



Taxonomic circumscription of *Adenomera martinezi* (Bokermann, 1956) (Anura: Leptodactylidae: Leptodactylinae) with the recognition of a new cryptic taxon through a bioacoustic approach

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Abstract

In this paper, we provide a taxonomic circumscription of *Adenomera martinezi* from its type locality (Cachimbo, southwestern State of Pará) since its description (57 years ago) based on a newly collected series of eleven adult topotypes, and through a bioacoustic approach, recognize an undescribed cryptic taxon under this nominal species, which is widely distributed in central and northern Brazil. *Adenomera martinezi* and *Adenomera saci* **sp. nov.** can be diagnosed from all congeners by their distinctive 4–6 symmetrically arranged rows of longitudinal dark-colored spots on dorsum. They differ from each other through advertisement call structure, pulsed in *Adenomera martinezi* (audibly pulsed to the human ear), and non-pulsed in *Adenomera saci* **sp. nov.** (a whistle to the human ear). The recognition of *Adenomera saci* **sp. nov.** has conservation implications. Based on our assumed distribution of *A. martinezi* and *Adenomera saci* **sp. nov.**, the IUCN conservation status of *A. martinezi* requires a reassessment, inasmuch as we herein reconsider this species, as far as we know, as endemic to Cachimbo, southwestern State of Pará, Brazil. The 2004 extinction risk assessment included both *A. martinezi* and *Adenomera saci* **sp. nov.**, and the conservation status category of ‘Least Concern’ might only be applied to *Adenomera saci* **sp. nov.**, a widely distributed and abundant species in central and northern Brazil.

Key words: *Adenomera saci* **sp. nov.**, Cachimbo, Chapada dos Veadeiros, Cerrado, Conservation status, taxonomy

Introduction

The species is a widely used and fundamental unit of analysis in biology, although species concepts and delineation of species boundaries is a longstanding biological and philosophical issue (Dayrat 2005; de Queiroz 2007; Vences & Wake 2007). The problem of species delineation and identification can be exemplified by groups that exhibit little morphological variation (Jaiswara *et al.* 2012), the so-called cryptic species. Bickford *et al.* (2007) extensively discussed definitions and applicability of this term, being defined as typically closely related species that are very similar and difficult to distinguish morphologically. Integrative taxonomy has been proposed as a framework to bring together conceptual and methodological developments, employing non-morphological suites of characters, as molecular phylogenetics and bioacoustics, for the unraveling of taxonomic complexity and uncovering undetected diversity under cryptic species complexes (Heyer *et al.* 1996; Padial & De la Riva 2009; Glaw *et al.* 2010; Padial *et al.* 2010).

Frogs have species recognition and mate choice systems that rely on non-morphological characteristics (advertisement calls), and might harbor a great cryptic diversity (Bickford *et al.* 2007). Integrating independent lines of evidence to properly address underlying unresolved taxonomic complexity might, thereafter, lead to elucidation of biological identities in *Adenomera*, uncovering an expected cryptic diversity within this group of frogs, whose comprising taxa share general morphology relatedness, and for which complementary datasets (e.g. acoustic, molecular) are often needed for taxonomic resolution (Heyer 1984; Angulo & Icochea 2010).

The genus *Adenomera* Steindachner currently comprises 15 recognized species distributed throughout South America east of the Andes (Frost 2013). Several studies have revised and discussed the definition and phylogenetic position of *Adenomera*, as well as the interrelationships of its comprising taxa. Historically, Lutz (1930) was the first author to assemble *Adenomera* species at a lower rank under *Leptodactylus*, the subgenus *Parvulus*: *Leptodactylus (Parvulus) trivittatus* (see Lutz 1926), currently under *A. marmorata* (Heyer 1973), and *L. (Parvulus) nanus* Müller. Subsequently, Parker (1932) claimed that the older available name *Adenomera* had priority, and proposed its use as a subgenus of *Leptodactylus* instead of *Parvulus*, and Parker (1935) reallocated *A. marmorata* Steindachner to *Leptodactylus (L. marmoratus)*. Heyer (1969a) followed Parker's nomenclatural rearrangements, and assigned the subgenus *Adenomera* to members of the *L. marmoratus* species group, both *L. marmoratus* (Steindachner) and *L. hylaedactylus* (Cope) being included in the same group by Heyer (1969b); and Heyer (1973) assigned three additional species [*L. andreae* Müller, *L. bokermanni* Heyer, and *L. martinezi* Bokermann]. Heyer (1974a) resurrected the genus *Adenomera*, and recovered *Adenomera + Lithodytes* (imbedded with *Leptodactylus discodactylus*) as sister group of the remaining *Leptodactylus* taxa. While there have been additional subsequent studies, the phylogenetic position of *Adenomera* is still disputed based upon different lines of evidence (external morphology, osteology, molecular biology, natural history), with two current hypotheses: i) corroboration of the preferred phylogenetic relationship hypothesis in Heyer (1974a), placing *Adenomera + Lithodytes* as sister group of *Leptodactylus* in the narrow sense (Frost *et al.* 2006; Ponsa 2008; Ponsa *et al.* 2010), in spite to the phylogenetic position and generic status of *Leptodactylus discodactylus* (including other generic combinations, under *Lithodytes* and *Vanzolinius*; see Heyer 1974a, b; Heyer 1998; De Sá *et al.* 2005; Ponsa 2008; Pyron & Wiens 2011); rendering its comprising taxa (*L. marmoratus* group) paraphyletic in relation to *Leptodactylus*, nested within the *L. fuscus* group (Heyer 1998), or placed as a subset of this species group (Giaretta *et al.* 2011). It worth stressing that Frost *et al.* (2006) changed the generic statuses of *Adenomera* and *Lithodytes*, synonymizing the former with the latter, which was ranked as a subgenus of *Leptodactylus* in an endeavor to avoid a potential paraphyly based on Heyer's (1998) and Kokubum and Giaretta's (2005) evidence, discussed earlier. The two most recent phylogenetic studies (Pyron & Wiens 2011; Fouquet *et al.* 2013) recovered the genera *Lithodytes* and *Adenomera* as consisting of the sister clade of *Leptodactylus* in the narrow sense as well. In this respect, Fouquet *et al.* (2013) tested the phylogenetic position of *Adenomera martinezi*, which was recovered within the genus *Adenomera*, corroborating the first proposition of generic reallocation of *Leptodactylus martinezi* (Bokermann, 1956) to *Adenomera* (Heyer 1974a). Thus, we assign the new species of the study to this genus as well, assuming a putative close relationship between both taxa.

Bokermann (1956) described *Adenomera martinezi* (as *Leptodactylus martinezi*) from Cachimbo, southwestern State of Pará, based on two adult specimens (holotype and allotype) collected in January 1955. This name has subsequently been applied to several non-topotype populations of central and northern Brazil (Heyer 1973; Vitt *et al.* 2005; Silva Jr. *et al.* 2009; Kopp *et al.* 2010). We visited the type locality of *A. martinezi* 57 years later and succeeded in obtaining a newly collected series of adult topotype specimens, as well as recording its previously unknown advertisement call. In this paper, we bring forward the taxonomic circumscription of *Adenomera martinezi*, as well as the description of its advertisement call, and through a bioacoustic approach, we recognize an undescribed cryptic taxon previously subsumed under this nominal species.

Material and methods

Specimens and vocalizations of *Adenomera martinezi* were obtained at its type locality: Campo de Provas Brigadeiro Velloso (9°22'S, 54°54'W; approximately 440 m a.s.l.), Cachimbo, Municipality of Novo Progresso, southwestern State of Pará, northern Brazil. Specimens and/or vocalizations of the new species were obtained at four sites in central Brazil: i) Chapada dos Veadeiros (14°10'S, 47°47'W; approximately 1030 m a.s.l.), Municipality of Alto Paraíso de Goiás, State of Goiás; ii) Municipality of Cristalina (16°43'S, 47°33'W; approximately 1095 m a.s.l.), State of Goiás; iii) Municipality of Pontal do Araguaia (15°58'S, 52°17'W; approximately 320 m a.s.l.), State of Mato Grosso; and iv) Municipality of Alto Araguaia (17°22'S, 53°13'W; approximately 730 m a.s.l.), State of Mato Grosso.

A sample of five tadpoles was collected in Cristalina (State of Goiás) in February 2013. Tadpoles were found within shallow pools (2 cm deep) with standing water on a rocky bed at a site with scattered short grass-like vegetation (< 30 cm tall). The new species was the only calling frog species at this study site (N = 3 fieldtrips).

Three tadpoles were preserved and two were raised in laboratory, one of them almost metamorphosed (Gosner's stage 41; well-developed hind limbs). As the general morphology of the tadpoles are in accordance with the expected morphology for exotrophic tadpoles of *Adenomera* (De la Riva 1995), given that it is the only species of this genus in the area, and that the foot features of these larvae are in compliance with those of adult specimens, we assume that the collected sample represents tadpoles of the new species.

Type specimens and additional examined specimens (Appendix 1) are housed in the following Brazilian zoological collections: Coleção de Anuros do Museu de Biodiversidade do Cerrado, Universidade Federal de Uberlândia (AAG-UFU), Uberlândia, State of Minas Gerais; Coleção Herpetológica da Universidade de Brasília (CHUNB), Brasília, Distrito Federal; Museu de Zoologia da Universidade de São Paulo (MZUSP), São Paulo, State of São Paulo; Museu de Zoologia da Universidade Estadual de Campinas (ZUEC), Campinas, State of São Paulo; Museu Nacional do Rio de Janeiro (MNRJ), Rio de Janeiro, State of Rio de Janeiro.

Twelve morphological measurements were taken by T.R.C from adult specimens using a micrometric ocular piece coupled to a stereomicroscope; snout-vent length (SVL) was measured with calipers to the nearest 0.1 mm under a stereomicroscope. Nine measurements followed Duellman (1970): snout-vent length (SVL), head length (HL), head width (HW), eye diameter (ED), tympanum diameter (TD), eye-nostril distance (END) (= snout length), internarial distance (IND), shank length (SL) (= tibia length), and foot length (FL). Four measurements followed Heyer *et al.* (1990): hand length (HAL), forearm length (FRL), thigh length (TL), and tarsus length (TSL). Head shape terminology followed Heyer *et al.* (1990). Five morphometric characters were measured from a single tadpole using a micrometer ocular piece coupled to a stereomicroscope: interorbital distance (IOD); internarial distance (IND), tail muscle height (TMH), maximum tail height (MTH), and tail muscle width (TMW); three morphometric characters were measured with calipers to the nearest 0.1 mm under a stereomicroscope: total length (TL), body length (BL), and tail length (TAL). Measurement standards followed Altig (2007); morphological nomenclature followed Altig and McDiarmid (1999), and Altig (2007); larval staging followed Gosner (1960). Pictures of both live and preserved specimens were slightly edited to remove flash shadows caused by camera.

Vocalizations were recorded using digital equipment (M-Audio Microtrack II, Marantz PMD 670, Marantz PMD 671) set at a sampling rate of 48.0 kHz and a 16-bit resolution, coupled to directional microphones (Sennheiser K6/ME66 or K6/ME67). Calls were analyzed on a personal computer with Windows XP Professional operating system using the software Raven Pro version 1.5, 64-bit version (Bioacoustics Research Program 2012). Temporal variables were measured from audiospectrograms; dominant frequency was obtained in the software (Peak Frequency measurement function). Raven Pro settings: window type = Hanning; window size = 256 samples; brightness = 50%; contrast = 50%; overlap = 85%; DFT size = 256 samples; grid spacing = 188 Hz. Sound figures were obtained using Seewave version 1.6.4 package (Sueur *et al.* 2008) of the R platform version 2.15.1, 64-bit version (R Development Core Team 2012). Seewave settings: window name (Fourier transform window) = Hanning; window length = 256 samples; overlap = 85%. Bioacoustic terminology mostly followed Duellman and Trueb (1994). Given that the advertisement calls of the present study presented either the first (fundamental) or the second harmonic as the dominant frequency (*sensu* Duellman & Trueb 1994), we opted to refer to both the first and second harmonic frequencies as 'peaks of sound energy', consisting of the peaks of greatest sound energy emphasized in both harmonics obtained in the software of bioacoustics analysis. Total mean values of bioacoustic variables (mean and standard deviation) given in the advertisement call sections and tables were obtained from mean individual values due to different call samples for each recorded individual, an approach to try to reduce any bias from differential individual call samples, whereas the range of values encompassed the minimum and maximum values of all analyzed call samples. Detailed information on figured sound files are summarized in Appendix 2. Voucher specimens: *Adenomera martinezi*—AAG-UFU 1515–1520 (Cachimbo, Pará); *Adenomera sp. nov.*—AAG-UFU 0109 (Chapada dos Veadeiros, Goiás); AAG-UFU 0809, 1761 (Cristalina, Goiás); AAG-UFU 0208 (Pontal do Araguaia, Mato Grosso).

The overall thermal dependency of temporal variables of the advertisement calls of *Adenomera martinezi* and *Adenomera sp. nov.* was tested via principal component analysis (PCA) using Fitopac 2.1 (Shepherd 2010) from mean individual values to understand the interactions between sound variables. Then, a multiple correlation analysis on the first component scores was performed using Systat 10.2 (Wilkinson 2000) to identify potential temperature-dependent variables. Air temperature, mean individual values of the temporal variables of *Adenomera martinezi* and *Adenomera sp. nov.* advertisement calls and their respective first principal component scores are summarized in Appendix 3. This statistical approach was not likewise applied to calling male size (SVL) dependency of spectral variables (peaks of sound energy) of the advertisement calls of both taxa due to the lack of

either a minimum sample of voucher males or a non-correspondence of voucher males and recordings. A second PCA of temporal and spectral bioacoustic variables of *Adenomera* **sp. nov.** populations was performed on a correlation matrix. The analysis was performed on log₁₀-transformed variables. Eigenvectors, eigenvalues and variation explained along the first three principal components are summarized in Appendix 4.

Bioacoustic data of *Adenomera* species were extracted from their original descriptions, or additional studies/unpublished doctoral theses. Several works present bioacoustic data of *Adenomera* species, yet we made an effort to only make use of bioacoustic variables from topotype specimens or information available from the nearest point to type localities, so as to make unequivocal comparisons with respect to *A. martinezi* and the new species, inclusive of bioacoustic diagnoses, since we faced several species identity problems in literature, with populations either unassigned to a nominal species or under uncertain taxonomic status. Comparative bioacoustic variables and their respective sources are listed in Table 3.

Results

Taxonomic accounts

Redescription of *Adenomera martinezi* (Bokermann)

Leptodactylus martinezi Bokermann, 1956: Type locality: Cachimbo (9°22'S, 54°54'W), southwestern Pará, Brazil.

Revised diagnosis. *Adenomera martinezi* is assigned to the genus (*L. marmoratus* species group and *Adenomera* genus definitions; *sensu* Heyer 1973, 1974, respectively) by the following set of characters: 1) small body size (up to 34.1 mm; *sensu* Kok *et al.* 2007); 2) toes lacking fringing or webbing; 3) adult males lacking thumb spines; 4) first and second fingers of approximately equal length. *Adenomera martinezi* is diagnosed from the other 14 species of *Adenomera* by the following combination of characters: 1) presence of 4–6 symmetrically arranged rows of longitudinal dark-colored spots on dorsum; 2) medium-sized species (adult male SVL 21.9–24.2 mm); 3) vertebral pin-stripe always present; 4) toe tips unexpanded and unflattened; 5) long advertisement call (63–151 ms) with 15–21 pulses (audibly pulsed to the human ear).

Comparison with other species. *Adenomera martinezi* can be diagnosed from all congeners by its distinctive 4–6 symmetrically arranged rows of longitudinal dark-colored spots on dorsum (figs. 1, 2A).

Adenomera martinezi (adult male SVL 21.9–24.2 mm; Table 1) can additionally be diagnosed from *A. ajurauna*, *A. araucaria*, and *A. nana* (combined adult male SVL 16.3–20.0 mm; Kwet & Angulo 2002; Kwet 2007; Berneck *et al.* 2008) by its larger size, and from *A. lutzi* and *A. simonstuarti* by its smaller size (combined adult male SVL 25.9–34.1 mm; Kok *et al.* 2007; Angulo & Icochea 2010). *Adenomera martinezi* always has a vertebral pin-stripe, whereas no specimens of *A. bokermanni* (Heyer 1973), *A. engelsi* (Kwet *et al.* 2009), and almost no specimens of *A. andreae* (Heyer 1973) do. *Adenomera martinezi* is diagnosed from *A. thomei* by not presenting a mask-like pattern on the inverted triangle of the interorbital region (Almeida & Angulo 2006). *Adenomera martinezi* has neither expanded nor flattened toe tips, whereas specimens of *A. andreae*, *A. marmorata*, and *A. nana* do (Heyer 1973; Kwet 2007); from *A. lutzi*, by lacking tubercles on forearms, posterior surface of thighs black with distinct yellow, orange or red spotting or mottling, and males with yellow to orangish yellow throat and belly (Heyer 1975; Kok *et al.* 2007).

The advertisement call (fig. 3; Tables 2–3) distinguishes *Adenomera martinezi* from *A. ajurauna*, *A. engelsi*, *A. heyeri*, *A. lutzi*, and *A. nana*, by possessing a pulsed call structure (non-pulsed structure in all aforementioned comparative species). *Adenomera araucaria* was reported to possess calls with 5–11 severe amplitude modulations (see Kwet & Angulo 2002), and *A. simonstuarti* to possess 3–4 pulse-like, strong amplitude modulations (see Angulo & Icochea 2010), whereas *A. martinezi* calls possess 15–21 pulse calls (see fig. 3); from *A. andreae*, *A. hylaedactyla*, and *A. lutzi* (combined value range 16–62 ms) by a longer call duration (63–151 ms); from *A. marmorata* (dominant frequency 4.50–5.60 kHz), as well as *A. andreae*, *A. diptyx*, *A. nana*, and *A. thomei* [combined value range: 2.15–3.05 kHz (1st harmonic); 4.20–5.56 kHz (2nd harmonic)] by lower peaks of sound energy [1.88–2.06 kHz (1st harmonic); 3.38–4.13 kHz (2nd harmonic)]; from *A. andreae*, *A. coca*, and *A. hylaedactyla* (combined value range 2–15 pulses/call) by a greater number of pulses per call (15–21 pulses/call).

TABLE 1. Morphological measurements (mm) of adult topotype specimens of *Adenomera martinezi* from Cachimbo (Novo Progresso), State of Pará, Brazil; *Adenomera saci* sp. nov. type series (including the holotype) from the Chapada dos Veadeiros (Alto Paraíso de Goiás), State of Goiás, Brazil; and adult non-topotype specimens from Cristalina, State of Goiás; Brasília, Distrito Federal; Pontal do Araguaia and Xingu River basin (Ribeirão Cascalheira and Santa Terezinha), State of Mato Grosso, Brazil. Mean±SD (minimum–maximum). Measurement abbreviations are defined in the Material and Methods section.

	<i>Adenomera martinezi</i>										<i>Adenomera saci</i> sp. nov.	
	Cachimbo (PA)		Chapada dos Veadeiros (GO)		Cristalina (GO)		Brasília (DF)		Pontal do Araguaia (MT)		Xingu River basin (MT)	
	Males (N=10)	Female (N=1)	Males (N=6)	Males (N=5)	Males (N=5)	Male (N=1)	Males (N=4)	Female (N=1)	Males (N=1)	Males (N=5)		
SVL	23.3±0.7 (21.9–24.2)	25.7	21.5±1.0 (20.1–22.5)	20.3±0.5 (19.7–21.0)	21.5	22.2±0.5 (21.5–22.6)	24.2	22.7±0.7 (21.7–23.8)				
HL	9.3±0.2 (9.0–9.7)	9.8	8.5±0.4 (8.2–9.1)	8.5±0.5 (7.7–9.0)	8.4	9.1±0.1 (8.9–9.2)	9.3	9.0±0.1 (8.9–9.2)				
HW	7.2±0.3 (6.7–7.8)	8.0	6.7±0.4 (6.2–7.1)	6.8±0.3 (6.3–7.2)	6.9	7.3±0.2 (7.1–7.6)	7.6	7.5±0.3 (7.2–8.0)				
ED	2.3±0.2 (2.0–2.5)	2.8	2.2±0.1 (2.1–2.3)	2.1±0.1 (2.0–2.3)	2.2	2.3±0.1 (2.1–2.4)	2.7	2.2±0.1 (2.1–2.4)				
TD	1.5±0.1 (1.3–1.6)	1.7	1.3±0.2 (1.1–1.6)	1.3±0.1 (1.2–1.4)	1.4	1.5±0.1 (1.4–1.5)	1.8	1.4±0.1 (1.4–1.5)				
END	2.0±0.1 (1.8–2.2)	2.4	1.9±0.1 (1.8–2.0)	1.6±0.1 (1.5–1.8)	1.6	1.8±0.1 (1.7–1.9)	2.1	2.0±0.1 (1.8–2.1)				
IND	2.0±0.1 (1.8–2.1)	2.1	1.9±0.1 (1.7–2.1)	1.8±0.1 (1.8–1.9)	1.9	1.9±0.1 (1.8–1.9)	2.1	1.9±0.1 (1.8–2.0)				
HAL	5.7±0.2 (5.3–6.2)	6.6	5.2±0.4 (4.8–5.7)	5.1±0.4 (4.7–5.7)	4.9	5.1±0.4 (4.6–5.5)	5.9	5.4±0.2 (5.2–5.7)				
FRL	4.9±0.3 (4.5–5.3)	5.0	4.5±0.3 (4.2–4.9)	4.3±0.1 (4.2–4.3)	4.6	4.6±0.2 (4.3–4.8)	5.2	5.1±0.2 (4.8–5.3)				
TL	10.2±0.4 (9.4–10.8)	10.9	9.4±0.4 (9.6–10.6)	8.5±0.3 (8.2–8.8)	9.2	9.8±0.3 (9.5–10.1)	10.7	10.1±0.4 (9.5–10.6)				
SL	10.8±0.4 (10.0–11.3)	12.0	10.1±0.4 (9.6–10.6)	9.1±0.4 (8.5–9.5)	10.0	10.4±0.3 (10.0–10.7)	11.3	10.8±0.2 (10.5–11.0)				
TSL	7.1±0.3 (6.7–7.5)	7.6	6.6±0.3 (6.3–7.1)	6.1±0.3 (5.7–6.4)	6.5	6.9±0.1 (6.8–7.0)	7.8	7.2±0.2 (7.0–7.5)				
FL	13.3±0.5 (12.7–14.0)	14.9	11.8±0.5 (11.3–12.3)	10.6±0.3 (10.2–11.0)	11.2	11.6±0.5 (11.0–12.1)	13.4	12.2±0.2 (12.0–12.4)				

TABLE 2. Advertisement call variables and range of recording air temperatures of topotypes of *Adenomera martinezi* from Cachimbo (Municipality of Novo Progresso), State of Pará, northern Brazil; and *Adenomera saci* sp. nov. from its type locality (Chapada dos Veadeiros, Municipality of Alto Paraíso de Goiás, State of Goiás), and from the Municipalities of Cristalina (State of Goiás), Pontal do Araguaia, and Alto Araguaia (State of Mato Grosso), central Brazil. Mean±SD (minimum–maximum). N = number of recorded specimens (number of analyzed calls).

Bioacoustic variables	<i>Adenomera martinezi</i>		<i>Adenomera saci</i> sp. nov.		Cristalina (GO) N=4 (200)	Pontal do Araguaia (MT) N=7 (288)	Alto Araguaia (MT) N=1 (12)
	Cachimbo (PA) N=15 (750)	Chapada dos Veadeiros (GO) N=7 (343)	Chapada dos Veadeiros (GO) N=7 (343)	Alto Araguaia (MT) N=1 (12)			
Call duration (ms)	116.8±11.4 (63–151)	112.0±11.0 (90–139)	112.0±11.0 (90–139)	110.7±22.7 (72–140)	181.6±26.2 (119–241)	188.4±5.3 (184–203)	
Intercall interval (ms)	391.2±80.2 (200–1000)	361.4±77.4 (220–513)	361.4±77.4 (220–513)	308.6±81.1 (204–423)	385.2±67.0 (306–952)	685.9±141.9 (528–982)	
Calls/second	2.1±0.3 (1–3)	2.2±0.3 (1–3)	2.2±0.3 (1–3)	2.4±0.4 (2–3)	1.8±0.2 (1–2)	1.1±0.3 (1–2)	
Calls/minute	121.7±15.2 (97–142)	123.2±10.3 (111–132)	123.2±10.3 (111–132)	145.1±42.3 (115–175)	103.3±8.6 (90–114)	-----	
Pulses/call	18.3±1.3 (15–21)	No pulses	No pulses	No pulses	No pulses	No pulses	
Peak of sound energy (1 st harmonic) (kHz)	1.93±0.08 (1.88–2.06)	1.85±0.07 (1.69–2.06)	1.85±0.07 (1.69–2.06)	1.92±0.09 (1.88–2.06)	2.09±0.05 (2.06–2.25)	1.87	
Peak of sound energy (2 nd harmonic) (kHz)	3.74±0.18 (3.38–4.13)	3.67±0.18 (3.38–3.94)	3.67±0.18 (3.38–3.94)	3.81±0.13 (3.56–3.94)	4.18±0.15 (3.94–4.41)	3.79±0.08 (3.75–3.94)	
Temperature (°C)	24.6–27.1	20.0–27.0	20.0–27.0	21.0–26.0	26.0–36.0	23.4	

TABLE 3. Advertisement call data (range of values) of topotypes of *A. martinezi*, *A. saci* sp. nov., and comparative *Adenomera* species from their original descriptions, from topotypes, or information available from the nearest site to type localities, and their respective sources.

	Call duration (ms)	Pulses/call	Peak of sound energy (1 st harmonic) (kHz)	Peak of sound energy (2 nd harmonic) (kHz)	Source
<i>A. ajurauana</i>	130–190	No pulses	3.72–5.43	-----	Berneck <i>et al.</i> (2008)
<i>A. andreae</i> ¹	16–30	2–7	2.82–3.05	4.61–5.16	Kokubum (2008)
<i>A. araucaria</i>	86–140	5–11	1.72–3.36	4.63–5.40	Kwet & Angulo (2002)
<i>A. bokermanni</i> ¹	99–152	No pulses	1.79–1.83	3.40–3.57	Kokubum (2008)
<i>A. coca</i>	110–145	10–15	1.69–1.91	3.45–3.75	Angulo & Reichle (2008)
<i>A. diptyx</i> ²	57–88	Pulsed	2.18–2.28	4.20–4.50	Marquez <i>et al.</i> (1995)
<i>A. engelsi</i>	96–163	No pulses	~2.00	3.46–4.29	Kwet <i>et al.</i> (2009)
<i>A. heyeri</i>	137–185	No pulses	1.82–1.88	3.57–3.84	Boistel <i>et al.</i> (2006)
<i>A. hylaedactyla</i>	35–62	4–6	1.95–2.21	3.96–4.48	Angulo <i>et al.</i> (2003)
<i>A. lutzii</i>	41–64	No pulses	1.64–1.81	3.27–3.62	Kok <i>et al.</i> (2007)
<i>A. marmorata</i> ³	100	No pulses	< 1.00	4.50–5.60	Straughan & Heyer (1976)
<i>A. martinezi</i>	63–151	15–21	1.88–2.06	3.38–4.13	Present study
<i>A. nana</i>	67–122	No pulses	2.30–2.70	4.62–5.44	Kwet (2007)
<i>A. saci</i> sp. nov.	72–241	No pulses	1.69–2.25	3.38–4.41	Present study
<i>A. simonstuarti</i>	57–71	3–4	1.81–2.03	3.71–4.05	Angulo & Icochea (2010)
<i>A. thomei</i>	120–210	10–21	2.15–2.81	4.57–5.56	Almeida & Angulo (2006)

¹ Based on topotypes, extracted from the M.N.C. Kokubum unpublished doctoral thesis;

² Bioacoustic data of *A. diptyx* extracted from Marquez *et al.* (1995) as *A. andreae*; see De la Riva *et al.* (2000); pulsed structure of *A. diptyx* call was obtained in the V.H. Zaracho unpublished doctoral thesis and T.R. Carvalho unpubl. data;

³ Non-pulsed structure of *A. marmorata* call was based on fig. 28 in Heyer (1973), and T.R. Carvalho unpubl. data.

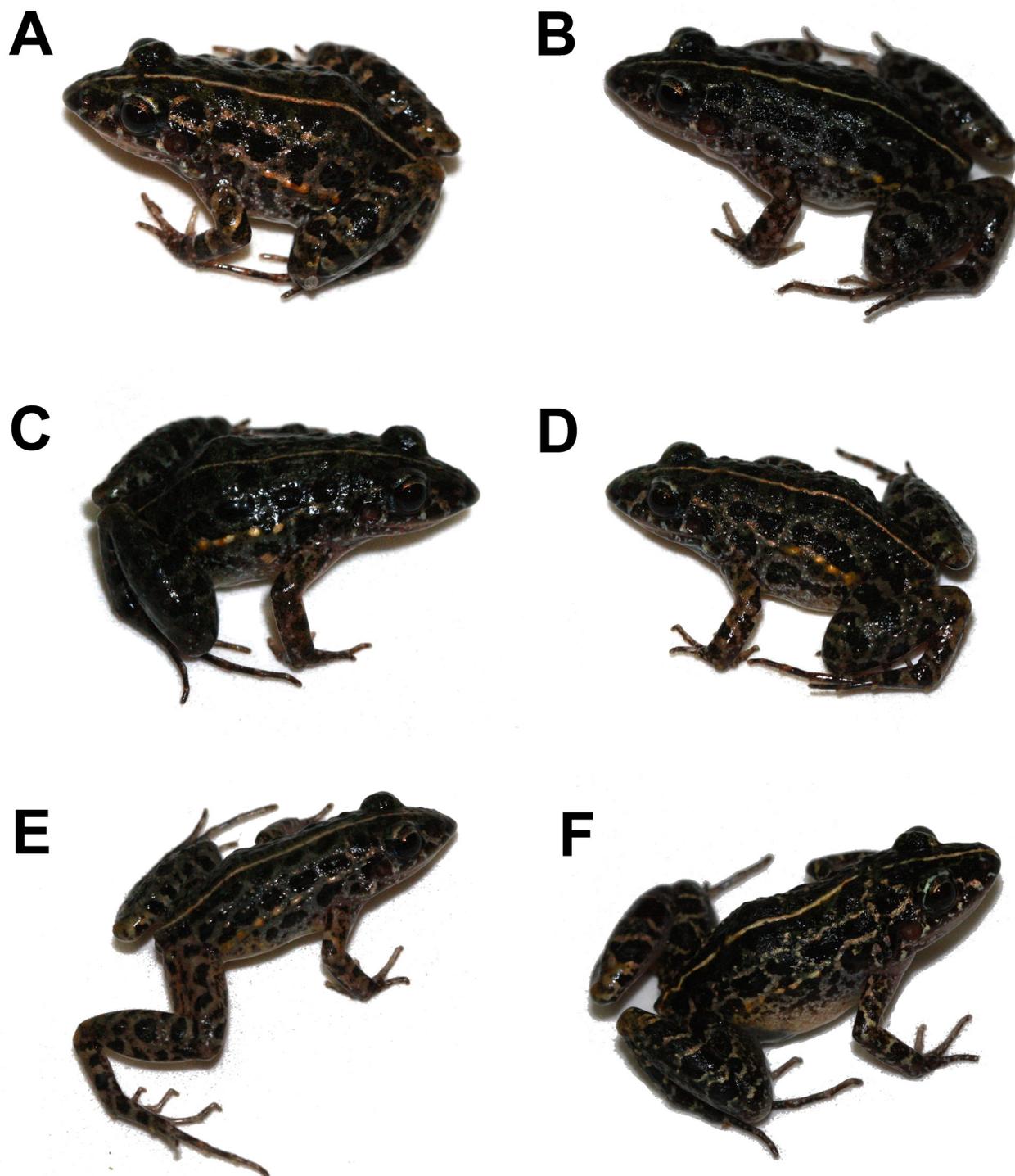


FIGURE 1. Live adult toptype specimens (Cachimbo, Pará) of *Adenomera martinezi*: (A) Voucher male AAG-UFU 1517 (SVL 23.7 mm); (B) Voucher male AAG-UFU 1515 (SVL 23.7 mm); (C) Voucher male AAG-UFU 1516 (SVL 24.2 mm); (D). Voucher male AAG-UFU 1520 (SVL 21.9 mm); (E) Male AAG-UFU 1522 (SVL 23.5 mm); (F) Female AAG-UFU 1521 (SVL 25.7 mm).

Description. Reference specimen: AAG-UFU 1517 (figs. 1A, 2A–B, 4), adult male. Body slender in dorsal view. Snout pointed in dorsal view (fig. 4A), acuminate in lateral view (fig. 4B). Snout tip with a well-developed shovel-like fleshy ridge. Nostrils positioned dorsolaterally, closer to snout tip than to eyes; canthus rostralis indistinguishable; loreal region concave; upper eyelids smooth. Supratympanic folds extending from posterior margin of eyes, passing over tympani, and extending to base of arms. A discrete, elongated post-commissural gland. Vocal sac subgular, internal. Vocal slits present; vomerine teeth in two straight rows posterior to choanae;

tongue elongated, free behind. Relative finger lengths $I \simeq II \simeq IV < III$; finger tips rounded, not expanded, and with no webbing or fringing. Inner metacarpal tubercle elongated; outer metacarpal tubercle nearly rounded (fig. 4D); subarticular and supernumerary tubercles rounded. No thumb asperities. Posterior half of dorsum glandular; dorsal surface of shanks, and dorsal and posterior surfaces of tarsi covered with minute tubercles. Vertebral pin-stripe present. Four longitudinal rows of symmetrically arranged spots. Flanks with longitudinal granular rows from posterior half of body towards groin. Throat and belly smooth. Ventral surface of thighs areolate. Posterior surface of thighs striped. Relative toe lengths $I < II < V \simeq III < IV$; toe tips rounded, not expanded (pointed toe tips: character state A; see fig. 1A in Heyer 1973); toes ridged laterally, with no webbing. Inner metatarsal tubercles ovoid, outer conical (fig. 4C); subarticular and supernumerary tubercles rounded. Tarsal folds extending from inner metatarsal tubercle to 1/2 length of tarsi, ending in a very slightly enlarged tubercle. Heel smooth.

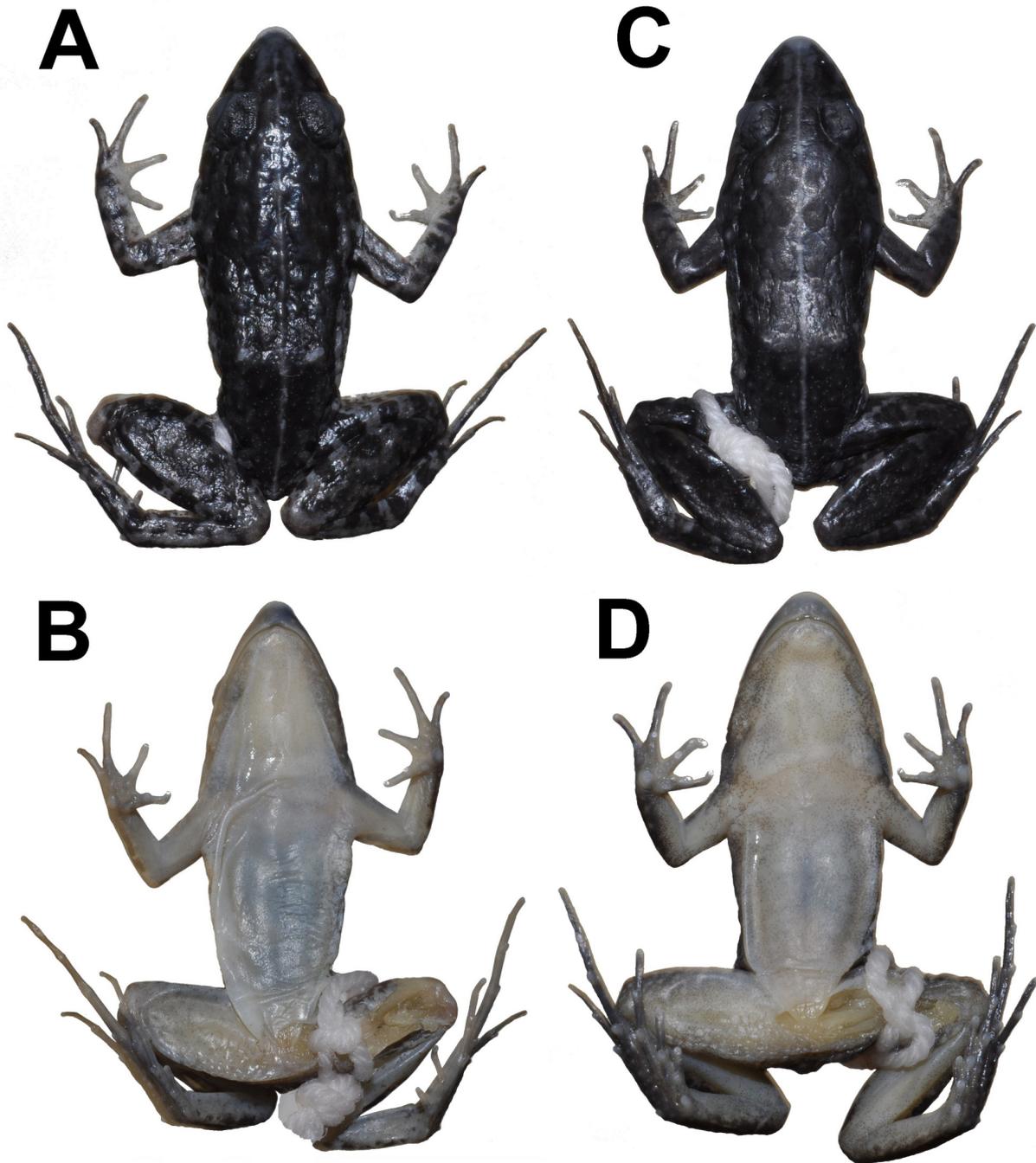


FIGURE 2. Dorsal (A) and ventral (B) views of an adult male topotype of *Adenomera martinezi* (AAG-UFU 1517; SVL 23.7 mm); and dorsal (C) and ventral (D) views of the holotype of *Adenomera saci* sp. nov. (AAG-UFU 1339; SVL 22.5 mm).

Coloration in alcohol (figs. 2A–B). Faded white shovel-like fleshy ridge on snout tip. Tympani reddish brown. Upper jaw with sinuous cream-colored stripes, and a white-colored post-commissural gland. Dorsum with four longitudinal rows of symmetrically arranged black spots on a very dark brown background, some portions faded gray. Flanks with cream-colored longitudinal row of granules on a light gray background. Green-colored vertebral stripe with some portions faded. White-tipped tubercles scattered on posterior half of dorsum, dorsal surface of shanks, and dorsal and posterior surfaces of tarsi. Dorsal surface of limbs with black stripes/blotches on a brownish gray background. Throat, belly, and ventral limb surfaces cream, with melanophores, but no distinctive color pattern. Posterior surface of thighs with cream-colored and black longitudinal stripes.

Coloration in life (fig. 1A). Iris bronze, upper eyelids bordered by an ill-outlined silver stripe. Tympani reddish brown. Dorsum with black longitudinal rows of spots on a moss green background. Spots and blotches on lateral of head and flanks with a whitish silver coloration. Flanks with orange longitudinal granular rows on a medium brown background. Vertebral stripe cream, with some portions tending toward an orange coloration. Dorsal surface of limbs with black stripes/blotches on a golden or moss green background. Throat and ventral surface of limbs cream, belly uniformly yellow.

Variation. Morphometric variation is summarized in Table 1. Variation within the topotype series is restricted to dorsal texture (smooth or glandular), and color pattern (medium gray to very dark brown background); the four to six longitudinal rows of symmetrically arranged black spots are variable due to the dorsal coloration, which might become evident or barely indistinguishable in preserved specimens. Posterior surface of thighs vary from a spotted or mottled pattern, which can form ill-defined and fragmented stripes (AAG-UFU 1515, 1522–1523, 1525) or a well-defined striped pattern (AAG-UFU 1516, 1518–1520, 1524). All specimens (except the female AAG-UFU 1521) have a well-defined faded white shovel-like fleshy ridge. Specimens in life presented some variation with respect to coloration, such as dorsal coloration (light gray/medium brown to moss green/dark brownish gray), vertebral stripe (cream to golden), granular rows on flanks (pale yellow to orange) (fig. 1).

Description of female. Reference specimen: AAG-UFU 1521 (fig. 1F), adult female. Body robust in dorsal view. Snout sub-acuminate in dorsal view, acuminate in lateral view. Snout tip lacks a well-developed shovel-like fleshy ridge. Nostrils closer to snout tip than to eyes; canthus rostralis indistinguishable; loreal region concave; upper eyelids smooth. Supratympanic folds extending from posterior margin of eyes, passing over tympani, and extending to base of arms. A discrete, elongated post-commissural gland. Vocal sac and vocal slits absent; vomerine teeth in two straight rows posterior to choanae; tongue elongated, free behind. Relative finger lengths $I < II \simeq IV < III$; finger tips rounded, not expanded, and with no webbing or fringing; inner metacarpal tubercle elongated; outer metacarpal tubercle nearly rounded; subarticular and supernumerary tubercles rounded. No thumb asperities. Dorsum smooth; dorsal surface of shanks, and posterior surface of tarsi with minute tubercles. Vertebral pin-stripe present. Four longitudinal rows of symmetrically arranged spots. Flanks with longitudinal granular rows from posterior half of body towards groin. Throat and belly smooth. Ventral surface of thighs areolate. Posterior surface of thighs mottled, forming ill-defined stripes. Relative toe lengths $I < II < V < III < IV$; toe tips rounded, not expanded (pointed toe tips: character state A; see fig. 1A in Heyer 1973); toes ridged laterally, with no webbing. Inner metatarsal tubercles rounded, outer conical; subarticular and supernumerary tubercles rounded. Tarsal folds extending from inner metatarsal tubercle to almost the entire length of tarsi, ending in a very slightly enlarged tubercle. Heel smooth.

Coloration in alcohol of the female. Upper jaw with sinuous cream-colored stripes. Tympani reddish brown. Dorsum with longitudinal rows of black spots on a gray background. Flanks with cream-colored row of granules on a light gray background. Cream-colored vertebral stripe. White-tipped tubercles scattered on the dorsal surface of shanks, and posterior surface of tarsi. Dorsal surface of limbs with black stripes/blotches on a brownish gray background. Posterior surface of thighs mottled, with cream and dark-colored spots/blotches, forming ill-defined cream longitudinal stripes. Throat, belly, and ventral surface of limbs cream-colored, with melanophores, but with no distinctive color pattern.

Coloration in life of the female (fig. 1F). Iris bronze, upper eyelids bordered by an ill-outlined bluish silver stripe. Tympani reddish brown. Dorsum with black longitudinal rows of spots on a grayish brown background. Flanks with golden/yellow longitudinal granular rows on a grayish brown background. Vertebral stripe cream, with some portions tending to an orange coloration. Dorsal surface of limbs with black stripes/blotches on a golden or grayish brown background. Throat and ventral surface of limbs cream, belly uniformly yellow.

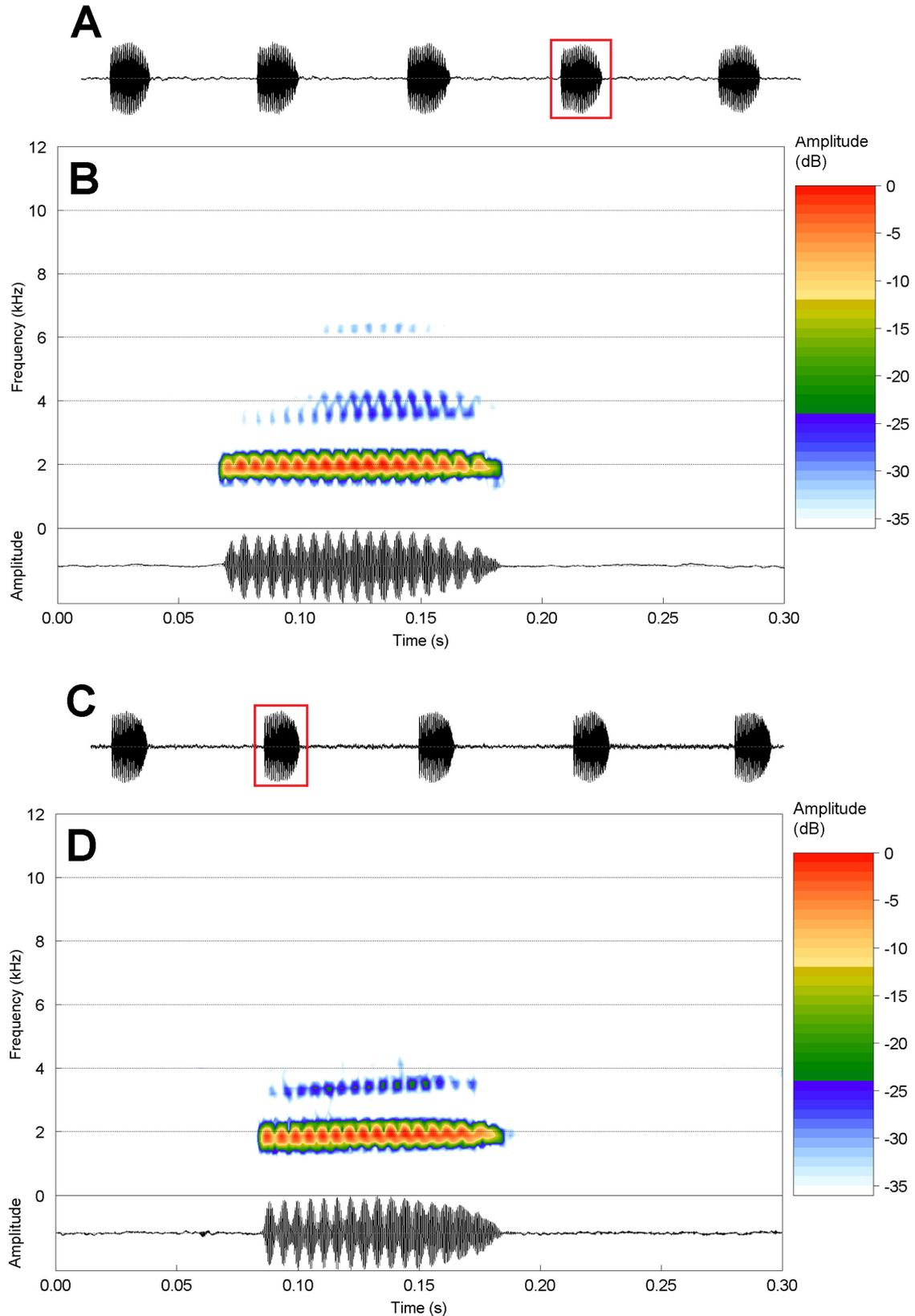


FIGURE 3. Advertisement call of two male topotypes (Cachimbo, Pará) of *Adenomera martinezi*. (A) A waveform section (2 seconds) with five calls; (B) Audiospectrogram (above) and respective oscillogram (below) of the fourth call highlighted by a red outline. Voucher specimen: AAG-UFU 1517; (C) A waveform section (2 seconds) with five calls; (D) Audiospectrogram (above) and respective oscillogram (below) of the second call highlighted by a red outline. Unvouchered recording.

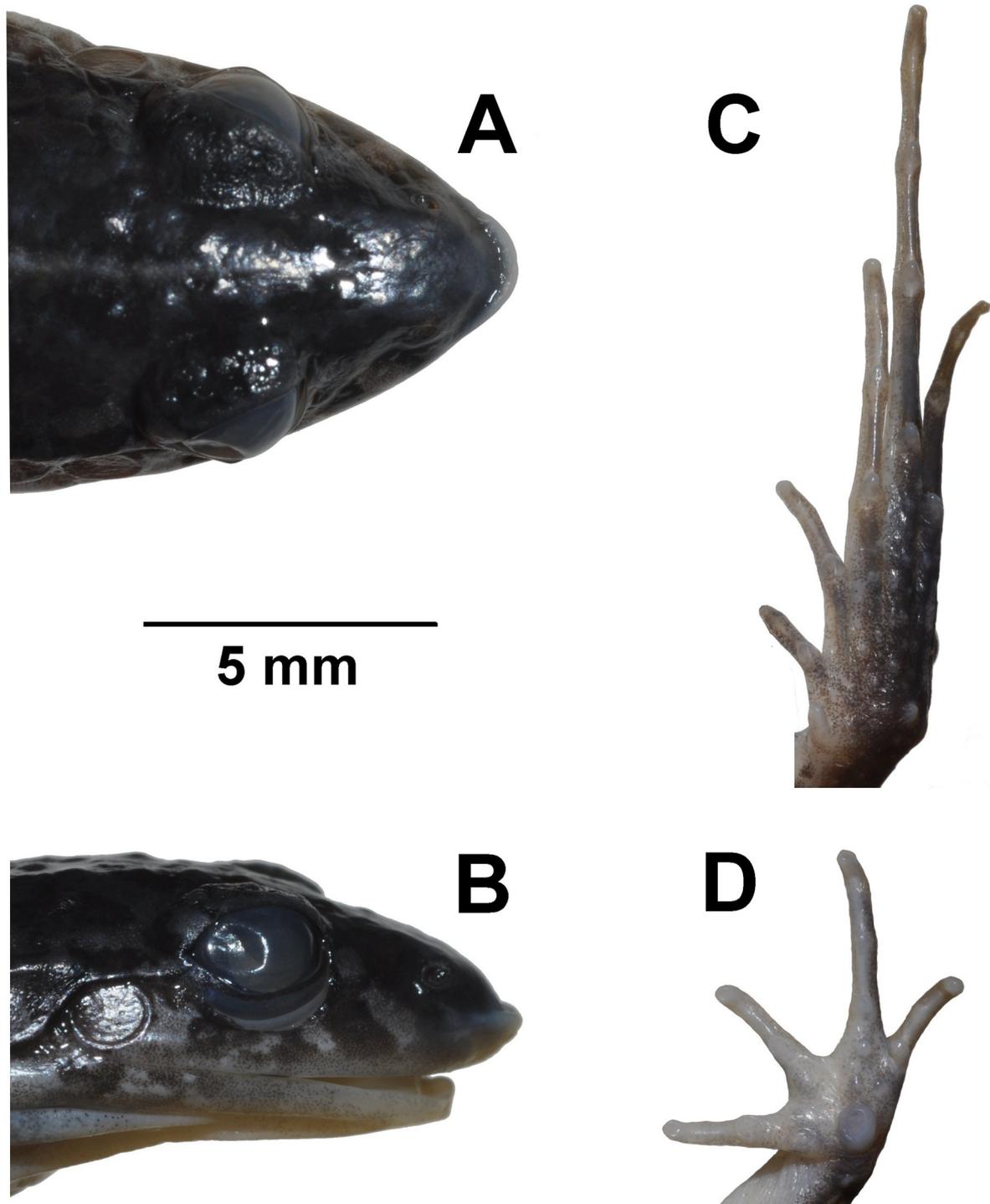


FIGURE 4. *Adenomera martinezi*, adult male toptype re-described (AAG-UFU 1517). Dorsal (A) and lateral (B) views of head, and ventral views of foot (C) and hand (D).

Advertisement call. Fifteen males recorded (N = 750 calls analyzed). Voucher toptypes (figs. 1A–D). Advertisement call (fig. 3; Table 2) consists of a pulsed (audible to the human ear) signal with deep and regular amplitude modulation. Calls have up to 6 visible harmonics and possess no or a very slight ascendant frequency modulation along their extent. Calls have 15–21 pulses (mean 18.3, SD = 1.3), and are emitted at a rate of 1–3 calls/second (mean 2.1; SD = 0.3), and at a rate of 97–142 calls/minute (mean 121.7; SD = 15.2). Call duration varies from 63–151 ms (mean 116.8; SD = 11.4), and intercall interval from 200–1000 ms (mean 391.2; SD = 80.2). Dominant frequency coincides with either the first (60%) or the second harmonic (13%) among the recorded

individuals, or can alternate between the first and second harmonics (27%) among analyzed calls of the same individual. Peak of sound energy varies from 1.88–2.06 kHz (mean 1.93 kHz; SD = 0.08) in the first harmonic, and/or from 3.38–4.13 kHz (mean 3.74 kHz; SD = 0.18) in the second harmonic. The other harmonics, if present, are increasingly weaker in sound energy.

Natural history. *Adenomera martinezi* occurs in grassy field environments associated with rock outcrops in sandy/muddy soil. Males call within underground chambers or from exposed calling sites, most times among grassy tufts. The species was heard only after nightfall.

Geographic distribution. *Adenomera martinezi* is known only from its type locality (Cachimbo, southwestern State of Pará, Brazil), a transitional Cerrado/Amazonian region (see Bokermann 1956).

Remarks. Bokermann (1956) stated that *Adenomera martinezi* had a very large tongue, occupying almost the entire mouth, almost double the dimension of those of *A. marmorata* and *A. hylaedactyla*. Topotype specimens showed no evidence of an exceptionally larger tongue in comparison with congeners, or even a potential distinctive shape of tongue. The type specimens re-examined by us and additional examined specimens (see Appendix I) are in compliance with our redescription with respect to the previously expected dimension of tongue for *Adenomera* species. Regarding dimorphic morphometric variables, such as larger tympanum (see Bokermann 1956), no evident differences were found either. Tympanum diameter of the allotype was indicated in the original description as the same of that of the holotype (1.0 mm). Values of this morphometric variable were greater both for adult males (1.3–1.6 mm; N=10) and adult female (1.7 mm; N=1). Morphological measurements of the adult female topotype were larger than those of the adult male topotypes, most probably explained by isometric differences due to the larger SVL. Our small sample (N=1 female) hampers any proper statistical approach to assess the significance of morphometric differences, as well as to seek potential allometric differences related to sexual dimorphism.

Examined material. Holotype (MZUSP 73695); Allotype (MZUSP 73684); Topotype specimens—BRAZIL: PARÁ: Novo Progresso, Cachimbo (AAG-UFU 1515–1525; CHUNB 40218–40221).

Adenomera saci, new species

Figures 2C–D, 5–8

Holotype. AAG-UFU 1339, adult male, collected at the Parque Nacional da Chapada dos Veadeiros (14°10'S, 47°47'W; approximately 1030 a.s.l.), Municipality of Alto Paraíso de Goiás, northern State of Goiás, central Brazil, on 10–15 November 2012, by T. R. de Carvalho, B. F. V. Teixeira, and L. B. Martins.

Paratopotypes. Five adult males: AAG-UFU 0108–0109, on 2–3 December 2010, by A. A. Giaretta; AAG-UFU 0762–0763, on 13–19 November 2011, by A. A. Giaretta and K. G. Facure; ZUEC 3287, on 10 January 1974, by W. C. A. Bokermann, all collected at the Chapada dos Veadeiros, northern State of Goiás, central Brazil.

Referred specimens. Non-topotype specimens under the name *Adenomera martinezi*: Heyer 1973; Vitt *et al.* 2005; Cintra *et al.* 2009; Moreira *et al.* 2009; Oda *et al.* 2009; Silva Jr. *et al.* 2009; Kopp *et al.* 2010; Morais *et al.* 2011; Valdujo *et al.* 2012.

Diagnosis. *Adenomera saci* **sp. nov.** is assigned to the genus (*L. marmoratus* species group and *Adenomera* genus definitions; *sensu* Heyer 1973, 1974, respectively) by the following set of characters: 1) small body size (up to 34.1 mm; *sensu* Kok *et al.* 2007); 2) toes lacking fringing or webbing; 3) adult males lacking thumb spines; 4) first and second fingers of approximately equal length. The new species is diagnosed from the other 15 species of *Adenomera* by the following combination of characters: 1) presence of four-six symmetrically arranged rows of longitudinal dark-colored spots on dorsum; 2) medium-sized *Adenomera* (adult male SVL 19.7–22.6 mm); 3) vertebral pin-stripe always present; 4) toe tips unexpanded and unflattened; 5) non-pulsed (a whistle to the human ear), long advertisement call (72–241 ms).

Comparison with other species. *Adenomera saci* **sp. nov.** is diagnosed from all congeners (except *A. martinezi*) by its distinctive 4–6 symmetrically arranged rows of longitudinal dark-colored spots on dorsum (figs. 2C–D, 5–7).

Adenomera saci **sp. nov.** (adult male SVL 19.7–22.6 mm; Table 1) can additionally be diagnosed from *A. araucaria*, and *A. nana* (combined adult male SVL 16.3–19.4 mm; Kwet & Angulo 2002; Kwet 2007) by its larger size, and from *A. lutzi*, and *A. simonstuarti* by its smaller size (combined adult male SVL 25.9–34.1 mm; Kok *et al.*

2007; Angulo & Icochea 2010). *Adenomera saci* **sp. nov.** has always a vertebral pin-stripe, whereas no specimens of *A. bokermanni* (Heyer 1973), *A. engelsi* (Kwet *et al.* 2009), and almost no specimens of *A. andreae* (Heyer 1973) do. *Adenomera saci* **sp. nov.** is diagnosed from *A. thomei* by not presenting a mask-like pattern on the inverted triangle of the interorbital region (Almeida & Angulo 2006); from *A. lutzii*, by lacking tubercles on forearms, posterior surface of thighs black with distinct yellow, orange or red spotting or mottling, and males with yellow to orangish yellow throat and belly (Heyer 1975; Kok *et al.* 2007). *Adenomera saci* **sp. nov.** has neither expanded nor flattened toe tips, whereas specimens of *A. andreae*, *A. marmorata*, and *A. nana* do (Heyer 1973; Kwet 2007).

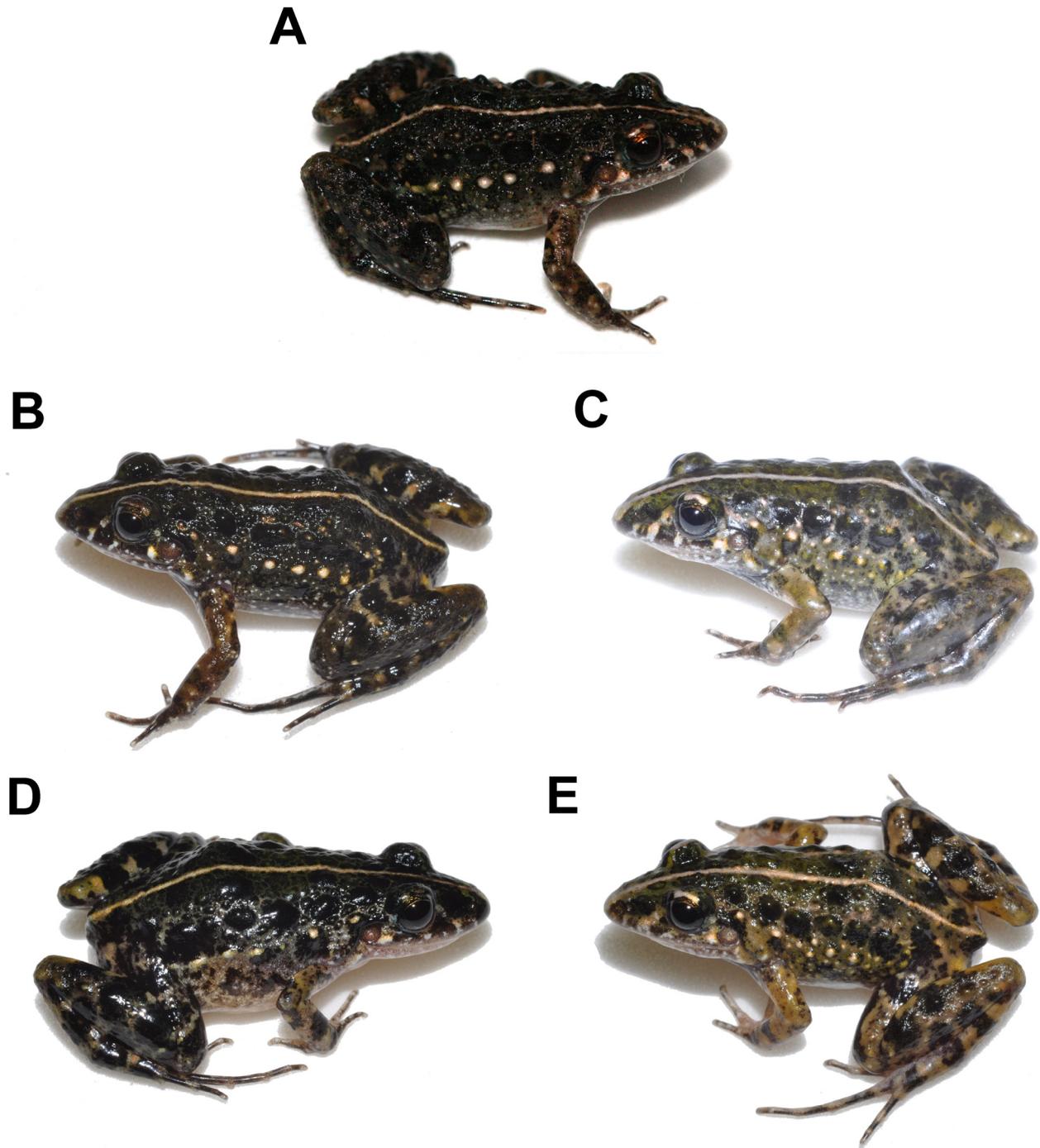


FIGURE 5. Live adult male specimens of *Adenomera saci* **sp. nov.** from the type locality (Chapada dos Veadeiros, Goiás): (A) Holotype AAG-UFU 1339 (SVL 22.5 mm); (B) Voucher paratopotype AAG-UFU 0109 (SVL 22.5 mm); (C) Paratopotype AAG-UFU 0108 (SVL 20.1 mm); (D) Paratopotype AAG-UFU 0762 (SVL 20.5 mm); (E) Paratopotype AAG-UFU 0763 (SVL 22.0 mm).

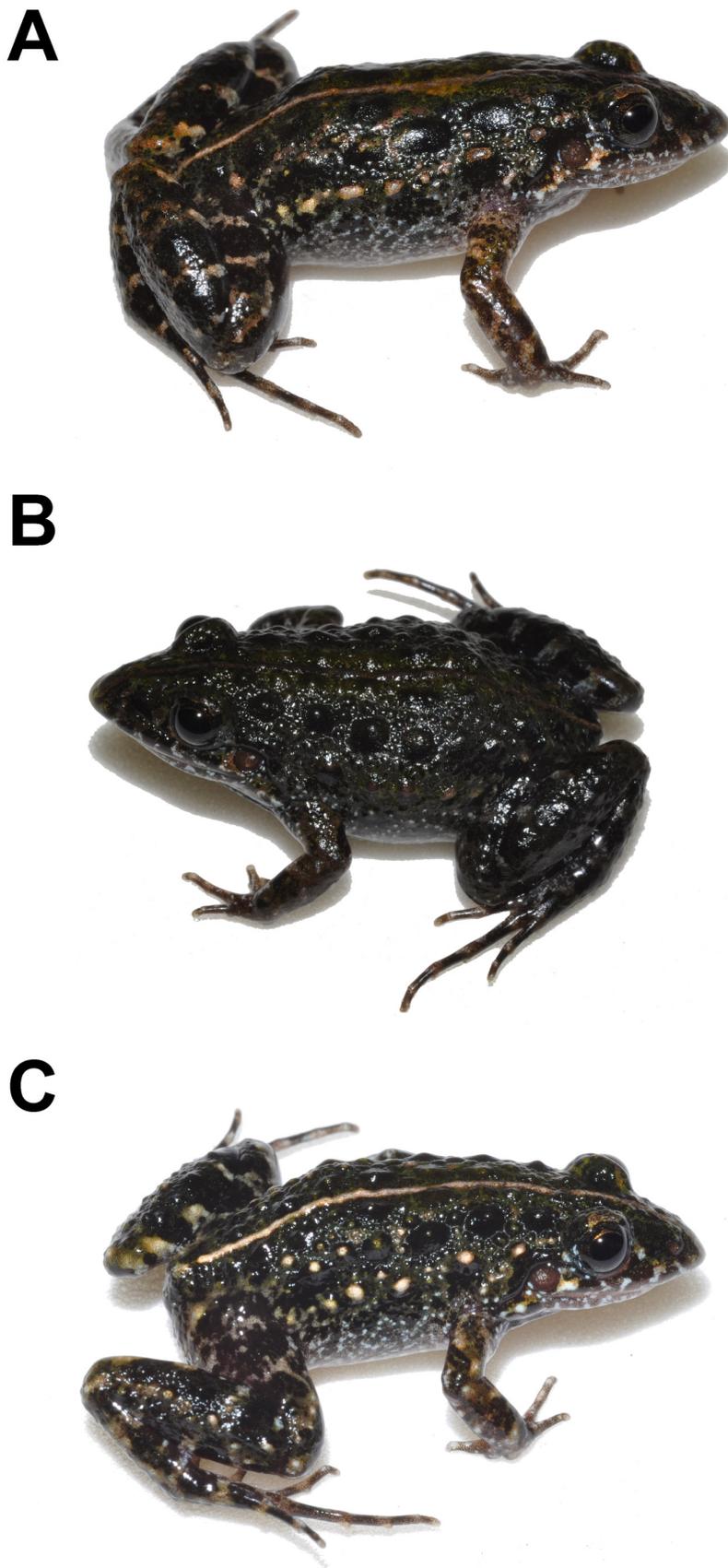


FIGURE 6. Live adult specimens of *Adenomera saci* sp. nov. from Cristalina, Goiás: (A) Voucher male AAG-UFU 1761 (SVL 20.5 mm); (B) Voucher male AAG-UFU 0809 (SVL 20.4 mm); (C) Male AAG-UFU 1673 (SVL 21.0 mm).

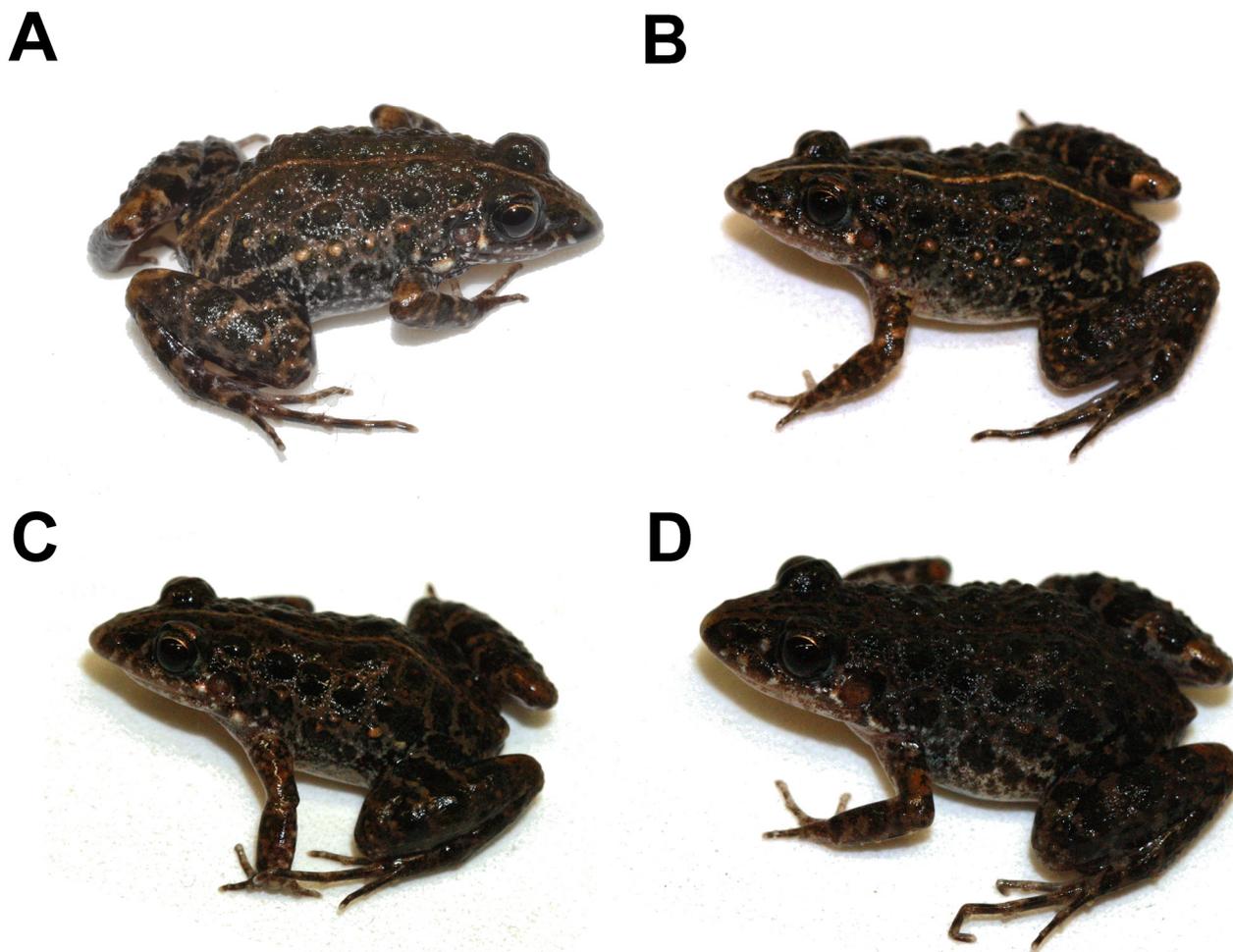


FIGURE 7. Live adult specimens of *Adenomera saci* **sp. nov.** from Pontal do Araguaia, Mato Grosso: (A) Voucher male AAG-UFU 0208 (SVL 21.5 mm); (B) Male AAG-UFU 1747 (SVL 22.2 mm); (C) Male AAG-UFU 1745 (SVL 22.6 mm); (D) Female AAG-UFU 1748 (SVL 24.2 mm).

The advertisement call (figs. 9–11; Tables 2–3) distinguishes *Adenomera saci* **sp. nov.** from *A. andreae*, *A. coca*, *A. hylaedactyla*, *A. martinezi* (present study), and *A. thomei*, by its non-pulsed structure, pulsed call structure in all aforementioned species (see Table 3). *Adenomera araucaria* was reported to possess calls with 5–11 severe amplitude modulations (see Kwet & Angulo 2002), and *A. simonstuarti* to possess 3–4 pulse-like, strong amplitude modulations (see Angulo & Icochea 2010), whereas *Adenomera saci* **sp. nov.** calls lack any strong amplitude modulations forming ‘pulse-like’ sections along their extent (see figs. 9–11). *Adenomera saci* **sp. nov.** can also be diagnosed from *A. andreae*, *A. hylaedactyla*, *A. lutzi*, and *A. simonstuarti* (combined value range 16–71 ms) by its longer call duration (72–241 ms); from *A. marmorata* (dominant frequency 4.50–5.60 kHz), as well as *A. andreae* and *A. nana* [combined value range: 2.30–3.05 kHz (1st harmonic); 4.61–5.44 kHz (2nd harmonic)] by its lower peaks of frequency [1.69–2.25 kHz (1st harmonic); 3.38–4.41 kHz (2nd harmonic)]. Bioacoustic values of *A. diptyx* from Santa Cruz, Bolivia (Marquez *et al.* 1995; see Table 3) had a marginal overlap with those of *Adenomera saci* **sp. nov.** in call duration, and peaks of sound energy of the first and second harmonics, but different from each other taking mean values into consideration. Furthermore, specimens recorded from Paraguay and Argentina (V.H. Zaracho doctoral thesis) and from the State of Mato Grosso do Sul, western Brazil (T.R. de Carvalho unpubl. data), assigned to *A. diptyx* had a pulsed call, which can help diagnose this species from the non-pulsed advertisement call pattern of *Adenomera saci* **sp. nov.**

Adenomera saci **sp. nov.** can additionally be diagnosed from *A. andreae* (Hero 1990; Menin & Rodrigues 2013), *A. hylaedactyla* (Heyer & Silverstone 1969; Menin *et al.* 2009), *A. marmorata* (Heyer *et al.* 1990), and *Adenomera* sp. (Kokubum & Giaretta 2005), by having exotrophic larvae, with tooth rows on oral papillae, and

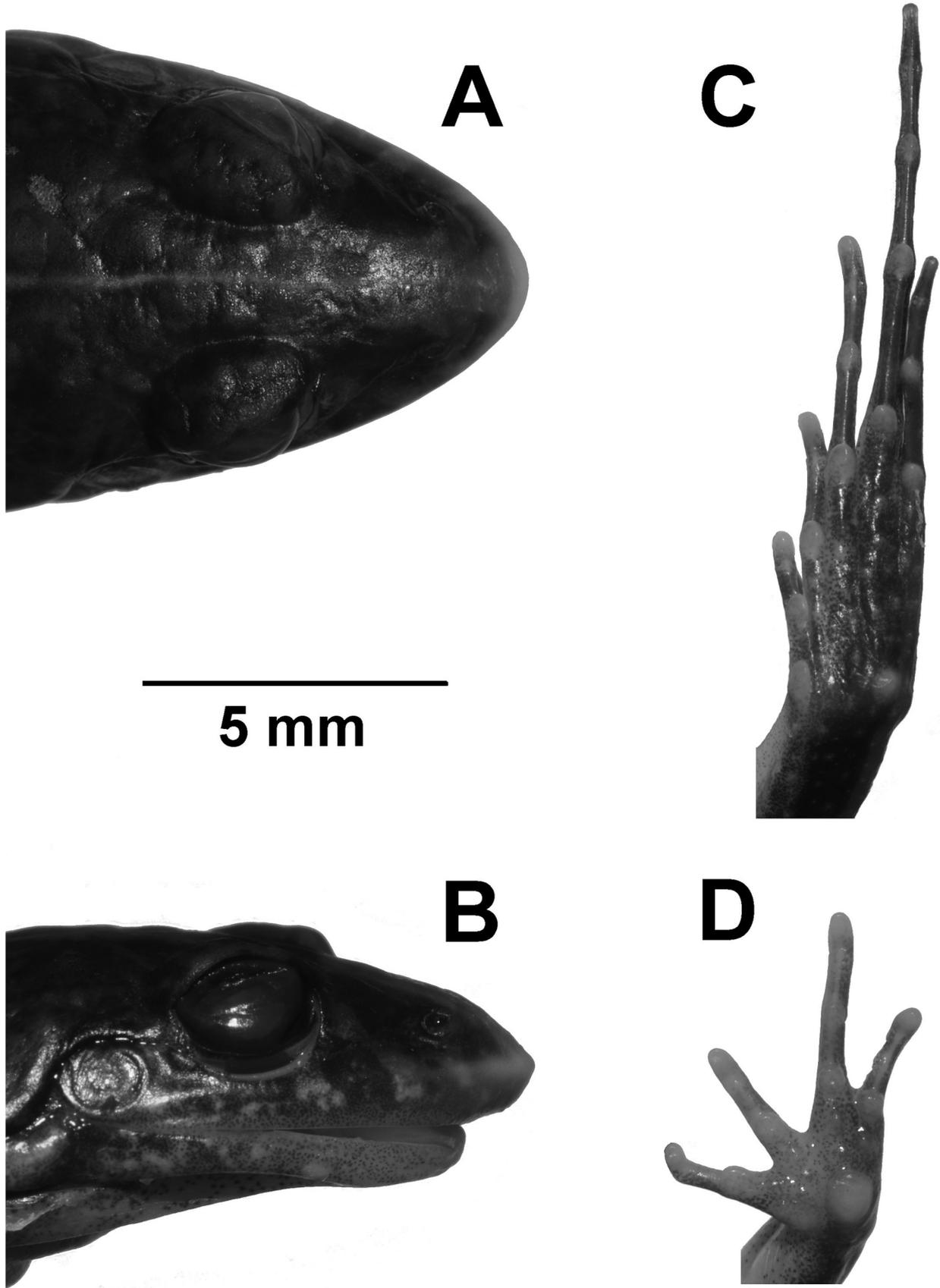


FIGURE 8. *Adenomera saci* sp. nov., holotype (AAG-UFU 1339), adult male. Dorsal (A) and lateral (B) views of head, and ventral views of foot (C) and hand (D).

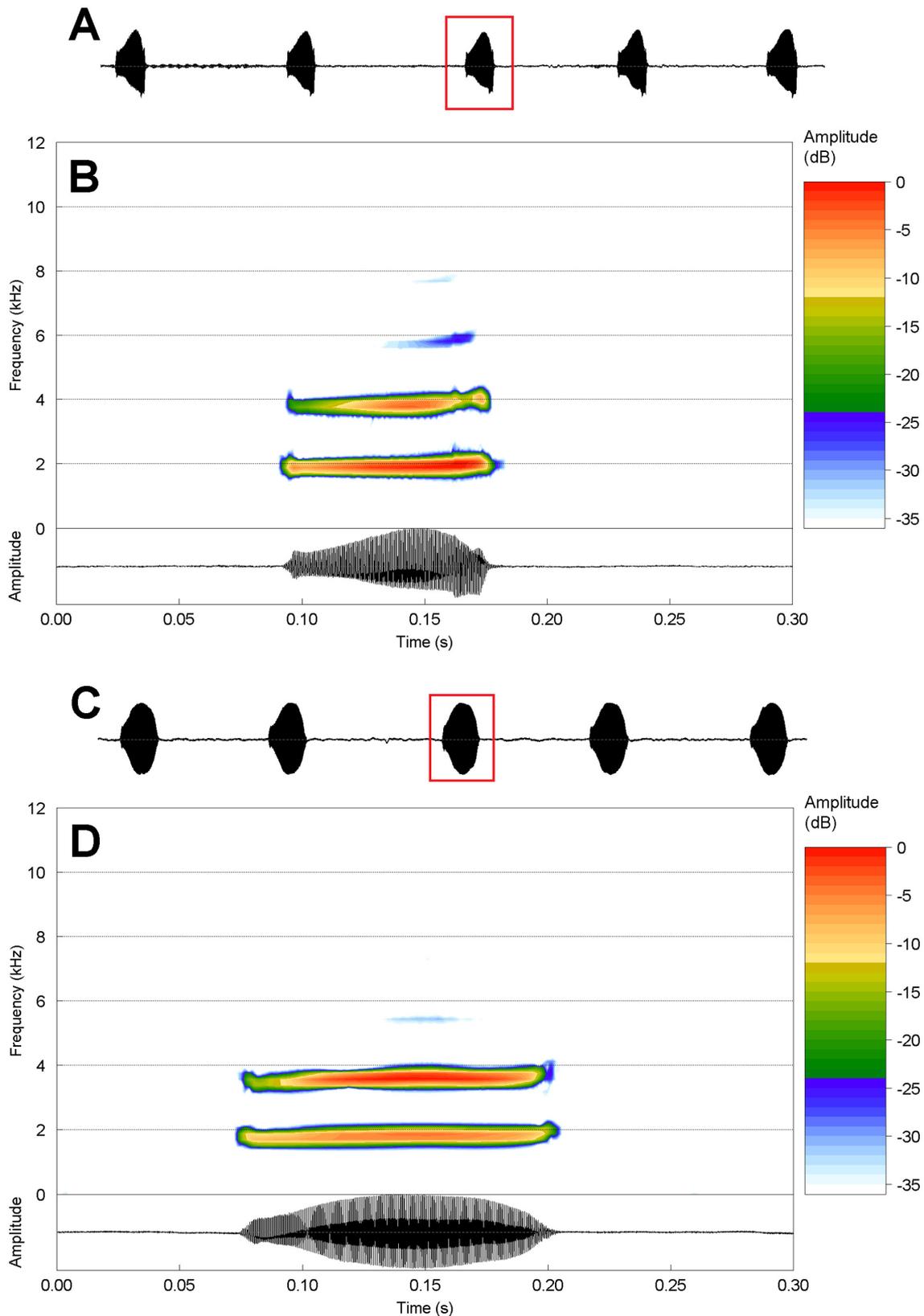


FIGURE 9. Advertisement call of two male specimens of *Adenomera saci* sp. nov. from the type locality. (A) A waveform section (2 seconds) with five calls from the Parque Nacional da Chapada dos Veadeiros (Goiás); (B) Audiospectrogram (above) and respective oscillogram (below) of the third call highlighted by a red outline. Unvouchered recording. (C) A waveform section (2.5 seconds) with five calls from Alto Paraíso de Goiás (Goiás); (D) Audiospectrogram (above) and respective oscillogram (below) of the third call highlighted by a red outline. Voucher paratype: AAG-UFU 0109.

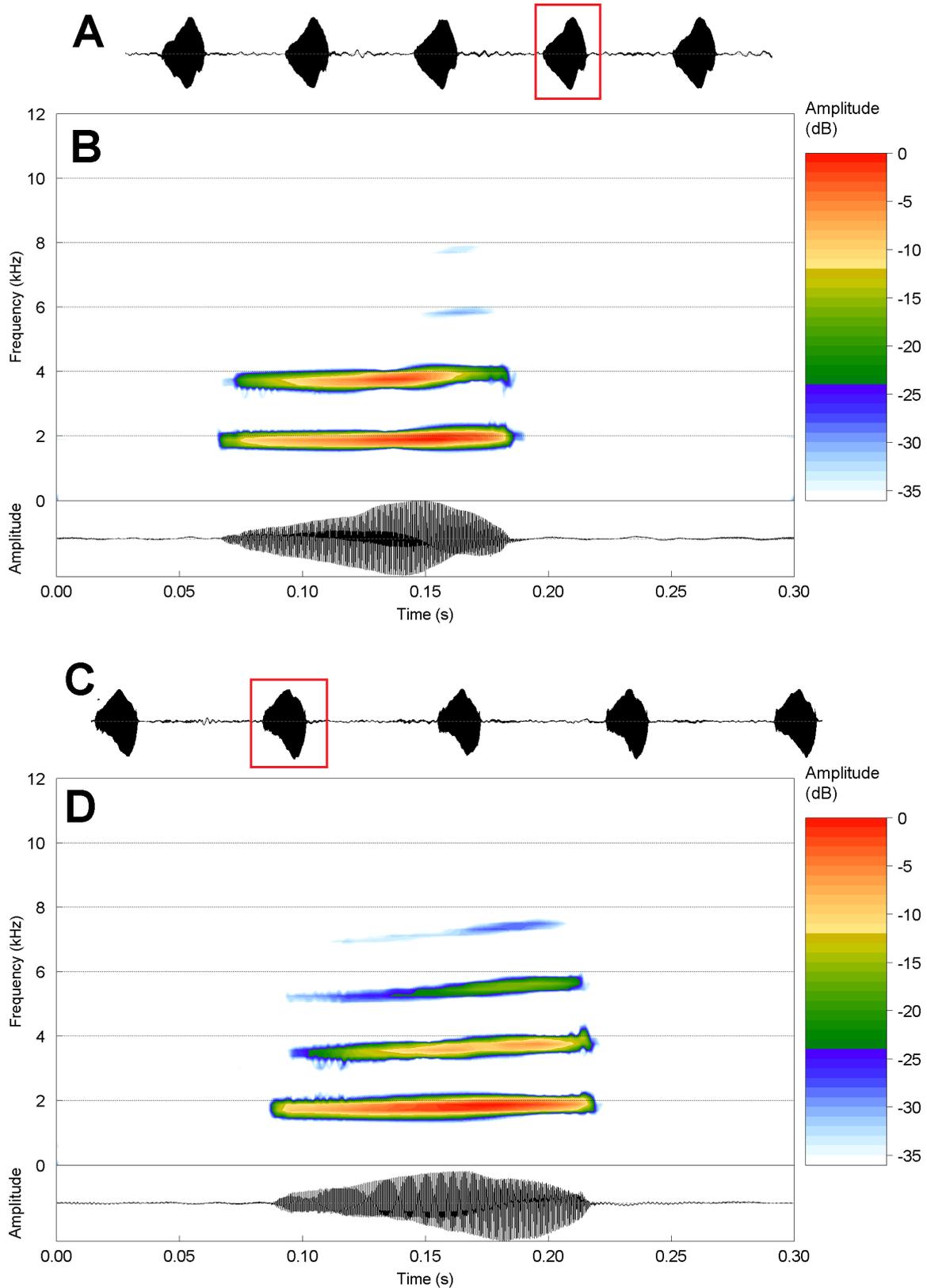


FIGURE 10. Advertisement call of two male specimens of *Adenomera saci* sp. nov. from Cristalina (Goiás). (A) A waveform section (2 seconds) with five calls; (B) Audiospectrogram (above) and respective oscillogram (below) of the fourth call highlighted by a red outline. Voucher specimen: AAG-UFU 1761. (C) A waveform section (2 seconds) with five calls; (D) Audiospectrogram (above) and respective oscillogram (below) of the second call highlighted by a red outline. Voucher specimen: AAG-UFU 0809.

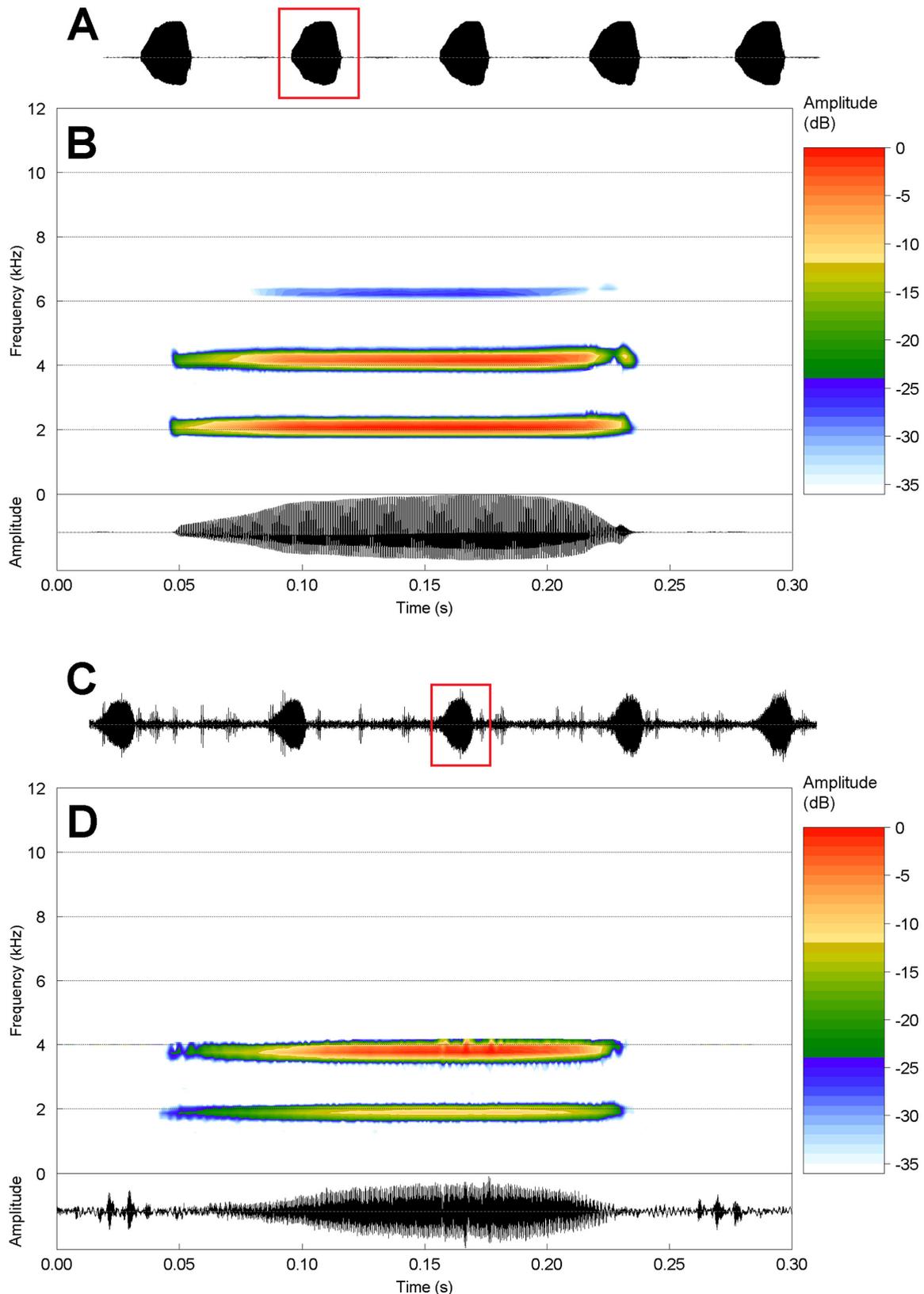


FIGURE 11. Advertisement call of two male specimens of *Adenomera saci* sp. nov. from the State of Mato Grosso. (A) A waveform section (2.5 seconds) with five calls from Pontal do Araguaia; (B) Audiospectrogram (above) and respective oscillogram (below) of the second call highlighted by a red outline. Voucher specimen: AAG-UFU 0208. (C) A waveform section (3.5 seconds) with five calls from Alto Araguaia; (D) Audiospectrogram (above) and respective oscillogram (below) of the third call highlighted by a red outline. Unvouchered recording.

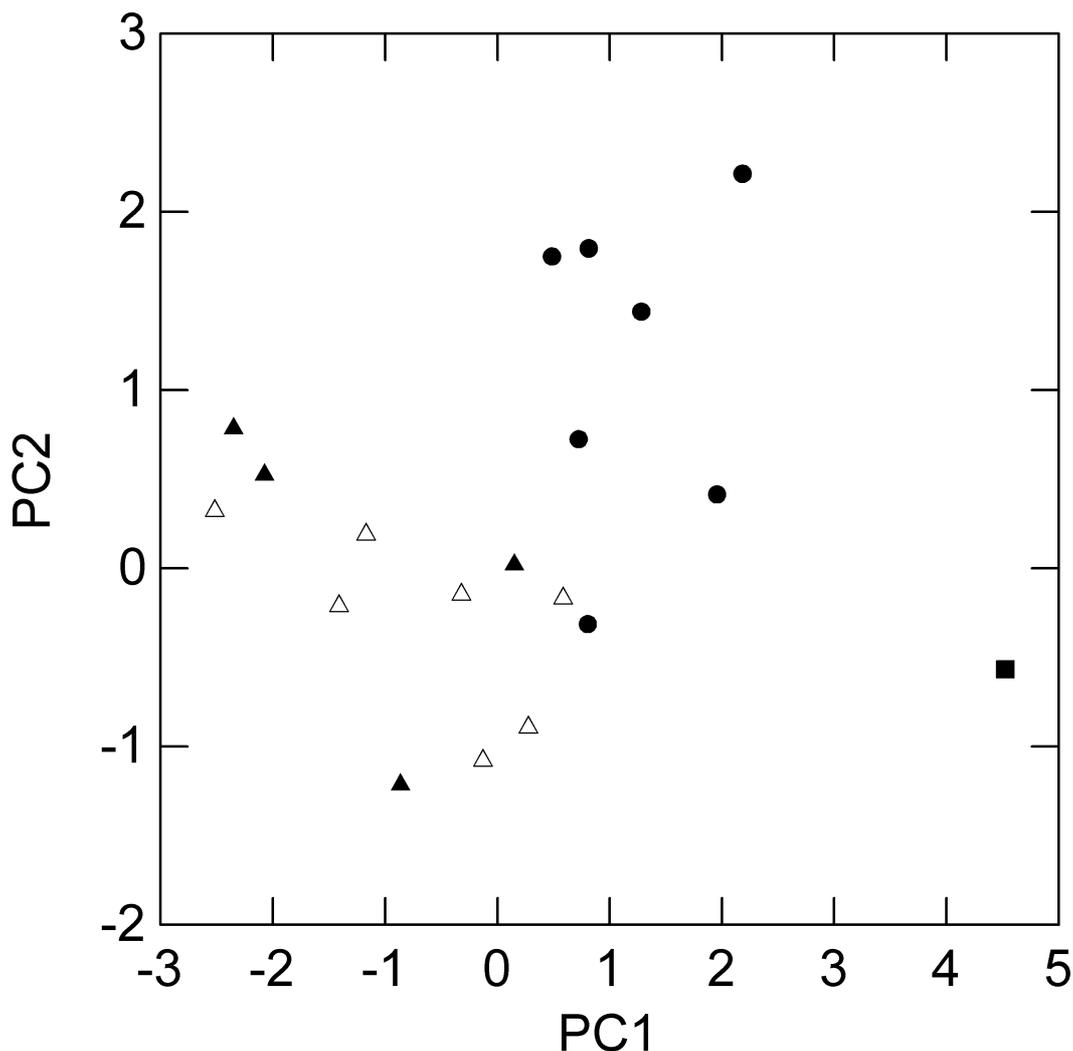


FIGURE 12. A scatterplot on the first two principal components (PCs) of bioacoustic variables of *Adenomera saci* sp. nov. populations. Open triangles (N = 7 individuals from the type locality, Chapada dos Veadeiros, Goiás); Filled triangles (N = 4 individuals from Cristalina, Goiás); Circles (N = 7 individuals from Pontal do Araguaia, Mato Grosso); Square (N = 1 individual from Alto Araguaia, Mato Grosso).

spiracle (fig. 12) (endotrophic larvae with both tooth rows and spiracle absent in all aforementioned species; except *A. marmorata* larvae, which was reported to have a spiracle). Among *Adenomera* species with exotrophic larvae, *Adenomera saci* sp. nov. larvae are distinguished from those of *A. thomei* (first posterior tooth row with no gaps; Almeida & Angulo 2006) by having a short gap in the first posterior tooth row (fig. 13). Morphological features of *A. diptyx* mouthparts (see fig. 2 in De la Riva 1995) agree with those of *Adenomera saci* sp. nov. (fig. 13C) by having marginal papillae with a dorsal gap, and two anterior and three posterior tooth rows sharing the following labial tooth row formula: [LTFR 2(2)3/(1)].

Description of holotype. AAG-UFU 1339 (figs. 2C–D, 5A, 8). Adult male. Snout pointed in dorsal view (fig. 8A), acuminate in lateral view (fig. 8B). Weakly developed shovel-like fleshy ridge on snout tip. Nostrils positioned dorsolaterally, closer to snout tip than to eyes; canthus rostralis indistinguishable; loreal region concave; upper eyelids glandular. Supratympanic folds extending from posterior margin of eyes, passing over tympani, and extending to base of arms. A discrete, elongated post-commissural gland. Vocal sac subgular, internal. Vocal slits present; vomerine teeth in two straight rows posterior to choanae; tongue ovoid, free behind. Relative finger lengths $I \simeq II \simeq IV < III$; finger tips rounded, not expanded, and with no webbing or fringing; inner metacarpal tubercle elongated; outer metacarpal tubercle nearly rounded (fig. 8D); subarticular and supernumerary tubercles rounded. No thumb asperities. Dorsum and dorsal surface of shanks glandular; posterior half of body, dorsal surface of shanks, and posterior surface of tarsi with minute tubercles. Vertebral pin-stripe present. Four

longitudinal rows of symmetrically arranged spots. Flanks with longitudinal granular rows from posterior margin of tympani to groin. Throat and belly smooth. Ventral surface of thighs areolate. Posterior surface of thighs spotted. Relative toe lengths $I < II < V \approx III < IV$; toe tips rounded, not expanded (pointed toe tips: character state A; see fig. 1A in Heyer 1973); toes ridged laterally, with no webbing. Inner metatarsal tubercles ovoid, outer conical (fig. 8C); subarticular and supernumerary tubercles rounded. Tarsal folds formed by ill-defined rows of tubercles, extending from inner metatarsal tubercle to approximately 1/2 length of tarsi. Heel smooth.

Measurements of holotype. Morphological measurements (mm) and ratios (%) in relation to SVL (22.5 mm): HL 8.8 (39.1), HW 7.1 (31.6), ED 2.3 (10.2), TD 1.6 (7.1), END 2.0 (8.9), IND 2.1 (9.3), FRL 4.8 (21.3), HAL 5.6 (24.9), TL 9.9 (44.0), SL 10.5 (46.7), TSL 6.8 (30.2), FL 12.3 (54.7).

Coloration of holotype in alcohol (fig. 2C–D). Snout tip has a faded coloration. Tympani reddish brown. Upper jaw with sinuous cream-colored stripes, white spots/blotches, and a white-colored gland. Dorsum with four longitudinal rows of symmetrically arranged black spots barely distinguishable from the very dark brown background. Flanks with cream-colored longitudinal row of granules on a black background. Pale gray vertebral stripe. White-tipped tubercles scattered on posterior half of dorsum, dorsal surface of shanks, and outer surface of tarsi. Dorsal surface of limbs with brown blotches on a very dark brown background. Posterior surface of thighs with white spots on a very dark brown background. Throat and belly cream, and ventral surface of limbs cream-colored, with melanophores, but with no distinctive color pattern.

Coloration of holotype in life (fig. 5A). Iris copper, upper eyelids bordered by an ill-outlined cream stripe. Tympani reddish brown. Dorsum with black longitudinal rows of spots on a moss green and grayish brown background. Spots and blotches on lateral of head and flanks with a whitish silver or yellow coloration. Flanks with cream-colored longitudinal granular rows on a grayish brown background. Vertebral stripe cream, with some portions tending to an orange coloration. Dorsal surface of limbs with black stripes and/or blotches on a brown background. Throat, belly, and ventral surface of limbs cream.

Variation. Morphometric variation is summarized in Table 1. Variation within the type series is restricted to dorsal texture (smooth or glandular), and color pattern (dark gray to very dark brown background), considering that the four to six longitudinal rows of symmetrically arranged black spots are variable due to the dorsal coloration itself, which might become evident or barely indistinguishable in preserved specimens. Posterior surface of thighs vary from a spotted or mottled pattern, and which can form ill-defined and fragmented stripes (AAG-UFU 0109, 0762–63, 0809, 1673, 1761–63, 2671, and ZUEC 3287) or a well-defined striped pattern (AAG-UFU 0108). Lower jaw can be dark-colored coinciding with the lateral expansion of vocal sac. Besides the melanophores scattered on ventral surface, specimens AAG-UFU 0109, 0809, 1673, 1761–63, have throat, belly, and ventral surface of thighs finely covered with white dots and/or spots.

Non-topotype specimens also vary in dorsal texture (smooth or glandular), and color pattern (dark gray to very dark brown background). Four to six longitudinal rows of symmetrically arranged black spots on dorsum are variable due to the dorsal coloration itself, which might become evident or barely indistinguishable in preserved specimens. Specimens AAG-UFU 0809, 1745–46, and 1761 have a faded white, well-developed shovel-like fleshy ridge on snout. Dorsal surface of thighs have spotted or mottled pattern in all specimens (AAG-UFU 0208, 1745–48).

The adult female AAG-UFU 1748 has a robust body shape, head sub-elliptical in dorsal view, with no shovel-like fleshy ridge on snout tip, as in the case of the adult female topotype of *A. martinezi* (AAG-UFU 1521). Specimens in life have some variation with respect to coloration, such as dorsal coloration (olive green to black), vertebral stripe (cream to brownish orange), granular rows on flanks (cream to yellow) (figs. 5–7).

Advertisement call from the type locality (Chapada dos Veadeiros). Seven males recorded (N = 343 analyzed calls). Advertisement call (fig. 9; Table 2) consists of a non-pulsed signal (a whistle to the human ear) with up to nine harmonics and with a slight ascendant frequency modulation, emitted at a rate of 1–3 calls/second (mean 2.2; SD = 0.3), and at a rate of 111–132 calls/minute (mean 123.2; SD = 10.3). Call duration varies from 90–139 ms (mean 112.1; SD = 11.0), and intercall interval from 220–513 ms (mean 361.4; SD = 77.4). Dominant frequency coincides with either the first (14%) or the second harmonic (72%) among the recorded individuals, or can alternate between the first and second harmonics (14%) among analyzed calls of the same individual. Peak of sound energy varies from 1.69–2.06 kHz (mean 1.85 kHz; SD = 0.07) in the first harmonic, and/or from 3.38–3.94 kHz (mean 3.67 kHz; SD = 0.18) in the second harmonic. The other harmonics, if present, are increasingly weaker in sound energy.

Bioacoustic comparisons. Dominant frequency of non-topotype populations of *A. saci* **sp. nov.** coincides with either the first (75%) or the second harmonic (15%) among the recorded individuals from Cristalina (N = 4; fig. 10); with either the first (57%) or the second harmonic (43%) among the recorded individuals from Pontal do Araguaia (N = 7; figs. 11A–B); and with the second harmonic among the analyzed calls of the individual from Alto Araguaia (N = 1; figs. 11C–D).

Bioacoustic data of topotypes of *Adenomera martinezi*, and *Adenomera saci* **sp. nov.** from the type locality and of comparative non-topotype populations are summarized in Table 2. There was no correlation between the first principal component, taking all three temporal variables tested into account, and the temperature [$r = 0.13$ ($r^2 < 2\%$), $p = 0.463$; N = 34], in other words, temperature did not affect the temporal variables and did not explain the variability found in the calls of topotypes of *A. martinezi* and all four populations of *A. saci* **sp. nov.**

The first three principal components (PCs) accounted for around 96% of the overall bioacoustic variability among the populations of *A. saci* **sp. nov.** A scatterplot of bioacoustic variables on the first two principal components (fig. 12) showed that the topotype (Chapada dos Veadeiros) and Cristalina populations were almost completely distinguished from the populations from Pontal do Araguaia and Alto Araguaia along the PC1, an expected result based on bioacoustic differences previously observed by us in the quantitative data comparisons (see Table 2) of populations from Goiás (topotypes and Cristalina) and Mato Grosso (Pontal do Araguaia). The insufficient call sample of the single recorded individual from Alto Araguaia (Mato Grosso) did not allow us to assume that the bioacoustic characteristics of this population are similar to that of Pontal do Araguaia, or different from both Pontal do Araguaia and populations from Goiás (topotypes and Cristalina).

Tadpole (fig. 13). Stage 37. Body tending to ovoid in dorsal view, compressed dorsoventrally. Eyes and nares positioned dorsally, just nearer the eyes than the snout tip, with a slight rim, but lack any papillae or ornamentations (fig. 13B). Oral disc positioned anteroventrally. Spiracle singular, sinistral. Spiracular opening with its inner wall as a slight ridge adhered to body (fig. 13A). Right wall of vent tube displaced dorsally and anteriorly. Dorsal fin originates at body-tail juncture; ventral fin originates at the vent tube. Tail height just greater than body height. Dorsal and ventral fins with the same height. Tail tip with a narrow and pointed shape. Oral disc lacks tooth rows (see variation below). Marginal papillae with a wide dorsal gap surround the oral disc. Presence of keratinized of both upper (arched) and lower jaw (v-shaped) sheaths with serrated cutting edges. Dorsal surface of body dark brown, ventral surface cream. Tail with dark brown blotches on both dorsal and ventral fins, and on tail muscle. Measurements (mm): TL 34.8; BL 10.1; TAL 24.6; IOD 3.4; IND 1.6; TMH 2.4; MTH 3.9; TMW 2.5.

Variation of tadpoles. Two tadpoles (Gosner's stages 36–37) have well-defined tooth rows: LTRF 2(2)/3(1) (fig. 13C). The second anterior tooth row has a wide medial gap, approximately 1/3 length of the entire row. The first posterior tooth row has a very slight medial gap.

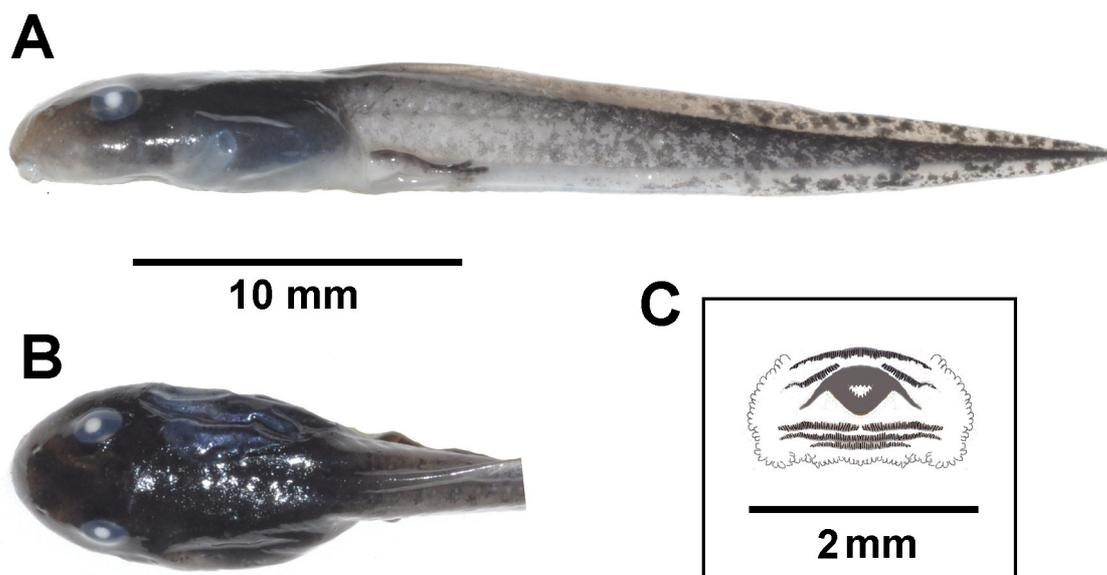


FIGURE 13. Lateral (A) and dorsal (B) views, and schematic diagram of the oral disc (C) of a tadpole (stage 37) of *Adenomera saci* **sp. nov.** from Cristalina, State of Goiás.

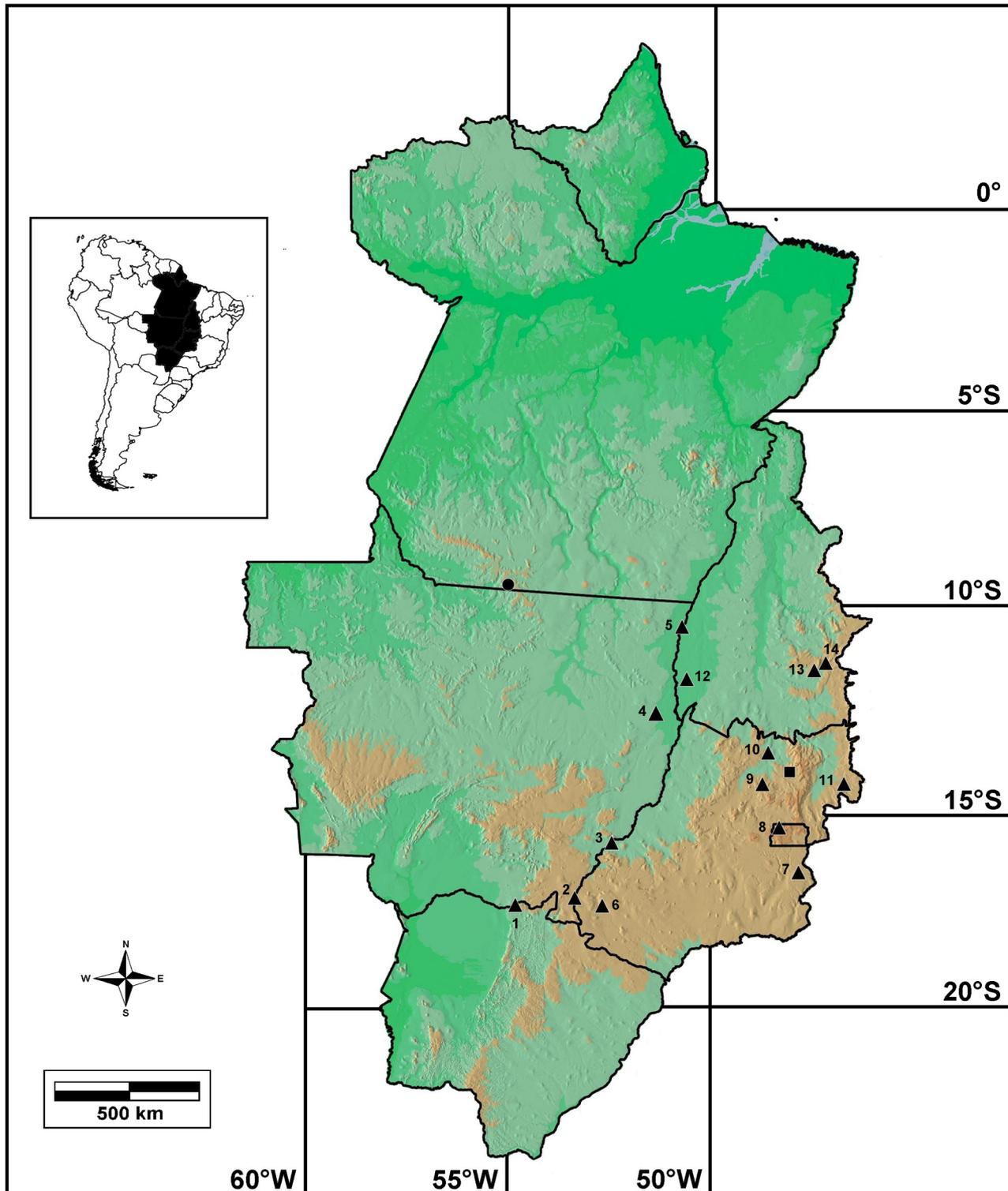


FIGURE 14. Geographic distribution of *Adenomera martinezi* and *Adenomera saci* sp. nov. on a topographic map. Type localities: Circle—*A. martinezi* (Cachimbo, Pará); Square—*Adenomera saci* sp. nov. (Chapada dos Veadeiros, Goiás). Triangles correspond to the distributional records for *Adenomera saci* sp. nov.: (1) Sonora, State of Mato Grosso do Sul; (2) Alto Araguaia, (3) Pontal do Araguaia, (4) Ribeirão Cascalheira, and (5) Santa Terezinha, State of Mato Grosso; (6) Mineiros/Chapadão do Céu, (7) Cristalina, (8) Brasília, (9) Niquelândia, (10) Minaçu, and (11) Buritinópolis, State of Goiás/Distrito Federal; (12) Formoso do Araguaia/Ilha do Bananal, (13) Almas, and (14) Rio da Conceição/Jalapão, State of Tocantins. Records were based on our data and extracted from Heyer (1973); Vitt *et al.* (2005); Cintra *et al.* (2009); Moreira *et al.* (2009); Oda *et al.* (2009); Silva Jr. *et al.* (2009); Kopp *et al.* (2010); Moraes *et al.* (2011); Valdujo *et al.* (2012).

Natural history. *Adenomera saci* **sp. nov.** occurs in montane (> 1000 m a.s.l.) rock fields with sandy/muddy soil, or lowland (\approx 350 m a.s.l.) grassy fields with sandy/muddy soil that are almost always associated with palm grove marshes (Veredas). Males call within underground chambers or from exposed calling sites, most times among grassy tufts. The species is mainly active during the night, but males may also be heard during daylight in rainy days.

Geographic distribution. The widespread pattern of distribution of *Adenomera saci* **sp. nov.** encompasses both rocky Cerrado environments of central Brazil and transitional Amazonian regions of the Araguaia River and Xingu River basins, central-western and northern Brazil (see fig. 14 for a distribution map and references).

Etymology. The proper name ‘saci’ in Portuguese (*sa’si*, *sassy perere*, or *matintape’re* in Tupi indigenous language) stands for a kind of whistling imp, which according to the native Tupi ethnic groups in Brazil, is an annoying prankster to whoever sees him. The name of the species, an invariant noun in apposition, is an allusion to the whistle call pattern emitted by the species that we associate to this well-known character in Brazilian folklore.

Remarks. It is noteworthy to add that the advertisement calls of *A. martinezi* and *A. saci* **sp. nov.** are distinguishable to each other to the ear. Specimens reported from other localities/regions in addition to those discussed earlier in the geographic distribution section (Vitt *et al.* 2005; Silva Jr. *et al.* 2009; Morais *et al.* 2011) compared either to our study areas (Chapada dos Veadeiros, Cristalina, Alto Araguaia, and Pontal do Araguaia) or to localities from where we have bioacoustic information available (Formoso do Araguaia and Santa Terezinha) were assigned to *Adenomera saci* **sp. nov.** (see fig. 14). Specimens reported from the Ilha do Bananal, southwestern State of Tocantins, and the Xingu River basin, State of Mato Grosso (Heyer 1973), were unambiguously assigned to *Adenomera saci* **sp. nov.** based on digitized recordings of Adão J. Cardoso available at the Fonoteca Neotropical Jacques Viellard from Formoso do Araguaia, State of Tocantins, and Santa Terezinha, State of Mato Grosso, respectively (sound files FNJV 11223–11224). Taking also the proximity of those localities into account, reinforced by the widespread distribution pattern of the species against a putative ‘Cachimbo endemic’, restricted distribution pattern of *A. martinezi*, we tentatively assigned the specimens reported from the State of Mato Grosso do Sul (Silva Jr *et al.* 2009), and the Jalapão and nearby localities, southeastern State of Tocantins (Vitt *et al.* 2005; Morais *et al.* 2011) to *Adenomera saci* **sp. nov.** as well (fig. 14).

Regardless of the bioacoustic differences (fig. 12; Table 2) and geographic distance (fig. 14) among populations of *Adenomera saci* **sp. nov.** discussed earlier, our results are still not conclusive. We believe that these populations ought to benefit from a molecular evidence, as well as additional efforts to increase call sample, combining two datasets to properly address the taxonomic status of populations from Mato Grosso and uncover a potential cryptic diversity among the widely distributed populations currently assigned to *Adenomera saci* **sp. nov.** through a bioacoustic evidence.

Examined material. Topotype specimens—GOIÁS: Alto Paraíso de Goiás (CHUNB 42537, 49506–49509, 58405, 58884, 58886); Non-topotype specimens –DISTRITO FEDERAL: Brasília (AAG-UFU 2671; CHUNB 58358); GOIÁS: Colinas do Sul (CHUNB 44706); Cristalina (AAG-UFU 0809, AAG-UFU 1673, AAG-UFU 1761–1763); MATO GROSSO: Alto Araguaia (CHUNB 65849); Nova Xavantina (CHUNB 64343–64344); Novo Santo Antônio (CHUNB 57787, 57861, 57982, 57985); Pontal do Araguaia (AAG-UFU 0208, 1745–1748); Ribeirão Cascalheira (ZUEC 7496–7498); Santa Terezinha (ZUEC 7459–7460); MATO GROSSO DO SUL: Cassilândia (CHUNB 58798); TOCANTINS: Caseara (CHUNB 45600); Colinas do Tocantins (CHUNB 50969, 50972–50975, 52822–52825, 53140–53141); Guaraí (CHUNB 52446–52447); Lagoa da Confusão (CHUNB 58135, 58140, 58186); Mateiros (CHUNB 27314–27320, 27322, 27324–27327, 41764, 41766, 42005–42006, 42008–42017); Palmas (CHUNB 11245–11249, 14702, 24266, 24407–24412, 24415–24420, 24435–24436, 24439–24440, 48094–48097); Porto Nacional (CHUNB 47732).

Discussion

Bokermann (1956) suggested a terrestrial reproductive mode with non-feeding larvae for *A. martinezi* based on presumably large-sized ovarian eggs (0.8 mm) from the allotype. We refute his assumption considering that, in fact, endotrophic *Adenomera* species have much larger ovarian eggs (e.g. *Adenomera* sp.: 2.6–3.7 mm; Kokubum & Giaretta 2005). Still, we could not neglect the possibility of the female of *A. martinezi* examined by Bokermann (1956) bearing immature ovarian eggs. De la Riva (1995), likewise, attributed a mean mature ovarian egg size of

1.8 mm to the Bolivian Buenavista-Amboró population of *A. diptyx*, which possesses a reproductive mode with exotrophic larvae (population referred as *A. bokermanni* or an unnamed species by De la Riva 1995). An additional consideration is that *Adenomera saci* **sp. nov.**, a morphologically cryptic species in relation to *A. martinezi*, has exotrophic tadpoles, as described earlier. With the description of *Adenomera saci* **sp. nov.** larvae, it is possible to recognize an overall morphological similarity with those of *A. diptyx* (De la Riva 1995), and the presumably similar morphology to its sibling species *A. martinezi*, suggesting that all three species could share the same general reproductive mode with exotrophic larvae. Comparisons with larvae of *A. bokermanni* (Heyer 1973) were avoided, since there are no comments about the locality of the tadpole described by Heyer (1973). Later, Heyer (1977, 1984) suggested that the type series of *A. bokermanni* might actually be a composite of at least two morphologically similar species, leading us to believe that the described tadpole in Heyer (1973) might not correspond to the tadpole of *A. bokermanni*.

An available specific name prior to our description, *Leptodactylus glandulosus*, was described by Cope (1887) from the Chapada dos Guimarães, State of Mato Grosso, and is currently a junior synonym of *A. diptyx* (see De la Riva 1996 for nomenclatural history). Heyer (1973) re-examined *L. glandulosus* type series, referring to them as possibly being composed of juvenile specimens, and stated that some individuals had a vertebral pin-stripe, in addition to dorsum with indistinct spots. This superficial resemblance with *A. martinezi* and *A. saci* **sp. nov.** based solely on coloration pattern is not enough to assign them to *L. glandulosus*. The character state of vertebral pin-stripe is always present in all specimens of both *A. martinezi* and *A. saci* **sp. nov.**, whereas it varied among the specimens re-examined by Heyer (1973). Additionally, Heyer (1973) assigned this morphotype to what he called ‘form II species’, clustered with the general similar morphotype of *A. hylaedactyla* (including *A. diptyx* as a junior synonym) and *A. bokermanni*, whereas *A. martinezi* was the only morphotype assigned to ‘form III species’, which would also encompass the morphotype of *A. saci* **sp. nov.**, morphologically cryptic to *A. martinezi*. Populations of one species of *Adenomera* currently under uncertain taxonomic status is known to occur at the Chapada dos Guimarães and on its outskirts (Municipality of Cuiabá, and District of São Vicente), whose morphological and bioacoustic features fit those of *A. diptyx* or a closely related form (V.H. Zaracho unpublished doctoral thesis; T.R. de Carvalho unpubl. data; see Appendix I for examined specimens of this region), so that these specimens should eventually correspond to the available name *L. glandulosus* instead of *A. diptyx*, but this name neither is applicable to *A. martinezi* nor *A. saci* **sp. nov.**, which share the distinctive four to six longitudinal rows of symmetrically arranged black spots on dorsum and a vertebral pin-stripe.

The recognition of *Adenomera saci* **sp. nov.** also has conservation implications. Based on our assumed distribution of *A. martinezi* and *A. saci* **sp. nov.** (fig. 14), the IUCN Red List of Threatened Species extinction risk assessment of *A. martinezi* (Bastos *et al.* 2004) requires a reassessment, inasmuch as we reconsidered this species, as far as we know, as endemic to Cachimbo, southwestern State of Pará so far. The 2004 conservation status assessment in fact encompassed both *A. martinezi* and *A. saci* **sp. nov.**, while this conservation status category of ‘Least Concern’ might only be applied to *A. saci* **sp. nov.** as a widely distributed and abundant species in central and northern Brazil. On the other hand, *Adenomera martinezi* is known to occur only at its type locality (Cachimbo, southwestern State of Pará, northern Brazil), supporting priorities for conservation actions of this region, as well as the necessity of more extensive taxon sampling efforts in the region to corroborate a potential micro-endemism of *A. martinezi*, with distribution restricted to a single location. Based on its very restricted distribution, we suggest classifying *Adenomera martinezi* as a ‘Near Threatened’ species according to IUCN guidelines for the next Red List of Threatened Anuran Species (IUCN 2011). This species partially fits the requirements of criteria B and D to belong to a near threatened category: ‘a very small extent of occurrence (< 100 km²), and in existing only in one location’, and ‘Restricted area of occupancy or number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time’. Other criteria can not be applied to this species for as much as our micro-endemism suspicion is not thoroughly addressed by other evidence, such as studies on population fluctuations to assess a potential decline in the future, and a better taxon sampling in the region to reinforce the hypothesis of Cachimbo micro-endemism distribution pattern of *Adenomera martinezi*. Hence, revealing insights into additional conservation priorities and actions of the region and the species, and a reappraisal of this preliminary IUCN threat category proposal.

The bioacoustic approach has been employed in recent works studying the taxonomy of Cerrado anuran taxa, and has proven very useful in the unraveling and/or reassessing unresolved species identities, revealing new species under morphologically cryptic taxa (Carvalho *et al.* 2010; Carvalho 2012; Andrade & Carvalho 2013) or at

least sharing similar overall morphological patterns (Giaretta *et al.* 2007; Martins & Giaretta 2011; Carvalho *et al.* 2012). It is worth stressing that this study represents one more case of the use of bioacoustics addressing cryptic species complexes, in this case a species that is widely distributed in central Brazil, under similar overall morphology shared with *A. martinezi*.

Acknowledgments

Special thanks go to B. F. V. Teixeira, K. G. Facure, and L. B. Martins for assistance in the field, G. R. Colli, H. Zaher, L. F. Toledo, and J. P. Pombal Jr. for making available specimens under their care, L. F. Toledo for making available recordings from the Fonoteca Neotropical Jacques Vielliard under his care, K. G. Facure for statistical support, Miguel Vences and two anonymous reviewers, whose comments greatly improved the manuscript. We are indebted to Tenente Coronel Aviador Francalacci and his team for providing facilities at Cachimbo. This work was supported by FAPESP, FAPEMIG and CNPq. FAPESP provided a research grant to T.R.C, CNPq to A.A.G. Collection permits: ICMBio/SISBIO 29954–3 and 02015.008064/02–51.

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APPENDIX 1. Additional examined specimens.

Adenomera ajurauna—BRAZIL: SÃO PAULO: Santo André (ZUEC 6377); *Adenomera andreae*—BRAZIL: PARÁ: Porto Trombetas (MNRJ 52886-87); *Adenomera* cf. *andreae*—BRAZIL: RONDÔNIA: Cacoal (AAG-UFU 2550-56); Espigão d'Oeste (AAG-UFU 2284-85); *Adenomera bokermanni*—BRAZIL: PARANÁ: Morretes (ZUEC 4722); *Adenomera* cf. *diplyx*—BRAZIL: MATO GROSSO: Chapada dos Guimarães (AAG-UFU 2138-39); Cuiabá (AAG-UFU 2123); Santo Antônio do Leverger (AAG-UFU 1435-38); *Adenomera engelsi*—BRAZIL: SANTA CATARINA: Rancho Queimado (MNRJ 72637, 72543-44); *Adenomera* cf. *hylaedactyla*—BRAZIL: MATO GROSSO: Rondolândia (AAG-UFU 2621); *Adenomera marmotara*—BRAZIL: RIO DE JANEIRO: Bangu (MNRJ 51091, 53817-18, 53820, 54081-82, 55684, 58132-38, 58140-42); Macaé (AAG-UFU 0529; 0756-57); Saquarema (MNRJ 76775, 76778-79); *Adenomera* cf. *marmorata*—BRAZIL: MINAS GERAIS: Chiador (AAG-UFU 0688); SÃO PAULO: Santo André (AAG-UFU 3031); São Sebastião (AAG-UFU 3007); *Adenomera* sp.—BRAZIL: MATO GROSSO: Pontal do Araguaia (AAG-UFU 0201, 0203); MINAS GERAIS: Perdizes (AAG-UFU 0609); Uberlândia (AAG-UFU 4633); GOIÁS: Caldas Novas (AAG-UFU 0018); *Adenomera thomei*—BRAZIL: BAHIA: Itabuna (ZUEC 998); *Lithodytes lineatus*—BRAZIL: AMAZONAS: Itacoatiara (MNRJ 56699); Barcelos (MNRJ 36243); PARÁ: Piçarra (MNRJ 67289-90).

APPENDIX 2. Additional information on figured sound files.

FIGURE 3. A–B) Adeno_martinCachimboPA11TRC_AAGm671; 19:50 h, 29 Nov 2012; Cachimbo, State of Pará, Brazil; air 27.1°C; C–D) Adeno_martinCachimboPA2bTRC_AAGm671; 20:36 h, 28 Nov 2012; Cachimbo, State of Pará, Brazil; air 26.7°C;

FIGURE 9. A–B) Adeno_saciVeadGO6TRC_AAGm671; 00:40 h, 13 Nov 2012; Parque Nacional da Chapada dos Veadeiros, State of Goiás, Brazil; air 21.3°C; C–D) Adeno_saciVeadGO3dAAGm; 18:25 h, 2 Dec 2010; Municipality of Alto Paraíso de Goiás, State of Goiás, Brazil; air 23.3°C;

FIGURE 10. A–B) Adeno_saciCristalinaGO4aAAGm671; 18:20 h, 12 Feb 2013; Municipality of Cristalina, State of Goiás, Brazil; air 26.0°C; C–D) Adeno_saciCristalinaGO1aAAGm671; 19:24 h, 20 Nov 2011; Municipality of Cristalina, State of Goiás, Brazil; air 21.0°C;

FIGURE 11. A–B) Adeno_saciPontAragMT3eAAGm; 17:48 h, 18 Jan 2011; Municipality of Pontal do Araguaia, State of Mato Grosso, Brazil; air 36.0°C; C–D) Adeno_saciAltoAragMT1TRC_AAGm671; 21:51 h, 24 Jan 2013; Municipality of Alto Araguaia, State of Mato Grosso, Brazil; air 23.4°C.

APPENDIX 3. Mean individual values of the advertisement call temporal variables of topotypes (Cachimbo, Pará) of *Adenomera martinezi* (mart) and four populations of *Adenomera saci* **sp. nov.** (saci) and their respective first principal component scores (PC1). CD = call duration; II (intercall interval); CS = call rate (seconds); T = air temperature. Individuals of *Adenomera saci* **sp. nov.** from the type locality (Chapada dos Veadeiros, Goiás) are in bold type. Values were rounded to three decimal places.

	CD (s)	II (s)	CS	T (°C)	PC1
mart1	0.107	0.393	1.778	26.7	0.28842443
mart2	0.106	0.353	2.182	26.7	-0.738348601
mart3	0.128	0.346	2.1	26.7	-0.327237565
mart4	0.134	0.414	2.111	26.7	0.172357479
mart5	0.112	0.434	2.0	24.6	0.181314505
mart6	0.108	0.481	1.9	24.6	0.612072058
mart7	0.125	0.530	1.7	24.6	1.534750878
mart8	0.112	0.394	2.0	24.6	-0.061385867
mart9	0.103	0.412	1.7	27.1	0.491545486
mart10	0.111	0.346	2.222	27.1	-0.791942721
mart11	0.120	0.541	2.2	27.1	0.59954086
mart12	0.142	0.342	2.1	27.1	-0.159742375
mart13	0.106	0.280	2.7	27.0	-2.179317965
mart14	0.121	0.322	2.3	24.8	-0.945991958
mart15	0.117	0.281	2.5	24.8	-1.637170398
saci1	0.117	0.304	2.333	25.3	-1.179614465
saci2	0.107	0.481	2.286	27.0	-0.134090913
saci3	0.133	0.418	1.889	25.3	0.597567371
saci4	0.116	0.345	2.0	25.3	-0.307357345
saci5	0.105	0.257	2.8	24.9	-2.518000721
saci6	0.103	0.408	1.8	21.3	0.280123952
saci7	0.103	0.318	2.4	20.0	-1.414140647
saci8	0.132	0.383	2.0	21.0	0.150086692
saci9	0.078	0.371	2.1	23.0	-0.862681307
saci10	0.116	0.263	2.667	26.0	-2.075013981
saci11	0.116	0.218	2.667	26.0	-2.349687639
saci12	0.139	0.473	2.0	27.0	0.805755531
saci13	0.195	0.349	2.0	36.0	0.813097476
saci14	0.185	0.354	1.7	26.0	1.281357695
saci15	0.164	0.403	2.0	27.5	0.724514872
saci16	0.178	0.508	1.8	27.5	1.956706363
saci17	0.186	0.317	2.0	28.0	0.486969434
saci18	0.224	0.382	1.6	28.0	2.182677989
saci19	0.188	0.686	1.1	23.4	4.522861399

APPENDIX 4. Eigenvectors, eigenvalues, and explained variation of the first three principal components of bioacoustic variables of *Adenomera saci* **sp. nov.** populations.

BIOACOUSTIC VARIABLES	PC1	PC2	PC3
CALL DURATION	0.4667	-0.0291	-0.8002
INTERCALL INTERVAL	0.3972	-0.5150	0.5027
RATE (CALLS/MINUTE)	-0.4527	0.5048	0.0569
1 st HARMONIC	0.4675	0.4572	0.2875
2 nd HARMONIC	0.4483	0.5197	0.1452
EIGENVALUES	2.818	1.394	0.124
EXPLAINED VARIATION (%)	56.361	27.882	11.509