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A new species of *Pseudopaludicola* Miranda-Ribeiro (Leiuperinae: Leptodactylidae: Anura) from the Cerrado of southeastern Brazil with a distinctive advertisement call pattern

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Abstract

A new species of *Pseudopaludicola* is described from the Cerrado of southeastern Brazil. The new taxon is diagnosed from the *P. pusilla* species group by the absence of either T-shaped terminal phalanges or toe tips expanded, and promptly distinguished from all (13) recognized taxa currently assigned to *Pseudopaludicola* by possessing isolated (instead of regular call series), long (117–187 ms) and non-pulsed advertisement calls.

Key words: Advertisement call, Cerrado, *Pseudopaludicola giarettai* new species, State of Minas Gerais

Introduction

The genus *Pseudopaludicola* Miranda-Ribeiro currently comprises 13 recognized species distributed throughout South America (Frost 2011). The monophyly of the genus is supported by external morphology (hypertrophied antebrachial tubercle) (Lynch 1989) and osteology (Lobo 1995). This genus encompasses two phenetic species groups (*sensu* Lynch 1989): (i) *P. pusilla* (Ruthven 1916) species group, defined by the presence of T-shaped terminal phalanges, includes five species: *P. boliviana* Parker, *P. canga* Giaretta and Kokubum (2003), *P. ceratophyes* Rivero and Serna (1984), *P. llanera* Lynch (1989), and *P. pusilla*; and (ii) *P. falcipes* (Hensel 1867) species group, with no distinctive set of morphological characters supporting its monophyly, includes eight species: *P. falcipes*, *P. mineira* Lobo (1994), *P. murundu* Toledo *et al.* (2010), *P. mystacalis* (Cope 1887), *P. riopiedadensis* Mercadal de Barrio and Barrio (1994), *P. saltica* (Cope 1887), *P. serrana* Toledo (2010), and *P. ternetzi* Miranda-Ribeiro. Cytogenetic data corroborated the monophyly of the *P. pusilla* species group with chromosome number 2n=18 (Duarte *et al.* 2010), previously supported only by a morphological approach (Lynch 1989). In constrast, cytogenetic data of some taxa currently assigned to the *P. falcipes* species group presented chromosome number varying from 2n=16 to 2n=22 (Fávero *et al.* 2011), providing no conclusive results to support its monophyly, previously regarded as a paraphyletic group (see Lynch 1989; Lobo 1995).

During a survey of anurans in human-altered areas (smallholding) of Cerrado remnants in the State of Minas Gerais, southeastern Brazil, I found a new species that I describe herein on the basis of bioacoustic and morphological/morphometric data. The new taxon is not assigned to the *P. falcipes* species group as it should probably not represent a monophyletic grouping. Future studies based on a phylogenetic approach will assess its phylogenetic position and interrelationships in the genus *Pseudopaludicola*.

Material and methods

Specimens, advertisement call, and data on habitat of the new species were obtained on the Mato do Engenho

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smallholding (18°46'08.54"S, 44°26'53.83"W; 621 m above sea level), Municipality of Curvelo, State of Minas Gerais, southeastern Brazil.

Type series is housed in the Collection of frogs at the Universidade Federal de Uberlândia (AAG-UFU), Municipality of Uberlândia, State of Minas Gerais, Brazil. Pictures presented in Figures 2–3 were slightly edited in order to remove flash shadows caused by camera.

Seven morphometric characters of adult specimens were measured under a stereomicroscope coupled to an ocular micrometer. Three morphometric characters (snout-vent length, head length, and head width) were taken with calipers to the nearest 0.1 mm under a stereomicroscope. Eight measurements follow Duellman (1970): snout-vent length (SVL), head length (HL), head width (HW), internarial distance (IND), eye-nostril distance (END) (= snout length), eye diameter (ED), shank length (SL) (= tibia length), and foot length (FL); two measurements follow Heyer *et al.* (1990): hand length (HAL), and thigh length (TL). Toe tips were dissected from two male paratopotypes (AAG-UFU 0314 and 0319) so as to verify shape (simple / T-shaped) of terminal phalanges (*sensu* Lynch 1971, 1989). Systematic classification follows Pyron and Wiens (2011). For additional examined specimens, see Appendix 1.

Vocalizations were recorded using a digital recorder (M-audio Microtrack II) set at 48.0 kHz sample rate and 16 bits resolution, coupled to a directional microphone (Sennheiser K6/ME66). Bioacoustic variables were analyzed with Audacity software version 1.3.13 Beta (Audacity Team 2011); sound graphs were obtained with Seewave (version 1.6) (Sueur *et al.* 2008), R (version 2.13) package (R Development Core Team 2011); Seewave settings were Hanning window, 85% overlap, and 512 points resolution (FFT). Call terminology generally followed McLister *et al.* (1995), and Duellman and Trueb (1994). Voucher specimens for call recordings: *Pseudopaludicola giarettai* **sp. nov.**: AAG-UFU 0309–0313.

Bioacoustic data on topotypic specimens of *P. mystacalis*, *P. ternetzi*, and populations of *Pseudopaludicola* from the region of São José do Rio Preto (State of São Paulo) that might tentatively be assigned to *P. riopiedadensis* were made available by André Pansonato. Thus, bioacoustic data will not be provided herein but published in a forthcoming in-depth taxonomic review of the genus.

Species account

Pseudopaludicola giarettai, new species

Figures 1–3

Holotype. AAG-UFU 0312, adult male collected on the Mato do Engenho smallholding (18°46'08.54"S; 44°26'53.83"W, 621 m above sea level), Municipality of Curvelo, State of Minas Gerais, southeastern Brazil, in February 2011 by T. R. de Carvalho. **Paratopotypes.** Nine adult males: AAG-UFU 0309–0311, AAG-UFU 0313–0317, and AAG-UFU 0319; one adult female: AAG-UFU 0318. All collected with the holotype.

Diagnosis. *Pseudopaludicola giarettai* **sp. nov.** is assigned to the genus by possessing hypertrophied antebrachial tubercle. The new taxon is diagnosed by the following combination of characters: (1) large size (SVL 16.2–18.0 mm in adult males); (2) absence of either T-shaped terminal phalanges or expanded toe tips (disks or pads); (3) short hindlimbs (tibiotarsal articulation reaching the eye); and (4) distinctive whistled advertisement call possessing a non-pulsed structure.

Comparison with other species. The new taxon (SVL 16.2–18.0 mm in adult males) is diagnosed from the species of the *P. pusilla* group (*P. boliviana*, *P. ceratophyes*, *P. canga*, *P. llanera*, and *P. pusilla*) by the absence of either T-shaped terminal phalanges or expanded toe tips (disks or pads). *Pseudopaludicola giarettai* **sp. nov.** is diagnosed from almost all congeners by possessing a unique advertisement call (fig. 4) with non-pulsed pattern in comparison with that of congeners [pulsed advertisement calls: *P. boliviana* (Duré *et al.* 2004), *P. saltica* and *P. falcipes* (Haddad & Cardoso 1987), *P. mystacalis* (A. Pansonato unpubl. data), *P. murundu* (Toledo *et al.* 2010), *P. serrana* (Toledo 2010), *P. mineira* (Pereira & Nascimento 2004), *P. riopiedadensis* (L.D. Vizotto pers. comm.; A. Pansonato unpubl. data), and *P. ternetzi* (A. Pansonato unpublished data)]; and from the non-pulsed pattern of *P. canga* (Giaretta & Kokubum 2003) by the emission of isolated long (117–187 ms) non-pulsed notes, whereas *P. canga* releases sequences of up to nine short ($\underset{\sim}{}$ 52 ms; Giaretta & Kokubum 2003) non-pulsed notes.

Pseudopaludicola giarettai **sp. nov.** (adult male SVL 16.2–18.0 mm) is distinguished from almost all congeners [except *P. ternetzi* (16.0–18.6; Lobo 1996)] by its larger size (see Tables 1–2): *P. boliviana* (11.1–13.4; Lynch 1989), *P. canga* (14.6–16.2; Giaretta & Kokubum 2003), *P. ceratophyes* (female SVL 13.1; Rivero & Serna 1985), *P. falcipes* (13.5–16.0; Lobo 1994), *P. llanera* (12.5–14.6; Lynch 1989), *P. mineira* (12.1–14.8; Lobo 1994), *P. murundu* (13.7–15.4; Toledo *et al.* 2010), *P. mystacalis* (11.0–16.8; Lobo 1996), *P. pusilla* (11.9–14.2; Lynch 1989), *P. saltica* (15.2–16.9; Haddad & Cardoso 1989), and *P. serrana* (15.0–15.8; Toledo 2010). Morphological/morphometric comparisons with *P. riopiedadensis* were very limited due to the lack of data on the species in the original description (see Mercadal de Barrio & Barrio 1994). The new taxon can also be distinguished from *P. murundu*, *P. saltica*, and *P. serrana* by having short hindlimbs (tibiotarsal articulation reaching the eye), whereas all three abovementioned taxa have long hindlimbs (tibiotarsal articulation extending beyond the tip of snout).

TABLE 1. Morphometric characters (in millimeters) of *Pseudopaludicola giarettai* **sp. nov.** type series (including the holotype) from the Municipality of Curvelo, State of Minas Gerais, Brazil. Mean±SD (minimum–maximum). The letter 'N' corresponds to the number of specimens measured.

Morphometric characters	*P. giarettai* **sp. nov.** Males (N=10)	Female (N=1)
SVL	17.1±0.7 (16.2–18.0)	20.5
HL	7.4±0.3 (7.0–7.9)	8.4
HW	5.8±0.3 (5.4–6.6)	6.6
IND	1.2±0.1 (1.1–1.4)	1.2
END	1.3±0.1 (1.0–1.5)	1.7
ED	1.9±0.1 (1.7–2.0)	2.2
HAL	4.3±0.1 (4.1–4.5)	4.7
TL	7.5±0.4 (6.9–8.0)	8.9
SL	8.6±0.2 (8.3–8.9)	9.0
FL	9.0±0.4 (8.4–9.5)	10.1

TABLE 2. Comparative minimum-maximum adult male body sizes (in millimeters) of *Pseudopaludicola*. * Based on the holotype, a female; ** Based on the holotype, probably a female considering its body size.

Species	Body size
P. boliviana	11.1–13.4
P. canga	14.6–16.2
P. ceratophyes	13.1*
P. falcipes	13.5–16.0
P. giarettai **sp. nov.**	16.2–18.0
P. llanera	12.5–14.6
P. mineira	12.1–14.8
P. murundu	13.7–15.4
P. mystacalis	11.0–16.8
P. pusilla	11.9–14.2
P. riopiedadensis	19.7**
P. saltica	15.2–16.9
P. serrana	15.0–15.8
P. ternetzi	16.0–18.6

Description of holotype. Snout rounded in dorsal and lateral (figs. 3A–B) views (Heyer *et al.* 1990). Dorsal surfaces of body and limbs smooth. Lateral of head (upper lip and under the eyes and tympanum area) and flanks

with white granules. Cloacal region granular. Vomerine teeth absent; tongue ovoid, free behind; dorsal surface smooth; belly and throat smooth; tympanic ring undefined; outer and inner metacarpal tubercles ovoid; small supernumerary tubercle indistinct (fig. 3C); relative length of fingers I < II ≃ IV < III; inner metatarsal tubercle oval; outer metatarsal tubercle round and conical (fig. 3D); relative length of toes I < II < III ≃ V < IV; finger and toe tips not expanded; finely keratinized nuptial asperities on the base of thumbs; toes barely webbed and with extensive fringing; one round antebrachial tubercle present on distal portion of forearms, no distinctive tubercle on heel; outer edge of tarsus and forearm smooth; a dermal ridge present from inner metatarsal tubercle to mid-length of tarsus; no pigmentation on the base of tongue; body elliptical. Nostrils subtly protuberant, directed anterolaterally. Canthus rostralis rounded. Loreal region slightly concave. Choanae rounded. Eye protuberant, its diameter larger than interorbital distance. Interorbital area flat. Vocal sac single, externally expanded, large, and with longitudinal folds; vocal slits present.

FIGURE 1. Adult male paratopotype (AAG-UFU 0311) of *Pseudopaludicola giarettai* **sp. nov.** in life from the Municipality of Curvelo, State of Minas Gerais, Brazil.

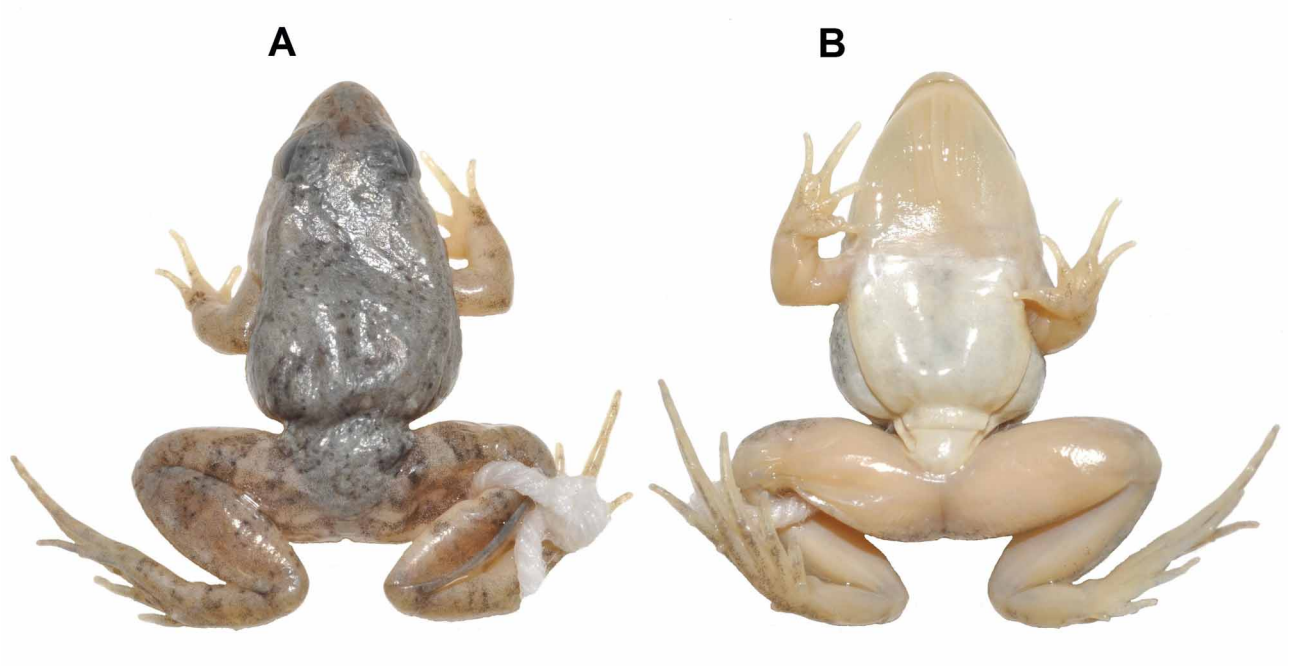

FIGURE 2. *Pseudopaludicola giarettai* **sp. nov.**, adult male, holotype (AAG-UFU 0312). Dorsal (A) and ventral (B) views of body. SVL = 17.1 mm.

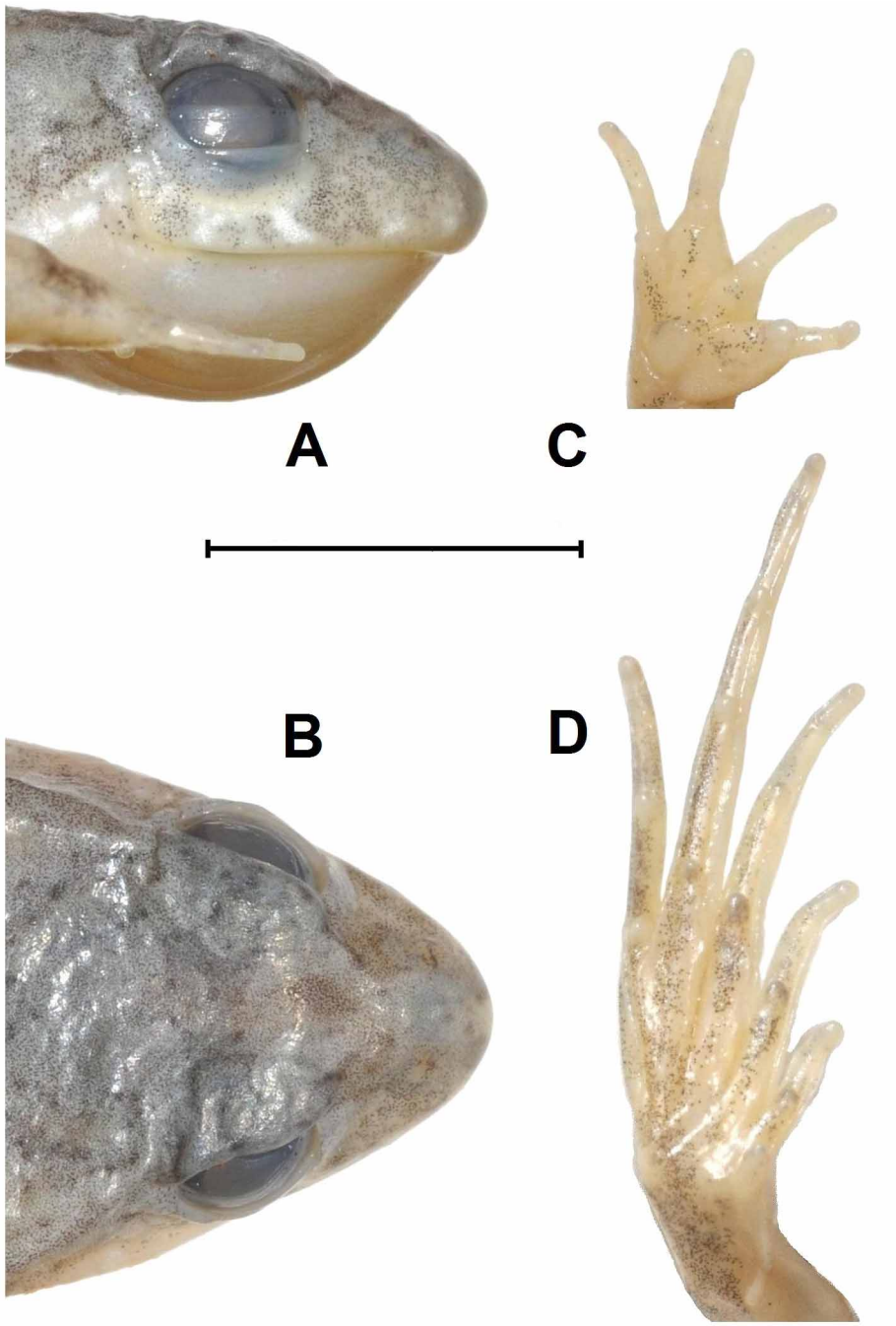

FIGURE 3. *Pseudopaludicola giarettai* **sp. nov.**, adult male, holotype (AAG-UFU 0312). Dorsal (A) and lateral (B) views of head; ventral view of hand (C), and foot (D). Scale bar = 5 mm.

Measurements of holotype. Snout-vent length 17.1 mm, head length 7.5 mm, head width 5.9 mm, internarial distance 1.2 mm, eye-nostril distance 1.3 mm, eye diameter 2.0 mm, hand length 4.5 mm, thigh length 7.9 mm, shank length 8.5 mm, and foot length 9.1 mm.

Color of holotype in preservative (fig. 2). In preservative, dorsal surfaces of dorsum and limbs pale brown with dark brown spots or irregularly shaped stripes; belly cream; vocal sac yellowish cream. White spots on upper lips extending to the flanks.

Color in life. Color in life (fig. 1) was based on three adult male paratopotypes (AAG-UFU 0309–0311). Dorsal surfaces of body and limbs light brown. Dorsum smooth with a few granules, some of them larger on scapular region, tending to red. Dorsum and flanks with irregular dark brown blotches. Lateral of head bordering upper jaw and flanks with white spots, extending to the flanks. Belly cream, vocal sac yellowish. Ill-defined dark brown stripes on dorsal surface of thighs (a few) and interorbital region (single).

Variation. The female (AAG-UFU 0318) has a more robust body, nuptial pads absent, and gular region without longitudinal folds. The specimens AAG-UFU 0309–0311, 0314, and 0316 have undulating-like paravertebral stripes from the posterior corner of eyes to the half of dorsum. The specimens AAG-UFU 0311 and 0315 have copper color stains on scapular region. The specimens AAG-UFU 0309, 0311, 0314–0315, and 0319 have a chevron-like stripe between eyes. The specimen AAG-UFU 0316 has cream broad longitudinal stripes from the posterior corner of eyes to the half of dorsum.

Natural history. Males call during daytime and decrease call activity after nightfall. Males call on the margins of artificial ponds and slow-flowing streamlets with clean water and muddy bottom. Several males were in calling activity during a period with no precipitation for about two months long in the study site in February/2011. Syntopic species include *Leptodactylus fuscus*, *Physalaemus cuvieri*, *Pseudopaludicola* sp., *Dendropsophus rubicundulus*, *Hypsiboas albopunctatus*, *Hypsiboas crepitans*, *Scinax* sp. (gr. *ruber*), *Elachistocleis cesarii*, and *Rhinella schneideri*.

Distribution. *Pseudopaludicola giarettai* **sp. nov.** is known from the type locality, and from the Municipality of Buritizeiro (State of Minas Gerais), approximately 160 km in a straight line northward from the type locality (vocalizations, M.N.C. Kokubum).

Etymology. The name is a noun in the genitive case honoring Ariovaldo A. Giaretta for his extensive contribution to the knowledge of Brazilian anurans.

***Pseudopaludicola giarettai* advertisement call.** Eight males recorded (N = 247 advertisement call samples). Quantitative variables are summarized in Table 3. Advertisement call (fig. 4) consists of a whistled structure (non-pulsed note) with 4 detected harmonics with ascendant frequency modulation along its extent. Advertisement call may present a slight or a strong descendant intensity modulation in the first third or in the half of calls so that sound energy may even be barely identified. Advertisement call is emitted at a rate of 117–153 calls/minute (mean 136.2, SD = 14.8), and at a rate of 2.0–2.6 calls/second (mean 2.3, SD = 0.2). Call duration was 117–187 ms (mean 153.9, SD = 15.8) with intercall interval from 181–1,316 ms (mean 302.1, SD = 54.1). Ascendant dominant frequency modulation was emphasized from less than 4,000 Hz to more than 5,000 Hz along each call. Peak of sound energy was 3,981–4,719 Hz (mean 4,374, SD = 150.0). Dominant frequency coincided with the fundamental harmonic, the other three harmonics were increasingly weaker in sound intensity, emphasized from 8,278–9,337 Hz (mean 8,847, SD = 321.0), from 11,871–13,931 Hz (mean 12,977, SD = 742.0), and from 15,703–18,189 Hz (mean 17,320, SD = 672.0), being the third and fourth harmonics invisible in sound figures (less than -36 dB in the relative amplitude scale bar).

TABLE 3. Advertisement call variables of *Pseudopaludicola giarettai* **sp. nov.** from the Municipality of Curvelo, State of Minas Gerais, Brazil. Mean±SD (minimum–maximum). The letter 'N' corresponds to the number of recorded specimens.

Advertisement call variables	*P. giarettai* **sp. nov.** (N=8)
Call duration (ms)	153.9±15.8 (117–187)
Intercall interval (ms)	302.1±54.1 (181–1,316)
Peak of sound energy (Hz)	4,374±150.0 (3,981–4,719)
Call rate (calls/minute)	136.2±14.8 (117–153)
Call rate (calls/second)	2.0±2.6 (2.3–0.2)

Remarks. One population of *Pseudopaludicola* sp. from the Municipality of Muriaé, State of Minas Gerais, was also reported to emit whistled calls (non-pulsed note structure) (Santana *et al.* 2010). Morphological/bioacoustic evaluation is required to assess the species identity of that population so as to assign it as being conspecific to *P. giarettai* **sp. nov.** or to an additional undescribed species.

Assessment of the richness in the Neotropical genus *Pseudopaludicola* species is particularly difficult due to the conservative morphology of its species. Hence, bioacoustic data are essential for the recognition of cryptic lineages currently assigned to a few available specific names within the genus.

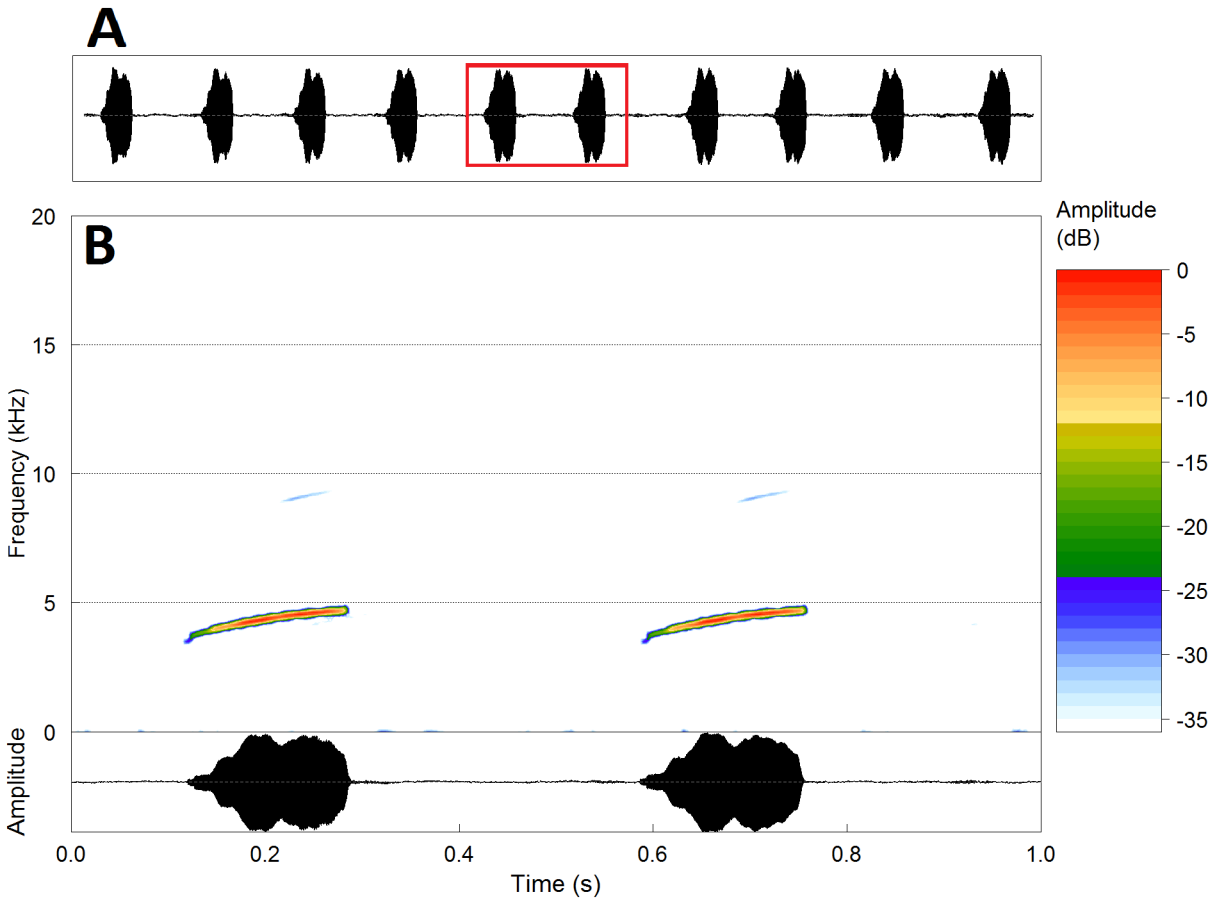

FIGURE 4. A. Oscillogram (5 seconds) of a sequence of ten advertisement calls of *Pseudopaludicola giarettai* sp. nov. from the Municipality of Curvelo, State of Minas Gerais, Brazil. B. Audiospectrogram (above) and corresponding oscillogram (below) detailing two advertisement calls (fifth and sixth calls delimited by a red rectangle outline) of the sequence of ten advertisement call of *Pseudopaludicola giarettai* **sp. nov.** Sound file: Pseudop_giarettaiMG8TRC_AAGmt; 18:21h, 23 February 2011; air 24ºC, water 26ºC. Vouchered recording.

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APPENDIX 1. Additional examined specimens.

Pseudopaludicola cf. *mineira*—BRAZIL: MINAS GERAIS: Curvelo (AAG-UFU 0307–0308, 0386–0387); *Pseudopaludicola mystacalis*—BRAZIL: MATO GROSSO: Cuiabá (AAG-UFU 4721); *Pseudopaludicola* cf. *mystacalis*—BRAZIL: GOIÁS: Rio Verde (AAG-UFU 0462–0469); MINAS GERAIS: Uberlândia (AAG-UFU 2605, 2623, 3939–3940, 3943, 3945, 3947); SÃO PAULO: São José do Rio Preto (AAG-UFU 2572); *Pseudopaludicola* cf. *ternetzi* —BRAZIL: GOIÁS: Caldas Novas (AAG-UFU 4322–4324, 4343–4349, 4353); MATO GROSSO: Pontal do Araguaia (AAG-UFU 3122); MATO GROSSO DO SUL: Bela Vista (AAG-UFU 0158); MINAS GERAIS: Araporã (AAG-UFU 0405, 0409, 0413); Monte de Alegre de Minas (AAG-UFU 4607, 4609, 4611); Uberlândia (AAG-UFU 4624–4625, 4627); *Pseudopaludicola* sp.—BRAZIL: MINAS GERAIS: Uberlândia (AAG-UFU 4728–4732).