap on the row of marginal papillae of their oral discs (gap absent in these species). *S. canastrensis* and *S. carnevallii* also differ from *S. pombali* by the absence of bi- or trifurcated marginal papillae in the anterior portion of their oral discs, trapezoidal-shaped and large papillae in the posterior portion their oral discs, and rows of submarginal papillae between the anterior and posterior parts of their oral discs and between anterior tooth rows (present in *S. pombali*).

As mentioned in the original descriptions, some species of this group (i.e., *S. albicans*, *S. angrensis*, *S. ariadne*, *S. aromothyella*, *S. flavoguttatus*, *S. heyeri*, *S. kautskyi*, *S. machadoi*, *S. pombali*, *S. trapicheiroi*, and *S. tripui*) have a brightly-colored banding pattern in life. Of these, *Scinax angrensis*, *S. aromothyella*, *S. flavoguttatus*, *S. heyeri*, *S. trapicheiroi,* and *S. tripui* have a concentration of tiny golden iridophores restricted to the snout region and forming an anterior band, whereas the remaining species have an additional golden band on the posterior third of the body. It is noteworthy that for many species, this brightly-colored pattern in life is ontogenetically variable and seems to be affected by environmental conditions (Bokermann, 1964; Carvalho-e-Silva and Carnaval, 1997; Carvalho-e-Silva and Carvalho-e-Silva, 1994; Carvalho-e-Silva et al., 1995). Despite evidence of variation, the presence/absence of golden bands is a useful diagnostic character (see Faivovich, 2002) since it has never been observed in many species of this group (i.e., *S. argyreornatus*, *S. berthae*, *S. catharinae*, *S. hiemalis*, *S. humilis*, *S. melanodactylus*, *S. littoralis*, *S. luizotavioi*, *S. longilineus*, *S. obtriangulatus*, *S. ranki*, *S. rizibilis*, and *S. strigilatus*), including the tadpoles described herein.

The lateral line system has rarely been mentioned for the species of the *S. catharinae* group. It was briefly described for *S. aromothyella*, mentioned for *S. berthae* (Kolenc et al., 2007), and evident in

the illustration of *S. kautskyi* (Carvalho-e-Silva et al., 1995). While *S. canastrensis* and *S. carnevallii* have ten and eight lines, respectively, only five were reported for *S. aromothyella*, with angular, posterior-infraorbital, dorsal, middle-body and middle-caudal lines being absent.

4.2. Ordination in morphospace

The larvae of the *S. catharinae* group exhibit great morphological and ecological diversity (e.g., Bertoluci et al., 2007; Bokermann, 1967; Bokermann and Sazima, 1973; De-Sá et al., 1997; Kolenc et al., 2007; Lourenço et al., 2013; Pombal and Gordo, 1991), which remains poorly understood. The external shape also exhibited diversity, but with many species overlapping in morphological space. Yet unexpectedly the ordination of the tadpoles of *S. catharinae* group was not clearly related to lentic and lotic habitats. Species from streams and lentic environments were not discriminated in the components of the analysis, and neither were distributed along a clear morphological continuum related to the type of water body in which they occur.

Relationships between tadpole external shape and habitat (lotic-lentic) where they live have been reported for many anuran lineages (Altig and McDiarmid, 1999; Baldo et al., 2014; Haad et al., 2011; Van Buskirk, 2009). In general, lotic and lentic tadpoles are distributed along a continuum of morphotypes (Baldo et al., 2014; Haad et al., 2011). For example, the most common ecomorphological characteristics for stream tadpoles include a more depressed body and a long tail with lower fins, the dorsal one originating more caudally. This pattern was recovered for stream-dwelling species of the Neotropical bufonid genus *Melanophryniscus* (Baldo et al., 2014; Haad et al., 2011), and for suctorial forms and gastromyzophorous tadpoles, which occur in several anuran lineages (see Aguayo et al., 2009). On the other hand, lentic forms have a high, globular body and a short tail with fins higher than the body.

In the present study, lotic tadpoles were found to occupy the entire morphospace. Some of them (i.e., *S. tripui*, *S. ariadne*, *Scinax* sp. 1) have shallow bodies, proportionally longer tails with low fins and more robust musculature, dorsal fins originating more caudally, more dorsal eyes, and large, ventral oral discs; all features related to lotic environments (Altig and McDiarmid, 1999). *S. longilineus*, *S. canastrensis*, and *S. pombali*, all stream dwellers, were grouped in another extreme of the morphological ordination. Besides having some of the aforementioned features of lotic forms (i.e., proportionally long tails with robust musculature), these species have a higher tail, more anterior origin of dorsal fin, and a longer rostrum. Other lotic tadpoles were discriminated from the tadpoles of all other species by having, in general, slender tail musculature (i.e., *S. machadoi*, *Scinax* sp. 2) and proportionally larger bodies (i.e., *S. catharinae S. machadoi*, *Scinax* sp. 2). The extensive occupation of morphospace by stream tadpoles could be indicative of the influence of other factors, such as microhabitat use, in selection for these varied trait combinations.

To date, two species of *Scinax* (i.e., *S. ariadne* and *S. pombali*) are known to have large, modified oral discs. *Scinax pombali* larvae have distinct adherent papillae (Lourenço et al., 2013) and those of *S. ariadne* have three to four rows of marginal papillae (Bokermann, 1967), features probably related to their torrential streams habitats and allow them to be considered suctorial. Despite these similarities, both species were discriminated in morphological space due to differences in body and tail heights. Beyond external shape, correlations between internal morphological features (e.g., oral cavity, musculoskeletal morphology) and habitat have been found for many species from lotic systems (e.g., Aguayo et al., 2009; Baldo et al., 2014; Vera Candioti, 2008). Further studies on the inter-

nal morphology of the tadpoles of *S. ariadne*, *S. pombali* and other species of the group are essential for better understanding what features are involved in the adaptation of these tadpoles to fast flowing streams.

Tadpoles that occurred in swamps and other lentic water bodies occupied a narrower morphospace, but they also were not segregated from lotic species in the ordination analyses. Some of them (i.e., *S. luizotavioi*, *S. littoralis*, and *S. argyreornatus*) have more depressed bodies, proportionally long tails with low fins and the dorsal fin originating more posteriorly, thus resembling some stream-dwelling larvae. This morphotype probably reflects adaptations to the shallow swamps they inhabit and their benthic habit. The other lentic species (i.e., *S. aromothyella*, *S. berthae*, and *S. brieni*) have high, globular bodies, proportionally short tails with higher fins, and anteroventral oral discs, morphological traits frequently found among typical pond-type larvae (Baldo et al., 2014; Haad et al., 2011; Van Buskirk, 2009).

Bertoluci et al. (2007) highlighted the morphological similarity between the tadpoles of the sympatric species *S. luizotavioi* and *S. longilineus.* Herein we demonstrate great differences in external shape between both species (with *S. longilineus* having a higher body and tail and a more anterior origin of dorsal fin than *S. luizotavioi*). Since the tadpoles of *S. longilineus* occur in streams, and those of *S. luizotavioi* occur in ponds and swamps (TLP, personal observation), the differences in shape are not consistent with the ecomorphological relationships found for other anuran lineages in lentic and lotic habitats (Baldo et al., 2014; Van Buskirk, 2009; Haad et al., 2011). Such morphological and ecological divergences between sympatric and closely related species are interesting subjects that deserve further study addressing general ecological and evolutionary aspects to those of plasticity and functional morphology.

Despite the absence of a comprehensive phylogenetic hypothesis of the internal relationships among the members of the *S. catharinae* group, the similarity in shape of the tadpoles of *S. canastrensis* and *S. longilineus* in morphospace is consistent with the similarities among the adults (Haddad et al., 1988) and the close relationship of these species proposed in by Faivovich (2002). Therefore, this result reinforces the significance of tadpole characters in assessing the internal phylogenetic relationships of the *S. catharinae* group.

Body shape differences in anuran larvae are often indicative of adaptation to specific ecological variables (Altig and Johnston, 1989). Although the general categorization of habitat (i.e., lotic and lentic) was not sufficient to explain all the complex morphological variation exhibited by the tadpoles of the *S. catharinae* group, some known ecomorphological relationships were recovered, such as the suctorial and pond-type guilds. Moreover, morphological similarities in shape may also reflect interspecific variation in microhabitat use, such as different water depths, current velocities, and substratum compositions (Altig and McDiarmid, 1999). In addition, other contemporary factors, such as foraging position in the water column (e.g., Van Buskirk, 2009) and adaptation to predation/locomotion (Hoff and Wassersug, 2000; Van Buskirk and McCollum, 2000), plus evolutionary relationships (Marques and Nomura, 2015), may also have an influence in determining morphotypes.

Our data indicate extensive, and complex, variation in larval external morphology that remains to be understood. This will require additional research to acquire more detailed environmental, natural history and phylogenetic data. Furthermore, future ecomorphological studies should be performed on broader phylogenetic scales, especially including species of the *S. perpusillus* and *S. ruber* groups. Such efforts promise to result in a more complete

understanding of the evolution of this speciose genus of Neotropical frogs.

Acknowledgments

Appendix A.

Specimens examined

Tadpoles: Brazil, Minas Gerais: *Scinax berthae*: Itatiaiuçu (Lot UFMG 1142); *Scinax canastrensis:* São Roque de Minas (Lot DZSJRP1353.1), Sacramento (Lots UFMG1668-9), Tapiraí (Lot UFMG1670); *Scinax carnevalli*: Conceição do Mato Dentro (Lot UFMG604); *Scinax longilineus*: Congonhas (Lot UFMG 293); *Scinax luizotavioi*: Catas Altas (Lot UFMG 809); *Scinax pombali*: Capitólio (Lot UFMG 1146); *Scinax tripui*: Nova Lima (Lot UFMG 1277); *Scinax machadoi*: Santana do Riacho (Lot UFMG 1347). São Paulo: *Scinax argyreornatus*: Picinguaba (Lot DZBSJRP 2584.3); *Scinax ariadne*: Serra da Bocaina (Lots DZBSJRP 2013.1; DZBSJRP 2033.1); *Scinax brieni*: Bertioga (Lots DZBSJRP 1108.2; DZBSJRP 1237.6); *Scinax* sp. 1: Picinguaba (Lots DZBSJRP 2512.4; DZBSJRP 2553.5); *Scinax* sp. 2: Campos do Jordão (Lot DZBSJRP 1407.1), Serra da Bocaina (Lot DZBSJRP1985.1); Paraná and Santa Catarina: *Scinax aromothyella*: Vargem Bonita, SC (Lot DZBSJRP 1706.2), General Carneiro, PR (Lot DZBSJRP 1586.2); *Scinax catharinae*: São José dos Pinhais, PR (Lot DZBSJRP 914.2); *Scinax littoralis*: Guaraqueçaba, PR (Lot DZBSJRP 1026.2).

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