



A new species of *Sarcohyla* (Anura: Hylidae: Hylini) from the Sierra Madre del Sur of Guerrero and Estado de México, México

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Abstract

We describe a new species of frog *Sarcohyla floresi* **sp. nov.** from the Sierra Madre del Sur of Guerrero and the southern part of Estado de México, based on specimens previously referred to as *S. pentheter* and newly obtained specimens. The new species has stream-dwelling tadpoles with labial tooth row formula 2(2)/3 and adults with a distinctive dark dorsolateral band bordered by a white line. *S. floresi* can be included in the *S. bistincta* group.

Resumen

Describimos una nueva especie de rana *Sarcohyla floresi* **sp. nov.** de la Sierra Madre del Sur de Guerrero y la parte sur del Estado de México basado en especímenes previamente considerados *S. pentheter* así como especímenes recién colectados. La nueva especie tiene renacuajos con fórmula dental 2(2)/3 que viven en arroyos, y adultos con una banda dorsolateral oscura bordeada por una línea blanca. *S. floresi* puede ser incluida en el grupo *S. bistincta*.

Key words: Amphibia, Taxonomy, *Sarcohyla pentheter*, *Sarcohyla floresi*, *Sarcohyla bistincta* group

Introduction

The genus *Sarcohyla* contains 24 species distributed in Mexico west of the Isthmus of Tehuantepec (Frost 2019). The highest species diversity for this genus is found in the states of Oaxaca, Veracruz, and Guerrero (Frost 2019). All the species of *Sarcohyla* have small distributional ranges, with the notable exception of *S. bistincta* (Cope 1877), which is considered to be widely distributed in México (Duellman 2001, Campbell *et al.* 2018). However, genetic studies suggest this species contains several distinct species (Zarza *et al.* 2018; Caviedes-Solis and Leache 2018). *Sarcohyla pentheter* (Adler 1965) is a species closely related to *S. bistincta*. It was originally described from a few specimens from a locality slightly north of San Gabriel Mixtepec, along the Pacific slopes of the Sierra Madre del Sur of Oaxaca (Adler 1965). Since then, 29 additional populations of *S. pentheter* have been discovered in Oaxaca, all on the Pacific slope of the Sierra Madre del Sur and within 80 km of the type locality (Campbell & Duellman 2000; Ustach *et al.* 2000; Duellman 2001; Campbell *et al.* 2018).

Campbell & Duellman (2000) and Palacios-Aguilar *et al.* (2017) assigned several *Sarcohyla* populations from central Guerrero to *S. pentheter*, and Parra-Olea *et al.* (2003) did likewise with one population from Estado de México, presumably based on external similarity. However, Caviedes-Solis & Nieto-Montes de Oca (2018) removed these populations from *S. pentheter* due to “personal observation,” and Campbell *et al.* (2018: 378) reassigned the population from Estado de Mexico to a newly-described species, *S. hapsa* (Campbell *et al.* 2018), because of “distribution and morphology.” However, the lack of strong supporting evidence for these decisions leaves it unclear whether they should be considered part of *S. pentheter*.

Zarza *et al.* (2018) conducted a molecular phylogenetic analysis that clarified many relationships within *S. bistincta* and closely-related species. This study showed a deeply divergent lineage in the Transvolcanic Belt, which

was later described as *S. hapsa* (Campbell *et al.* 2018). It also showed that *S. calthula* was a sister species to the rest of *S. bistincta*+*S. pentheter*. Within the latter group, *S. pentheter* (represented by one individual from near San Juan Lachao, Oaxaca. UMMZ 239772) was sister to, but very divergent from, two *S. bistincta* individuals from near Puerto del Gallo, Guerrero (UMMZ 239739-40), suggesting these *S. bistincta* individuals could actually belong to an undescribed species from Guerrero (see Campbell *et al.* 2018 for a similar conclusion).

The scarce number of individuals of *S. pentheter* from Guerrero and Estado de Mexico in collections have made it difficult to examine, from a morphological perspective, whether the individuals from near Puerto del Gallo Guerrero represent a new undescribed species and if the other known populations of *S. pentheter* from Guerrero (e.g., Yerbabuena, Mazatlán, Coyuca de Catalán) are part of this new species. For the same reasons, it has been difficult to assess the taxonomic status of the population from Estado de Mexico, in particular whether it belongs to *S. pentheter*, *S. hapsa*, or is part of a new species from Guerrero.

To address these questions and further resolve species-level relationships within *S. bistincta* and closely-related species *S. pentheter* and *S. hapsa*, we obtained and examined tadpoles and adults of *S. pentheter* from various localities in central Guerrero, including the vicinity of Puerto del Gallo. We also reexamined most museum specimens of *S. pentheter* from Oaxaca, Guerrero, and Estado de Mexico, as well as several specimens of *S. hapsa*. Our results show that the populations from Guerrero and Estado de Mexico currently assigned to *S. pentheter* constitute a new species, which we describe here.

Material and methods

We obtained one adult and several tadpoles from Sierra de Alquitran on March 2003 and tadpoles from three other localities near Chilpancingo, Guerrero, including near Puerto del Gallo, on March 2004 (see Examined Specimens). The tadpoles were transported to México City (2240 m) and reared through metamorphosis to the juvenile state, except for a few that were preserved in 10% formalin.

For morphological comparisons, we examined the complete type series of *S. pentheter*; specimens from four additional Oaxacan populations, photographs of dorsal, ventral, lateral, posterior, and frontal views of most known specimens of *S. pentheter* from Guerrero (KU 140424–26; LACM 92416; MZFC 30710–11) and Estado de México (IBH 138072), and most of the type series of *S. hapsa* (see Examine Specimens). For comparisons of larval morphology, we used one individual of *S. hapsa* in stage 36 (UMMZ 239928), and the most recent descriptions of the tadpoles in stage 36 of *S. pentheter* (Kohler *et al.* 2016) and *S. labeculata* (Ustach *et al.* 2000; Meik *et al.* 2005).

Morphological terminology and measurements of adults follow that of Duellman (2001). Criteria to identify thoracic and tarsal folds follow those of Kaplan *et al.* (2015). Tadpoles were staged following Gosner (1960). Terminology and measurements of tadpole morphology follow that of Altig & McDiarmid (1999). Webbing formula follows that of Myers and Duellman (1982). Aerial distance between known populations of *S. pentheter* was estimated using the measuring tool in Google Earth.

Museum acronyms: CNAR = Colección Nacional de Anfibios y Reptiles, Instituto de Biología, Universidad Nacional Autónoma de México (UNAM); KU = University of Kansas Biodiversity Institute; LACM = Natural History Museum of Los Angeles County; MK = Moises Kaplan field series; UMMZ = University of Michigan Museum of Zoology.

Results

Sarcohyala floresi sp. nov.

Holotype. UMMZ 239718 (original field number MK 774), an adult female from Sierra del Alquitran, 2128 m (17° 26' N 99° 31' W), south of Chilpancingo and west of Mazatlán, Guerrero, Mexico, obtained by Rafael Aguilar in March, 2003.

Paratypes. UMMZ 239798, El Salado, east of Mazatlán, Guerrero, UMMZ 239739-43, on the Atoyac de Alvarez to Puerto del Gallo road, Guerrero, UMMZ 239744, near Carrizal de Bravo, Guerrero, all juveniles collected by Moises Kaplan, Peter Heimes, Rafael Aguilar, and Juan Manuel Romero Aguilar from March 1-5, 2004; KU

140424–26 (original field numbers MN 4528–30), 5.6 km (by road) NE Yerbabuena, Guerrero, juveniles, collected on 1969; LACM 92416 7–9 mi W Mazatlán, Guerrero, collected by B. Borman and T. Papenfuss on August 16, 1973; IBH 138072, 9 km E El Salitre on road to Nanchititla, collected by G. Parra-Olea and M. Garcia-Paris on April 19, 2002; and MZFC 30710–11 Rio Frio, Municipality of Coyuca de Catalán, collected by Elizabeth Beltrán-Sánchez on December 12, 2007.

Diagnosis. A large, robust tree frog with long fingers, vestigial webbing on fingers, stream-dwelling tadpoles with labial tooth row formulae (hereafter LTRF) 2(2)/3, oral disc of tadpoles completely surrounded by marginal papillae and a single row of large submarginal papillae between the anterior and posterior tooth rows and marginal papillae. The phylogenetic analysis of Zarza *et al.* (2018) showed that *S. floresi* is nested within *Sarcohyla*.

S. floresi can be distinguished from all known species of *Sarcohyla*, except *S. pentheter*, by having adults with a bold broad chocolate-brown band (hereafter dorsolateral band) edged by a pale line on side of head from edge of upper lip through nostril and eye, along supratympanic fold and sides of body and similar bands along inner and outer edges of limbs (Figs 1, 2A, 2B).

S. floresi differs from *S. pentheter* (condition in parentheses) by having dorsum of body, head, and limbs peppered with small dark flecks (dark flecks absent); dark bands on posterior surfaces of limbs wide, peppered with small pale spots (narrow, pale spot absent) (Figs. 1, 2A, 2B, 2E, 2F); dorsolateral bands on head converging medially and extending, as a single broad band, from nostril to upper lip (dorsolateral bands on head reach upper lip independently from one another) (Figs. 2C and 2D); dorsolateral band wide, with jagged dorsal edge, breaking ventrally and posteriorly into long sinusoidal interconnected blotches that cover most of flank (dorsolateral band narrow, lobate on both edges, covering little of flank's surface, keeping its integrity except for few small disconnected spots nearby) (Figs. 2A and 2B); thin dark band along upper lip not broadening below anterior edge of eye (broadening) (Fig. 1; see Adler 1965 plate I, figs. D and E); thin dark band along lower lip widens at angle of jaw, breaking into irregular dark spots along edge of throat (band narrow at angle of jaw, throat spots absent) (Fig. 1); dark irregular blotches present on body dorsally to arm insertion (blotches absent) (Fig. 1); dorsal fin of tadpole with scattered light blotches in life (dorsal fin with dense pattern of dark blotches [Kohler *et al.* 2016, Fig. 9e]).



FIGURE 1. Holotype of *Sarcohyla floresi* UMMZ 239718.

Description of the holotype (measurements in millimeters). snout–vent length (SVL) 55.9; head length (HL) 17.9; head width (HW) 21.2; eye diameter (ED) 6.0; tympanum diameter (TD) 3.3; interorbital distance 4.5; eye to nostril distance 4.3; eye to tip of snout distance 8.2; eye to tympanum distance 2.7; diameter of terminal disc of Finger III 3.7; thigh length 26.9; shank length 29.3; foot length 25.8; inner metatarsal tubercle longest diameter 2.9; outer metatarsal tubercle diameter 0.6; diameter of terminal disc of Toe IV 3.1.

Body robust; head slightly wider than long (HL/HW 0.84); snout long, round in dorsal, ventral and lateral views, extending well beyond jaw in ventral view; *canthus rostralis* round, barely distinct; loreal region slightly concave; rostral keel absent; eyes small (ED 34 % of HL; tympanum large (TD 55% ED), concealed dorsally by supratympanic fold and ventroposteriorly by skin; tympanic ring distinct, slightly more elevated anteriorly than posteriorly.

Fingers long; webbing marginal between Fingers I and II; webbing formulae II2-3-III3+⁻²/₂-IV; distal subarticular tubercles of Fingers II and III large, conical; distal subarticular tubercle of Finger IV large, round, not bifid; proximal subarticular tubercles of Fingers III and IV small, conical; supernumerary tubercles round, small; terminal disc of Fingers II, III, and IV elliptical, large (diameter of terminal disc of Finger III 1.1 times diameter of tympanum); terminal disc of Finger I round, slightly larger than the rest of finger, smaller than discs of other fingers; webbing formulae of foot I1-2II1-2^{1/2}-III1^{1/2}-3⁺-IV3⁺-IV; terminal discs of toes nearly round, less expanded than discs of fingers (diameter of terminal disc of Toe III 84% of diameter of terminal disc of Finger III); inner metatarsal tubercle ovoid; outer metatarsal tubercle present, slightly larger than supernumerary tubercles of foot.

Skin of dorsum of body, head, and limbs smooth; skin of flanks smooth; throat and chest slightly tuberculate; belly and medial part of thighs shagreened; thoracic fold groove-like, complete (not interrupted medially); axillary membrane absent; venter of arms slightly tuberculate; ulnar tubercles distinct, independent, nearly flat, forming row; tarsal fold ridge-like, tuberculate, long, nearly reaching heel; anal opening at midlevel of thighs; anal sheath split by medial, deep, longitudinal groove and several shallow lateral grooves; anal sheath slightly longer medially than laterally; perianal tubercles slightly larger and more prominent than other tubercles of posterior surface of thighs; tongue wide, cordiform, slightly notched posteriorly; vomerine patches ovoid, transverse, elevated, each with 5 to 7 small vomerine teeth, located between two small ovoid choanae.

Lateral surfaces of dorsum peppered with small dark flecks (Figs. 1, 2A, 2B, 2E, 2F). Bold broad dark dorsolateral bands edged dorsally by pale line extend from snout through nostrils and eyes, along supratympanic folds and flank of body. Dorsolateral bands on head converge medially and extend, as a single broad band, from an area below nostrils to upper lip. Side of head posterior to eye, including tympanum, very dark, indistinguishable from dorsolateral band. Upper and lower lips bordered by narrow dark bands; band on lower lip widens at angle of jaw, breaking into irregular dark spots that extend along edge of throat. Dorsolateral bands extend posterior to arm insertion along flank of body, breaking ventrally and posteriorly into long sinusoidal mostly interconnected blotches that cover most of surface of flank (Figs. 2A and 2B). Large, irregular dark blotches present on body dorsally to arm insertion (Fig. 1). Dorsum of limbs sparsely peppered with small dark flecks. Posterior surfaces of limbs covered by wide medium dark bands peppered with small pale spots (Figs 1, 2A, 2B, 2E, 2F). Dorsal edges of bands on thighs jagged. Anterior surfaces of thighs and arms covered with light reticulations and dark band, respectively. Ventrums of body and head immaculate except for dark spots on the periphery of throat (Fig. 1).

In preservative, dorsum of body, head, and limbs pale grayish brown with soft reddish hue; dorsum of Fingers I and II and terminal discs of toes dull yellow; ventrum of body, head, and limbs yellow, slightly paler on belly; ground color of flank pale cream; dorsolateral bands on head, body, and limbs dark chocolate-brown; band on snout and head posterior to eye, including tympanum, dark chocolate-brown; row of flat ulnar tubercles whitish.

In life (Fig. 1) dorsum of body and head beige; dorsum of limbs and loreal region of head reddish dark beige; tips of fingers and toes yellowish brown; dorsolateral band on head, body, and limbs as well as blotches on flank, throat, and chest dark chocolate-brown; hidden surfaces and ventrum of body and limbs pale yellow; flank of body dorsal to arm insertion dark yellow; row of ulnar tubercles pale yellow; iris copper.

Natural history. The holotype was found inside a fissure of a large boulder on a mountain crest far from a body of water. The type locality consists of dry deciduous forest characteristic of the Pacific slopes of the Sierra Madre del Sur of Guerrero (Rzedowski, 1978). All tadpoles were found during the day in pools formed in streams.

Variation. Adults LACM 92416, KU 140424-26, and IBH 13807 have snout truncate in dorsal view and IBH 13807 has band on upper lip broadening below eye.

All juveniles (UMMZ 239798, 239739-43, 239744) (SVL 35.3–41.9) have dorsolateral bands partially fused to

one another at the midline; loreal regions very dark, almost indistinguishable from dorsolateral bands; dorsolateral band on body short, breaking anterior to arm insertion into large, mostly independent, round or elongated spots that cover most of surface of pale to whitish flank; dark, sinuous, and mostly interconnected spots forming reticulated pattern over posterior surfaces of thighs; flank cream-yellow, hidden surfaces yellow-orange, anal sheath reaching ventral level of thighs, and thoracic grooves medially interrupted. Juveniles can lack dark flecks on dorsum of body and limbs (UMMZ 239743), have band of upper lip broaden below eye (UMMZ 239798), and flank surface partially covered by dark spots (UMMZ 239744).

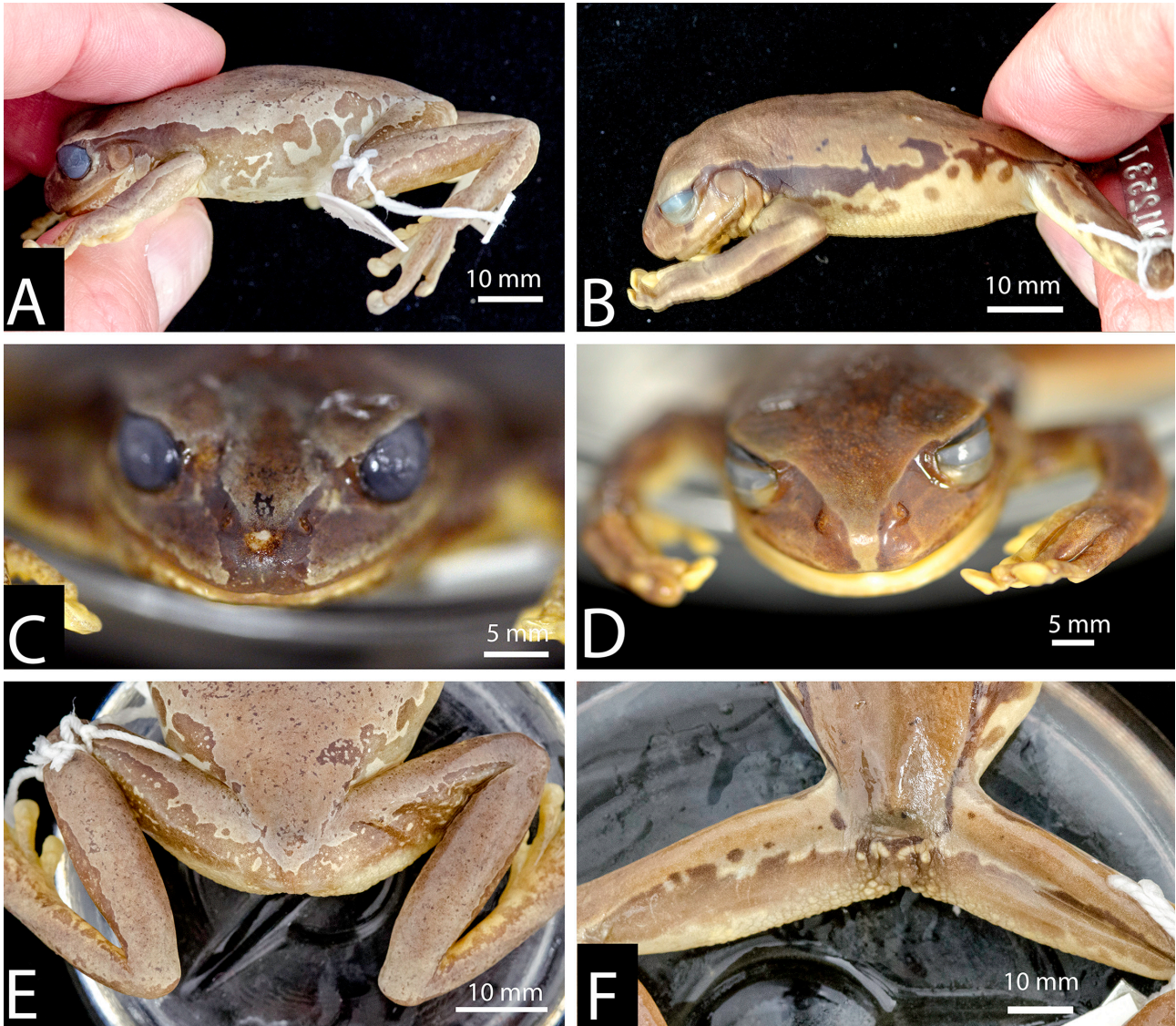


FIGURE 2. Various views of *Sarcophyla floresi* UMMZ 239718 (A, C, E) and *S. pentheter* UMMZ 125378 (B, D, F).

Description of the tadpole (UMMZ 23992) (Stage 36) (measurements in millimeters). Total length 55.8; body length 17.4; tail length 38.4; height of caudal musculature (at base of tail) 6.4; width of caudal musculature (at base of tail) 5.4; tail maximum height 9.5; maximum height of dorsal fin 2.7; maximum height of ventral fin 2.7; body width 9.8; body height 8.3; eye diameter 2.2; interorbital distance 3.6; nostril length 5.0; snout to opening of spiracle distance 11.7; oral disc diameter (transverse) 4.9.

Body ovoid (Fig. 4A), elongate in dorsal view, widest posterior to eyes at level of spiracle, slightly wider than high, not depressed in lateral view; eyes moderate in size, round, situated dorsolaterally; nostril oval, directed anterolaterally, situated closer to eye than to tip of snout; spiracle sinistral, forming round aperture, situated on midline, slightly closer to tip of snout than to posterior end of body; vent tube dextral; caudal musculature robust, highest at base, gradually tapering to pointed tip; caudal fin tip rounded; dorsal and ventral fins of nearly equal heights throughout their lengths.

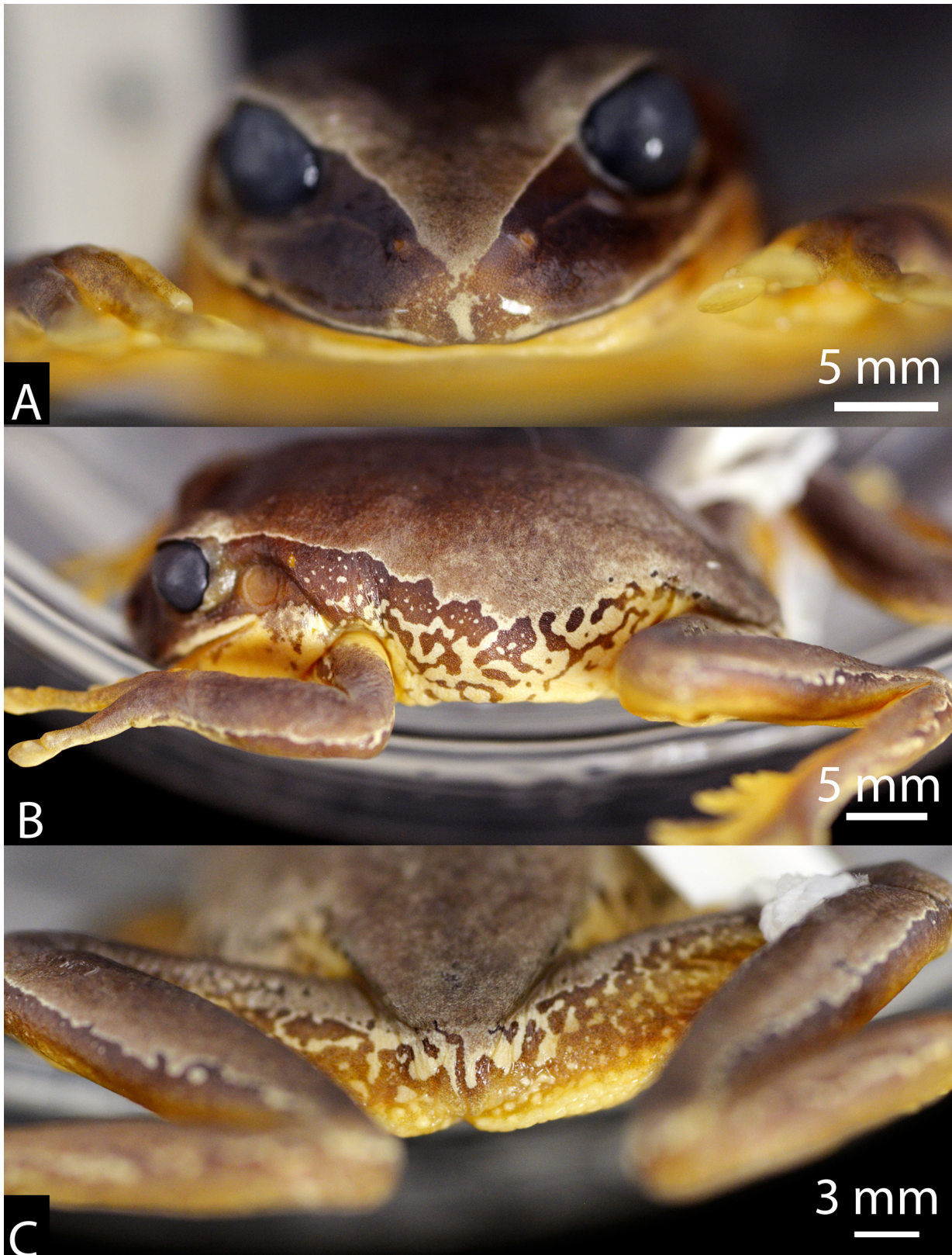


FIGURE 3. *Sarcohyla floresi* UMMZ 239743. Juvenile. (SVL = 37.7 mm) in (A) frontal, (B) lateral, and (C) posterior views.

Oral disc large (Fig. 4B), not emarginated, completely bordered by marginal papillae; marginal papillae single, short, and densely packed at anterior and posterior ends of oral disc, double, long, and flexible at lateral, anterolateral, and posterolateral parts of oral disc; one complete row of large submarginal papillae between anterior tooth row and submarginal papillae and one row of small submarginal papillae between posterior tooth row and marginal

papillae; 15 to 20 small submarginal papillae clump laterally to anterior and posterior tooth rows and slightly anterolaterally and posterolaterally to them; LTRF 2(2)/3; A1 slightly longer than A2; P2 and P3 as long as A2, slightly longer than P1; relative lengths of labial teeth A1, A2, P1 > P2 > P3. Lower sheath, well cornified; upper sheath poorly cornified except on lateral extensions; serration on upper sheath larger and better defined than that of lower sheath.

In preservative, dorsum of body yellowish brown, belly dark bluish gray; tail musculature beige; blotches on tail musculature and fins light brown, small, rounded, denser on posterior 2/3 of tail; anterior 1/5 of tail musculature unpigmented in dorsal view; subdermal white blotches on sinistral flank of body; scattered white subdermal pigment on other parts of ventrum of body.

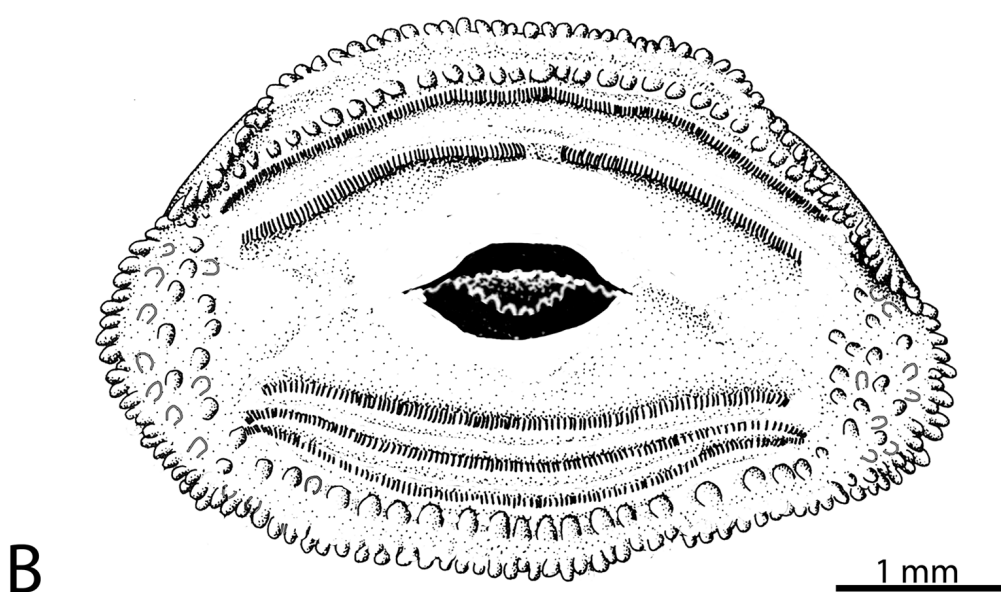


FIGURE 4. Tadpole of *Sarcophyla floresi* UMMZ 239921, stage 36 (A) Lateral and dorsal views, (B) Oral disc.

In UMMZ 239925, upper sheath of oral disc very small, cornified only medially and along lateral extensions, not serrated.

Etymology. This species is named after Oscar Flores Villela, a researcher and teacher at the Museo de Zoología, Facultad de Ciencias, Universidad Nacional Autónoma de México, to recognize his life-long commitment to the science and conservation of amphibians and reptiles in México.

Discussion

Campbell *et al.* (2018) formally recognized the *Sarcohylla bistrincta* group to include *S. bistrincta*, *S. labeculata* (Shannon 1955), *S. hapsa*, and *S. pentheter*. *S. floresi* would also be included in this group because it is sister to *S. pentheter* (Zarza *et al.* 2018) and has all the morphological diagnostic characters of this group (Campbell *et al.* 2018).

Campbell *et al.* (2018:378) assigned the only known specimens (IBH 138072) of *S. floresi* from Estado de Mexico (then *S. pentheter*) to *S. hapsa* “based on distribution and morphology,” but did not report which characters they examined. We found that this specimen has the diagnostic characters of *S. floresi*, and thus assign it to that species.

The tadpole of *S. floresi* in stage 36 differs from those of *S. hapsa*, *S. labeculata*, and *S. pentheter* in the same stage by having single marginal papillae at anterior and posterior borders of oral disc (Ustach *et al.* 2000; Meik *et al.* 2005; Kohler *et al.* 2016). This character is not known to vary ontogenetically (Ustach *et al.* 2000) but it may vary intraspecifically (e.g., compare tadpole of *S. labeculata* in Ustach *et al.* [2000] and Meik *et al.* [2005]). In addition, the tadpole of *S. floresi* differs from those of *S. labeculata* and *S. pentheter* by lacking dorsal fin with dense pattern of dark blotches (Ustach *et al.* 2000; Meik *et al.* 2005; Kohler *et al.* 2016) and from *S. hapsa* (in parenthesis) by having in preservative round small spots on fins (absent). The tadpole of *S. bistrincta* remains unknown, and a full description of the tadpole of *S. hapsa* in stage 36 is presently unavailable (i.e., Duellman [1961] described a specimen in a developmental stage earlier than 34 according to Ustach *et al.* [2000:248]).

Our results show that significant species-level diversity still awaits discovery in the topographically complex central Mexican highlands. Many *Sarcohylla* species are only known from limited specimens or from their type locality, and the ranges of many species appear to overlap (Zarza *et al.* 2018). Further sampling and a full genus-level phylogeny are needed to determine species limits and accurate geographic ranges.

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APPENDIX.

Examined specimens

Sarcohyla floresii: MEXICO: **Guerrero**: UMMZ 239925–6 (tadpoles), 239744 (Juvenile), Carrizal de Bravo to Jaleaca road, 2–3 km from the road's trifurcation, 1767 m, 17° 32' N 99° 54' W; UMMZ 239921 (tadpoles), 239798 (juvenile), near village “El Salado”, 6 to 10 km E Mazatlán 1461m, 17° 24' N 99° 25' W; UMMZ 923924 (tadpoles), 239739–43 (juveniles), via Atoyac to Puerto del Gallo; UMMZ 239718 (adult), el Alquitran; KU 140424–26, 5.6 km by road NE Yerbabuena, 2000 m; LACM 92416, 11–13 km W Mazatlan; MZFC 30710–11 Rio Frio, Municipality of Coyuca de Catalán. **Estado de Mexico**: IBH 138072, 5km “El Salitre” on road to Nanchititla, 1900 m, 18° 52' N 100° 19' W.

Sarcohyla pentheter: MEXICO: **Oaxaca**: UMMZ 125377–81, about 37 km N San Gabriel Mixtepec, 1700 m; KU 136863, 0.2 km N Jalatengo; KU 86936, 29 km SSE Juchatengo; USNM 304931, 25 km N Putla; AMNH 13447, Pluma Hidalgo; UTA 62065, Santa Catarina Juquila to Puerto Escondido road.

Sarcohyla hapsa: MEXICO: **Michoacán**: UMMZ 244413 (Holotype), 244417–25 (Paratypes), 239928 (tadpole, stage 36), Parque Nacional Uruapan, 1676 m.