

A new striped species of *Dendropsophus* (Anura: Hylidae) with a composite advertisement call and comments on the *D. rubicundulus* group

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Abstract

Herein we describe *Dendropsophus rozenmani* sp. nov. based on morphological, bioacoustic, and molecular data. This new species is distinguished from other species of *Dendropsophus* by its small size (SVL 18.7–21.1 mm in adult males and 19.6–23.2 mm in females); in life, dorsal ground coloration brown, with two anterior parallel and straight, dark brown stripes and a middorsal sacral stripe; and lateral limits of dorsal coloration above tympanum. In addition, the new species differs from all other species of the *D. rubicundulus* group (along with *D. anataliasiasi*) by having a composite advertisement call, i.e., a series of calls consisting of two call types. In a phylogenetic tree based on 494 bp of the 16S mitochondrial gene, four species of *Dendropsophus*, *D. cruzi*, *D. juliani*, and *D. sanborni* and one candidate species, *D. juliani* A, are positioned within the *rubicundulus* species group which poses questions on the monophyly of this group as well as its morphological definition. The occurrence of both single and composite calls in the *D. rubicundulus* group suggests future studies on the call evolution in that group as well as the whole genus.

Key words

Advertisement call; Amphibia; bioacoustics; Cerrado; Chiquitania; *Dendropsophus tritaeniatius*; species delimitation; taxonomy.

Introduction

The Neotropical realm sensu WALLACE (1876) has a greater amphibian diversity than any other region of the world (DUELLMAN, 1999; AMPHIBIAWEB, 2018). A recent update of Wallace's zoogeographic regions acknowledged that South America, and especially the southern part of this continent, harbors a significant number of phylogenetically distinct lineages (HOLT *et al.*, 2013). Several recent studies in South America suggested that cryptic diversity is high in frogs, and that many species possibly have smaller distributions and smaller population sizes than previously thought (e.g., FOUQUET *et al.*, 2007; JANSEN *et*

al., 2011; GEHARA *et al.*, 2013, 2014; ORTEGA-ANDRADE *et al.*, 2015; FERRÃO *et al.*, 2016; CAMINER *et al.*, 2017; VACHER *et al.*, 2017). Despite this repeated discovery of candidate species in the Neotropics, a taxonomic assessment of most of these species or lineages is still lacking. Because of the frequent failure of DNA extraction of museum specimens and/or often lacking additional (bioacoustic or larval) data from old species descriptions, new topotypic material and data are important for the clarification of many taxonomic problems (e.g., JANSEN *et al.*, 2011; TEIXEIRA *et al.*, 2013; TEIXEIRA & GIARETTA,

2015). Bioacoustic data from type localities have a large potential for species delimitation, and thus, a standardized bioacoustical methodology for the use in integrative taxonomy of anurans was recently proposed (KÖHLER *et al.*, 2017).

A DNA barcoding study by JANSEN *et al.* (2011) identified several lineages of frogs in the eastern lowlands of Bolivia (Chiquitano and Beni / Moxos Plains regions) with some of these possibly corresponding to unnamed distinct species. The Chiquitano region has a moderate to high amphibian diversity with up to 45 species at one locality (e.g., SCHULZE *et al.*, 2009, 2015; JANSEN *et al.*, 2011; BÁLINT *et al.*, 2018). This might be due to its biogeographical position as a transition zone (sensu FERRO & MORRONE, 2014) between the wet forests of Amazonia, the dry and often impenetrable forests of the Chaco, and the open savannas of the Cerrado, leading to a mosaic of overlapping natural habitats. Indeed, some of the open areas in the lowlands correspond to the western outliers of the Brazilian Cerrado (i.e., the Cerrado of the Chiquitano region, and the Cerrado of Beni; IBISCH & MÉRIDA, 2004; KILLEEN *et al.*, 2006). The patchy horizontal structure of habitats of the Chiquitano region may have led to local endemism as proposed for similar and neighboring regions (COLLI *et al.*, 2002; RODRIGUES & JUNCÁ, 2002; RODRIGUES *et al.*, 2008), and in fact, some evidence for the distinctiveness of the Chiquitano herpetofauna has been provided by JANSEN *et al.* (2007, 2009), JANSEN & KÖHLER (2008), and CAMINER *et al.* (2017).

The *Dendropsophus rubicundulus* group (fide NAPOLI & CARAMASCHI, 1998) is currently composed of nine species. Briefly, these species can be morphologically grouped into those with an immaculate (predominant green) dorsum [*D. cachimbo* (Napoli & Caramaschi, 1999a), known only from type locality, and *D. elianeae* (Napoli & Caramaschi, 2000), distributed from east-central Paraguay to east central and southern Brazil], and those with stripes [*D. tritaeniatus* (Bokermann, 1965), *D. araguaya* (Napoli & Caramaschi, 1998), *D. cerraensis* (Napoli & Caramaschi, 1998), *D. jimi* (Napoli & Caramaschi, 1999b), *D. rhea* (Napoli & Caramaschi, 1999b), *D. anataliasiasi* (Bokermann, 1965), *D. rubicundulus* (Reinhardt & Lütken, 1862)]. The first five of those species compose the *tritaeniatus* species complex sensu NAPOLI and CARAMASCHI (1999b) who stated that these species are always associated with permanent springs and streams (as opposed to the remaining species of the group that occur at permanent or temporary ponds), and are further characterized by two anterior parallel brown stripes from the posterior corner of the eyes to nearly the middle of the body, followed by a single sacral stripe.

In this study, we taxonomically re-evaluate populations from the eastern lowlands of Bolivia formerly assigned to *Dendropsophus tritaeniatus* (e.g., DE LA RIVA *et al.*, 2000; MÁRQUEZ *et al.*, 2002; JANSEN *et al.*, 2011; in the following: *D. cf. tritaeniatus* “Bolivia”) based on new available (topotypic) molecular, bioacoustic, and morphological data of the *D. rubicundulus* group (TEIXEIRA *et al.*, 2013; TEIXEIRA & GIARETTA, 2015; this study).

The aim of this work is to describe these populations as a new species.

Materials & Methods

Field methods and morphology

Voucher specimens were collected during several field trips from November 2004 to February 2012. Collected specimens were euthanized by injection of T61®, fixed with a preservative solution of 5 ml formalin (36%) in 1 L ethanol (94%), and stored in 70% ethanol. Tissue samples (muscle) for DNA analyses were preserved in 96% non-denaturated ethanol. Measurements are given in millimetres (mm) and were taken to the nearest 0.1 mm under a dissecting microscope using digital callipers. Webbing formulae follow MYERS & DUELLMAN (1982), and all other terminology and definitions of morphometric measurements follow WATTERS *et al.* (2016). Abbreviations for measurements used are: EN = eye to nostril distance, ED = horizontal eye diameter, UEW = upper eyelid width, FL = foot length, HL = head length, HW = head width, IOD = interorbital distance, SVL = snout–vent length, TD = tympanum diameter, and TL = tibia length. Specimens examined are listed in Appendix 1. The capitalized colors and color codes (the latter in parentheses) are those of KÖHLER (2012). Terminology of markings used in color descriptions follows KÖHLER (2012). Institutional acronyms used are those listed in SABAJ (2016) except for MNKA (= NKA) Museo Noel Kempff Mercado, Santa Cruz de la Sierra (amphibians).

Bioacoustics

Calls of frogs were recorded in the field using a digital recorder (Olympus DM-550) and external directional microphones (Sennheiser ME80/M66), using a sampling rate of 44.1 kHz (32-bit resolution) and were saved as uncompressed .wav files. Recordings were deposited in the Animal Sound Archive (www.tierstimmenarchiv.de; for accession numbers see Appendix 2). Advertisement calls were computer-analysed using the software RAVEN PRO 1.5 (BIOACOUSTICS RESEARCH PROGRAM 2011). Frequency information was obtained through Fast Fourier Transformation (FFT, width 1024 points). Spectrograms were obtained at Hanning window function with 256 bands resolution. Temporal measurements of calls such as repetition rates, duration of notes, and number of pulses, were measured on the waveforms. Graphs of the audiospectrograms and waveforms were built with the SEEWAVE R package (SUEUR *et al.*, 2008). Terminology in call descriptions follows KÖHLER *et al.* (2017). In contrast to TEIXEIRA & GIARETTA (2015) who used a note-centered approach sensu KÖHLER *et al.* (2017) by terming the two distinct emissions of *Dendropsophus anataliasiasi* “note

type A and B”, we here follow the call-centered approach sensu KÖHLER *et al.* (2017) by using the terms “call type A and B” for the two types of emissions existent in *D. anataliasiasi* and the new species described herein. A series starting with emission of one call type A and subsequent calls of type B (e.g., ABBBBB) is herein referred to a “composite call”. All statistics were conducted in R (R CORE TEAM, 2017).

Molecular methods

Additionally to the 16S rRNA sequence data already used in an earlier study (JANSEN *et al.*, 2011; SCHULZE *et al.*, 2015), we included new sequence data and complemented our data set with selected sequences from GenBank (see list of sequences in Appendix 3). The nomenclature used herein follows FROST (2018). Additionally, we used the terminology of candidate species suggested by JANSEN *et al.* (2011) for unnamed distinct lineages in Bolivia (e.g., *Dendropsophus cachimbo* A). We selected sequences from GenBank based on the following criteria: for phylogenetic analyses we chose available sequences attributed to species of *Dendropsophus* including all 16S rRNA sequences of the *D. microcephalus* species group available, but excluding those sequences that could not be aligned to the other sequences (*D. berthallutzae* KU495201 and KU495202, *D. leali* AY819550 and MG030717, *D. microcephalus* AF308109, AF308110, AY819503, *D. nanus* AY819505, EF376062, EU201104, JF973304, GQ366298, *D. robertmertensi* AY819551, *D. sartori* AY819552), and additionally one member of each of the other species groups of *Dendropsophus*, i.e., *D. columbianus* (Boettger), *D. labialis* (Peters), *D. leucophyllatus* (Beireis), *D. marmoratus* (Laurenti), *D. minimus* (Ahl), and *D. parviceps* (Boulenger) species groups. As outgroup and to root the trees we chose *Xenohyla truncata* (Izecksohn), the sister taxon of *Dendropsophus* according to FAIVOVICH *et al.* (2005). An alignment of 494 bp containing 122 sequences in total was performed in MEGA6 (TAMURA *et al.*, 2013) with the implemented ClustalW algorithm (HIGGINS *et al.*, 1994). The best nucleotide substitution model for our dataset was identified using PartitionFinder2 (LANFEAR *et al.*, 2016), with linked branch lengths.

Phylogenetic analyses were performed with the aligned sequences and with the implemented GTR+G+I best-fit model following the Akaike Information Criterion with a correction for finite sample sizes (AICc). Bayesian Inference analysis (BI) was performed with MrBayes 3.2 (HUELSENBECK & RONQUIST, 2001; RONQUIST & HUELSENBECK, 2003). Runs were performed in duplicate with 1,000,000 generations each, trees sampled every 100 generations, and convergence assessed graphically. Of each run, the first 1250 trees were discarded as “burn-in”.

Maximum-likelihood (ML) analysis was performed using the IQTREE webserver (TRIFINOPOULOS *et al.*, 2016). To estimate clade support we run an analysis using 10,000 ultrafast bootstrap approximation (UFBoot) rep-

licates with 10,000 maximum iterations and Minimum correlation coefficient of 0.99 plus 10,000 replicates of Shimodaira-Hasegawa approximate likelihood ratio (SH-aLRT), which proved to be accurate with a high statistical power (GUINDON *et al.*, 2010). We used FigTree 1.3.1 for tree viewing (<http://tree.bio.ed.ac.uk/software/figtree/>). We followed DE QUEIROZ *et al.* (2002) in the definition of weak (50–69 bootstrap percentages), moderate (70–89), and strong (90–100) support. However, we emphasize that the goal of this study is to call attention to the degree of genetic differentiation among populations, and not to provide an in-depth or comprehensive analysis of phylogenetic relationships within *Dendropsophus* at any level. This would require more comprehensive data sets, e.g., including additional molecular markers.

For members of the *Dendropsophus rubicundulus* group including additional species that are positioned in the same clade according our analyses (*D. cruzi*, *D. juliani*, *D. juliani* A, and *D. sanborni*, see below) we estimated evolutionary genetic divergence for the 16S gene among sequences, computing uncorrected pairwise p-distances with MEGA 6 (TAMURA *et al.*, 2013) to assess the degree of intra- and interspecific differences, using a Bootstrap estimation method of 10,000 replications.

Results

The analysis of our molecular data revealed several distinct genetic clusters among *Dendropsophus* species (Fig. 1 and 2). The recovered phylogeny shows the candidate species within a major clade containing species of the *D. rubicundulus* species group plus *D. cruzi*, *D. juliani*, *D. juliani* A, and *D. sanborni*. This clade received weak support by ML (69%) and by Bayesian analyses (62 posterior probabilities). Within this clade, in the ML analysis our candidate species is sister to a clade formed by *D. sanborni* along with *D. cachimbo* A and *D. elianae* (Fig. 1). In the Bayesian analysis our candidate species is sister to *D. cachimbo* (Fig. 2). In both cases, our candidate species forms a group with strong support (ML: 100%; Bayesian: 1.0), and is separated by genetic distances to the other members of the clade as follows (p-distances, followed by K2-distance in parentheses of closest relatives; see also Tab. 1 for more details): *D. cf. tritaeniatus* “Bolivia” differs from *D. anataliasiasi* (mean) by 7.2 (7.7)%, *D. cachimbo* (UFU 1632) by 6.1 (6.4)%, from *D. cachimbo* A (mean) by 5.7 (6.0)%, from *D. elianae* (mean) by 5.7 (6.0)%, and *D. sanborni* (AY843663) by 5.1 (5.3)%. The voucher specimen of the sequence AY843661 of *D. rubicundulus* from GenBank most probably was misidentified and actually belongs to *D. elianae* instead of *D. rubicundulus* according to (1) the position in the tree and (2) 7.5% genetic p-distance from AY843661 to the sequence of *D. rubicundulus* from Serra do Cipó (ca. 60 km distant from type locality) used herein.

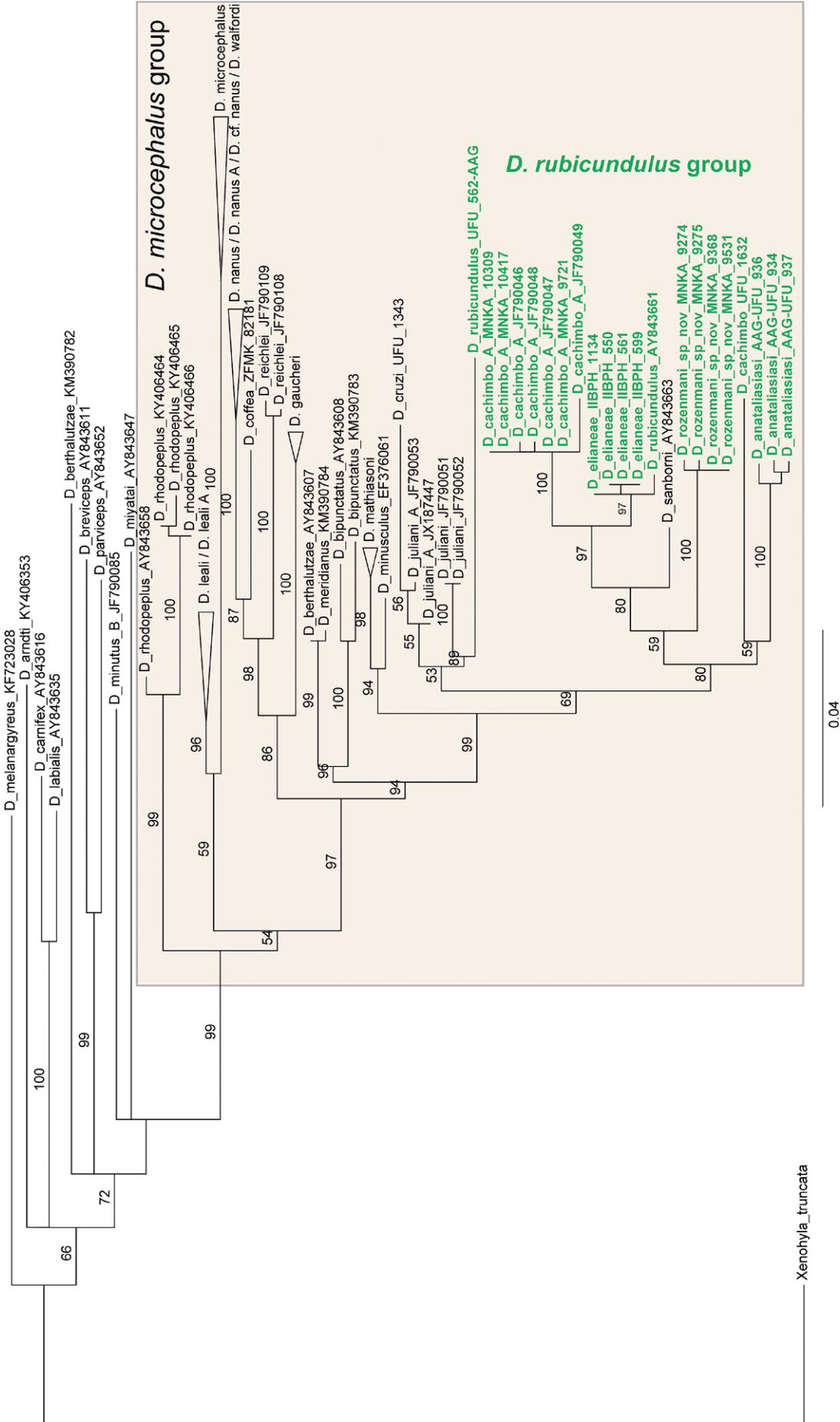


Fig. 1. Phylogenetic tree of *Dendropsophus* species based on Maximum Likelihood analysis of partial sequences of the 16S rRNA gene (494 bp). *Xenohyla truncata* was used as outgroup. Numbers at nodes show support from bootstrap analysis (not shown if bootstrap values < 50). Clade containing species of the *Dendropsophus microcephalus* species group marked. Numbers after species names refer to GenBank accession numbers (see Appendix 3).

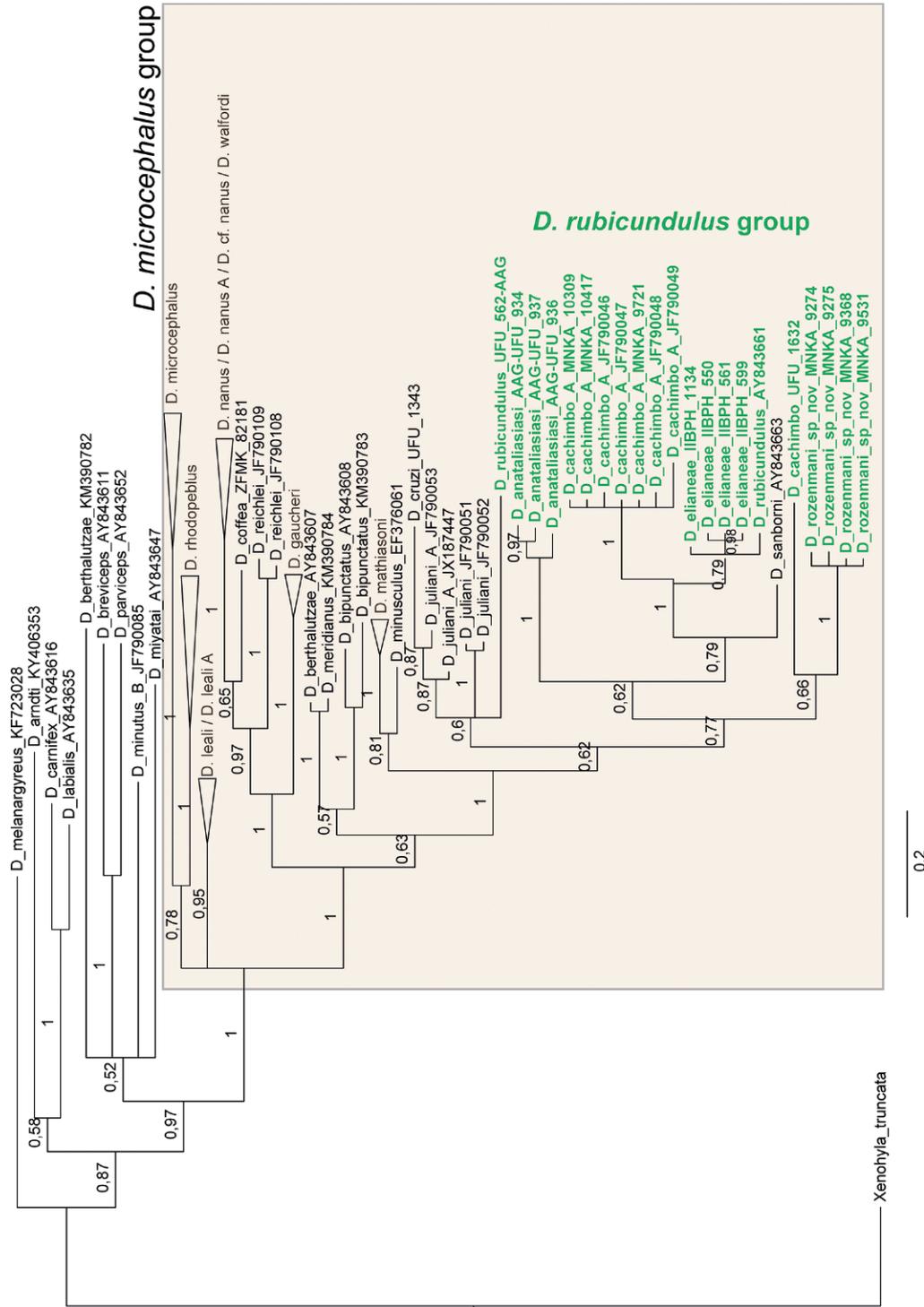


Fig. 2. Phylogenetic tree of *Dendropsophus* species based on Bayesian analysis of partial sequences of the 16S rRNA gene (494 bp). *Xenohyla truncata* was used as outgroup. Numbers at nodes show support from Bayesian posterior probabilities (not shown if posterior probability < 0.50). Clade containing species of the *Dendropsophus microcephalus* species group marked. Numbers after species names refer to GenBank accession numbers (see Appendix 3).

Regardless of the affiliation to any species group (see discussion below) we describe the populations *Dendropsophus* cf. *tritaeniatus* “Bolivia” as a new species due to divergences from other species in the genus in morphology, bioacoustics and molecular data.

***Dendropsophus rozenmani* sp. nov.**

ZOOBANK urn:lsid:zoobank.org:act:8D7B2428-4473-46AD-AE1F-6E8CEE4441F7 (Figures 3, 4, 6, Appendix 4)

Dendropsophus tritaeniatus – JANSEN *et al.* (2011)
Hyla tritaeniata – REICHLÉ & KÖHLER (1996), REICHLÉ (1997), REICHLÉ & KÖHLER (1998), DE LA RIVA *et al.* (2000), MÁRQUEZ *et al.* (2002)

Holotype. MNKA 11504, adult male, Caparú Ranch, outpost Las Lagunitas (-14.836217, -61.177783, 185 m asl), Provincia Velasco, Department of Santa Cruz, Bolivia, collected on 17 January 2006 by M. JANSEN; original field tag MJ 805.

Paratypes. All (4 specimens) from Caparú Ranch, outpost Las Lagunitas, Provincia Velasco, Department of Santa Cruz, Bolivia: MNKA 9922, SMF 88450, -14.812300, -61.171967, 184 m asl,

Table 1. Estimates of evolutionary divergence of *D. rozenmani* sp. nov. to other species of the clade (Fig. 1 and 2). The pairwise genetic distances between sequences or mean genetic divergence between groups (when more than one sequence referred to the same species were available) are shown.

| | p-Distance | K2-distance |
|---|------------|-------------|
| <i>D. anataliasiasi</i> | 0.072 | 0.077 |
| <i>D. cachimbo</i> (UFU 1632) | 0.061 | 0.064 |
| <i>D. cachimbo</i> A (mean) | 0.057 | 0.060 |
| <i>D. cruzi</i> (UFU 1343) | 0.061 | 0.064 |
| <i>D. elianae</i> (mean) | 0.057 | 0.060 |
| <i>D. juliani</i> (NMP 6V72799) | 0.051 | 0.053 |
| <i>D. juliani</i> A | 0.056 | 0.059 |
| <i>D. rubicundulus</i> (UFU 562) | 0.091 | 0.097 |
| <i>D. sanborni</i> (Entre Rios, Brazil, AY843663) | 0.051 | 0.053 |

collected on 18 February 2012 by M. JANSEN and O. BARROSO; SMF 88490, -14.812500, -61.169050, 160 m asl, collected on 19 February 2012 by M. JANSEN and O. BARROSO; MNKA 9531, male, collected on 3 December 2009 by A. SCHULZE.

Referred specimens. Seven specimens. BOLIVIA: Beni: Los Lagos, -12.768367, -65.815250, 136 m asl; SMF 88449, SMF 88491, SMF 88453, MNKA 9368, MNKA 9276–78.

Diagnosis. A species of the genus *Dendropsophus* that is assigned to the *D. microcephalus* species group based on the results of a molecular analysis of a fragment of the 16S rRNA gene, general morphological appearance, and overall call structure. Further, it is tentatively assigned to the *D. rubicundulus* group (fide NAPOLI & CARAMASCHI, 1998) based on morphological and molecular data awaiting further studies on the monophyly of this group. *Dendropsophus rozenmani* is distinguished from other species of *Dendropsophus* by the following combination of characters: (1) small size, SVL 18.7–21.1 mm in adult males and 19.6–23.2 mm in females; (2) head longer than wide; (3) snout short, rounded in dorsal view, acute to protruding in lateral view; (4) canthus rostralis rounded, loreal region slightly concave; (5) tympanum indistinct or not visible; (6) skin on dorsal surfaces smooth; (7) in life, dorsal ground coloration brown, with two anterior parallel and straight, dark brown stripes and a middorsal sacral stripe; (8) lateral limits of dorsal coloration above tympanum; (9) composite advertisement call consisting of two types of pulsed calls (type “A” and type “B”) that are emitted usually in series starting with one call type A and followed by 1 to 12 calls type B; call type A is 42 seconds in average long and has 3–9 pulses; type B is in average 12 ms long and has 1–3 pulses; dominant frequency of both call types is around 4100 Hz.

Comparisons. External morphology and comparisons of a sequence of the 16S rRNA gene indicate that *Dendropsophus rozenmani* sp. nov. is related to species currently placed in the *D. rubicundulus* group (fide NAPOLI & CARAMASCHI, 1998).

In external appearance, *Dendropsophus rozenmani* sp. nov. is most similar to *D. tritaeniatus*, mainly because of similar dorsal markings composed of two, well defined straight and parallel anterior dorsal brown stripes, and a middorsal sacral stripe (NAPOLI & CARAMASCHI, 1999b) [character states of *D. rozenmani* sp. nov. in brackets in the following]. However, *D. tritaeniatus* as well as all the other species of the *D. rubicundulus* group, has a green dorsal ground coloration [brown in *D. rozenmani* sp. nov.]. In addition, *D. tritaeniatus* is readily distinguished from *D. rozenmani* sp. nov. by having only one single call type [versus two different call types forming a composite call (TEIXEIRA *et al.*, 2013; JANSEN, own data)]. Such qualitative characters in anuran advertisement calls have been suggested to be very valuable for delimitation of different species (see KÖHLER *et al.*, 2017). Besides this qualitative difference, *D. tritaeniatus* has 3.4 pulses in average (2–4) per call [5.5 pulses in average (3–9) per call type A; 1.8 pulses (1–3) per call type B], and an average of 32 ms (17–49) call duration [42 ms (18–66) in call type A; 12 ms (4–23) in call type B]. Furthermore, *D. tritaeniatus* differs from *D. rozenmani* sp. nov. its habitat preferences: *D. tritaeniatus* is associated with permanent springs and streams (NAPOLI & CARAMASCHI, 1998) whereas *D. rozenmani* sp. nov. inhabits permanent and temporary ponds as well as inundated areas of savannas (Fig. 4B).

The other species of the *rubicundulus* group having a striped dorsal pattern (*D. anataliasiasi*, *D. araguaya*, *D. cerradensis*, *D. jimi*, *D. rhea*, *D. rubicundulus*) differ from *D. rozenmani* sp. nov. by exhibiting the following characters (NAPOLI & CARAMASCHI, 1998, 1999a,b, 2000): *D. anataliasiasi*, *D. araguaya*, *D. cerradensis*, *D. jimi*, *D. rhea*, and *D. rubicundulus* have a green dorsal ground coloration in life [brown], and a violet dorsal ground coloration in preservative [brown]. In addition, *D. jimi*, and *D. rubicundulus* have a single advertisement call type [composite call]; *D. anataliasiasi* and *D. rubicundulus* do not have a single sacral stripe [present], and sometimes these two species have a middorsal pin stripe [absent]; *D. anataliasiasi* has two anterior divergent dorsal brown stripes, fused with two brown sacral stripes, or, if parallel, stripes are irregular or marked with blotches [two straight, well defined and parallel anterior dorsal brown stripes, and a middorsal sacral stripe]; *D. rubicundulus* has a head as long as wide [longer than wide]; *D. araguaya* has interrupted dorsal stripes that might diverge [well defined and parallel stripes]; *D. cerradensis* has dorsal stripes that always diverge [parallel stripes]; *D. jimi* has irregular dorsal stripes [well defined]; *D. rhea* has divergent dorsal stripes [parallel].

Two species of the *rubicundulus* group, namely *Dendropsophus cachimbo* and *D. elianae*, as well as *D. cachimbo* A, another candidate species fide JANSEN *et al.* (2011), are readily distinguished from *D. rozenmani* sp. nov. by having an immaculate green dorsum [striped dorsal pattern on brown dorsal ground color]; the lateral limits of the dorsal coloration below the tympanum [above]; advertisement call composed of only a single call type

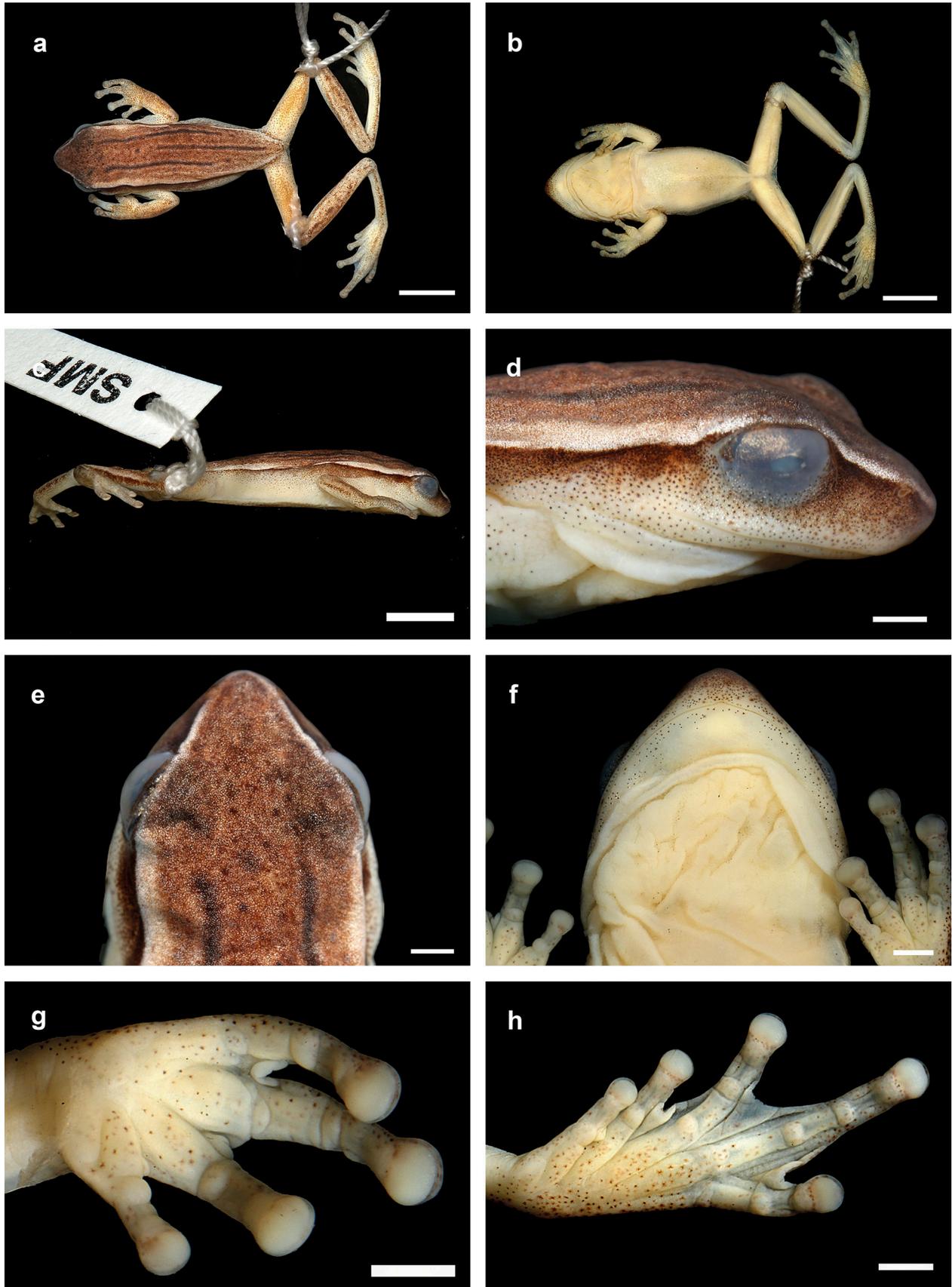


Fig. 3. Holotype of *Dendropsophus rozenmani* sp. nov. (MNKA-11504): (a) dorsal view (b) ventral view (c) lateral view (d) lateral view of head (e) dorsal view of head (f) ventral view of head (g) ventral surface of right hand (h) ventral surface of left foot. Scale bars = 5.0 mm in a–c and 1.0 mm in d–h. Photos: G. Köhler.

Table 2. Selected measurements and proportions of type material of *Dendropsophus rozenmanni*. Range is followed by mean value and standard deviation in parentheses. For abbreviations see text.

| | | <i>D. rozenmanni</i> (5 males, 2 females) |
|---------|---------|---|
| SVL | males | 18.7–21.1 (19.7±0.9) |
| | females | 19.6–23.2 (21.4±1.8) |
| TL/SVL | males | 0.474–0.506 (0.489±0.012) |
| | females | 0.456–0.578 (0.517±0.086) |
| FL/SVL | males | 0.295–0.353 (0.332±0.024) |
| | females | 0.289–0.381 (0.335±0.065) |
| HW/ SVL | males | 0.265–0.296 (0.280±0.012) |
| | females | 0.263–0.296 (0.280±0.025) |
| HL/SVL | males | 0.246–0.299 (0.283±0.019) |
| | females | 0.251–0.287 (0.269±0.025) |
| EN/HL | males | 0.147–0.202 (0.175±0.019) |
| | females | 0.191–0.236 (0.213±0.032) |
| IOD/HW | males | 0.285–0.384 (0.327±0.034) |
| | females | 0.318–0.457 (0.388±0.099) |

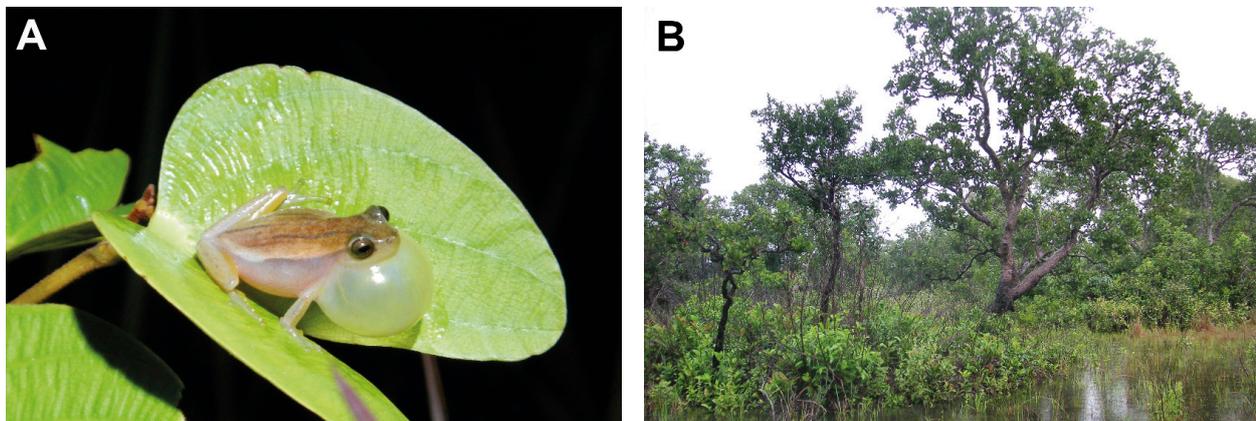


Fig. 4. (A) Calling paratype *Dendropsophus rozenmanni* sp. nov. (MNKA 9922); (B) temporary inundated Cerrado at the type locality Caparú Ranch, Bolivia, the typical habitat of *Dendropsophus rozenmanni* sp. nov. Photos: M. Jansen

[two call types forming a composite call]. In addition, *D. elianae* has a larger SVL of around 20 to 26 mm in males and 25 to 26 mm in females [around 19 to 21 mm in males and 23 mm in females] (NAPOLI & CARAMASCHI, 1999a,b, 2000; MARTINS & JIM, 2004; JANSEN *et al.*, 2011; TEIXEIRA & GIARETTA, 2015; JANSEN own data).

Because *Dendropsophus cruzi* (Pombal & Bastos, 1998), *D. juliani* Moravec, Aparicio & Köhler, 2006, *D. juliani* A, and *D. sanborni* (Schmidt, 1944) are nested in the same clade (Fig. 1 and 2; see discussion), we herein include these species in the comparisons with the new species. *Dendropsophus cruzi* mainly differs from *D. rozenmanni* sp. nov. by having a brown dorsum with variable, but often X-shaped dorsal pattern [brown dorsum with well-defined stripes], a small SVL of 16 to 20 mm in males [around 19 to 21 mm in males], as well as in advertisement call composed of a single note or type with two pulses [two call types with up to 10 pulses]. *Dendropsophus juliani* mainly differs from *D. rozenmanni* sp. nov. by having a pale yellowish-tan to reddish-tan dorsum with inconspicuous dark brown markings [brown dorsum with well-defined stripes]. *Dendropsophus juliani* A mainly

differs from *D. rozenmanni* sp. nov. by having a reddish-tan dorsum without markings [brown dorsum with well-defined stripes]. *Dendropsophus sanborni* mainly differs from *D. rozenmanni* sp. nov. by having a brown dorsum with fine punctuations [brown dorsum with well-defined stripes], an average SVL of 16 mm in males [20 mm] (SCHMIDT, 1944; POMBAL & BASTOS, 1998; MARTINS & JIM, 2003; MORAVEC *et al.*, 2006; JANSEN *et al.*, 2011).

Similar to *D. anataliasiasi* and *D. rozenmanni* sp. nov., two different call types were reported for *D. sanborni* (“introductory note” and “typical advertisement call” in chorus situations, MARTINS & JIM, 2003) and *D. juliani* (“initial note” and “subsequent notes”, MORAVEC *et al.*, 2006). Indeed, following the call centered approach of KÖHLER *et al.* (2017), we argue that the different “note types” in *D. sanborni* and *D. juliani* actually are different call types. However, because such “initial” or “introductory” calls are often skipped and therefore not strictly linked, we doubt that the call types in *D. sanborni* and *D. juliani* form a composite call (in *D. rozenmanni* sp. nov., call types “A” and “B” are usually emitted together, and thus, might, have a straight functional linkage).

Table 3. Some characteristics of advertisement calls of *D. rozenmani* sp. nov. (365 calls; n=10 individuals) and related species of the *D. rubicundulus* group where call data are available. Range followed by mean ± standard deviation in parentheses. See text for more details.

| Bioacoustic traits | <i>D. rozenmani</i> sp. nov. (n=10) | | <i>D. anataliasiasi</i> (n=10) | | <i>D. cachimbo</i> (n=14) | <i>D. elianae</i> (n.d.)* | <i>D. jimi</i> (n.d.)* | <i>D. rubicundulus</i> (n=13) | <i>D. triaeniatatus</i> (n=5) |
|--------------------------------|-------------------------------------|----------------------|--------------------------------|------------------------|-----------------------------|---------------------------|------------------------|-------------------------------|---------------------------------|
| | type A | type B | type A | type B | | | | | |
| call duration [ms] | 42±9 (18–66) | 12±3 (4–23) | 52.1±4.6 (21–69) | 22.7±3.1 (13–34) | 15.0±1.9 (5–34) | 18.0±2.9 (14–26) | 52.4±9.6 (37–72) | 19.3±3.2 (10–32) | 32±4.8 (17–49) |
| pulses per call | 5.5±1.1 (3–9) | 1.8±0.5 (1–3) | 7.0±0.6 (5–9) | 3.2±0.4 (2–4) | 2.1±0.2 (1–3) | 3±1 (2–5) | 4±2 (3–9) | 3.6±0.4 (2–5) | 3.4±0.2 (2–4) |
| pulse duration[ms] | 5±1 (2–10) | 5±2 (2–17) | 7.6±0.2 (5–10) | 6.9±0.3 (5–13) | 7.5±0.7 (4–17) | 4.9±0.8 (2–6) | 6.0±1.0 (3–6) | 5.3±0.4 (2–11) | 9.9±1.0 (3–14) |
| pulse rate [pulses per second] | 131±17 (82–167) | 154±41 (43–250) | 135.2±8.7 (95.2–381.0) | 142.9±6.5 (90.9–200.0) | 148.2±18.7 (66.7–333.3) | n.d. | n.d. | 190.4±17.7 (125–300) | 107.3±8.6 (82–133) |
| Dominant frequency [Hz] | 4136±211 (3531–4593) | 4135±209 (3531–4565) | 4024±113.6 (3843–4312) | 4023±118 (3843–4312) | 4166±153.2 (3890–4406) | 3200–3300 | 3900 | 3730±235.8 (3093–4171) | 3191±104.3 (2924–3533) |
| Source | this study | | Teixeira & Giarretta (2015) | | Teixeira & Giarretta (2015) | Martins & Jim (2004) | Martins & Jim (2004) | Teixeira & Giarretta (2015) | Teixeira <i>et al.</i> , (2013) |

n.d. = no data; * = in chorus situation

Therefore, the existence of a composite call in *D. rozenmani* sp. nov. distinguishes this species readily from *D. juliani* and *D. sanborni*. Nevertheless, the “typical advertisement call” of *D. sanborni* differs quantitatively from the one of *D. rozenmani* sp. nov. by having a dominant frequency of 4000 to 5500 Hz (MARTINS & JIM, 2003) [3575–4593]; in average 5.0 (3–8) pulses [call type A: 5.5 (3–9) pulses per call; call type B: 1.8 (1–3)], and a mean call duration of 38 ms (26–65) [call type A: 42 ms (18–66), call type B: 12 ms (4–23)]. Explicit values for the “initial note” (= call, see above) of *D. juliani* were not given, but both note (call) types have 3.8 pulses in average (3–6) [call type A: 5.5 (3–9) pulses per call; call type B: 1.8 (1–3)], and mean note (call) duration is 17.6 ms (11–26) [call type A: 42 ms (18–66), call type B: 12 ms (4–23)]. See Tab. 3 for an overview of comparative bioacoustic data.

Description of holotype. Adult male as indicated by presence of vocal slits and large vocal sac; SVL 21.1; head about same width as body, longer than wide (HW/HL = 0.86); snout short, in dorsal view rounded, rounded in lateral view; distance from nostril to eye less than diameter of eye (EN/ED = 0.59); canthus rostralis distinct, rounded; loreal region slightly concave, sloping to upper lip; nostrils barely protuberant, openings directed laterally; eye quite large (ED 2.3); tympanic membrane round, indistinct, hardly visible, its diameter more than one third of eye length; tympanic annulus not visible; supratympanic fold absent; UEW = 1.65; IOD = 1.7; forelimbs not hypertrophied; abbreviated axillary membrane present, extends along proximal upper arm; minute ulnar tubercles absent; finger discs round, wider than digit (Finger III: digit width/disc width = 0.72); relative length of fingers I<II<IV<III; webbing vestigial between Finger I and II, basal between Fingers II to IV; remaining webbing formula I 2.5–3 II 2+–3 III 2½–2.5 IV; distal subarticular tubercle in fourth finger not bifid; supernumerary tubercles not visible; palmar tubercle flat, elliptical; subarticular tubercle large, rounded; nuptial excrescences absent; hind limbs long, slender, lacking calcar tubercles, tarsal fold absent; TL = 10.7; FL = 8.0; toes moderately long, toe discs round (Toe IV: toe width/disc width = 0.82); relative

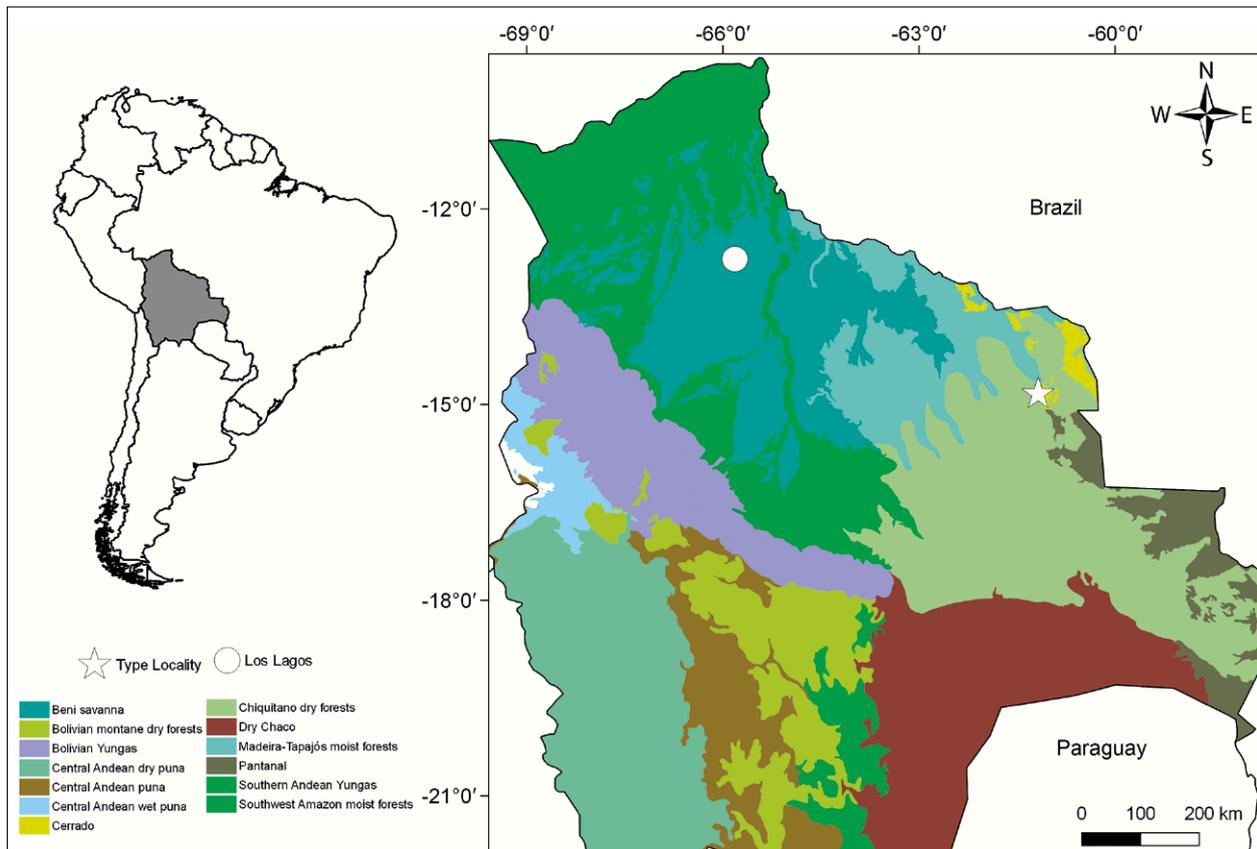


Fig. 5. Map showing type locality (star) and locality of referred specimens (circle) of *Dendropsophus rozenmani* sp. nov.

length of toes I<II<III<IV<V; outer metatarsal tubercle not visible; inner metatarsal tubercle large, flat, elliptical; subarticular tubercles large, rounded; supernumerary tubercles minute, subconical; toe webbing formula I 2–2.5 II 1.5–3 III 1.75–3 IV 2+–1.5 V; dorsal surfaces of head and ventral surfaces of limbs smooth; dorsum with scattered minute tubercles; skin on belly coarsely granular; cloacal opening directed posteriorly at upper level of thighs; cloacal sheath wrinkled and long, covering almost the entire cloacal opening; cloacal folds present; vomerine odontophores present; choanae clearly visible; tongue approximately round, clearly notched and free posteriorly; pectoral fold absent; vocal slit extends from midlateral base of tongue nearly to angle of lower jaw; vocal sac single, median, folds visible in gular region.

Coloration after almost nine years preservation in 70% ethanol was as follows: Dorsal surface of head Verona Brown (37); dorsal surface of body Raw Umber (23), grading into Pale Pinkish Buff (3) laterally and with Sepia (279) longitudinal stripes; hidden portions of limbs Pale Pinkish Buff (3) with a suffusion of Yellow Ocher (15); a Burnt Sienna (38) longitudinal lateral line along body, heavily suffused with Verona Brown (37) below; ventral surfaces Pale Pinkish Buff (3).

Variation. The paratypes agree well with the holotype in terms of general morphology and coloration. For variation of selected morphometric characters see Tab. 2. Coloration in life of an adult male (MNKA 9922) was

recorded as follows: Dorsal surfaces of head, body, and non-hidden portions of limbs Dark Yellow Buff (54) with a suggestion of Dark Salmon Color (59); lateral surface of head Straw Yellow (53); lateral surface of body Pinkish White (216), suffused with Drab-Gray (256); fingers and distal portions of toes as well as dorsal surface of digital discs Dark Yellow Buff (54); iris Kingfisher Rufous (296).

Vocalization. The composite advertisement call consists of two distinct types of pulsed calls. Call type A (Fig. 5A) is usually the initial call followed by a series of calls of type B (Fig. 5B), e.g. ABBBBB (see example call in Fig. 6). A composite call (A+nB) consists of one call type A followed by 1–12 calls type B (2.48 ± 2.27 , $n=114$ composite calls from 9 individuals). However, call type A can be emitted solely as well.

We recorded and analysed advertisement calls of 10 individuals, including the holotype and three paratypes (MNKA 9922, SMF 88450, SMF 88490; Tab. 3). All but one emitted composite calls, resulting in 114 composite calls composed of 114 calls type A and 284 calls type B from 9 individuals. Additionally, 45 solely emitted calls type A from all 10 individuals were included in the analyses. In total, 5 to 30 (16.77 ± 8.53) calls type A and 0 to 64 (29.22 ± 19.48) calls type B were analysed per individual. Call duration of a composite call was 143 to 1563 ms ($337 \text{ ms} \pm 276$). In a composite call, intervals between calls of type A and B or B and B were 77–119 ms (99 ms

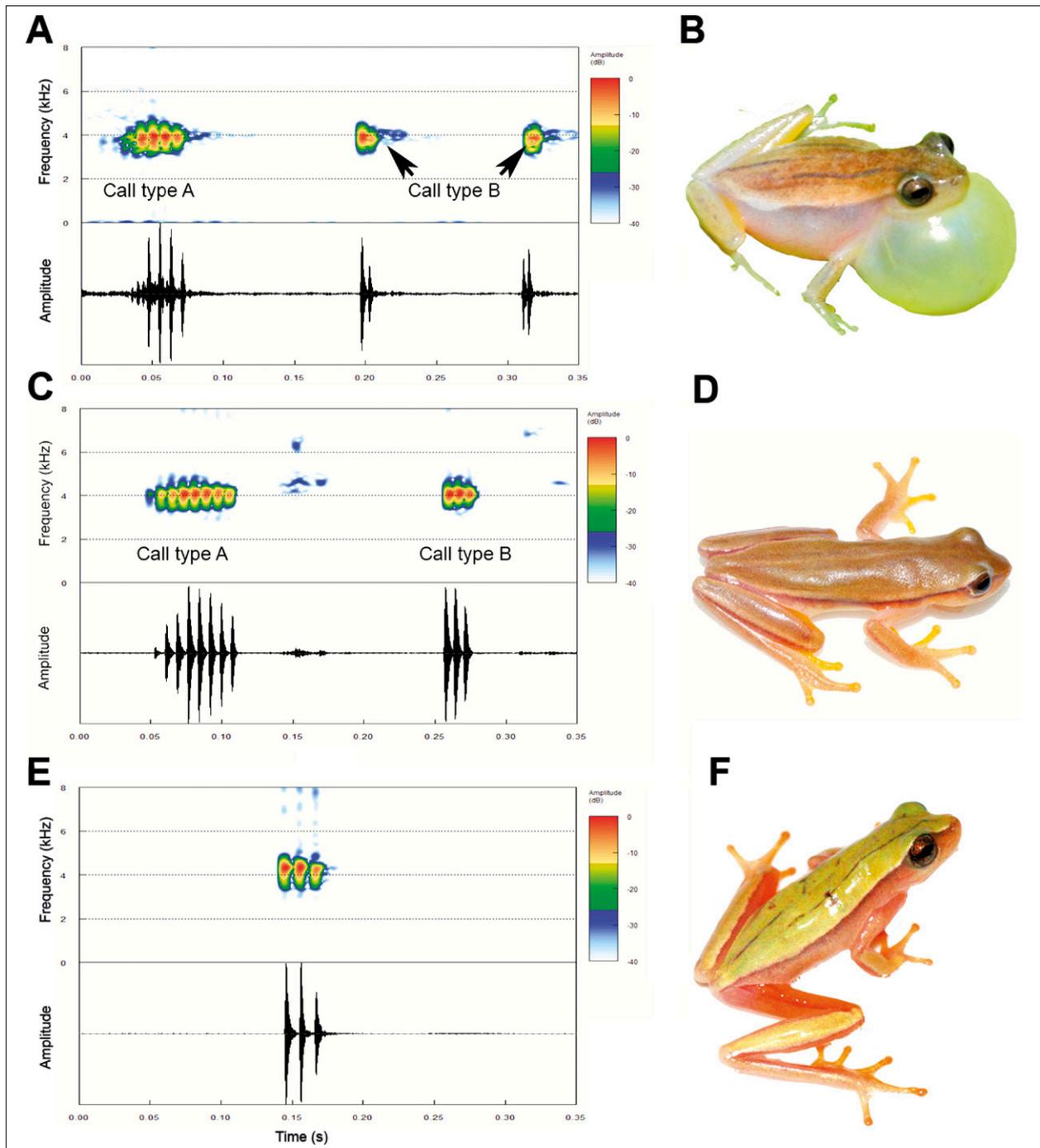


Fig. 6. Audiospectrogram (above) and waveform (below) of advertisement calls and fotos in live of three closely related species of the *D. rubicundulus* group: (A) advertisement call of paratype SMF 88490 *D. rozenmani* sp. nov., recorded on 19 February 2012 by Martin Jansen; air temperature 25.6°C; (B) MNKA 9922 in live; photo: Martin Jansen; (C) toptotypical advertisement call of *D. anataliasiasi*, recorded on 26 November 2011 by Bernardo Teixeira; air temperature 28°C (TEIXEIRA *et al.* 2015); (D) *D. anataliasiasi* in live; photo: Ariovaldo A. Giaretta; (E) advertisement call of *D. tritaeniatius*, recorded on 24 November 2012 by Bernardo Teixeira; air temperature 20.5°C (TEIXEIRA *et al.* 2013); (F) *D. tritaeniatius* in live; photo: Thiago R. de Carvalho.

±9.7). The interval between a composite call (e.g., ABBB interval ABB interval ABB) or solely emitted calls of type A was 0.93–8.40 sec (3.06 sec±1.28; n=126 intervals measured from 10 individuals). Numerical call parameters of call type A are as follows (range followed by mean±standard deviation in parentheses): call duration 18–66 ms (42±9; n=159); pulses per call 3–9

(5.45±1.14; n=159); pulse duration 2–10 ms (5 ms; ±1; n=579); pulse rate 82–167 pulses/sec (131±17; n=159); dominant frequency 3531–4565 Hz (4135±209; n=159). Numerical call parameters of call B are: call duration 4–23 ms (12±3; n=284); pulses/call 1–3 (1.8±0.5; n=284); pulse duration 2–17 ms (5 ms; ±2; n=253); pulse rate 43–250 pulses/sec (154±41;

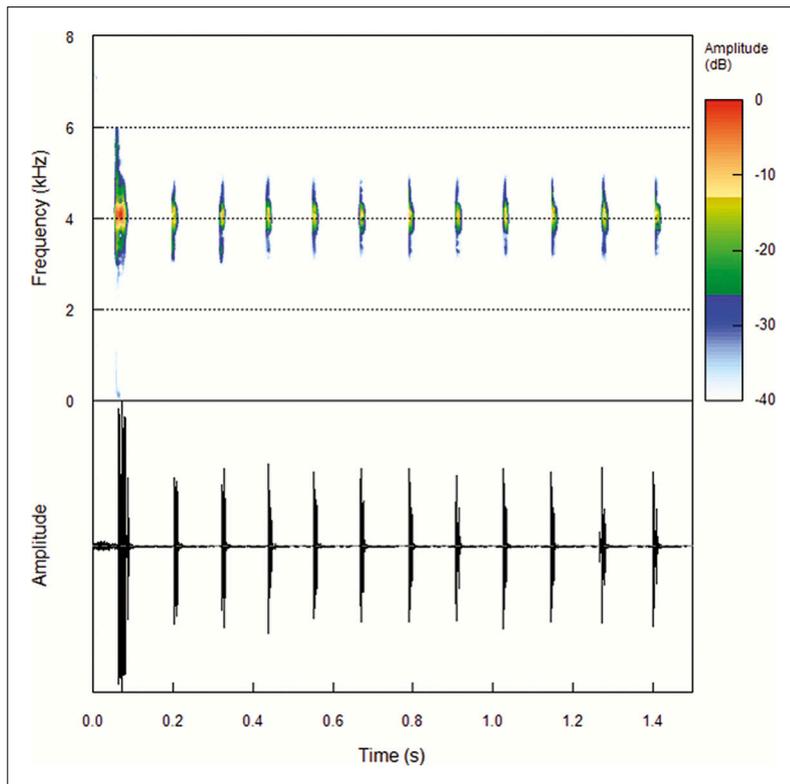


Fig. 7. Audiospectrogram (above) and waveform (below) of a composite advertisement call of *Dendropsophus rozenmani* sp. nov. (paratype SMF 88490). Same data as in Figure 6A.

$n=284$); dominant frequency 3575–4593 Hz (4136 ± 211 ; $n=284$). Fig. 8 shows the distribution of values in histograms.

Distribution, habitat, and conservation status. *Dendropsophus rozenmani* sp. nov. is known from two localities, one in the Department of Santa Cruz, Bolivia (Caparú Ranch), and a second locality (Los Lagos) in the Department of Beni. However, we assume that other authors refer to *Dendropsophus rozenmani* sp. nov. when reporting recordings of *Hyla tritaeniata* from the Estación Biológica del Beni (EBB) (REICHLÉ & KÖHLER, 1996; REICHLÉ, 1997; REICHLÉ & KÖHLER, 1998; DE LA RIVA *et al.*, 2000; MÁRQUEZ *et al.*, 2002).

The type locality (Fig. 5), the cattle ranch Caparú, is situated in the contact zone of the ecoregions Cerrado, Pantanal, Madeira-Tapajós moist forests, and Chiquitano dry forest (*sensu* DINERSTEIN *et al.*, 2017). The average annual precipitation varies between 1100 and 1500 mm, and average annual temperature is 25–30°C. The second locality, Los Lagos, as well as the Estación Biológica del Beni (EBB) is located in the ecoregion Beni savannas i (*sensu* DINERSTEIN *et al.*, 2017) and the dominant vegetation type consists of open Cerrado savannas.

Other hylid species found in sympatry at Caparú Ranch (CAP) and Los Lagos (LL) include *Dendropsophus* cf. *nanus* (CAP, LL), *D. cachimbo* A (CAP; *fide* JANSEN *et al.*, 2011), *D. cf. minutus* (CAP: lineage 33 *fide* GEHARA *et al.*, 2014; LL: lineage 30), *Boana raniceps* (CAP, LL), *Scinax fuscomarginatus* (CAP, LL), *S. madeirae* (CAP, LL) and at least two species of the *S. ruber* clade (CAP, LL).

All individuals included in the study herein were found in recently flooded Cerrado savannas (Fig. 4B) or along lakeshores. We assume this species to be associated with the Pantanal Flooded Savannas, Moxos Plain Flooded Savannas, and the Cerrado of Beni and Chiquitano (*fide* IBISCH & MÉRIDA, 2004) and is, thus, restricted to the these regions in the eastern lowlands of Bolivia. Reproductive mode and larvae are unknown.

Etymology. The specific name is a patronym for JAIME ROZENMAN, one of the owners of Caparú Ranch, Bolivia, in recognition of his long-lasting logistic support of taxonomic research on his property, and in honor of his great effort for conservation of the local flora and fauna.

Discussion

Dendropsophus rozenmani is morphologically most similar to the species of the *D. tritaeniatus* complex, because of its striped dorsal pattern. NAPOLI & CARAMASCHI (1998, 1999a,b) stated that *D. tritaeniatus* should be seen as a complex of species due to large intra- and inter-populational variations (without giving details on variation). The eastern Bolivian lowland populations indeed could be separated by morphology, DNA, their habitat, and also by bioacoustics. Advertisement calls have been described for the following species of the *D. rubicundulus* group: *D. anataliasiasi* (TEIXEIRA & GIARETTA, 2015),

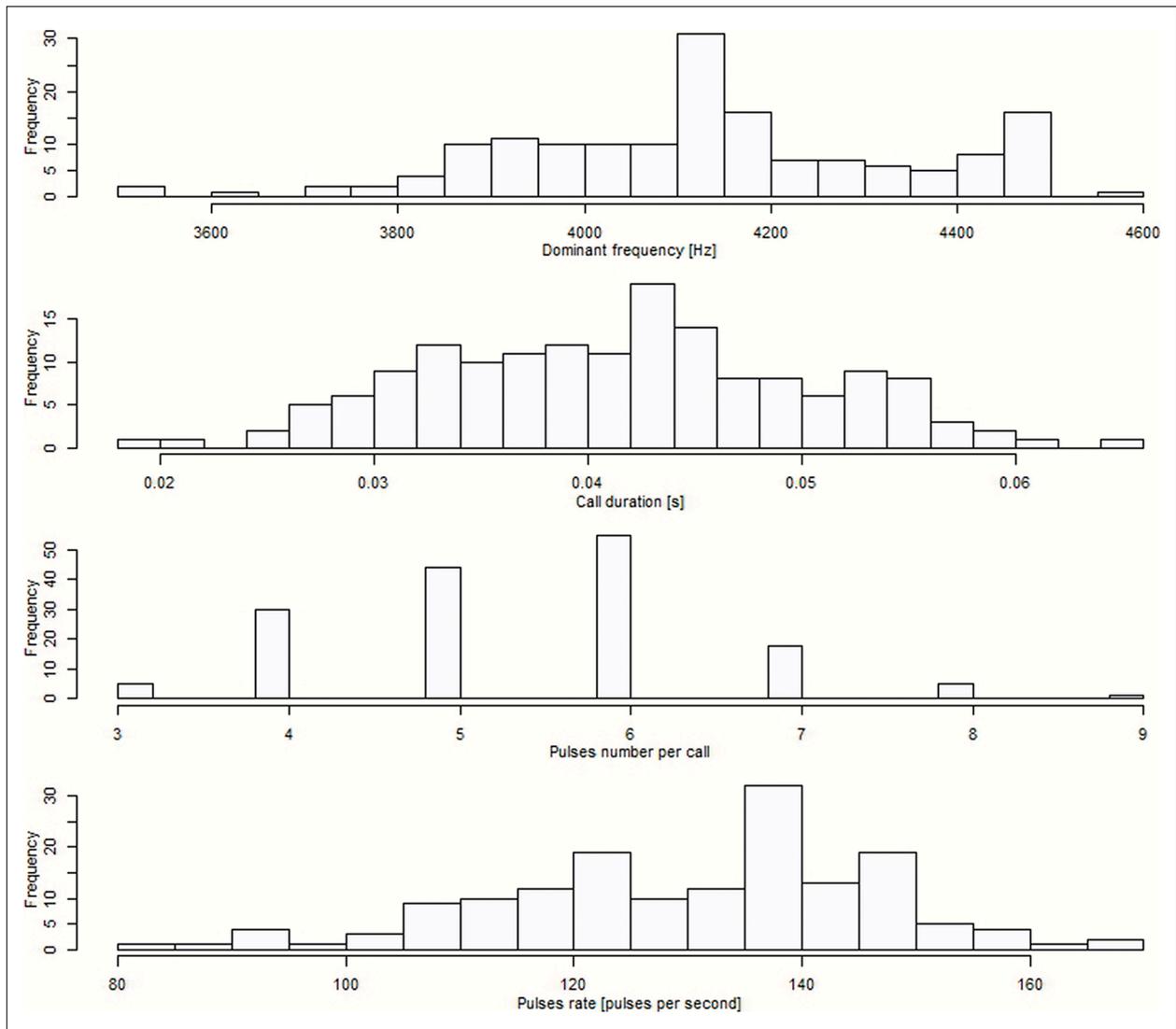


Fig. 8. Histograms showing distribution of values of dominant frequency, call duration, pulses number, and pulse rate of 159 calls type A from 10 individuals of *D. rozenmani*. See text for details.

D. cachimbo (TEIXEIRA & GIARETTA, 2015), *D. elianeae* (MARTINS & JIM, 2004), *D. jimi* (MARTINS & JIM, 2004), *D. rubicundulus* (CARDOSO & VIELLIARD, 1985; TEIXEIRA & GIARETTA, 2015), and *D. tritaeniatus* (TEIXEIRA *et al.*, 2013). Among these, *D. anataliasiasi* and *D. rozenmani* sp. nov. are unique by having a composite call consisting of two types of calls (this study, TEIXEIRA & GIARETTA, 2015). In their comprehensive review of the use of advertisement calls in anuran taxonomy, KÖHLER *et al.* (2017) suggested that qualitative call differences, such as number of different call types, are robust indicators in acoustic delimitation of anuran species. Indeed, bioacoustical methods have proven to be very valuable in the delimitation of species (e.g., TEIXEIRA *et al.*, 2013; TEIXEIRA & GIARETTA 2015; CAMINER *et al.*, 2017), and especially qualitative acoustic characters clearly evidenced the distinctiveness of *Dendropsophus rozenmani*. Besides, the occurrence of only few species of the *rubicundulus* group with a composite call raises questions on the call evolution within that group. Similar as

proposed for species related to *D. elegans* (FORTI *et al.*, 2017), the respective phylogenetic positions of *D. anataliasiasi* and *D. rozenmani* sp. nov. (not directly related) let assume that the composite call in these two species have independent origins. Regarding the *microcephalus* group, the existence of two call types is known in only few species as noted by KÖHLER & LÖTTTERS (2001; e.g., in *D. juliani*, *D. joannae*, *D. microcephalus*, *D. nanus*, and *D. sanborni*). However, in how far these call types actually present a composite call, i.e., in how far these two call types are actually functionally linked with each other (as they most probably are in *D. rozenmani* sp. nov. and *D. anataliasiasi*), or, alternatively, if they are independently related to different social contexts, remains to be studied. As an example for the latter, *D. nanus* emits longer (“initial”) calls as first of a call series that might be skipped as well (JANSEN, pers. obs.), probably due to different densities of calling males.

Nevertheless, the methodological potential of bioacoustical analyses for frog species delimitation is still not

yet exploited (KÖHLER *et al.*, 2017). However, although studies on individual call variation, as well as descriptions of anuran call repertoires are important for taxonomy, they are still scarce (e.g. BEE *et al.*, 2013a, b; JANSEN *et al.*, 2016a, b). For example, a trait that is static on the intra-specific level might be informative for species delimitation. Therefore, it would be interesting to assess the variability of call traits in the *D. rubicundulus* group with the aim to test for traits useful for species delimitation, and to further develop the methodology of acoustic species delimitation in frogs.

Comments on the *D. rubicundulus* group

Regarding the species described herein the results of our molecular analyses suggest a nested position within the *Dendropsophus microcephalus* species group. The closeness of the new species to the (morphologically defined) *rubicundulus* group (fide NAPOLI & CARAMASCHI, 1998) is supported by general morphological appearance and overall call structure. The *D. rubicundulus* species group was first defined by NAPOLI & CARAMASCHI (1998) as having the following characters: size small (16–26 mm), thighs immaculate, dorsum predominantly green in life and pink to violet in preservative. Currently, 11 species are recognized as belonging to the *D. rubicundulus* group distributed mainly in open environments in the Cerrado domain (see introduction). FAIVOVICH *et al.* (2005) defined the *Dendropsophus rubicundulus* clade based solely in one sequence of *D. rubicundulus* (“AY843661”, most probably belonging to *D. elianaeae*, see above). A recent molecular phylogenetic analysis of the *microcephalus* group (MEDEIROS *et al.*, 2013) demonstrated that this species group does not constitute a monophyletic group in respect to *D. sanborni*, although the authors did not further discuss their finding. Our data support the non-monophyly of the *rubicundulus* group (Fig. 1 and 2), particularly because of the position of *D. sanborni*, *D. cruzi* and *D. juliani*. The morphological and molecular definition of the *D. rubicundulus* group fide NAPOLI & CARAMASCHI (1998) and *D. rubicundulus* clade fide FAIVOVICH *et al.* (2005), all remain to be tested.

Our study, next to many other recent studies, shows that the actual amphibian diversity in the Neotropics is still far from being sorted out and completely described, notably in the genus *Dendropsophus* (e.g., JANSEN *et al.*, 2011; GEHARA *et al.*, 2014; CAMINER *et al.*, 2017). More field surveys are needed to cover especially the vast, remote and understudied areas (e.g., in eastern Bolivia the Beni savannas and the Chiquitano region or Chiquitania). Moreover, studies repeatedly found that “widespread” frog species actually represent complexes of species with often much smaller distribution areas (GEHARA *et al.*, 2014). It is obvious that decision makers must react, and that much more protected areas are needed to actual cover the still increasing number of recognized anuran species, including micro-endemics (e.g., PIE *et al.*, 2013), in the future.

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Appendix 1

Additional specimens examined

- Dendropsophus aperomeus*: PERU: El Boquerón, ZFMK 39323–41.
- Dendropsophus brevifrons*: PERU: Andoas, ZFMK 40157–59.
- Dendropsophus coffea*: BOLIVIA: La Paz: 55 km on road from Caranavi to Palos Blancos, 800 m, MNKA 6538 (holotype), ZFMK 80590 (paratype); 5 km N Río Beni bridge, near Sapecho, 550 m, ZFMK 82182 (paratype).
- Dendropsophus cruzi*: BOLIVIA: Santa Cruz: P.N. Noel Kempff Mercado, ZFMK 72672–73.
- Dendropsophus delarivai*: BOLIVIA: Cochabamba: road from Paracito to Cochabamba via El Palmar, ZFMK 67139–142, 70317 (paratypes); La Paz: Colonia Eduardo Avaroa, 1300 m, MNKA 6539, ZFMK 80587–588.
- Dendropsophus joannae*: BOLIVIA: Pando: Cobija, 250 m, ZFMK 67119–120, 67121–124 (paratypes).
- Dendropsophus juliani* A (fide Jansen *et al.*, 2011): BOLIVIA: Santa Cruz: Caparú, MNKA 9579, 9919.
- Dendropsophus leali*: BOLIVIA: Beni: Río Ibaré, 300 m, ZFMK 60721–22; Santa Cruz: Buenavista, MNKA 9479–80; Hacienda San Sebastián and Centro de Investigaciones Ecológicas Chiquitos, MNKA 9431, 9434, 9458, 9703–06.
- Dendropsophus leali* A (fide Jansen *et al.*, 2011): BOLIVIA: Santa Cruz: Caparú, MNKA 9575.
- Dendropsophus melanargyreus*: BOLIVIA: Santa Cruz: Caparú, MNKA 9541.
- Dendropsophus meridianus*: BRAZIL: Rio de Janeiro: 20 km N of Rio de Janeiro, ZFMK 39499–500.
- Dendropsophus “minutus”* (probably contains more than a single species): BOLIVIA: Chuquisaca: W of Vaca Guzmán, 1360 m, ZFMK 66045; Santa Cruz: Samaipata, 1900 m, ZFMK 60403–407; Laguna de Bermejo, 1130 m, ZFMK 60440; W of Río Seco, 900 m, ZFMK 67053–055; La Hoyada, 1700 m, ZFMK 72634–635; Pando: Cobija, 250 m, ZFMK 66790.
- Dendropsophus minutus* A (fide Jansen *et al.*, 2011): BOLIVIA: Hacienda San Sebastián and Centro de Investigaciones Ecológicas Chiquitos, MNKA 9453–54, 9711–12, 9719–20, 9723.
- Dendropsophus minutus* B (fide Jansen *et al.*, 2011): BOLIVIA: Beni: Los Lagos (Selva Blue), MNKA 9283, 9360;
- Dendropsophus “nanus”* (probably contains more than a single species): BOLIVIA: Beni: Puerto Almacén, ZFMK 60458–462; Santa Cruz: Buenavista, 250 m, ZFMK 80011–014, MNKA 9474, MNKA 9989, SMF 88421, SMF 88420; Campamento, MNKA 9960; Hacienda Caparú, MNKA 9540, 9578, 9586, SMF 88442; Hacienda San Sebastián and Centro de Investigaciones Ecológicas Chiquitos, MNKA 9405, 9408–09, 9424, 9427, 9495, 9667–68, 9675–76, 9784, 9824; San Ramón, ZFMK 60391–392; La Florida, ZFMK 60374–381; Santa Cruz de la Sierra, 400 m, ZFMK 67001; PARAGUAY: Chaco: 23 km S of Filadelfia, ZFMK 53262–266.
- Dendropsophus cf. nanus*: BOLIVIA: Beni: Los Lagos (Selva Blue), MNKA 9305, 9321–22, 9388, 9390; Santa Cruz: Estancia Büchler, MNKA 9802.
- Dendropsophus nanus* A (fide Jansen *et al.*, 2011): BOLIVIA: Campamento, MNKA 9960; Hacienda Caparú, MNKA 9530, 9540, 9578, 9586, SMF 88442; Hacienda San Sebastián and Centro de Investigaciones Ecológicas Chiquitos, MNKA 9405, 9408–09, 9424, 9427, 9495, 9667–68, 9675–76, 9784, 9824.
- Dendropsophus sanborni*: PARAGUAY: Misiones: Isla Yacyreta: SMF 105080–82.

Appendix 2

Call vouchers, localities, and Animal Sound Archive (<http://www.tierstimmenarchiv.de/>) accession numbers of some of the recordings used in the analyses.

| Species | Voucher | Locality | Animal Sound Archive | Remarks |
|------------------------------|--------------------------|---|------------------------------------|--|
| <i>D. rozenmani</i> sp. nov. | MNKA 9368 | Los Lagos, Department of Santa Cruz, Bolivia | Dendropsophus_rozenmani_DIG0201_01 | 2 February 2010; 21:15 hrs; 29.2°C |
| <i>D. rozenmani</i> sp. nov. | SMF 88449 | Los Lagos, Department of Santa Cruz, Bolivia | Dendropsophus_rozenmani_DIG0201_02 | 6 January 2007; 22:00 hrs |
| <i>D. rozenmani</i> sp. nov. | MNKA 9922 (paratype) | Caparú Ranch, Department of Santa Cruz, Bolivia | Dendropsophus_rozenmani_DIG0201_03 | 18 February 2012; 22:30 hrs; 26.6°C |
| <i>D. rozenmani</i> sp. nov. | SMF 88450 (paratype) | Caparú Ranch, Department of Santa Cruz, Bolivia | Dendropsophus_rozenmani_DIG0201_04 | 18 February 2012; 22:50 hrs; 26.1°C |
| <i>D. rozenmani</i> sp. nov. | SMF 88490 (paratype) | Caparú Ranch, Department of Santa Cruz, Bolivia | Dendropsophus_rozenmani_DIG0201_05 | 19 February 2012; 01:22 hrs; 25.8°C |
| <i>D. rozenmani</i> sp. nov. | MNKA-11504 (holotype) | Caparú Ranch, Department of Santa Cruz, Bolivia | Dendropsophus_rozenmani_DIG0201_06 | 17 February 2006; 02:30 hrs; 24.4°C |
| <i>D. rozenmani</i> sp. nov. | Not collected #1 | Caparú Ranch, Department of Santa Cruz, Bolivia | Dendropsophus_rozenmani_DIG0201_07 | 6 January 2007; 22:00 hrs |
| <i>D. rozenmani</i> sp. nov. | Not collected #2 | Caparú Ranch, Department of Santa Cruz, Bolivia | Dendropsophus_rozenmani_DIG0201_08 | 02 February 2007; 22:00 hrs |
| <i>D. rozenmani</i> sp. nov. | Not collected #3 | Caparú Ranch, Department of Santa Cruz, Bolivia | Dendropsophus_rozenmani_DIG0201_09 | 02 February 2007; 01:30 hrs |
| <i>D. rozenmani</i> sp. nov. | Not collected #4 | Caparú Ranch, Department of Santa Cruz, Bolivia | Dendropsophus_rozenmani_DIG0201_10 | 02 February 2007; 01:30 hrs |
| <i>D. rozenmani</i> sp. nov. | Not collected #5 | Caparú Ranch, Department of Santa Cruz, Bolivia | Dendropsophus_rozenmani_DIG0201_11 | 22 February 2012; 01:50 hrs |

Appendix 3

Species, GenBank accession numbers and localities of individuals used in the phylogenetic analyses. For abbreviations of voucher numbers, refer to the publications listed.

| species | museum voucher | GenBank accession number | locality | author |
|-------------------------|----------------|--------------------------|--|--------------------------------|
| <i>D. arndti</i> | MNKA 10349 | MK919546 | Santa Cruz, Ñuflo de Chavez, San Sebastián, Bolivia | this study |
| <i>D. melanargyreus</i> | MNKA 10445 | MK919556 | Santa Cruz, Ñuflo de Chavez, San Sebastián, Bolivia | this study |
| <i>D. miyatai</i> | JPC 10772 | AY843647 | Sucumbios, Ecuador | FAIVOVICH <i>et al.</i> (2005) |
| <i>D. parviceps</i> | AMNH A-139315 | AY843652 | Universidade do Acre, Acre, Brazil | FAIVOVICH <i>et al.</i> (2005) |
| <i>D. minutus</i> B | MNKA 9360 | JF790085 | Los Lagos, Yucuma, Beni, Bolivia | JANSEN <i>et al.</i> (2011) |
| <i>D. labialis</i> | QULC 97005 | AY843635 | Parque Natural Nacional Chingaza, Colombia | FAIVOVICH <i>et al.</i> (2005) |
| <i>D. carnifex</i> | DFCH-USFQ 899 | AY843616 | Pichincha, Tandyapa, Ecuador | FAIVOVICH <i>et al.</i> (2005) |

Appendix 3 continued.

| species | museum voucher | GenBank accession number | locality | author |
|---|----------------|--------------------------|---|--|
| <i>D. anataliasiasi</i> | AAG-UFU 934 | MK919543 | Brejinho de Nazaré Tocantins, type locality | this study |
| <i>D. anataliasiasi</i> | AAG-UFU 936 | MK919544 | Brejinho de Nazaré Tocantins, Brazil (type locality) | this study |
| <i>D. anataliasiasi</i> | AAG-UFU 937 | MK919545 | Brejinho de Nazaré Tocantins, Brazil (type locality) | this study |
| <i>D. berthallutzae</i> | CFBH 5418 | AY843607 | Duque de Caxias, Rio de Janeiro, Brazil | FAIVOVICH <i>et al.</i> (2005) |
| <i>D. bipunctatus</i> | MRT5946 | AY843608 | Serra do Teimoso, Jussari, Bahia, Brazil | FAIVOVICH <i>et al.</i> (2005) |
| <i>D. cachimbo</i> | UFU 1632 | MK919550 | Vilhena, Mato Grosso, Brazil | this study |
| <i>D. cachimbo</i> A | SMF 88443 | JF790049 | San Sebastián, Ñuflo de Chavez, Santa Cruz, Bolivia | JANSEN <i>et al.</i> (2011) |
| <i>D. cachimbo</i> A | SMF 88442 | JF790048 | San Sebastián, Ñuflo de Chavez, Santa Cruz, Bolivia | JANSEN <i>et al.</i> (2011) |
| <i>D. cachimbo</i> A | MNKA 9655 | JF790046 | San Sebastián, Ñuflo de Chavez, Santa Cruz, Bolivia | JANSEN <i>et al.</i> (2011) |
| <i>D. cachimbo</i> A | MNKA 9656 | JF790047 | San Sebastián, Ñuflo de Chavez, Santa Cruz, Bolivia | JANSEN <i>et al.</i> (2011) |
| <i>D. cachimbo</i> A | MNKA 9721 | MK919547 | San Sebastián, Ñuflo de Chavez, Santa Cruz, Bolivia | This study |
| <i>D. cachimbo</i> A | MNKA 10309 | MK919548 | San Sebastián, Ñuflo de Chavez, Santa Cruz, Bolivia | This study |
| <i>D. cachimbo</i> A | MNKA 10417 | MK919549 | San Sebastián, Ñuflo de Chavez, Santa Cruz, Bolivia | This study |
| <i>D. coffea</i> | ZFMK 82181 | JF790050 | near Sapecho, Sur Yungas, La Paz, Bolivia | JANSEN <i>et al.</i> (2011) |
| <i>D. cruzi</i> | UFU 1343 | MK919551 | Silvania, Goiás, Brazil (type locality) | |
| <i>D. decipiens</i> | CFBHT07254 | KU495203 | Cananeia, Sao Paulo, Brazil | LYRA <i>et al.</i> (2016), direct submission |
| <i>D. elianeae</i> | IIBPH 1134 | MK919555 | Estancia Pirá Potrero, Amambay, Paraguay | this study |
| <i>D. elianeae</i> | IIBPH 550 | MK919552 | Reserva Natural Privada Cerrados del Tagatiyá, Estancia Garay Kué, Concepción, Paraguay | this study |
| <i>D. elianeae</i> | IIBPH 561 | MK919553 | Reserva Natural Privada Cerrados del Tagatiyá, Estancia Garay Kué, Concepción, Paraguay | this study |
| <i>D. juliani</i> | NMP6V 72799/3 | JF790051 | Barracón, Madre de Dios, Pando, Bolivia | JANSEN <i>et al.</i> (2011) |
| <i>D. leali</i> | MNHM 2005.0013 | JN206639 | Pidima, French Guiana | FOUQUET <i>et al.</i> (2011) |
| <i>D. microcephalus</i> | UTA A-50632 | AY843643 | Atlántida, Cordillera Nombre de Dios, Honduras | FAIVOVICH <i>et al.</i> (2005) |
| <i>D. nanus</i> | SMF 88421 | JX187442 | Buenavista, Ichilo, Santa Cruz, Bolivia | this study |
| <i>D. nanus</i> | MACN 37785 | AY549346 | Entre Rios, Islas del Ibicuy, Argentina | FAIVOVICH <i>et al.</i> (2005) |
| <i>D. reichlei</i> | EBT2 | JF790109 | E.B.Tahuamanu, Manuripi, Pando, Bolivia | JANSEN <i>et al.</i> (2011) |
| <i>D. rhodopeplus</i> | MHZ 462 | AY843658 | Jenaro Herrera, Loreto, Peru | FAIVOVICH <i>et al.</i> (2005) |
| <i>D. rubicundulus</i> | IT-H 0653 | AY843661 | Buri, Sao Paulo, Brazil | FAIVOVICH <i>et al.</i> (2005) |
| <i>D. rubicundulus</i> | UFU 562_AAG | MK919557 | Serra do Cipó – MG | |
| <i>D. sanborni</i> | MACN 38638 | AY843663 | Islas del Ibicuy, Entre Ríos, Argentina | FAIVOVICH <i>et al.</i> (2005) |
| <i>D. tritaeniatus</i> (<i>D. rozenmani</i> sp. nov.) | SMF 88491 | JF790113 | Los Lagos, Yucuma, Beni, Bolivia | JANSEN <i>et al.</i> (2011) |
| <i>D. tritaeniatus</i> (<i>D. rozenmani</i> sp. nov.) | SMF 88453 | JF790114 | Los Lagos, Yucuma, Beni, Bolivia | JANSEN <i>et al.</i> (2011) |

Appendix 3 continued.

| species | museum voucher | GenBank accession number | locality | author |
|---|----------------|--------------------------|---|--------------------------------|
| <i>D. tritaeniatus</i> (<i>D. rozenmani</i> sp. nov.) | MNKA 9368 | JF790115 | Los Lagos, Yucuma, Beni, Bolivia | JANSEN <i>et al.</i> (2011) |
| <i>D. tritaeniatus</i> (<i>D. rozenmani</i> sp. nov.) | MNKA 9531 | JF790112 | Los Lagos, Yucuma, Beni, Bolivia | JANSEN <i>et al.</i> (2011) |
| <i>D. walfordi</i> | MJH 129 | AY843683 | Brazil | FAIVOVICH <i>et al.</i> (2005) |
| <i>Xenohyla truncata</i> | — | AY843775 | Restinga de Marica, Rio de Janeiro, Brazil | FAIVOVICH <i>et al.</i> (2005) |

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