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A new species of *Pseudopaludicola* (Anura, Leiuperidae) from western Piauí State, Northeast Brazil

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Abstract

A new species of *Pseudopaludicola* from western Piauí State, Brazil, in the Cerrado domain is described. *Pseudopaludicola parnaíba* **sp. nov.** is a member of the genus *Pseudopaludicola*, on the basis of the presence of one hypertrophied antebrachial tubercle, posterolateral process of the hyoid outlined and epicoracoid cartilages slightly overlapped. The new species is characterized by an advertisement call composed of 6–46 non-pulsed notes per call and dominant frequency of 4794 ± 296 Hz, which supports an independent lineage. Additionally, the small size, body slender, toe tips knobbed with central groove, abdominal fold complete, tibio-tarsal articulation reaching the posterior border of the eye, and prepollex and prehallux composed of base and one element are character states that distinguish *P. parnaíba* from all the members of *Pseudopaludicola*. We provide its formal description with regard to external morphology, osteological characters and advertisement call.

Key words: Anura, *Pseudopaludicola* **sp. nov.**, external morphology, osteology, vocalization

Introduction

The natural group *Pseudopaludicola* comprises small leiuperid frogs, diagnosed by the presence of one antebrachial tubercle on the external border of the forearms, epicoracoid cartilages slightly superposed or not, and posterolateral process of the hyoid outlined or absent (Lobo 1995). This genus, widely distributed across northern and central South America, is currently composed of 15 species: *P. boliviana*, *P. canga*, *P. ceratophyes*, *P. falcipes*, *P. giarettai*, *P. hyleaustalis*, *P. llanera*, *P. mineira*, *P. murundu*, *P. mystacalis*, *P. pusilla*, *P. riopiedadensis*, *P. saltica*, *P. serrana*, and *P. ternetzi* (Frost, 2011, Carvalho, 2012, Pansonato *et al.*, 2012).

Lynch (1989) reviewed the taxonomy of the group and proposed the inclusion of *P. boliviana*, *P. ceratophyes*, *P. llanera* and *P. pusilla* (based on the presence of toe tips T-shaped) in a group that he named *P. pusilla*. In such an important contribution to the knowledge of the genus, Lynch (1989) emphasized the need for a thorough taxonomic review of species distributed in central and southern South America.

Lobo (1995) proposed a phylogenetic hypothesis of *Pseudopaludicola* using cladistic methodology. In this work, the *P. pusilla* group was recovered, supported by the same apomorphies previously proposed by Lynch (1989), where *P. falcipes*, *P. mineira*, *P. mystacalis*, *P. saltica*, and *P. ternetzi* are unassigned to any group.

Several species were subsequently described, considerably increasing taxonomic knowledge of the genus, but its taxonomy has become unstable and species identification difficult. The aim of this work was to describe a new species of *Pseudopaludicola* from western Piauí State, Brazil. We here provide its formal description based on external morphology, osteological characters, and advertisement call. Additionally, the distribution range and natural history notes are discussed.

Material and methods

Type specimens are deposited at Coleção Herpetológica da Universidade Regional do Cariri, Ceará, Brazil (URCA). The specimens examined in addition to the new species are housed in the following collections: Academy National of Science, Philadelphia, USA (ANSP); American Museum of Natural History, New York, USA (AMNH); Centro Nacional de Investigaciones Iológicas, Buenos Aires, Argentina (CENAI, actually housed in MACN), Coleção Zoológica da Universidade Estadual de Campinas, Brazil (ZUEC); Departamento de Zoologia, Instituto de Biociências, UNESP, Rio Claro, São Paulo, Brazil (CFBH); Fundación Miguel Lillo, San Miguel de Tucumán, Argentina (FML), Instituto de Ciencias Naturales, Universidad Nacional de Bogotá, Bogotá, Colombia (ICN); Instituto de Investigaciones Biológicas del Paraguay (IIBP); Instituto Nacional de Pesquisas da Amazonia, Brazil (INPA); Laboratorio de Genética Evolutiva, Instituto de Biología Subtropical, Argentina (LGE); Museo Argentino de Ciencias Naturales “Bernardino Rivadavia,” Capital Federal, Argentina (MACN); Museu Nacional do Rio de Janeiro, Brazil (MNRJ); Museu Paraense Emilio Goeldi, Brazil (MPEG); Coleção Zoológica de Vertebrados da Universidade Federal do Mato Grosso, Brazil (UFMT) and Museu de Zoologia, Universidade de São Paulo, Brazil (MZUSP).

Specimens collected for the present study were deeply anesthetized with lidocaine, fixed in 10% formalin followed by long-term storage in 70% ethyl alcohol. Eleven morphometric variables were measured for each specimen. Seven variables follow Duellman (1970): snout-vent length (SVL), head length (HL), head width (HW), eye diameter (ED), interorbital distance (IOD), internarial distance (IND) and TL (tibia length). Thigh length (THL) follows Heyer *et al.* (1990), while three other variables follow Napoli (2005): eye-nostril distance (END), NSD (nostril-snout distance) and FL (foot length). All measurements are in millimeters and were taken with a digital caliper to the nearest 0.1 mm. Sex was determined by visual inspection of secondary sexual characters, such as nuptial pads or extended vocal sacs in males and presence of ovarian follicles in females.

Osteology is described on the basis of three adult males (URCA 3864–5, 3868), previously cleared and stained using the technique of Taylor and Van Dyke (1985). For general osteology description, we followed Trueb (1973), and otherwise for cranial osteology (Jurgens, 1971), hyoid and larynx (Trewavas, 1933), phalangeal formula (Alberch & Gale, 1985), and carpal and tarsal morphology (Fabrezi, 1992; 1993; Fabrezi & Alberch, 1996). For comparison purposes, we observed cleared and stained adults of both sexes of *P. boliviana*, *P. canga*, *P. ceratophyes*, *P. falcipes*, *P. llanera*, *P. mineira*, *P. mystacalis*, *P. pusilla*, *P. saltica*, *P. serrana* and *P. ternetzi*. Additionally, we examined external morphology in all *Pseudopaludicola* species recognized, except *P. giarettai* (see Comparative material examined section).

We analyzed 21 advertisement calls obtained from five males (URCA 2160 and 2361 and three non-vouchered specimens), recorded at the type locality. Advertisement calls were recorded with an OLYMPUS S-11 digital tape recorder with internal microphone. The recordings were digitized at 44.1 kHz, resolution of 16 bits (FFT = 256 points resolution), with Raven Pro 1.1. The following temporal parameters were measured from the waveform: call duration, number of notes per call, note duration, and inter-note interval. The dominant frequencies were obtained from spectrograms. The call rate (calls per minute) and notes per second were calculated. Terminology for advertisement call descriptions follows Heyer *et al.* (1990) and Martins and Jim (2003).

Results

Pseudopaludicola parnaiba, new species

Holotype (figs. 1–2). URCA 2160 (Adult male) collected on April 14 2012 by I.J. Roberto, R.W. Ávila, C.F. Da Silva and D.B. Oliveira, approximately 12 kilometers (in straight line) southeast of Ribeiro Gonçalves (07°35'42.15"S/45°20'36.63"W; datum WGS 84), Municipality of Ribeiro Gonçalves, Piauí State, Brazil.

Paratypes. Three adult females (URCA 2164, 2166, 2181), and 12 adult males (URCA 2158, 2162–3, 2165, 2168, 2174, 2178, 2180, 2182, 2184, 2191 – 2) collected on 14 April 2012 by the same collectors and at the same locality as the holotype, and eight adult males (URCA 2361 – 3; URCA 3864–8) collected on 18 January 2011 by I.J. Roberto, S.C. Ribeiro and J.A. Araújo Filho at the same locality as the holotype.

Diagnosis. *Pseudopaludicola parnaiba* sp. nov. is a member of *Pseudopaludicola*, based on the presence of

one hypertrophied antibrachial tubercle on the external border of the forearms, posterolateral process of the hyoid outlined and epicoracoid cartilages slightly overlapped. The new species is characterized by the following: its small size (SVL in males 11.5–14.5, $n=21$; females: 13.0–14.3, $n=3$); body slender; toe tips knobbed with central groove; abdominal fold complete; tibio-tarsal articulation reaching the posterior border of the eye; prepollex and prehallux with base element and one segment; and advertisement call composed of a series of non-pulsed notes, with 6 to 46 notes per call and dominant frequency of 4794.7 ± 296.3 Hz.

Comparison with other species. The advertisement call with groups of 6–46 non-pulsed notes per call distinguishes *P. parnaiba* from all *Pseudopaludicola* species with pulsed advertisement calls: *P. boliviana* (Duré *et al.* 2004), *P. murundu* (Toledo *et al.* 2010), *P. serrana* (Toledo, 2010) *P. falcipes*, *P. mystacalis*, *P. saltica* (Haddad and Cardoso, 1987) and *P. mineira* (Pereira & Nascimento, 2004). In relation to *P. giarettai*, the vocalization of *P. parnaiba* is distinguished by the presence of groups of 6–46 non-pulsed notes per call, while only one non-pulsed note per call (with four harmonics) is present in *P. giarettai* (Carvalho, 2012). On the other hand, *P. parnaiba* dominant frequency of (4794.7 ± 296.3 Hz), and each note with an ascendant frequency at the beginning of the call, which gradually decreases to the end of the note, separates this taxon from *P. hyleaustralis* (dominant frequency 3938 ± 158.65 Hz, and each note with a slight ascendant frequency modulation in its first half, and another ascendant frequency modulation in its last half (Pansonato *et al.* 2012), and *P. canga* (dominant frequency 3692.1–4608.1 Hz, Giaretta & Kokubum, 2003; Pansonato *et al.* 2012) see Table 1. The advertisements calls of *Pseudopaludicola ceratophyes*, *P. llanera*, *P. pusilla*, *P. riopiedadensis* and *P. ternetzi* are undescribed.

TABLE 1. Acoustic parameters of *Pseudopaludicola* species with non-pulsed advertisement call.

Acoustic Parameters	<i>Pseudopaludicola parnaiba</i> (sp nov)	<i>Pseudopaludicola hyleaustralis</i>	<i>Pseudopaludicola canga</i>	<i>Pseudopaludicola giarettai</i>
Call duration (s)	0.9 ± 0.9 (0.4–3.9)	4.25 ± 2.1 (1.1–8.2)	0.2–1.3	$0.15 + 0.016$ (0.12–0.19)
Note duration (s)	0.02 ± 0.02 (0.01–0.4)	0.03 ± 0.003 (0.025–0.05)	0.014–0.03	*
Inter note duration (s)	0.07 ± 0.06 (0.04–0.6)	0.08 ± 0.02 (0.035–0.2)	0.04–0.11	*
Intercall intervall (s)	0.8 ± 0.5 (0.4–1.8)	46.8 ± 10.4 (29.7–58.8)	0.25–6.7	$0.3 + 0.05$ (0.18–1,3)
Note rate (min)	2762 ± 503 (1764–6000)	561.4 ± 41.9 (503.8–623.2)	689.6–944	$136.2 + 14.8$ (117–153)
Dominant Frequency (Hz)	4794.7 ± 296.3 (4220.5–5168)	3938.9 ± 158.6 (3605–4164.3)	3962.1–4608.1	$4374 + 150.0$ (3981–4719)
Minimum Frequency (Hz)	3295.7	3562.3	3297	*
Maximum Frequency (Hz)	6002.9	4379.8	5238	*
Air Temperature °C	26	24	25–29	*
Locality	Ribeiro Gonçalves, State of Piauí	Alta Floresta, State of Mato Grosso	Marabá, Conceição do Araguaia e Curionópolis, State of Pará	Curvelo, State of Minas Gerais
Country	Brazil	Brazil	Brazil	Brazil
Reference	This study	Pansonato <i>et al.</i> 2012	Pansonato <i>et al.</i> 2012	Carvalho, 2012

Additionally, the new species can be distinguished from all recognized *Pseudopaludicola* species by a combination of external morphology and osteological characters.

The smaller SVL of males (11.5–14.5 mm, $n = 20$) separates *P. parnaiba* from *P. giarettai* (range 16.2–18.0 mm, $n = 10$, Carvalho, 2012), *P. canga* (14.6–16.5 mm, $n=12$, Giaretta & Kokubum, 2003; Pansonato *et al.* 2012), *P. ternetzi* (16.0–18.6 mm, $n= 13$, Lobo, 1996), *P. saltica* (15.2–16.9 mm, $n = 9$, Haddad & Cardoso, 1987), and *P. serrana* (15.0–15.8 mm, $n = 5$, Toledo, 2010).

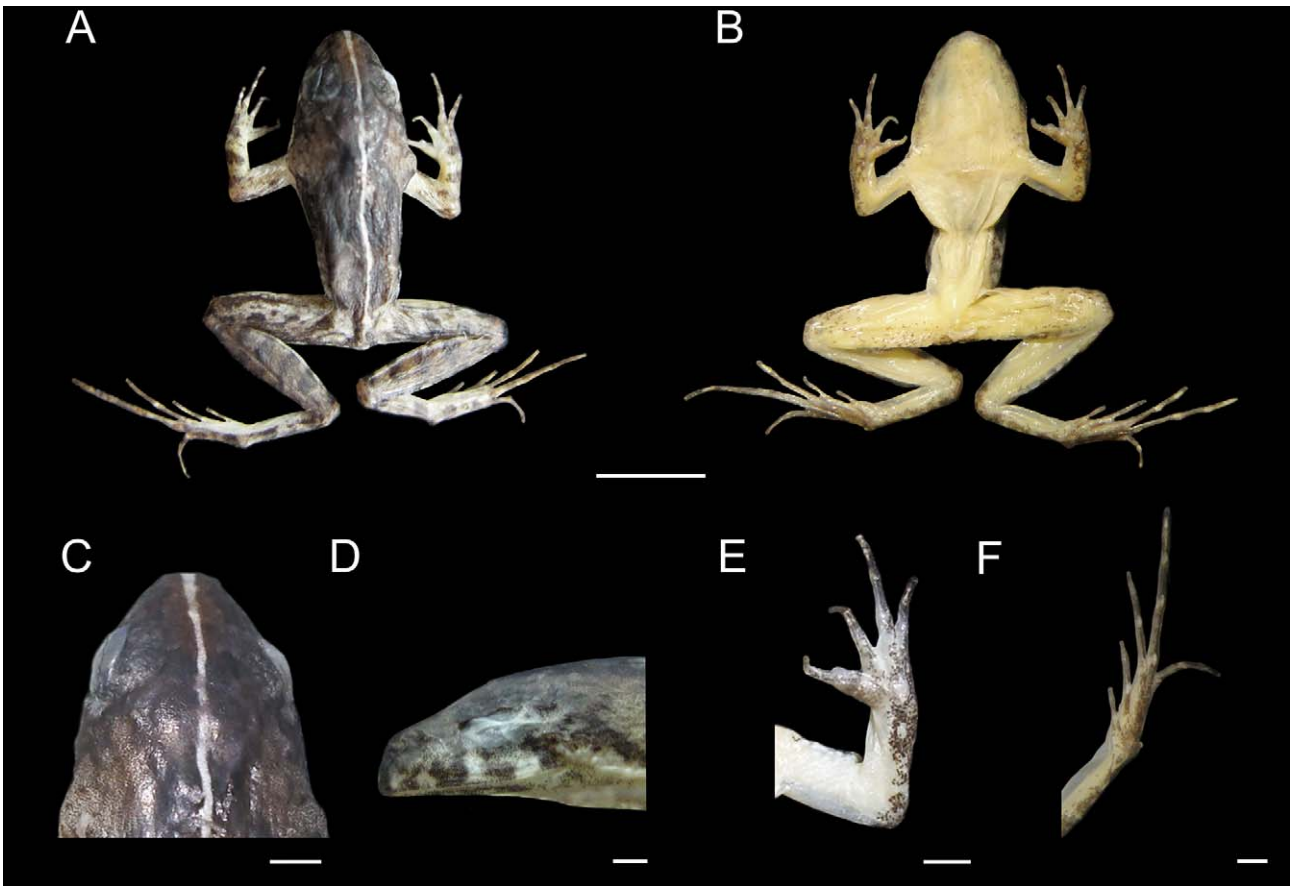


FIGURE 1. *Pseudopaludicola parnaiba* **sp. nov.** Holotype, URCA 2160. Dorsal and ventral views(A–B). Dorsal (C) and lateral view of the head (D); palmar view of hand (E); plantar view of foot (F). Scale bar 1 mm.



FIGURE 2. Male of *Pseudopaludicola parnaiba* **sp. nov.**, Municipality of Ribeiro Gonçalves, State of Piauí. Photo by I.J. Roberto.

The slender body separates *P. parnaiba* from *P. ternetzi*, and *P. riopiedadensis* (which have a more robust body aspect; Lobo, 1995, 1996; Giaretta & Kokubum, 2003), and *P. mineira* (globular body aspect; Lobo, 1994, 1995).

The fingertips knobbed, distinguish *P. parnaiba* from the species assigned to the *P. pusilla* group (*P. boliviana*, *P. ceratophyes*, *P. llanera*, and *P. pusilla*), which have T-shaped terminal phalanges (Lynch, 1989; Lobo, 1995, Cardozo & Suarez, 2012).

The presence of a complete abdominal fold differentiates *Pseudopaludicola parnaiba* from *P. falcipes* (incomplete or absent abdominal fold, Lobo, 1994, 1995).

The tibio-tarsal articulation reaching the posterior border of the eyes separates *P. parnaiba* from *P. saltica*, *P. murundu* and *P. serrana*, where the tibio-tarsal articulation extends beyond the tip of the snout (Lobo, 1994, 1995; Toledo, 2010; Toledo *et al.*, 2010).

The prepollex composed of the base element and a long mineralized segment distinguishes *P. parnaiba* from *P. falcipes*, *P. saltica*, and *P. ternetzi* (prepollex with base and two elements; Lobo, 1995). The prehallux formed by the base and one mineralized segment separates *P. parnaiba* from *P. boliviana*, *P. llanera*, *P. mystacalis*, *P. pusilla*, and *P. ternetzi* (prehallux with base and two mineralized segments; Lobo, 1995).

Although *P. ameghini* was referred to as valid species on the basis of karyological features by Fávero *et al.* (2011), there is no a formal revalidation of this taxon. According to Lobo (1996), the type specimens of *P. ameghini* and *P. mystacalis* collected by Cope (1887) are of similar external morphology, and should be considered as synonyms. In this sense, a taxonomic revision of the types specimens housed at ANSP in the framework of the new evidence available (Duarte *et al.* 2010; Fávero *et al.* 2011) is necessary to elucidate the real taxonomic status of *P. ameghini*. For this reason this taxon is not included in the comparisons of *P. parnaiba*, as in other recent descriptions of *Pseudopaludicola* species (Pansonato *et al.*, 2012, Carvalho, 2012).

On the other hand, although the advertisement calls of *P. ternetzi* and *P. riopiedadensis* are still undescribed, both taxa present pulsed advertisement calls according to Cardozo & Toledo (unpublished data). This character state and the external morphology (body size and slender aspect) presents in *P. parnaiba* are important characters to separate the new species from the taxon called *P. riopedadensis*

Description of holotype. Head longer than wide (cephalic index: head length/width = 1.24). Snout acuminate in dorsal view, protruding from the jaw in lateral view. Nostrils nearer to the tip of snout than to the eyes. Internarial distance smaller than interorbital space. Tympanum not visible. Superficial supratympanic fold. Undifferentiated *canthus rostralis*. Upper lip with white vertical stripes. Choanae rounded. Circular pupil. Tongue entire, oval, free behind without pigment at the base. Vocal sac single. Premaxillary and maxillary teeth present. Body slender. Skin smooth, with small flattened glandular warts on the flanks. An X-shaped glandular fold is evident in the interscapular region. Abdominal fold complete, thoracic fold present and gular fold indistinct. Antebrachial tubercle evident. Inner and outer metacarpal tubercles elongated and rounded, respectively. Length of fingers IV<II<I<III, with distal subarticular tubercles developed. Small supernumerary tubercles present at the base of the subarticular tubercles in the hand. Nuptial pads light cream, poorly developed, nuptial asperity present on the base of the thumb. Arms speckled dorsally, with dark crossbar. Inner metatarsal tubercles well developed, curved towards the tip of the leg, outer metatarsal tubercle conical and perpendicular to the plane of the foot. Tarsal fold slightly curved, with a thickening at the middle of the tarsus, simulating a tubercle. Toe webbing fringed. Length of the toes IV>III>V>II>I, with tips not expanded laterally.

Measurements of holotype (in mm). SVL 13.6; HW 4.6; HL 5.7; TL 7.0; THL 6.6; FL 8.1; ED 1.7; IOD 1.5; IND 1.1; NSD 0.9; END 1.2.

Color of the holotype. In life, dorsum brown, with two dorsolateral bands poorly defined, extending from postocular to inguinal regions. A thin white vertebral line extends from the tip of snout to cloaca. Belly white; dorsal view of arms uniform brown with two dark blotches; ventral region white, with scarce dark spots on chest, thighs and arms. The hind limbs have a dorsal striped pattern. The inner thighs have a light brown background finely spotted with black. Vocal sac yellowish with dark dots. Upper lip with white vertical stripes. Iris pale bronze with a black vertical line below the pupil. In preservative, dorsum and dorsal surface of limbs grayish brown, with dark dots on the ventral surface of legs and arms. Belly white; vocal sac white with scattered dark dots. The postocular gray stripe is less evident.

Variation. The dorsal color pattern varies from uniform brown to marble, with poorly defined dorsolateral bands. In most individuals of type series (87%), the vertebral line is absent. In some individuals without vertebral line (32%), a brown interorbital band is present. The paratypes (URCA 2162–4, 2166, 2174–6, 2178, 2180–2, and

2191) have a gray band perpendicular to the postocular region, reaching the upper arm. The presence/absence of X-shaped glandular fold varies among the paratypes. Eight individuals (URCA 2158, 2163–4, 2176, 2180, 2184, 2362–3) have a second antebrachial tubercle, always smaller than the first one and placed near the elbow. The paratype measurements as “mean \pm standard deviation (range)” for 21 males were SVL 12.9 ± 0.9 (11.5–14.5), HL 4.7 ± 0.5 (4.0–5.6), HW 4.2 ± 0.4 (3.5–4.9), IND 1.1 ± 0.1 (0.9–1.2), NSD 0.7 ± 0.2 (0.4–1.0), END 1.1 ± 0.2 (0.9–1.4), ED 1.6 ± 0.1 (1.3–1.8), IOD 1.3 ± 0.1 (1.1–1.5), THL 5.7 ± 0.4 (5.0–6.5), TL 6.7 ± 0.4 (6.0–7.8) and FL 7.8 ± 0.8 (7.1–10.2), and for three females SVL 13.6 ± 0.7 (13.0–14.3), HL 4.7 ± 0.3 (4.5–5.1), HW 4.5 ± 0.4 (4.1–4.8), IND 1.1 ± 0.1 (1.0–1.1), NSD 0.8 ± 0.1 (0.7–0.9), END 1.2 ± 0.3 (1.0–1.3), ED 1.7 ± 0.1 (1.6–1.8), IOD 1.5 ± 0.2 (1.3–1.6), THL 6.3 ± 0.5 (5.8–6.8), TL 7.2 ± 0.2 (7.0–7.3) and FL 8.2 ± 1.1 (7.0–9.1).

Osteology (fig. 3). Skull longer than wide. Complete maxillary arch. Alary processes of premaxillae directed dorsally, parallel to each other (frontal view). Premaxillae bearing 7–9 teeth and maxillae with 24–28 curved and pedicellated teeth. Nasal narrow and ovoid, with irregular inner margin and ending pointed posteriorly. The nasals are separated from each other and do not overlap the maxillary. In dorsal view, the nasal bone does not overlap the sphenethmoid. Anterior margin of the sphenethmoid not reaching the middle of the choana, posterior margin U-shaped. In dorsal view, sphenethmoid short with a thin internasal septum. Frontoparietals with regular inner margins that leaves the frontoparietal fontanelle partially exposed in the frontal region (frontoparietals with regular inner margins, leaving the frontoparietal fontanelle mostly hidden in URCA 3864). Optic foramen large sized, ovoid and located at the junction between the prootics and sphenethmoid. Oculomotor foramen of narrower diameter, located posterior to the optic foramen. Prootic foramen oval, placed posterior to the optic capsule. Jugular foramen composed of two holes of similar diameter. Triradiate pterygoid. The posterior ramus of the pterygoid is longer than middle and separated from the quadrate; medial ramus detached from the wings of the parasphenoid and supported by cartilage in the otic region of the skull. Anterior ramus separated from the palatine. Quadratojugal with anterior process reduced. Triradiate parasphenoid, with the tip of the cultriform process irregularly shaped. Parasphenoid wings directed backwards. Neopalatines poorly developed, investing the *pars fascialis* of maxillae. Prevomers irregularly shaped, wider in their middle region and without teeth. Squamosal with the ventral ramus wider at its ventral end, zygomatic ramus shorter than otic, with a descending process well developed. Tympanic annuli cartilaginous, opened dorsally. Plectrum of uniform width. Operculum cartilaginous, rounded. Mandible with a thin dentary covering the lateral margins of Meckel’s cartilage. The inner part of this cartilage is covered by the angular bone, which is thin and without coronoid process evident. Articular region of lower jaw cartilaginous, dentary plain, without denticle-like structures.

The larynx (Fig. 3C) has the arytenoid as two small oblong shells and the cricoid forms a complete ring. Esophageal process short and thin; muscular and bronchial processes thin. Cardiac and articular processes poorly developed.

Hyoid plate cartilaginous, with dispersed mineralization (Fig. 3C). Anteromedial processes of the hyoid short and divergent. Postero- and anterolateral processes vestigial and absent, respectively. Posteromedial processes with cartilaginous ends.

Vertebral column with eight procoelous, non-imbricate, presacral vertebrae (Fig. 3D). Cotylar facets of the atlas separated (type I of Lynch, 1971). Atlas body widest among the vertebrae. In dorsal view, the anterior margin of the atlas contacting presacral II through a wide neural process. Anterior portion of the ilium articulating with the ventral surface of the sacral diapophysis. Pubis cartilaginous. Sacral diapophysis narrow and not expanded. Urostyle with dorsal spine well developed and exit of spinal nerve X not visible. Urostilar articulation bicondylar.

Pectoral girdle arciferal (Fig. 3E), with the left epicoracoid cartilage slightly overlapping the right one, in ventral view (the right epicoracoid cartilage slightly overlaps the left in URCA 3868). Clavicle thin, posterior margin concave, separated from the acromial region of the scapula by an anterior projection of the procoracoid. Scapula with the *pars acromialis* and *glenoidalis* poorly developed. Anterior process of the suprascapula present. Omosternum cartilaginous, with expanded terminal end. Sternum simple, not bifurcated, with osseous mesosternum (mineralized in URCA 3865) and cartilaginous xiphisternum expanded.

Humerus with deltoid crest developed. Radius-ulna fused, leaving a narrow groove between them. Carpus composed of five elements: radial, ulnar, Y element, distal carpal V-IV-III and distal carpal II. Prepollex with osseous base and one mineralized long segment. Phalangeal formula: 2-2-3-3. Fingertips knobbed, with central groove.

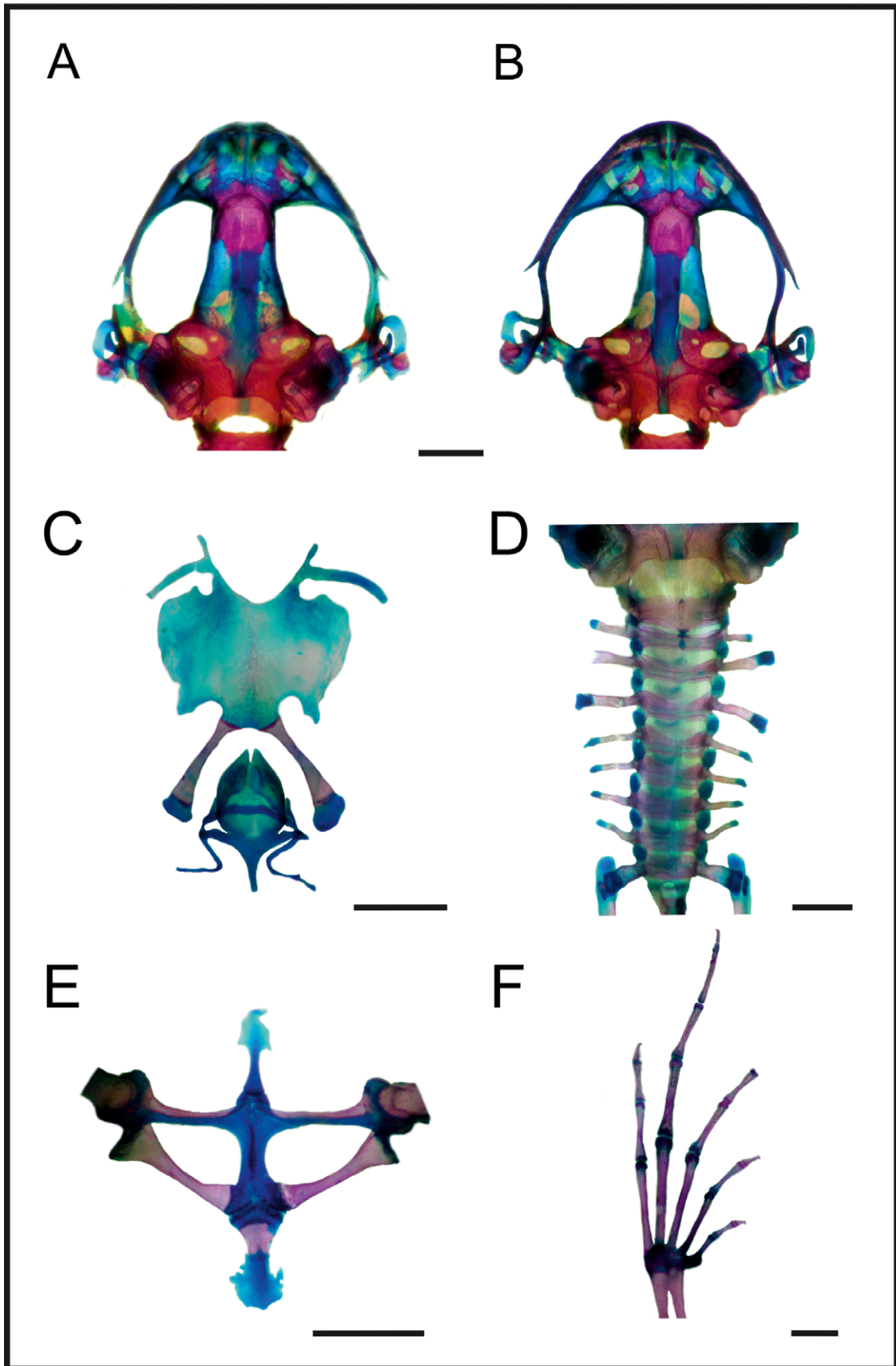


FIGURE 3. Skeleton of *Pseudopaludicola parnaiba* sp. nov., URCA 3864, adult male. Dorsal (A) and ventral (B) views of skull (C) Hyoid and larynx; (D) Vertebral column in dorsal view; (E) epicoracoid cartilages; (F) plantar view of foot. Scale bar 1 mm.

Hind limbs with the tibio-fibula fused at the proximal ends. Tarsus composed of central, distal tarsal I, and distal tarsal II–III. Prehallux composed by an osseous base and one long mineralized segment. Phalangeal formula: 2-2-3-4-3. Toe tips knobbed with central groove (Fig. 3F).

All specimens examined, have small osseous lateral projections at the anterior extremities of the metacarpal epiphysis and some phalanges. In the forelimbs, in dorsal view, there is a small rounded sesamoid bone over the distal carpal V-IV-III, embedded in the tendon of the *muscle carpi ulnaris*. In ventral view, the palmar sesamoid (in the *m. digitorum longus*) has an irregular quadrangular shape. Also are present glide sesamoids on the flexor tendons of the hands, at the junction of the proximal and medial phalanges in all fingers. The hind limbs have osseous lateral projections at the epiphysis of some metatarsals and phalanges, sesamoid graciella (at the union of femur with tibia-fibula, embedded in the tendon of the *m. gracilis major*); S. cartilage (in the tendon of the *m. plantaris profundus*) and two plantar sesamoids with ovoid shape and similar size, placed at the tendons that form the *aponeurosis plantaris*. Additionally, near the distal end of the sacral diapophyses, there are a couple of sesamoid bones (S. of the sacral vertebrae) with elongated shape and similar width as the diapophyses.

Advertisement call (fig. 4, Table 1). The individuals of *P. parnaiba* were recorded at night (18:00–20:00 h) on 18 January 2011 ($n=3$) and 14 April 2012 ($n=2$), with air temperature 26°C. The advertisement call is composed of a series of non-pulsed notes (call series) with 11.7 ± 9.7 notes per call (6–46). The mean call series duration is 0.9 ± 0.9 sec (0.4–3.9 s), emitted in short intervals from 0.4–1.8 sec (0.8 ± 0.5). The average number of notes per minute is 91.9 ± 41.9 (16–162). The mean note duration is 0.02 ± 0.02 sec (0.01–0.4) with inter-note interval of 0.07 ± 0.06 (0.04–0.6). The mean number of notes per second is 48.8 ± 12.6 (29.4–100). Each note has a slight ascendant frequency modulation at the beginning of the call, which gradually decreases to the end of the note. The species frequency range is 4338.5 ± 473.1 Hz (3295.7–4786.7) to 5364 ± 285.8 Hz (4788.5–6002.9), with dominant frequency of 4794.7 ± 296.3 (4220.5–5168).

Geographic distribution. *Pseudopaludicola parnaiba* is only known from its type locality, in the western region of Piauí State, bordering with Maranhão State, Northeast Brazil. This region is part of the Cerrado domain (sensu Ab' Saber, 1977).

Natural history notes. *Pseudopaludicola parnaiba* was found in a disturbed area close to the Parnaíba River in the months of February and April. On both field trips, we found adult males in calling activity. Individuals vocalized during afternoon and at late night. As other species of the genus, the individuals of *P. parnaiba* vocalized hidden on grass stems on muddy soil in swamp areas (e.g., Haddad & Cardoso, 1987; Lobo, 1996; Carvalho, 2012). *Scinax fuscomarginatus*, *S. nebulosus*, *Hypsiboas multifasciatus* and *H. punctatus* were also found in calling activity in the same area.

Etymology. The specific epithet *parnaiba* refers to the Parnaíba River, an allusion to the habitat of the species, which occurs along the banks of this river.

Remarks. Historically, the *Pseudopaludicola* species occurring in Northeast Brazil have been poorly studied. Lobo (1995, 1996) assigned the specimens from Ceará, Paraíba, Pernambuco and Bahia states, in Northeast Brazil to *P. mystacalis*.

Later on, Rodrigues (2005) mentioned two species of *Pseudopaludicola* inhabiting the Caatinga biome in Northeast Brazil, *P. falcipes* and *P. mystacalis*, which were later called as *Pseudopaludicola* sp.1 and *P. sp. 2* by Caramaschi (2008). In Piauí State, the taxonomic status of *Pseudopaludicola* populations remains unknown. Caramaschi and Jim (1983) mentioned the occurrence of *Pseudopaludicola falcipes* for Picos municipality, a typical Caatinga area, and Loebmann and Haddad (2010) assigned two indeterminate species to this biome (referring to them as *P. sp* (gr. *falcipes*) and *P. sp* (gr. *mystacalis*). However, the species groups referred by Loebmann and Haddad (2008) are not natural groups. The only group supported by an apomorphic character (end of the phalanges T-shaped) is the *P. pusilla* group (Lynch, 1989; Lobo, 1995).

On the other hand, Da Silva *et al.* (2007) assigned to *P. mystacalis* specimens from the municipality of Ilha Grande, along the coast of Piauí, and later, Loebmann and Mai (2008) sampled seven localities in the same area and cited the occurrence of an unidentified species, which they called *P. gr. falcipes*. In this sense, a major integrative taxonomic revision of *Pseudopaludicola* species inhabiting Northeast Brazil is needed to determine the true taxonomic status of multiple populations historically assigned to *P. falcipes*, *P. mystacalis* and/or indeterminate specimens of the genus.

In conclusion, several names have been assigned to different *Pseudopaludicola* populations. However, the distribution of *P. falcipes* involve Southern Brazil through southeastern Paraguay and Uruguay to northeastern

Argentina (Frost, 2011), and the presence of this taxon at northern Brazil is discarded by our revision, while the complete range of *P. mystacalis* is not fully understood, being necessary a complete revision of this taxon involving multiple lines of evidence like morphology, bioacoustics and genetic data.

It is important to remark that the specimens considered as *P. mystacalis* in the phylogenetic analysis of Lobo (1995) correspond to at least three species with different chromosome numbers: *P. mystacalis*, *P. canga*, and the populations from Bahia (see Giaretta & Kokubum, 2003; Duarte *et al.* 2010; Fávero *et al.* 2011), being necessary to recode the characters used by Lobo (1995), including all the species described up to the present, in order to obtain a more robust and inclusive phylogenetic hypothesis.

The area of occurrence of *Pseudopaludicola parnaíba*, within the Cerrado domain, and the higher level of deforestation for soy and cellulosic biofuel production, as well as dam constructions, is an increasing threat for the species. Despite the presence of a protected area in the region, Uruçuí-Una Ecological Station, we still need to determine if the species occurs in this area. In this sense the new species must be considered as poorly known. New inventories and ecological data surveys in the region are needed to determine the true conservation status of this species.

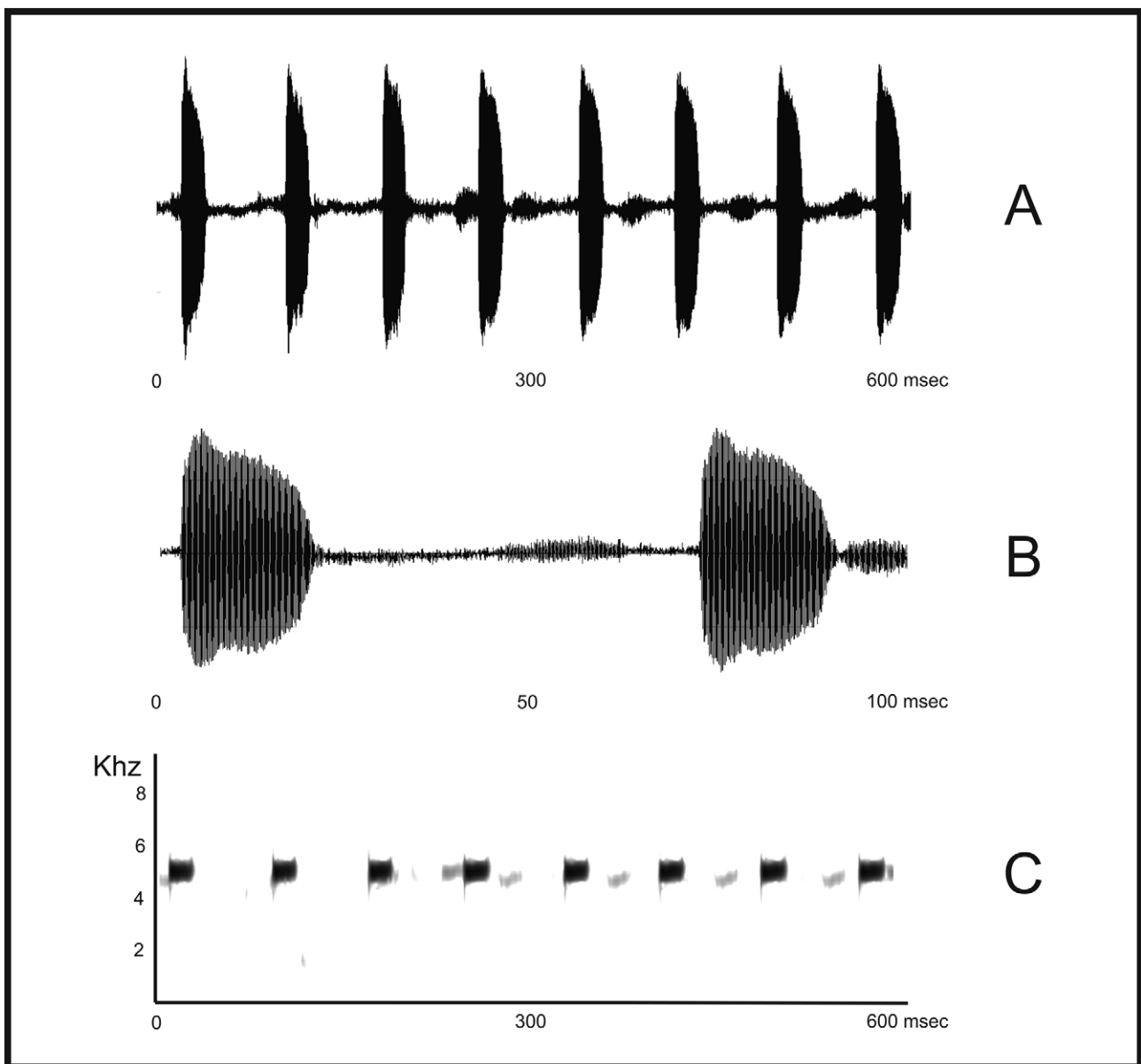


FIGURE 4. Advertisement call of *Pseudopaludicola parnaíba* sp. nov., URCA 2361. (A) Oscillogram of a sequence of advertisement calls (600 milliseconds); (B) Oscillogram detailing two calls; (C) Audio spectrogram. kHz, kilohertz; msec, milliseconds.

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APPENDIX I. Comparative material examined.

Institutional abbreviations are described in Materials and Methods section. CS = cleared and stained specimens.

Pseudopaludicola boliviana: ARGENTINA: CHACO: Bermejo: Isla del Cerrito, FML 4307, 4316–7, MACN 38522–7; Comandante Fernández: RN 95 Km. 1141; Roque Saenz Peña, FML 4337; San Fernando: Reserva Benítez, FML 2665; Antequera, RP No. 63 near Isla del Cerrito, LGE 2968 (CS); General Güemes: Juan José Castelli, FML 3670; CORRIENTES: Capital: Paraje Perichón, LGE 3019, 3028; General Paz: Itá Ibaté, CENAI 6020, 6036, 6043, 6061, 6195, 6456, LGE 1731, 2970 (CS), LGE 2972, 3026–7 (CS); FORMOSA: Formosa: Tatané, LGE 3032–6, 3039–42, 3044–6, 3048–53, 3055–71; Tres Marías, LGE 3072–5; Laishi: Reserva El Bagual, FML 10608, 10648, 10660; RP No. 1, near Herradura, LGE 3083 (CS); Patiño: Colonia Salvación, RP No. 20, LGE 0509–11. Pílagás: RP No. 3, near General Belgrano, LGE 0512; Virasol, RP No. 14, LGE 0504–5, 0515–9; Pilcomayo: near Clorinda, MACN 38528; Frontera, RP No. 6, LGE 3037, 3086; RP No. 14, Colonia Pastoril, LGE 0513–4; SANTA FE: General Obligado: between Reconquista and Puerto Reconquista, FML 4876; RP No. 1, Reconquista, LGE 2991, 3087, 3091–2. BRAZIL: MATO GROSSO: Vila Bela da Santíssima Trindade, MZUSP 52108–11, 91811–9.

Pseudopaludicola canga: BRAZIL: PARÁ: Conceição do Araguaia, MZUSP 85906–11; Curionópolis, URCA 2116-2124; Marabá: Marabá, MPEG 34371–2 (CS); Piçarreira, MPEG 28108; Projeto ALPA, 18 Km. from Amornin, MPEG 28290–2; Projeto ALPA, Influência Ramal, Marabá, MPEG 28293–4; Parauapebas: Carajás: Acampamentos N1, MNRJ 57812-5; Lago NL, MZUSP 61052-7, 61061-4; Lago N4, ZUEC 6086 (paratypes), ZUEC 6088 (holotype), 6089 (paratype), 9991

(paratypes); 9998 (paratypes); Canaã dos Carajas: Base do Niquel do Vermelho, MPEG 21277–8, 21281–2, 21284; Serra da Bocaína, MPEG 34368 (CS), 34369(CS), 34370 (CS).

Pseudopaludicola ceratophyes: BRAZIL: AMAZONAS: Rio Jurua, INPA 2274, 2276–9, 2282–3, 2284 (CS), 2285, 2287, 2547, 2776, 2951–2, 3065, 3070, 3077, 3210, 3221, 3327, 3403, 3448, 3482 (CS), 3497, 3539–40 (CS), 3551, 5096, 5114.

Pseudopaludicola falcipes: ARGENTINA: BUENOS AIRES: Luján, RN No. 5, LGE 3095, 3098–103; RP No. 47 near Luján, LGE 3104; CORRIENTES: Bella Vista, Toropí, LGE 2424–31, 3334–6; Curuzú Cuatiá: Perugorría, Estancia El Oscuro, LGE 2969 (CS), LGE 3105 (CS), 3106, 3108–11, 3112 (CS), 3116–9, 3121, 3123–4; General Paz: RP No. 13, 6 km. intersection RN No. 12, LGE 1748–50; Ituzaingó: Estancia Santo Domingo, LGE 1590, 2211–2, 3125 (CS), 3126–42; Ituzaingó, Parque Industrial, LGE 1723, 3143; Paso Tirante, LGE 3144; Paso de Los Libres: Tapebicuá, RN No. 14: LGE 3145–7; San Martín: Yapeyú, Río Uruguay, LGE 3148–52, 3154; Santo Tomé: Gobernador Virasoro, Arroyo Aguapeí, LGE 3155–63, 3164 (CS), 3165–6; Gobernador Virasoro, Campo Báez, LGE 1517; Yermal San Juan, stream tributary of Arroyo Garabí, LGE 2983, 3167–75; ENTRE RÍOS: Federación: Chajarí, Arroyo Chajarí, 3177–8 (CS), 3180–4, 3186–202, 3203 (CS), 3204–19; Islas del Ibicuy: Arroyo Martínez, LGE 3094, 3220, 3222–7; La Paz: La Paz, RP No. 6, 6.5 km from RN No. 12, LGE 3228–43, 3245–6, 3248–51, 3254–64; MISIONES: Candelaria: Candelaria, LGE 1433; Ñu Pyahú, RP No. 3, 3.5 km. of RN No. 12, LGE 1374–7, 1385–7, 1440, 1443, 1449, 1466–7, 1503–8, 1811–30, 1925, 2645, 2993, 3265–6, 3267 (CS), 3268–9, 3312 (CS), 3313–9, 3321–8, 3330–3; Capital: Arroyo Guazupí, RP No. 205, LGE 3271 (CS), 3272–5; Fachinal, LGE 3277–9; Parque Provincial Profundidad, LGE 3270; Posadas, laguna San José, LGE 3280; Posadas, RN No. 12 Jockey Club, LGE 3320; Posadas, RN No. 12, Km 1329, LGE 1512–6, 2051; RP No. 205 between Parque Provincial Fachinal and RN No. 105, LGE 3276; Villa Lanús, Empresa Dancer, LGE 3281; Concepción: Santa María, RP No. 2, Km 35, LGE 0503; San Javier: 3,5 Km. South Itacaruaré, LGE 0100; San José: Estancia La Tai Milagrosa, LGE 1510; SANTA FE: Castellanos: between Ataliva and La Providencia, LGE 3293; La Capital: Comuna de Leyes, Rivera del Arroyo Leyes, LGE 3283–8, 3289 (CS), 3290–1; San Justo: RP No. 62, 1.5 Km. outside El Laurel, near Videla, LGE 3294; LGE 3295–6, 3297 (CS), 3298–301.

Pseudopaludicola hyleaustralis: BRAZIL: Mato Grosso: Alta Floresta, Salto do Apiacas Waterfalls, UFMT 5560 (holotype), 5555–9, 5561–3 (paratypes).

Pseudopaludicola llanera: COLOMBIA: META: Puerto Gaitán, ICN 13558 (CS); 13579 (CS), 13804 (CS, paratype), 13807–14, 14017–20, 14021 (CS), 14022–3, 14024 – 5 (CS); 14026–33; Puerto López: ICN 20696. Km. 51, Route from Puerto Lopez to Puerto Gaitán: Hacienda La Esmeralda, ICN 21288–301; VICHADA: Puerto Carreño: Instituto de Policía: Puerto Murillo, Hacienda El Toro: ICN 14007–16. VENEZUELA: AMAZONAS: Puerto Ayacucho, AMNH-A 85565.

Pseudopaludicola mineira: BRAZIL: MINAS GERAIS: Área Alta, Serra do Cipó, MNRJ 42770–1, 42772 (CS), 42773–6; Jaboticatubas, MZUSP 57719–30; Serra do Cipó, MZUSP 56867, 75672, 76500, 77106–12, 88628–38, 131018–37; Serra do Cipó, MZUSP 56768–72; Serra do Cipó, Km. 115, MZUSP 75727; Serra do Cipó, Route MG 2 Km. 127, MZUSP 56858 (holotype), 56859–61 (paratypes).

Pseudopaludicola murundu: BRAZIL: SÃO PAULO: Rio Claro, ZUEC 14284–90 (paratypes).

Pseudopaludicola mystacalis: ARGENTINA: CORRIENTES: Curuzú Cuatiá: Perugorría, Estancia El Oscuro, LGE 2967; General Paz: Caá Catí, RP No. 5, 1 km. west of Loma Alta, LGE 2792 – 9, 2842, 3022, 3253; Itá Ibaté, LGE 1550, 1551 (CS), 1552–3, 1728–30, 1744–6, 2268–71 (CS), 3088; RP No. 13, 7 km. from Caá Catí, LGE 1732, LGE 1740 – 1; Ituzaingó: Estancia Santo Domingo, LGE 2217, 2980 – 1; Garapé, RN No. 12, LGE 2982, Near Ituzaingó city, LGE 0501, 1554 – 5, 1556 (CS), 1557–62 1717 – 20, LGE 1721, LGE 1722, 1724 – 5, 1726 (CS), 1727, 2683 – 5, 3082. Reserva Natural Rincón Santa María, LGE 2843 – 53, 2974 – 9; RN No. 12 and RP No. 22, near Villa Olivari, LGE 1548 – 9; San Miguel: Estero Carambola, Estancia Santa Julia, LGE 2001–4, 2008, 2016, 2018, 2057–65, 2468; RN No. 118, 17 km. outside Loreto, LGE 1733 – 5, 1739; ENTRE RÍOS: La Paz, RN No. 12 and RP No. 6, LGE 2984; MISIONES: Apóstoles: Azara, Arroyo Chimiraí, LGE 2990; Arroyo Manantial, LGE 2686, 2985 – 7, 2988 (CS), 2989; Candelaria: 5 km N Profundidad, LGE 2687 (CS), 2992; Ñu Pyahú, RP No. 3, 3 km S RN No. 12: LGE 2994–7; Capital: Arroyo Guazupí, RP No. 208, LGE 2999; Estancia Santa Inés, LGE 3004; Posadas, Laguna San José, LGE 3005–7, 3107; Posadas, RN No. 12, km 1329, LGE 3008, 2052–3; Villa Lanús, Campus Universidad Nacional de Misiones, LGE 3000 (CS), 3001 – 3; Concepción: Barra Concepción, Campo San Lucas, LGE 2998, 3009 – 12; San Javier: Itacaruaré, LGE 2691–2 (CS), 3014 – 5, 3017–8; 3.5 km S Itacaruaré, LGE 0151; Destacamento de prefectura Itacaruaré, LGE 3020–1.; BRAZIL: GOIAS: Jatui, MZUSP 27022–5; Rio Atalaíha, MZUSP 66504–7 (ME); Rio Verde, MZUSP 27075–6; MATO GROSSO: Barra do Tapirapés, AMNH-A 70180–1, 73745–6, MZUSP 26944 (CS), 26946 (CS), 26947–9; Cabeceiras do Rio Butantan, MZUSP 4382–8; Chapada dos Guimarães: ANSP 11238 (paralectotype), 11239 (lectotype), 11240 (paralectotype), 11262–3, ZUEC 14144–5; Aldeia Velha, CFBH 00116–7; Serra do Roncador, MZUSP 4403–5; Cuiaba: Campus da Universidade Federal de Cuiabá, MNRJ 71455–6; Dumbã, MZUSP 4312, 4354–80; Fazenda Santa Edwiges, MZUSP 71107–19; Fazenda Serrinha, MZUSP 71120–30; Lagoa Santa Teresinha, MZUSP 4395; Mato Verde, MZUSP 26993–7, 26998 (CS); Mombuca, MZUSP 4448 (CS), 4449–50, 100 Km. W São Domingos, MZUSP 26785–9; Rio das Mortes, MZUSP 26790–2; Nova Xavantina: Rio Areões, MNRJ 70800–83, 71290–319, 71471–87; Posto Leonardo, PL. Xingú, MZUSP 49273–4 (CS), 49276; São Domingos: Pindaíba: Lagoa Santa Terezinha, MZUSP 4399; Pindaíba, km 60, MZUSP 4406–8, 4409 (CS); MINAS GERAIS: Buriti, MZUSP 27085–8; Itaobim, MZUSP 57516. Lagoa Santa, MZUSP 25768–71; Santana do Araçuaí, MZUSP 20478; Vespaisano. MZUSP 12723–4; SÃO PAULO: Botucatu, MZUSP 14478, 14480–1; Buri, MZUSP

134955–6; Emas, MZUSP 11225–6. PARÁ: Estrada de Bragança y Ajuruteua: MPEG 9152–3, MPEG 9155, MPEG 9157, MPEG 9159, MPEG 9164. PARAGUAY: ÑEEMBUCÚ: Estancia San José, IIBP 0288 – 9, 0292.

Pseudopaludicola pusilla: COLOMBIA: ANTIOQUÍA: Puerto Triunfo, ICN 39751–5; ATLÁNTICO: Juan de Acosta: Serranía Pajuancho, ICN 49075–6; Sabana Grande: Ciénaga del Convento, ICN 46170; near Río Magdalena, ICN 49078; Tubará: corregimiento Juaruco, 49080–2; BOLIVAR: Santa Catalina, Hacienda El Ceibal, ICN 43305; CESAR: La Gloria, Hacienda Montecarlo, ICN 37286; Boyacá, Puerto Boyacá, ICN 52973; CÓRDOBA: Lorica: Estación piscícola CVS, ICN 48721; Lorica, Vereda Ceiba Tejado, Ciénaga Pantano Bonito, ICN 48901–2; Montería: Sitio El Lucido, SW Ciénaga Betanci, ICN 48710–3; Maracayo, N Ciénaga Betanci, ICN 48874, 48878, 48883; Los Araujos, ICN 48918; Pueblo Nuevo, Hacienda Toronto, ICN 48737, 48739; Tierra Alta, Urrá 1, ICN 43388–93; SANTANDER: Wilches, ICN 14700 (CS), 14712 (CS), 14778–9 (CS); Corregimiento el Pedral: ICN 14702, 14719, 14734, 14740, 14743. Puerto Parra, ICN 53875; Tolima, AMNH-A 75163, 149044.

Pseudopaludicola riopiedadensis: BRAZIL: SÃO PAULO: Rio Piedade, CENAI 2599 (holotype), 2600 (paratype).

Pseudopaludicola saltica: BRAZIL: DISTRITO FEDERAL: Brasília, MZUSP 25350–1; GOIAS: Amaro Leite, MZUSP 85610; Caldas Novas, MZUSP 75118; Chapada dos Veadeiros, MZUSP 85571–3; Sítio D'abadia, MNRJ 47598–606; MATO GROSSO: Brejinho de Nazaré, MZUSP 85545; Chapada dos Guimarães, ANSP 11230 (lectotype), 11234 (paralectotype), MZUSP 79844, ZUEC 5134, 5136–8, 5142–4, 5854–5; Mato Verde, MZUSP 25500–1; São Domingos, Rio das Mortes, MZUSP 896, 911, 973, 990, 4229–30; São Vicente: MZUSP 85622, 85764–6; MINAS GERAIS: Serra da Canastra, MZUSP 133002–3.

Pseudopaludicola serrana: BRAZIL: MINAS GERAIS: Serra do Cipó, Santana do Riacho (Jaboticatubas), between Vespasiano and Conceição do Mato Dentro, Km 110-42, ZUEC 02323; Municipio São João del Rei: Serra do Lenheiro: ZUEC 16447–52, 16453 (CS), 16455–6. Santuario do Caraça, Santa Barbara: MNRJ 78238–46.

Pseudopaludicola ternetzi: BRAZIL: GOIAS: Goiás, MNRJ 39818–25; Uruaçu, MNRJ 447, 5460–1 (paralectotypes), 5462 (lectotype); Rio Verde, MZUSP 25503–5; Santa Rita do Araguaia, Fazenda Babilônia, MZUSP 66668, 66670, 66672–7; Santa Rita do Araguaia, Fazenda Mutum, MZUSP 66728–31; Serra de Caldas Novas, MZUSP 75120–6; MATO GROSSO: Chapada dos Guimarães, Aldea Velha, CFBH 114–5, 149–50, MZUSP 60188–9, 37470–2, 79840–1, ZUEC 14138–9, 14141–3; Escola Evangélica de Buriti. CFBH 151; Porto Esperidião, MZUSP 376, 52224; Nova Xavantina: Rio Areões, MNRJ 71293; São Vicente, MZUSP 85582–6. PARAGUAY: CONCEPCIÓN: Cerrados del Tagatiyá, IIBPH 804–5 (CS); 808 (CS); 866, 868, 896–7, 900 (CS).