



A new species of the *Bokermannohyla circumdata* group (Anura: Hylidae) from southeastern Brazil, with bioacoustic data on seven species of the genus

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Abstract

We describe a new species of the *Bokermannohyla circumdata* group from the Estação de Pesquisa e Desenvolvimento Ambiental Galheiro (EPDA-Galheiro) (19°12'S; 47°08'W), Municipality of Perdizes, State of Minas Gerais, a mid-altitudinal (≈ 850 m above sea level) riparian forest environment in the Cerrado of southeastern Brazil. *Bokermannohyla napolii* sp. nov. is allied to the large-sized species of the group, diagnosed on the basis of adult morphology/morphometrics, and mainly vocalizations. Adult specimens of the new species are most closely related to those of *B. luctuosa* and *B. circumdata*, but can be differentiated from the former by having distal subarticular tubercle of finger III bifid/divided in males, and finger IV bifid/divided in males and females; and from both *B. luctuosa* and *B. circumdata* by a distinctive advertisement call structure. We also provide bioacoustic data on seven other species of the genus, including previously unknown advertisement calls of *B. circumdata* and *B. carvalhoi*, and re-description of the advertisement calls of *B. luctuosa*, *B. ibitiguara*, *B. nanuzae*, *B. sazimai*, and *B. hylax*.

Key words: Advertisement call, *Bokermannohyla carvalhoi*, *Bokermannohyla circumdata* species group, *Bokermannohyla luctuosa*, *Bokermannohyla napolii* sp. nov., Cerrado, State of Minas Gerais

Resumo

Nós descrevemos uma nova espécie do grupo de *Bokermannohyla circumdata* proveniente da Estação de Pesquisa e Desenvolvimento Ambiental Galheiro (EPDA-Galheiro) (19°12'S; 47°08'O), município de Perdizes, estado de Minas Gerais, um ambiente ripário de altitude mediana (≈ 850 metros de altitude) no Cerrado do sudeste brasileiro. *Bokermannohyla napolii* sp. nov. está relacionada às espécies de grande porte do grupo, diagnosticada com base em morfologia e morfometria de espécimes adultos e principalmente vocalizações. Espécimes adultos da nova espécie são mais intimamente relacionados aos de *B. luctuosa* e *B. circumdata*, mas podem ser diferenciados daqueles por apresentarem o tubérculo subarticular distal do dedo III bifido/dividido nos machos, e do dedo IV bifido/dividido nos machos e nas fêmeas; e de ambas as espécies supracitadas por apresentar estrutura distinta no canto de anúncio. Além disso, o canto de anúncio da espécie nova apresenta um padrão distinto em comparação com os cantos de *B. luctuosa* e *B. circumdata*. Nós também apresentamos dados bioacústicos de sete espécies do gênero, incluindo cantos de anúncio desconhecidos previamente de *B. circumdata* e *B. carvalhoi*, e redescrição dos cantos de anúncio de *B. luctuosa*, *B. ibiguara*, *B. nanuzae*, *B. sazimai* e *B. hylax*.

Palavras-chave: *Bokermannohyla carvalhoi*, *Bokermannohyla luctuosa*, *Bokermannohyla napolii* sp. nov., canto de anúncio, Cerrado, estado de Minas Gerais, grupo de *Bokermannohyla circumdata*

Introduction

The genus *Bokermannohyla* was erected by Faivovich *et al.* (2005) and currently comprises 29 species distributed throughout the Atlantic Forest and Cerrado formations in Brazil. The monophyly of the genus is supported by molecular data, and a thorough morphological study is still required (Faivovich *et al.* 2009). This genus encompasses four phenetic species groups: the *B. circumdata* (Cope), *B. pseudopseudis* (Miranda-Ribeiro), *B. martinsi* (Bokermann), and *B. claresignata* (Lutz & Lutz).

The *Bokermannohyla circumdata* species group includes 18 species (Napoli & Pimenta 2009), sharing some or all of the following combination of traits: brown dorsal surfaces (in life and preserved), simple (not dichotomized) transverse stripes on posterior surfaces of thighs and flanks, single (not bifid) large and sharp prepollex, and adult males having hypertrophied forearms (Heyer 1985; Napoli & Juncá 2006; Napoli & Pimenta 2009). This group is also defined by 52 transformations in the mitochondrial and nuclear protein, and ribosomal genes (Faivovich *et al.* 2005). This group is generally restricted to altitudinal riparian environments within the Atlantic Forest and Cerrado domains (Napoli & Pimenta 2009).

During field surveys in a mid-altitudinal (\approx 850 m above sea level) riparian environment in the Cerrado of southeastern Brazil (State of Minas Gerais), within the region known as Triângulo Mineiro/Alto Paranaíba, we collected specimens and recorded calls of a *Bokermannohyla* of the *B. circumdata* group that we could not assign to any previously available name. Herein we recognize those specimens as belonging to an undescribed species on the basis of adult morphology, morphometrics, and mainly vocalizations.

So as to improve differential diagnosis and bioacoustic knowledge of the genus *Bokermannohyla*, we describe for the first time the advertisement calls of (i) *B. circumdata*: from the southern sector of the Serra da Mantiqueira mountain range, State of Minas Gerais, as well as from the coastal Atlantic Forest in the State of São Paulo, and of (ii) *B. carvalhoi* (Peixoto 1981) from its type locality: at the Parque Nacional da Serra dos Órgãos, Municipality of Teresópolis, State of Rio de Janeiro. In addition, we re-describe the advertisement calls of *B. ibitiguara* (Cardoso 1983) (currently assigned to the *B. pseudopseudis* species group according to Faivovich *et al.* 2005), *B. nanuzae* (Bokermann & Sazima 1973), *B. luctuosa* (Pombal & Haddad 1993), *B. hylax* (Heyer 1985), and *B. sazimai* (Cardoso & Andrade 1982) from either their type localities or closely adjacent localities.

Material and methods

Specimens, vocalizations, and data on habitat and natural history of the new species were gathered at the Estação de Pesquisa e Desenvolvimento Ambiental Galheiro (EPDA-Galheiro) (approximately 19°12'S; 47°08'W, 750–900 m above sea level, 2,840 ha), Municipality of Perdizes, State of Minas Gerais, southeastern Brazil. This reserve belongs to the Companhia Energética de Minas Gerais (CEMIG) and was established as a compensation effort after the construction of the Nova Ponte dam reservoir on the Araguari River.

Type specimens and additional examined specimens (Appendix 1) are housed in the following public Brazilian zoological collections: Museu de Zoologia da Universidade Estadual de Campinas (ZUEC), Campinas, State of São Paulo; Célio F. B. Haddad Collection (CFBH), Rio Claro, State of São Paulo; Collection of amphibians of the Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, State of Minas Gerais; and Collection of frogs of the Universidade Federal de Uberlândia (AAG-UFU), Uberlândia, State of Minas Gerais.

Twelve morphometric characters were taken from adult specimens with calipers to the nearest 0.1 mm. Seven measurements follow Duellman (1970): snout-vent length (SVL), head length (HL), head width (HW), eye diameter (ED), tympanum diameter (TD), shank length (SL) (= tibia length), and foot length (FL). Two measurements follow Heyer *et al.* (1990): thigh length (TL), and hand length (HAL). Three measurements follow Napoli (2005): eye-nostril distance (END), third finger disk diameter (FDD), and fourth toe disk diameter (TDD). Webbing formula notation follows Savage and Heyer (1997). Eggs were measured with calipers under a stereomicroscope.

Morphometric and bioacoustic data of related species were based on their original descriptions (Bokermann & Sazima 1973; Jim & Caramaschi 1979; Peixoto 1981; Cardoso 1983; Caramaschi & Feio 1990; Peixoto & Cruz 1992; Pombal & Haddad 1993; Caramaschi *et al.* 2001; Napoli & Pimenta 2003; Vasconcelos & Giarretta 2003; Napoli & Caramaschi 2004; Napoli 2005; Lugli & Haddad, 2006; Napoli & Juncá 2006; Napoli & Pimenta, 2009), as well as on Heyer *et al.* (1990).

Almost all analyzed advertisement calls were recorded with digital recorders (Marantz PMD-670, Marantz PMD-671, Boss BR 864, or M-audio Microtrack II) set at 44.1 or 48.0 kHz sample rate and 16 bits resolution, cou-

pled to directional microphones [Sennheiser K6/ME67 (Marantz and Boss) or K6/ME66 (Microtrack)]; calls of *B. luctuosa* were recorded with a Nagra E tape recorder (19 cm/s) coupled to a Sennheiser MKH816T microphone. Bioacoustic variables were analyzed with SoundRuler software version 0.9.6.0. (Gridi-Papp 2007); sound graphs were obtained with Seewave (version 1.6) (Sueur *et al.* 2008), R (version 2.13) package (R Development Core Team 2011). Seewave settings were Hanning window and 85% overlap. Call mechanics and terminology generally follow McLister *et al.* (1995) for comparative purposes of interespecific advertisement calls, and Duellman and Trueb (1994) for standard terms. Call categories (advertisement and aggressive calls) follow Wells (2007). Assignment of letters to the note types (A, B, and C) of the new species, *B. circumdata*, and *B. luctuosa* is the assumption of putative homology of those note types in all three species.

Vocalizations of *B. circumdata* was recorded in the Municipality of Chiador, State of Minas Gerais, Brazil, southern sector of the Serra da Mantiqueira mountain range, as well as in the District of Paranapiacaba (Municipality of Santo André), coastal Atlantic Forest in the State of São Paulo, Brazil; advertisement call of *B. luctuosa* was recorded at the Parque Estadual de Itapetinga, Municipality of Atibaia, State of São Paulo, Brazil, approximately 35 km in a straight line from its type locality (Serra do Japi mountain range, Municipality of Jundiá); advertisement call of *B. carvalhoi* was recorded at the Parque Nacional da Serra dos Órgãos (type locality), Municipality of Teresópolis, State of Rio de Janeiro, Brazil; vocalizations of *B. hylax* was recorded in the District of Paranapiacaba (Municipality of Santo André), State of São Paulo, Brazil, approximately 55 km in a straight line from its type locality (Estação Biológica de Boracéia, Municipality of Salesópolis); advertisement call of *B. nanuzae* was recorded at the Parque Nacional da Serra do Cipó (type locality), in the District of Serra do Cipó (Municipality of Santana do Riacho), State of Minas Gerais, Brazil; advertisement call of *B. ibitiguara* was recorded at the Parque Nacional da Serra da Canastra, Municipality of São Roque de Minas, and in the Municipality of Capitólio (Serra da Canastra mountain range), State of Minas Gerais, Brazil, approximately 60–70 km in a straight line from its type locality (Municipality of Alpinópolis); advertisement call of *B. sazimai* was recorded in the Municipality of Vargem Bonita (Serra da Canastra mountain range), State of Minas Gerais, Brazil, approximately 10 km in a straight line from its type locality (Municipality of São Roque de Minas). Some advertisement call variables of *B. circumdata* from the State of Minas Gerais could not be quantified or figured due to the low quality of the recording (improper for bioacoustic analysis or sound figures).

Voucher specimens of call recordings: *Bokermannohyla napolii* sp. nov.: AAG-UFU 4767 and AAG-UFU 0860; *B. ibitiguara*: AAG-UFU 4849–4852, AAG-UFU 0060–0061; *B. nanuzae*: AAG-UFU 0024–0025; *B. hylax*: AAG-UFU 0261; *B. carvalhoi*: AAG-UFU 4959–4960; *B. circumdata*: AAG-UFU 0260 and AAG-UFU 0668. Pictures presented in Figure 3 were slightly edited in order to remove flash shadows caused by camera.

Species account

Bokermannohyla napolii sp. nov.

Figures 1, 2(left), and 3

Holotype. UFMG 3333 (Ex-AAG-UFU 4767), adult male, collected at the Estação de Pesquisa e Desenvolvimento Ambiental Galheiro (EPDA-Galheiro; 19°12'S; 47°08'W, 845 m a.s.l.), Municipality of Perdizes, State of Minas Gerais, southeastern Brazil, on 16 October 2009, by A. A. Giaretta, T. R. de Carvalho, L. B. Martins, and B. F. V. Teixeira. Paratopotypes. Five adult males: AAG-UFU 4774–4775, UFMG 3334 (Ex-AAG-UFU 4770), and ZUEC 16610 (Ex-AAG-UFU 4771), collected with the holotype; AAG-UFU 0860, on 3 December 2011, by A. A. Giaretta. Three adult females: AAG-UFU 4773, UFMG 3335 (Ex-AAG-UFU 4769), ZUEC 16609 (Ex-AAG-UFU 4768), collected with the holotype.

Diagnosis. *Bokermannohyla* is currently supported only by molecular data, and a thorough morphological study of the genus still needs to be done (Faivovich *et al.* 2005, 2009). Thus, we assign *B. napolii* sp. nov. to this genus on the basis of its phenotypic similarity to other species in the genus. *Bokermannohyla napolii* sp. nov. is assigned to the *B. circumdata* species group as it has transverse dark brown stripes on dorsum, simple (not dichotomized or anastomosed) dark brown transverse stripes on posterior surfaces of thighs and flanks, single (not bifid) large sharp prepollex, and adult males having hypertrophied forearms. The new taxon is diagnosed by the following combination of traits: (1) medium size (adult SVL 49.7–55.0 mm); (2) head wider than longer; (3) dark brown transverse stripes on dorsum; (4) dark brown vertical bars on posterior and superior surfaces of thighs; (5) vocal

slits present in adult males; (6) bifid/divided distal tubercle of finger III in males, and bifid/divided distal tubercle of finger IV in males and females; (7) distinctive advertisement call pattern (see call description section).

TABLE 1. Morphometric characters (mm) of adult males of *Bokermannohyla luctuosa* (topotypes and specimens from the Municipalities of Cabreúva and Atibaia, State of São Paulo, Brazil); adult males of *B. circumdata* from the Municipalities of Petrópolis (State of Rio de Janeiro, Brazil), Arapeí and District of Paranapiacaba (State of São Paulo, Brazil), and Chiador (State of Minas Gerais, Brazil); and type series of *B. napolii* sp. nov. Mean \pm standard deviation (minimum–maximum).

Characters	<i>Bokermannohyla luctuosa</i>	<i>Bokermannohyla circumdata</i>	<i>Bokermannohyla napolii</i> sp. nov.	
	N=7 males	N=10 males	N=6 males	N=3 females
Snout-Vent Length	56.3 \pm 3.4 (53.4–61.9)	59.0 \pm 3.4 (54.7–65.6)	53.1 \pm 1.0 (52.5–55.0)	52.3 \pm 2.2 (49.7–53.7)
Thigh Length	30.3 \pm 1.7 (28.5–32.7)	31.9 \pm 2.2 (28.7–36.3)	28.9 \pm 0.5 (28.0–29.4)	28.3 \pm 0.7 (27.7–29.0)
Shank Length	30.8 \pm 1.7 (29.2–33.9)	32.5 \pm 2.2 (29.2–36.6)	29.6 \pm 0.6 (28.8–30.3)	28.8 \pm 0.7 (28.1–29.4)
Foot Length	25.3 \pm 1.8 (23.7–28.8)	26.8 \pm 1.7 (23.2–29.3)	24.6 \pm 0.8 (23.2–25.4)	23.7 \pm 1.6 (21.8–24.8)
Hand Length	19.1 \pm 1.2 (17.9–20.8)	20.3 \pm 1.3 (18.3–22.5)	18.7 \pm 0.7 (18.1–20.0)	17.1 \pm 0.9 (16.1–17.8)
Head Length	20.1 \pm 1.1 (19.0–22.0)	21.5 \pm 1.3 (20.5–23.9)	19.3 \pm 0.4 (18.8–19.9)	18.5 \pm 0.7 (18.0–19.3)
Head Width	20.7 \pm 1.1 (19.4–22.5)	22.1 \pm 1.2 (20.9–24.2)	20.1 \pm 0.6 (19.6–21.0)	18.9 \pm 1.0 (18.0–19.9)
Eye Diameter	5.0 \pm 0.2 (4.7–5.3)	5.3 \pm 0.3 (4.8–5.9)	4.8 \pm 0.1 (4.7–5.0)	4.5 \pm 0.2 (4.3–4.6)
Tympanum Diameter	4.9 \pm 0.4 (4.1–5.3)	5.1 \pm 0.3 (4.6–5.3)	4.3 \pm 0.3 (4.0–4.7)	4.2 \pm 0.3 (3.9–4.5)
Eye-Nostril Distance	5.8 \pm 0.3 (5.4–6.2)	6.2 \pm 0.4 (5.6–6.7)	5.3 \pm 0.1 (5.1–5.4)	5.1 \pm 0.2 (5.0–5.3)
3 rd Finger Disk Diameter	2.9 \pm 0.2 (2.7–3.3)	3.2 \pm 0.3 (2.8–3.6)	3.1 \pm 0.2 (2.7–3.3)	3.1 \pm 0.2 (3.0–3.3)
4 th Toe Disk Diameter	2.8 \pm 0.2 (2.6–3.1)	3.0 \pm 0.3 (2.6–3.4)	2.8 \pm 0.2 (2.5–3.1)	2.8 \pm 0.2 (2.7–3.0)

TABLE 2. Advertisement call variables of *Bokermannohyla luctuosa* from the Municipality of Atibaia (State of São Paulo, Brazil); *B. circumdata* from the Municipality of Chiador (State of Minas Gerais, Brazil), and District of Paranapiacaba (State of São Paulo, Brazil); and *B. napolii* sp. nov. from the type locality. Mean \pm standard deviation (minimum–maximum). N = number of recorded males.

Variables	<i>Bokermannohyla luctuosa</i>	<i>Bokermannohyla circumdata</i> (MG)	<i>Bokermannohyla circumdata</i> (SP)	<i>Bokermannohyla napolii</i> sp. nov.
	N=1	N=1	N=1	N=6
Advertisement call duration (ms)	607.7 \pm 48.2 (550–708)	—	—	619.7 \pm 71.7 (460–807)
Note types A/B internote interval (ms)	110.8 \pm 11.1 (97–138)	—	—	133.3 \pm 17.2 (82–167)
Note type A duration (ms)	57.2 \pm 20.3 (23–93)	95.0 \pm 15.3 (71–120)	—	93.4 \pm 15.6 (53–156)
Note type A dominant frequencies (kHz) / harmonics	0.57 \pm 0.09 (0.49–0.65)	0.48 \pm 0.12 (0.33–0.66) / 0.73 \pm 0.05 (0.70–0.80)	—	0.43 \pm 0.07 (0.39–0.56) / 0.77 \pm 0.06 (0.73–0.90) / 1.47 \pm 0.05 (1.34–1.51) / 1.82 \pm 0.08 (1.68–1.85)
Advertisement call rate (calls/minute)	6.8 \pm 2.4 (4–8)	—	11.1 \pm 2.4 (8–14)	6.7 \pm 4.6 (1–14)
Note type B duration (ms)	440.6 \pm 46.6 (371–526)	778.0 \pm 42.4 (748–808)	495.3 \pm 55.8 (235–544)	399.5 \pm 77.4 (242–550)
Note type B dominant frequencies (kHz) / harmonics	0.47 / 0.88 \pm 0.04 (0.82–0.90) / 1.23 \pm 0.06 (1.16–1.34) / 1.65 \pm 0.04 (1.59–1.68) / 1.98 \pm 0.09 (1.85–2.02)	0.47 \pm 0.07 (0.42–0.52) / 0.89	0.54 \pm 0.04 (0.52–0.61) / 1.05 \pm 0.05 (0.98–1.08) / 1.46 \pm 0.03 (1.45–1.55)	0.51 \pm 0.06 (0.47–0.65) / 1.17 \pm 0.14 (0.82–1.34) / 1.57 \pm 0.07 (1.42–1.68) / 2.05 \pm 0.04 (2.04–2.11)
Harmonic groups/note	12.2 \pm 1.3 (10–15)	—	15.7 \pm 1.6 (7–16)	2.5 \pm 1.2 (1–5)



FIGURE 1. Adult specimens of *Bokermannohyla napolii* sp. nov. in life. Specimens from the Estação de Pesquisa e Desenvolvimento Ambiental Galheiro (EPDA-Galheiro), Municipality of Perdizes, State of Minas Gerais, Brazil. Upper, holotype UFMG 3333; Lower, female paratopotype ZUEC 16609.



FIGURE 2. Ventral view of hands of adult male specimens of *Bokermannohyla napolii* sp. nov. (left: ZUEC 16610) and *B. luctuosa* (right: AAG-UFU 0473). The arrows point to the divided tubercles of fingers III and IV in *B. napolii* sp. nov.

Comparisons with other species. *Bokermannohyla napolii* sp. nov. (adult male SVL 52.5–55.0 mm; adult female SVL 49.7–53.7 mm) is set apart by its larger size from the small-sized (combined SVL 30.1–47.6 mm; cf. Napoli 2000) species of the *B. circumdata* group [*B. astartea* (Bokermann 1967), *B. feioi* (Napoli & Caramaschi 2004), *B. ibitipoca* (Caramaschi & Feio 1990), *B. izecksohni* (Jim & Caramaschi 1979), *B. nanuzae*, *B. ravida* (Caramaschi, Napoli & Bernardes 2001), and *B. sazimai*].

Bokermannohyla napolii sp. nov. has a wider than longer head, whereas the head in *B. ahenea* (Napoli & Caramaschi 2004), *B. capra* Napoli and Pimenta (2009), *B. feioi*, *B. hylax*, and *B. lucianae* (Napoli & Pimenta 2003) is longer than wider. The new species is also distinguished by having dark brown transverse stripes on dorsum and limbs, which are immaculate in *B. ahenea*, *B. astartea*, *B. carvalhoi*, and *B. gouveai* (Peixoto & Cruz 1992); immaculate or with weak dark brown transverse bands in *B. capra*, *B. diamantina* Napoli and Juncá (2006), *B. izecksohni*, and *B. lucianae*; and with a reticulated pattern in *B. sazimai*. Furthermore, the new taxon is distinguished by having dark brown vertical bars on posterior surface of thighs, which is immaculate in *B. feioi*, *B. gouveai*, *B. nanuzae*, and *B. lucianae*; fragmented in *B. carvalhoi*, and anastomosed in *B. vulcaniae* (Vasconcelos & Giaretta 2003). From *B. caramaschii* (Napoli 2005) and *B. izecksohni*, the new species is also distinguished by having vocal slits in adult males (absent in the other two species).

The distal bifid/divided subarticular tubercles of fingers III and IV in males, and finger IV in males and females (fig. 2) diagnose *B. napolii* sp. nov. from *B. ahenea*, *B. astartea*, *B. carvalhoi*, *B. feioi*, *B. gouveai*, *B. hylax*, *B. ibitipoca*, *B. izecksohni*, *B. luctuosa*, *B. nanuzae*, *B. sazimai*, and *B. vulcaniae*.

The advertisement call of *Bokermannohyla napolii* sp. nov. differs from that of all species of the *B. circumdata* group with calls described so far (unknown advertisement calls: *B. ahenea*, *B. caramaschii*, *B. gouveai*, *B. izecksohni*, *B. ravida*, and *B. vulcaniae*), except *B. circumdata* and *B. luctuosa*, due to its harmonic structure. The adver-

tisement call of the new species (figs. 6 A–B) most resembles the call pattern of *B. circumdata* (fig. 6 C) and *B. luctuosa* (fig. 6 D). Advertisement calls of *B. circumdata*, *B. luctuosa*, and *B. napolii* sp. nov. are composed of a short note followed by a long note. The first two have long notes composed of several disjunctive and/or juxtaposed harmonic groups, whereas the long note of *B. napolii* sp. nov. has fewer well-defined harmonic groups (1–5) with more sound intensity at the beginning of the note, or ill-defined harmonic groups with increasingly weaker sound intensity along its extent.

Description of holotype. Adult male (UFMG 3333; figs. 1, 2(left), and 3). Body robust; head wider than longer. Snout rounded in dorsal and lateral views (figs. 3 A–B, respectively); nostrils directed laterally, much closer to the tip of snout than to the eye; canthus rostralis distinct; loreal region slightly concave; tympanum circular, 83% of the eye diameter; supra-tympanic fold present; pupil horizontal; vocal sac single, subgular, expanded; vocal slits present; tongue round; vomerine teeth in two almost contiguous, slightly arched series between choanae. Crenulated ridge on outer surface of forearms; forearm hypertrophied; finger lengths when put together $I < II < IV < III$ (fig. 3 C); disks of fingers II, III, and IV larger than that of I; disk of finger III 75% of the tympanum diameter; distal subarticular tubercles of fingers I and II ovoid, those of fingers III and IV bifid/divided; nuptial pads present; pollical tubercle large, elongated; prepollex well-developed, spine curved, completely covered by skin; inner metacarpal tubercle region formed by several smaller granular tubercles; palmar tubercle developed, elongated, divided; supernumerary tubercles present on the palm of hand; hand webbing formula $I 2-3 \ II 2-2 \ 2/3 \ III 2 \ 1/2-2 \ IV$. Toe lengths when put together $I < II < V < III < IV$ (fig. 3 D); disks of toes III, IV, and V larger than those of I and II; disk of toe IV 68% of the tympanum diameter; toe webbing formula $I 1-2 \ II 1-2 \ III 1-2^+ \ IV 2^+-1 \ V$; inner metatarsal tubercle ovoid, outer metatarsal tubercle barely distinct; toes fringed; supernumerary tubercles on the sole of foot; subarticular tubercles of toes rounded; inner tarsal fold weak, extending along full length of the tarsus; outer surface of tarsi. Dorsal surfaces and flanks smooth; belly granular; supra-vent granular ridge defined; discrete pointed dermal protuberance on outer heel present.

Measurements of holotype. Morphometric characters (mm) and ratios (%) in relation to SVL (52.5 mm): HL 19.2 (36.6), HW 19.6 (37.3), ED 4.8 (9.1), TD 4.0 (7.6), END 5.1 (9.7), TL 28.5 (54.3), SL 29.0 (55.2), FL 24.5 (46.7), HAL 18.6 (35.4), 3FD 3.0 (5.7), 4TD 2.7 (5.1).

Color of holotype in life (fig. 1). Dorsal surfaces uniformly pale cream, with subtly darker transverse stripes; a few white dots and blotches on dorsal surfaces and flanks; background color of the hidden parts of thighs and arms bluish and violet, with 8–9 dark brown vertical bars on posterior and superior surfaces; dorsal surface of shanks with 4–6 dark brown transverse stripes; flanks with subtle violet bars on a yellow marked region; inguinal region tending to the same color (violet) of the hidden parts of thighs, with a few dark brown transverse bars; supra-vent crenulated ridge white; crenulated ridge on outer forearm white; throat, chest, and belly light cream; iris gold, pupil black; tympanum tends to violet.

Color of holotype in preservative. Dorsum dark grayish brown with some faded parts on dorsum and limbs, and dark brown transverse stripes barely distinct on dorsum; a few white blotches scattered on dorsum, limbs, and flanks; hidden parts of thighs and arms light gray, their posterior and superior surfaces with 8–9 dark brown vertical bars; anterior surface of thighs immaculate; dorsal surface of shanks with 4–6 dark brown transverse stripes, sometimes fragmented; dark brown transverse stripes on dorsal surface of forearms indistinct; background color of flanks light gray, with a few dark brown reticulations, especially on inguinal region; supra-vent crenulated ridge white; crenulated ridge on outer forearm white; throat, chest, belly, and ventral surfaces of limbs cream, gular region with dark brown punctuations bordering lower jaw, region of tubercles and webbing of hands and feet slightly gray; tympanum brown, slightly lighter than dorsal coloration pattern.

Variation. Dorsum varies in color from medium brown (females) to dark gray (males) in ethanol preserved specimens. Number of dark brown vertical bars on dorsal surfaces of forearms (3–4), thighs (6–10), shanks (4–7), and tarsi (3–4). Dark brown transverse stripes on dorsal surfaces may be barely distinct. The male specimen AAG-UFU 0860 has no distinctive transverse stripes on dorsal surfaces. The presence and extent of white blotches on dorsum and limbs are variable, being completely absent in AAG-UFU 4775. Type series, except the holotype and AAG-UFU 0860, has a dark brown vertebral stripe, sometimes restricted to the first half of dorsal length. One female (AAG-UFU 4773) has distal subarticular tubercles of finger III divided; one male (AAG-UFU 4774) has distal subarticular tubercles fingers III and IV cordiform. Two male specimens (AAG-UFU 4775 and ZUEC 16610) have distal subarticular tubercles of finger I divided.

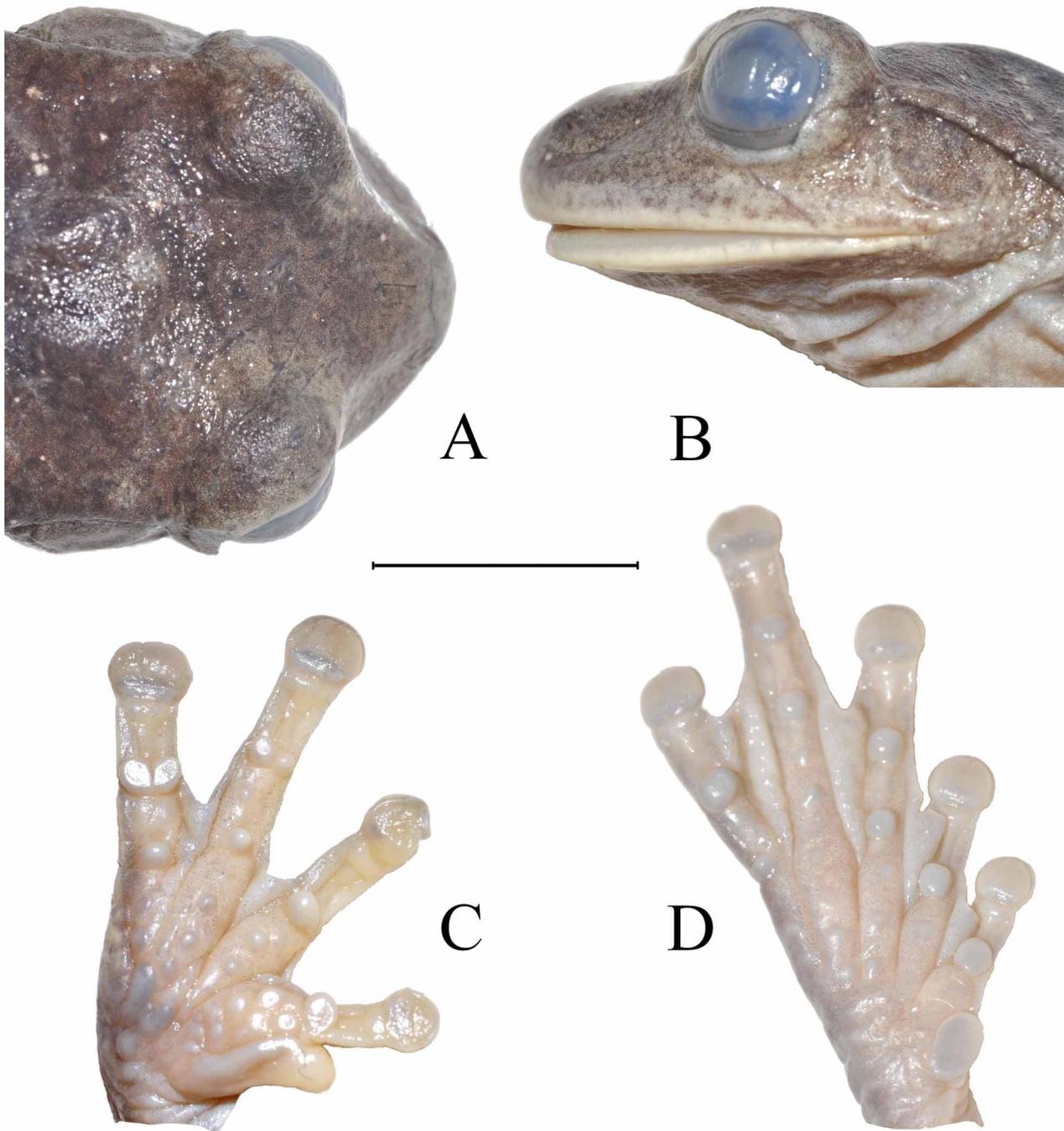


FIGURE 3. *Bokermannohyla napolii* sp. nov., holotype (UFMG 3333), adult male. Dorsal (A) and lateral (B) views of head; ventral view of hand (C) and foot (D). Scale bar = 10 mm.

Natural History. Despite extensive fieldworks since 2001, this species was only heard (found) in 2009, during an explosive breeding event. Afterwards, a few males were heard once at the end of 2011. Males started calling late at night (around 01:00 AM), and a few males were heard still calling at nearly midday on the next day. They gathered around a muddy slow-watered section of a stream at the forest border. Males ($N = 10$) were calling from the ground or perched on low (< 1 m high) vegetation. Egg clutches ($N = 4$; fig. 4) were laid 5–10 cm deep and hidden among dead broad leaves under water. Eggs were adhered to each other so that the entire egg mass (fresh, < 6 hours) could be removed from water using both hands to scoop it up. Number of eggs per clutch ranged from 373 to 742 (mean 637, $SD = 176$, $N = 4$ egg clutches); yolk diameter ranged from 1.2 to 2.3 mm (mean 1.8, $SD = 0.3$, $N = 3$ egg clutches); gelatinous capsules ranged from 3.8 to 5.4 mm (mean 4.4, $SD = 0.6$, $N = 4$ egg clutches). Three

collected females released ovocytes inside plastic bags: yolk diameter ranged from 1.5 to 2.2 (mean 2.0, SD = 0.6); gelatinous capsules ranged from 3.1 to 5.4 mm (mean 4.2, SD = 0.5). Some males had their backs scratched (fig. 1), probably as a result of agonistic interactions. The new species occurs sympatrically with *Bokermannohyla sazimai*, *Hypsiboas faber* (Wied-Neuwied), *Hypsiboas goianus* (Lutz), *Hypsiboas lundii* (Burmeister), and *Scinax canastrensis* (Cardoso & Haddad).



FIGURE 4. An egg clutch of *Bokermannohyla napolii* sp. nov. Eggs masses were laid hidden among dead broad leaves under water at the forest border. The egg clutch was exposed in order to take the picture. Clutches had an average of 637 eggs, each egg with a mean of 4.4 mm in diameter considering the gelatinous capsule.

Geographic distribution. *Bokermannohyla napolii* sp. nov. is known only from the type locality. (fig. 5).

Etymology. The name is a noun in the genitive case honoring Marcelo F. Napoli for his extensive contribution to the knowledge of the genus *Bokermannohyla*.

Vocalizations of *Bokermannohyla napolii* sp. nov. Six males recorded (N = 76 advertisement call samples; N = 43 aggressive call samples). Quantitative traits are summarized in Table 2. Advertisement call is composed of two note types (referred herein to as note types A and B; figs. 6 A-B) emitted consecutively at a rate of 1–14 calls/minute (mean 6.7, SD = 4.6). Additional notes B may eventually be emitted just after a typical A/B sequence though. Advertisement call duration (notes A + B) was 460–807 ms (mean 619.7, SD = 71.7). Note A is a short note (53–156 ms; mean 93.4, SD = 15.6) with 5–6 harmonics. Dominant frequencies from 0.39–0.56 kHz (mean 0.43, SD = 0.07), from 0.73–0.90 kHz (mean 0.77, SD = 0.06), from 1.34–1.51 kHz (mean 1.47, SD = 0.05), and from 1.68–1.85 kHz (mean 1.82, SD = 0.08), which correspond to the first four harmonics. Note B is a long note (242–550 ms; mean 399.5, SD = 77.4) with a harmonic structure (5–6 harmonics; sometimes ill-defined), and sound intensity concentrated the most on the first part of the note, and sound intensity modulations forming 1–5 disjunctive or juxtaposed harmonic groups (mean 2.5, SD = 1.2) along its extent, or with ill-defined harmonic structure (N = 8 note samples). A/B internote interval from 82–167 ms (mean 133.3, SD = 17.2). Dominant frequencies from 0.47–0.65 kHz (mean 0.51, SD = 0.06), from 0.82–1.34 kHz (mean 1.17, SD = 0.14), from 1.42–1.68 kHz (mean 1.57, SD = 0.07), and from 2.02–2.11 kHz (mean 2.05, SD = 0.04), which correspond to the first four harmonics.

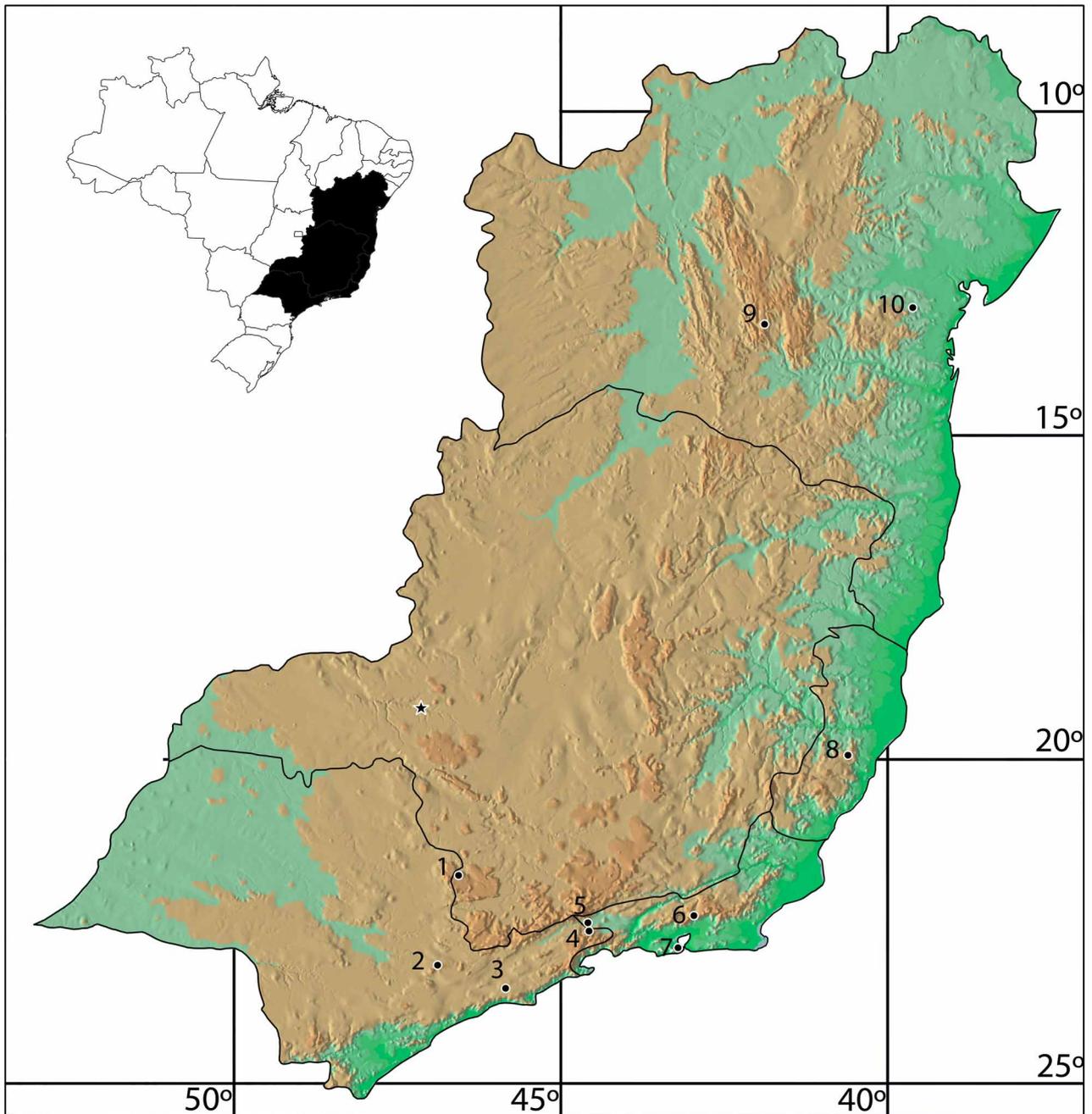


FIGURE 5. Type localities (based on original descriptions) of medium and large-sized species of the *Bokermannohyla circumdata* species group on a topographic map: *B. napolii* sp. nov. (star); *B. vulcaniae* (1); *B. luctuosa* (2); *B. hylax* (3); *B. ahenea* (4); *B. gouveaei* (5); *B. carvalhoi* (6); *B. circumdata* (7)*; *B. caramaschii* (8); *B. diamantina* (9); and *B. capra* (10). *Based on Frost 2011.

We have also identified a third note type (referred herein to as note type C; fig. 7 A) that should possibly be attributed to a kind of aggressive call (*sensu* Wells 2007) because it has an ill-defined lower sound intensity structure with remarkable differences in temporal traits (longer duration) in comparison with note B, yet similar in spectral traits (dominant frequencies). Besides, this aggressive call has no distinguishable harmonic structure as in notes A and B of the advertisement call. Note C is emitted at a rate of 12–26 notes/minute (mean 20.0, SD = 5.7) alone or just after a note A. The emission rate of advertisement calls of a given male was inversely proportional to the emission rate of aggressive calls. Note C duration was 437–1,120 ms (mean 763.9, SD = 210.4) with A/C internote interval from 90–128 ms (mean 115.3, SD = 14.6). Despite the absence of well-defined harmonic structure, dominant frequencies coincided with those of note type A.

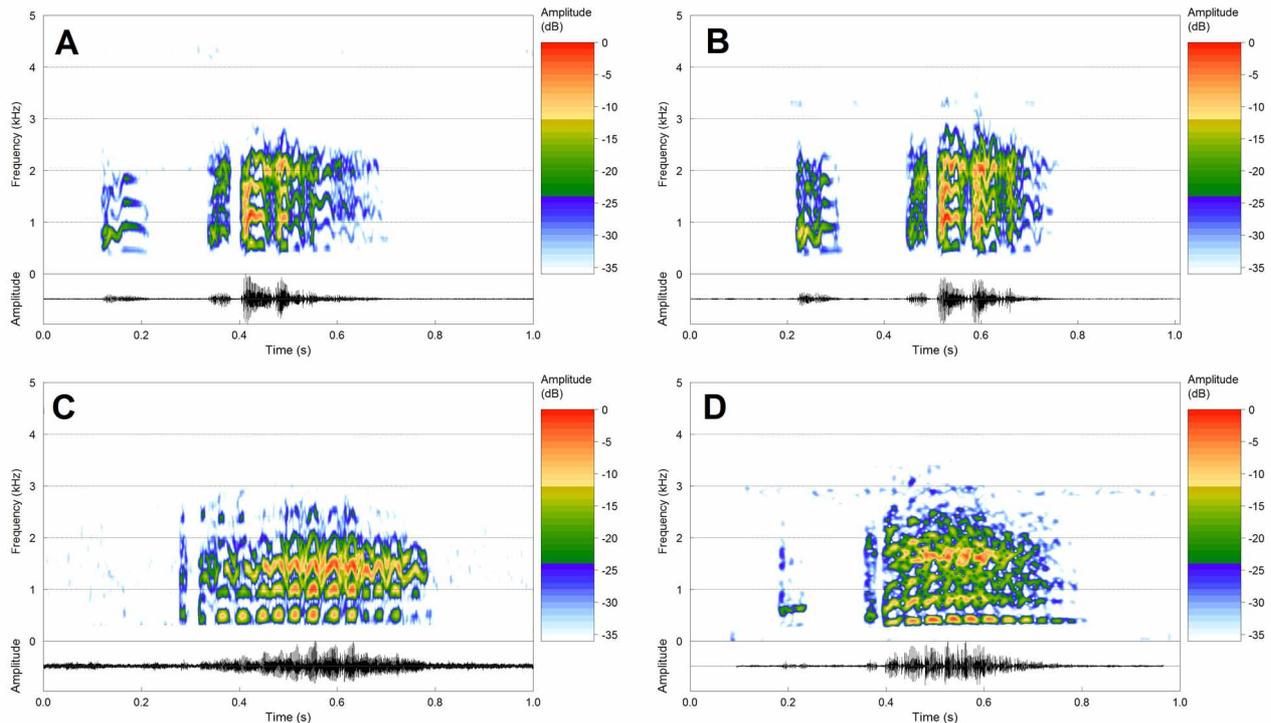


FIGURE 6. Audiospectrograms (above) and corresponding oscillograms (below) of the advertisement calls (note types A and B consecutively, when present) of: (A–B). A paratopotype of *Bokermannohyla napolii* sp. nov. from the EPDA–Galheiro (MG), Brazil. Record file: A. Bokerm_napoliiMG7aAAGm671; 01:50h, 3 December 2011; air 18.0°C, water 19.0°C; B. Record file: Bokerm_napoliiMG7bAAGm671; ca. 01:55h, 3 December 2011; air 18.0°C, water 19.0°C; (C). *Bokermannohyla circumdata* from Paranapiacaba (SP), Brazil. Record file: Bokerm_circumdSP1faAGm; ca. 03:15h, 29 January 2011; air 22°C, water 21°C; (D). *Bokermannohyla luctuosa* from Atibaia (SP), Brazil. Record file: Bokerm_luctuosaAAG9; 01:00h, 4 December 1997; air 18.5°C, water 18.5°C. All figures generated at 512 points resolution (FFT).

Bioacoustic accounts on *Bokermannohyla* species

Bokermannohyla circumdata advertisement call (coastal Atlantic Forest, State of São Paulo). One male recorded (N = 35 advertisement call samples). Quantitative traits are summarized in Table 2. Advertisement call (fig. 6 C) consists of a single note composed of a harmonic structure (4–5 harmonics) with sound intensity modulations forming 7–16 disjunctive or juxtaposed harmonic groups (mean 13.7, SD = 1.6) along its extent. Advertisement call is emitted at a rate of 8–14 calls/minute (mean 11.1, SD = 2.4). Call duration was 235–544 ms (mean 495.3, SD = 55.8) with intercall interval from 1,580–7,320 ms (mean 4,120.0, SD = 1,730.0). Dominant frequencies from 0.52–0.61 kHz (mean 0.54, SD = 0.04), from 0.98–1.08 kHz (mean 1.05, SD = 0.05), and from 1.45–1.55 kHz (mean 1.46, SD = 0.03), which correspond to the first three harmonics.

The recorded male was calling alone from the ground next to a streamlet inside the forest.

Vocalizations of *Bokermannohyla circumdata* (Serra da Mantiqueira range, State of Minas Gerais). One male recorded (N = 11 aggressive call samples). Quantitative traits are summarized in Table 2. Advertisement call is composed of two note types (referred herein to as note types A and B). Note A is a short note (71–120 ms; mean 95.0, SD = 15.3) with 5–6 harmonics. Dominant frequencies from 0.33–0.66 kHz (mean 0.48, SD = 0.12), and from 0.70–0.80 kHz (mean 0.73, SD = 0.05), which correspond to the first two harmonics. Note B is a long note with a harmonic structure (5–6 harmonics), and sound intensity modulations forming several disjunctive or juxtaposed harmonic groups along its extent. Dominant frequencies from 0.42–0.52 kHz (mean 0.47, SD = 0.07), and at 0.89 kHz, which correspond to the first two harmonics.

We have also identified a third note type (referred herein to as note type C; fig. 7 B) that should possibly be attributed to a kind of aggressive call (*sensu* Wells 2007). The aggressive call consists of a single note composed of sound intensity modulations forming 18–26 disjunctive or juxtaposed groups (mean 20.4, SD = 2.2) along its

extent. Note C is emitted at a rate of 26–29 notes/minute (mean 27.5, SD = 1.3) just after a note A. Note duration was 656–893 ms (mean 728.6, SD = 63.5) with A/C internote interval from 88–157 ms (mean 99.7, SD = 19.4). Dominant frequency coincides with fundamental frequency, from 0.42–0.47 kHz (mean 0.46, SD = 0.02).

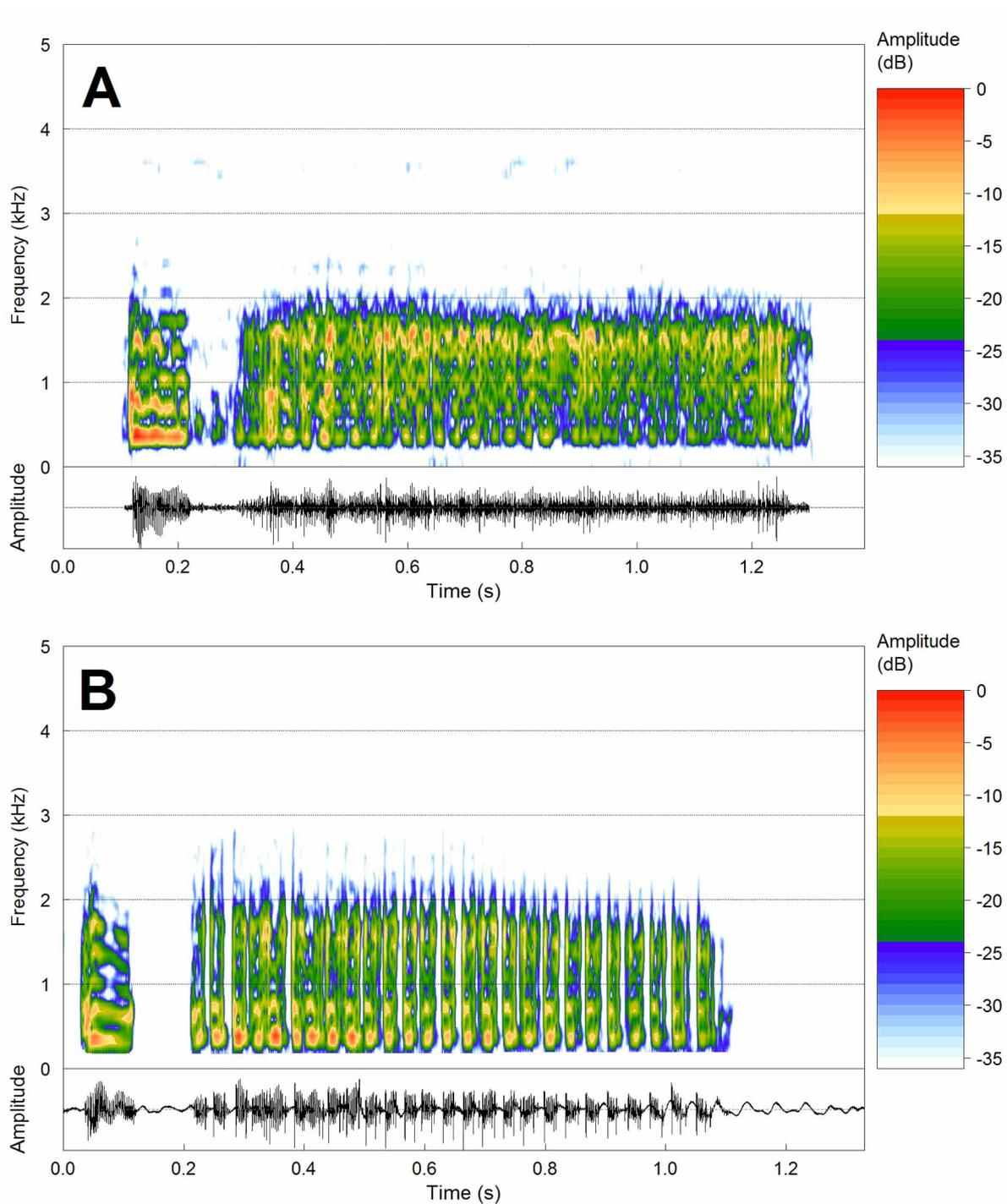


FIGURE 7. Audiospectrogram (above) and corresponding oscillogram (below) of a sequence of note type A followed by an aggressive call (note type C) of: (A). A topotype of *Bokermannohyla napolii* sp. nov. from the EPDA-Galheiro (MG), Brazil. Record file: Bokerm_napoliiMG1bAAGmt; ca. 01:00h, 16 October 2009; air 21.0°C, water 20.3°C; (B). *Bokermannohyla circumdata* from Chiador (MG), Brazil. Record file: Bokerm_circumdataChiadorMG1TRC_AAGmt; 01:28h, 3 December 2011; air 16.0°C, water 19.0°C. All figures generated at 512 points resolution (FFT).

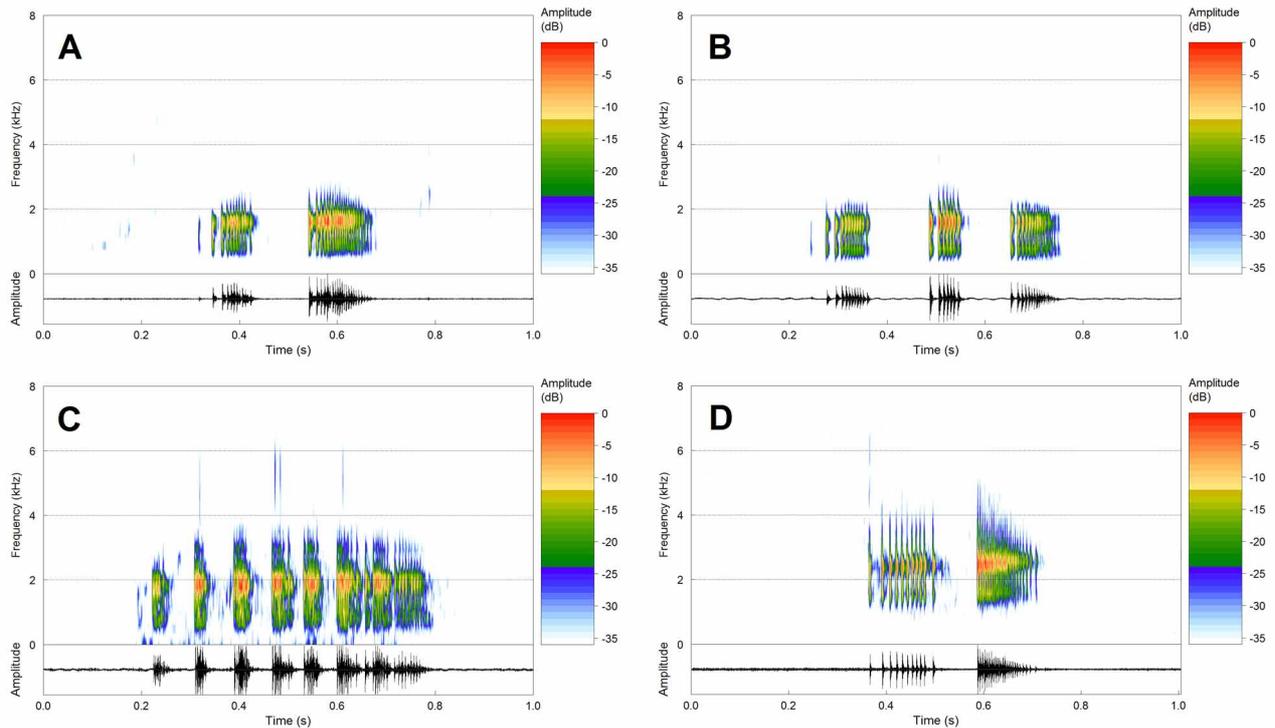


FIGURE 8. Audiospectrogram (above) and corresponding oscillograms (below) of the advertisement call of: [A (typical two-note call) and B (three-note call)]. Two topotypes of *Bokermannohyla carvalhoi* from the Serra dos Órgãos (RJ), Brazil. A. Record file: Bokerm_carvalhoiSP3bLM_AAG3mt; 20:26h, 7 January 2011; air 20°C; B. Record file: Bokerm_carvalhoiSP1bLM_AAGmt; 21:21h, 6 January 2011; air 21°C, water 18°C; (C). *Bokermannohyla hylax* from Paranaipacaba (SP), Brazil. Record file: Bokerm_hylaxSP1bAAGm; 19:57h, 28 January 2011; air 25°C, water 20°C; [D (note types A and B consecutively)]. A topotype of *Bokermannohyla nanuzae* from the Serra do Cipó (MG), Brazil. Record file: Bokerm_nanuzaeMG2TRC_AAGmt; 04:04h, 22 November 2010; air 15°C, water 15°C. All figures generated at 256 points resolution (FFT).

The recorded male was calling alone perched on vegetation (≈ 20 cm from the ground) on the margin of a puddle in a clearing approximately 3 m from the forest.

Bokermannohyla luctuosa advertisement call. One male recorded ($N = 19$ advertisement call samples). Quantitative traits are summarized in Table 2. Advertisement call is composed of two distinct types of notes (referred herein to as note types A and B) emitted consecutively (fig. 6 D); the emission of note B alone was observed a few times though. Advertisement call is emitted at a rate of 4–8 calls/minute (mean 6.8, $SD = 2.4$). Advertisement call duration was 550–708 ms (mean 607.7, $SD = 48.2$). Note A is a short note (23–93 ms; mean 57.2, $SD = 20.3$) with a harmonic structure (5–6 harmonics). Dominant frequency from 0.49–0.65 kHz (mean 0.57, $SD = 0.09$), which corresponds to the first two harmonics. Note B is a long note (371–526 ms; mean 440.6, $SD = 46.6$) with a harmonic structure (5–6 harmonics), and sound intensity modulations forming 10–15 disjunctive or juxtaposed harmonic groups (mean 12.2, $SD = 1.3$) along its extent. A/B internote interval from 97–138 ms (mean 110.8, $SD = 11.1$). Dominant frequencies at 0.47 kHz, from 0.82–0.90 kHz (mean 0.88, $SD = 0.04$), from 1.16–1.34 kHz (mean 1.23, $SD = 0.06$), from 1.59–1.68 kHz (mean 1.65, $SD = 0.04$), and from 1.85–2.02 kHz (mean 1.98, $SD = 0.09$), which correspond to the first five harmonics.

The recorded male was calling from the ground next to a streamlet outside, but near (< 20 m) the forest. Other males were heard calling inside the forest. Despite fifteen years of fieldworks in Atibaia, males were heard just once, when we witnessed an explosive reproductive event.

Bokermannohyla carvalhoi advertisement call. Three males recorded ($N = 93$ advertisement call samples). Quantitative traits are summarized in Table 3. Advertisement call (figs. 8 A-B) consists of a sequence of 1–3 similar multipulsed notes (mean 2.0, $SD = 0.1$) released at a rate of 13–32 notes/minute (mean 23.0, $SD = 6.8$). The last note tends to be more intense when in a sequence of two notes, and the middle note is the most intense when in a

sequence of three notes. Advertisement call duration was 260–536 ms (mean 315.3, SD = 12.4) with intercall interval from 621–4,667 ms (mean 2,192.9, SD = 581.8). Advertisement call is composed of 17–39 pulses (mean 27.7, SD = 1.0). Dominant frequency was 1.50–2.06 kHz (mean 1.74, SD = 0.12). Each note is composed of 7–22 pulses (mean 13.5, SD = 0.5) completely separated from each other, partially (medially) juxtaposed, or even completely juxtaposed. In addition, isolated pulses may appear at the beginning or at the end of the notes. Note duration was 64–147 ms (mean 98.3, SD = 6.4) with internote interval from 78–130 ms (mean 103.6, SD = 3.3).

TABLE 3. Advertisement call variables of *Bokermannohyla carvalhoi* from the Parque Nacional da Serra dos Órgãos, Municipality of Teresópolis (State of Rio de Janeiro, Brazil); *B. hylax* from the District of Paranapiacaba (State of São Paulo, Brazil); *B. ibitiguara* from the Serra da Canastra mountain range, Municipalities of Capitólio and São Roque de Minas (State of Minas Gerais, Brazil); *B. sazimai* from the Serra da Canastra mountain range, Municipality of Vargem Bonita (State of Minas Gerais, Brazil); and *B. nanuzae* from the Parque Nacional da Serra do Cipó, Municipality of Santana do Riacho (State of Minas Gerais, Brazil). Mean \pm standard deviation (minimum–maximum). N = number of recorded males.

Variables	<i>Bokermannohyla carvalhoi</i> N=3	<i>Bokermannohyla hylax</i> N=6	<i>Bokermannohyla ibitiguara</i> N=8	<i>Bokermannohyla sazimai</i> N=5	<i>Bokermannohyla nanuzae</i> N=2
Advertisement call duration (ms)	315.3 \pm 12.4 (260–536)	522.1 \pm 54.7 (361–686)	—	—	355.9 \pm 28.8 (310–496)
Intercall interval (ms)	2,192.9 \pm 581.8 (621–4,667)	2,393.2 \pm 1,211.4 (452–5,152)	—	—	1,249.3 \pm 1,039.2 (309–3,653)
Note duration (ms)	98.3 \pm 6.4 (64–147)	—	855.1 \pm 134.3 (435–1,208)	656.7 \pm 97.8 (476–892)	149.3 \pm 21.7 (95–229)
	Note type B	—	70.1 \pm 13.8 (37–104)	100.9 \pm 28.6 (80–165)	132.5 \pm 1.2 (111–185)
Internote interval (ms)	103.6 \pm 3.3 (78–130)	—	1,229.2 \pm 518.7 (91–3,575)	633.7 \pm 320.7 (303–2,109)	—
	Note type B	—	128.3 \pm 20.4 (77–171)	175.2 \pm 20.0 (124–199)	—
A/B internote interval (ms)	—	—	—	—	74.6 \pm 6.8 (32–151)
Dominant frequency (kHz)	Note type A 1.74 \pm 0.12 (1.50–2.06)	2.00 \pm 0.18 (1.50–2.44)	2.01 \pm 0.21 (1.50–2.20)	2.47 \pm 0.09 (2.24–2.58)	2.47 \pm 0.06 (2.25–2.63)
	Note type B	—	1.99 \pm 0.25 (1.50–2.20)	2.45 \pm 0.12 (2.24–2.58)	2.47 \pm 0.06 (2.25–2.63)
Advertisement call rate (calls/minute)	Note type A 23.0 \pm 6.8 (13–32)	17.5 \pm 4.4 (14–26)	21.0 \pm 12.8 (10–52)	35.6 \pm 16.0 (17–68)	37.0 \pm 28.3 (17–57)
	Note type B	—	19.0 \pm 7.2 (5–29)	31.9 \pm 15.7 (6–54)	—
Pulses/note	Note type A 13.5 \pm 0.5 (7–22)	—	64.9 \pm 14.5 (39–92)	26.7 \pm 4.6 (13–36)	10.0 \pm 0.4 (5–17)
	Note type B	—	—	—	24.6 \pm 1.1 (19–28)
Pulse groups/note	Note type A —	—	13.0 \pm 1.2 (7–17)	7.2 \pm 0.9 (5–9)	—
	Note type B	—	—	—	—

Males were calling perched on vegetation next to a streamlet inside the forest.

Vocalizations of *Bokermannohyla hylax*. Six males recorded (N = 91 advertisement call samples; N = 30 call type B samples). Quantitative traits are summarized in Table 3. Advertisement call (fig. 8 C) consists of a single note (herein referred to as call type A) with multipulsed structure, released at a rate of 14–26 calls/minute (mean 17.5, SD = 4.4). Pulses are arranged in well-defined pulse groups, especially in the first half of the calls. Call duration was 361–686 ms (mean 522.1, SD = 54.7) with intercall interval from 452–5,152 ms (mean 2,393.2, SD = 1,211.4). Dominant frequency was 1.50–2.44 kHz (mean 2.00, SD = 0.18). During the emission of typical advertisement calls (calls A), males may emit long sequences (\leq 16 consecutive calls) of longer calls (herein referred to

as call type B) (fig. 9 A) with lower intercall interval and ill-defined or absent pulse groups. Call type B duration was 506–922 ms (mean 754.3, SD = 75.6) with intercall interval from 116–575 ms (mean 270.3, SD = 205.0). Dominant frequency was 1.88–2.25 kHz (mean 2.00, SD = 0.17). Other two types of calls were recorded: call type C (fig. 9 B) is similar to the advertisement call in both temporal and spectral traits (especially in the first part of the call), but the last half of the call is distinguished by presenting nearly or completely juxtaposed pulses. Call type C is released once (N = 10 call samples) or in a sequence of two calls (N = 1 call sample) among typical advertisement calls (call type A). Call C duration was 383–572 ms (mean 495.7, SD = 63.7); dominant frequency was 1.69–2.25 kHz (mean 2.00, SD = 0.23). Call type D (fig. 9 C) was only recorded twice, being a low intensity emission (when compared to call types A, B, and C) with juxtaposed pulses. Call D duration was 425–457 ms (mean 440.9, SD = 22.1); dominant frequency peaked at 2.06 kHz.

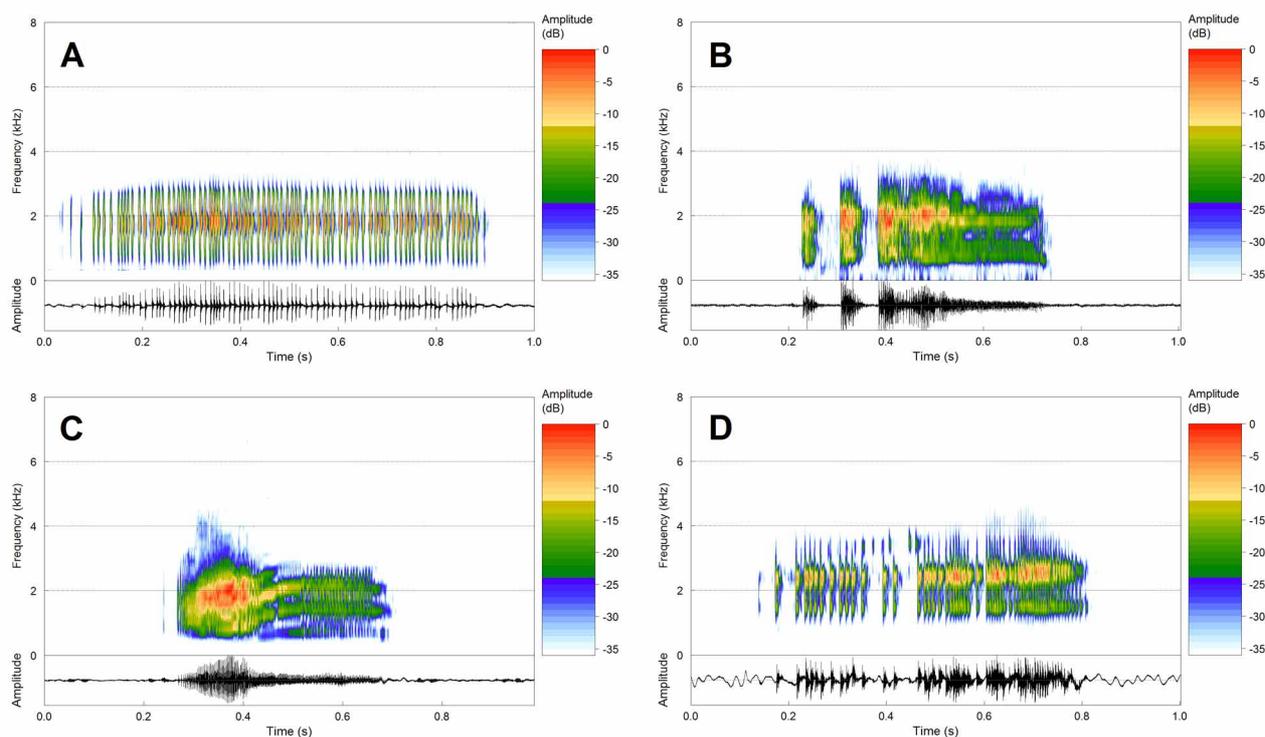


FIGURE 9. Audiospectrogram (above) and corresponding oscillograms (below) of: (A). Note type B of *Bokermannohyla hylax* from Paranapiacaba (SP), Brazil. Record file: Bokerm_hylaxSP3bAAGm; 22:35h, 28 January 2011; air 23°C, water 21°C; (B). Note type C of *Bokermannohyla hylax* from Paranapiacaba (SP), Brazil. Record file: Bokerm_hylaxSP1bAAGm; 19:57h, 28 January 2011; air 25°C, water 20°C; (C). Note type D of *Bokermannohyla hylax* from Paranapiacaba (SP), Brazil. Record file: Bokerm_hylaxSP5aAAGm; 19:57h, 28 January 2011; air 25°C, water 20°C; (D). Longer call of a topotype of *Bokermannohyla nanuzae* from the Serra do Cipó (MG), Brazil. Record file: Bokerm_nanuzaeMG1bTRC_AAGmt; 18:53h, 19 November 2010; air 15°C, water 19°C. All figures generated at 256 points resolution (FFT).

Males were calling from the ground or associated to bromeliads at up to approximately 6 m in height next to streamlets inside the forest.

Bokermannohyla nanuzae advertisement call. Two males recorded (N = 72 call samples). Quantitative traits are summarized in Table 3. Advertisement call (fig. 8 D) consists of the emission of two types of multipulsed notes (herein referred to as notes A and B) consecutively at a rate of 17–57 calls/minute (mean 37.0, SD = 28.3). Advertisement call duration was 310–496 ms (mean 355.9, SD = 28.8) with intercall interval from 309–3,653 ms (mean 1,249.3, SD = 1,039.2). Dominant frequency (both notes A and B) was 2.25–2.63 kHz (mean 2.47, SD = 0.06). Note A duration was 95–229 ms (mean 149.3, SD = 21.7) and each note is composed of 5–17 pulses (mean 10.0, SD = 0.4) arranged in a single group or irregularly arranged along its extent. Note B duration was 111–185 ms (mean 132.5; SD=1.2) and each note is composed of 19–28 juxtaposed pulses (mean 24.6, SD = 1.1) with descendent sound intensity modulation along its extent, yet isolated pulses may appear at the beginning (1–3) or at the end (1) of notes. Internote interval (A/B) was 32–151 ms (mean 74.6, SD = 6.8). One specimen released 14 calls pre-

senting longer note types A and B, whose pulses have a non-stopping sequence (no internote interval) between notes A/B (fig. 9 D). These calls may present less sound intensity compared to that of typical advertisement calls. Call duration was 501–719 ms (mean 599.7, SD = 73.8). Each call is composed of 46–60 (mean 53.4, SD = 5.3) pulses arranged in a single group or irregularly arranged with isolated pulses along its extent. Dominant frequency was 2.44–2.63 kHz (mean 2.55, SD = 0.10).

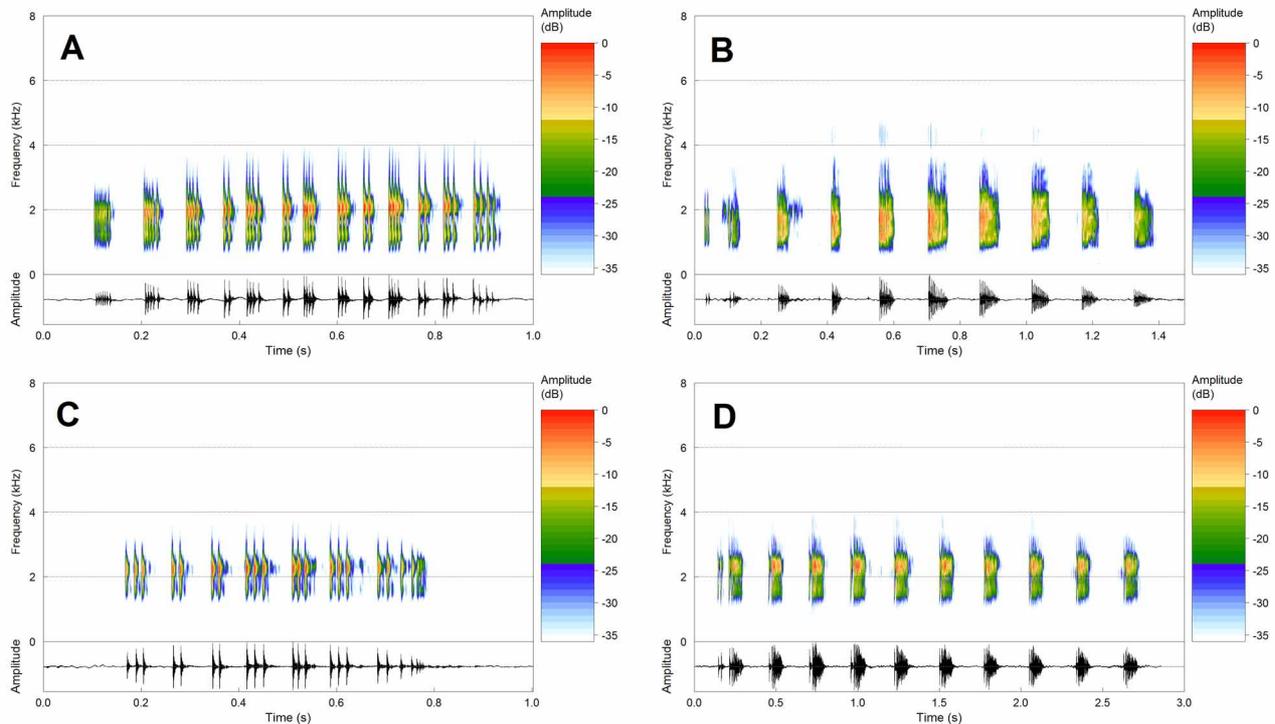


FIGURE 10. Audiospectrogram (above) and corresponding oscillogram (below) of: **(A)**, Note type A of the advertisement call of *Bokermannohyla ibitiguara* from Capitólio (MG), Brazil. Record file: Bokerm_ibitiguaraMG1bTRC_AAGmt; 19:20h, 18 December 2009; air 24.4°C, water 23.3°C; **(B)**, A sequence of ten notes type B of the advertisement call of *Bokermannohyla ibitiguara* from Capitólio (MG), Brazil. Record file: Bokerm_ibitiguaraMG3bTRC_AAGmt; 20:26h, 18 December 2009; air 24.4°C, water 23.3°C; **(C)**, Note type A of the advertisement call of *Bokermannohyla sazimai* from Vargem Bonita (MG), Brazil. Record file: Bokerm_sazimaiMG1TRC_AAGmt; 23:04h, 17 December 2009; air 19°C, water 21°C; **(D)**, A sequence of ten notes type B of the advertisement call of *Bokermannohyla sazimai* from Vargem Bonita (MG), Brazil. Record file: Bokerm_sazimaiMG2bTRC_AAGmt; 23:13h, 17 December 2009; air 19°C, water 21°C. All figures generated at 256 points resolution (FFT).

Males were calling perched on vegetation (≈ 1.5 m from the ground) next to rocky bottom streamlets at the border or inside the forest.

Bokermannohyla ibitiguara advertisement call. Eight males recorded (N = 200 note type A samples; N = 303 note type B samples). Quantitative traits are summarized in Table 3. Advertisement call composed of two types of notes (herein referred to as note types A and B). Note type A (fig. 10 A) consists of a single multipulsed structure with 7–17 pulse groups/note (mean 13.0, SD = 1.2), and with 39–92 pulses/note (mean 64.9, SD = 14.5) that may be separated from each other, medially juxtaposed, or even completely juxtaposed (especially the initial and final pulse groups) released at a rate of 10–52 notes/minute (mean 21.0, SD = 12.8). Note duration was 435–1,208 ms (mean 855.1, SD = 134.3) with internote interval from 91–3,575 ms (mean 1,229.2, SD = 518.7). Dominant frequency was 1.50–2.20 kHz (mean 2.01, SD = 0.21). Note type B (fig. 10 B) consists of a multipulsed structure released at a rate of 5–29 notes/minute (mean 19.0, SD = 7.2) in sequences of 5–10 notes/sequence (mean 7.1, SD = 0.5) emitted at a rate of 1–5 note sequences/minute (mean 2.6, SD = 1.1). Note composed of pulses usually juxtaposed, but initial isolated pulses may also be present. Note duration was 37–104 ms (mean 70.1, SD = 13.8) with internote interval from 77–171 ms (mean 128.3, SD = 20.4), and note sequence duration was 780–2,182 ms (mean 1,371.1, SD = 312.4). Dominant frequency was 1.50–2.20 kHz (mean 1.99, SD = 0.25). Note B may be emitted overlapping the beginning or middle of the emission of a note A (N = 20).

Males were calling from the ground in rock cavities or perched on vegetation (approximately 1–2 m from the ground) next to rocky bottom streamlets at the border or inside the forest.

Bokermannohyla sazimai advertisement call. Five males recorded (N = 74 note type A samples; N = 221 note type B samples). Quantitative traits are summarized in Table 3. Advertisement call composed of two types of note (herein referred to as note types A and B). Note type A (fig. 10 C) consists of a single multipulsed structure emitted at a rate of 17–68 notes/minute (mean 35.6, SD = 16.0). Note duration was 476–892 ms (mean 656.7, SD = 97.8) with internote interval from 303–2,109 ms (mean 633.7, SD = 320.7). Dominant frequency was 2.24–2.58 kHz (mean 2.47, SD = 0.09). Each note composed of 13–36 pulses (mean 26.7, SD = 4.6) with duration from 5–8 ms (mean 6.3, SD = 0.5), and interpulse interval from 5–21 ms (mean 11.5, SD = 3.2). Pulses arranged in well-defined groups. Each note composed of 5–9 pulse groups (mean 7.2, SD = 0.9). Pulse group duration was 21–95 ms (mean 48.2, SD = 14.3), and interpulse group interval was 14–68 ms (mean 47.5, SD = 8.7). Note type B (recorded from four specimens) (fig. 10 D) consists of a multipulsed structure with initial isolated pulses (the presence and number of single pulses at the beginning of each note are variable within each call) followed by several juxtaposed pulses. Note type B is released in sequences of 6–15 notes/sequence (mean 10.1, SD = 2.1) at a rate of 6–54 notes/minute (mean 31.9, SD = 15.7). Duration of each note was 80–165 ms (mean 100.9, SD = 28.6) with internote interval from 124–199 ms (mean 175.2, SD = 20.0). Note sequences are emitted at a rate of 1–5 note sequences/minute (mean 3.1, SD = 1.0). Duration of note sequence was 1,573–3,933 ms (mean 2,654, SD = 552.6). Dominant frequency was 2.24–2.58 kHz (mean 2.45, SD = 0.12). Note B may be emitted overlapping the beginning or middle of the emission of a note A (N = 10).

Males were calling perched on vegetation (approximately 1–2 m from the ground) next to streamlets at the border or inside the forest.

Additional remarks. The Estação de Desenvolvimento e Pesquisa ambiental Galheiro (EDPA-Galheiro) is geographically separated and ecologically isolated from the altitudinal environments within the Atlantic Forest domain (see Napoli 2005). *Bokermannohyla napolii* sp. nov. is known only from the aforementioned mid-altitudinal riparian environment in the Cerrado of southeastern Brazil, whereas its allied species (*B. caramaschii*, *B. circumdata*, and *B. luctuosa*) inhabit altitudinal environments (Serra do Mar and Serra da Mantiqueira mountain ranges) within the Atlantic Forest domain of southeastern, southern, and northeastern Brazil (Napoli 2005; Napoli *et al.* 2011). It may also be worth stating that specimens assigned to *B. circumdata* from the Serra do Espinhaço and Serra da Canastra mountain ranges (Appendix 1) require a more thorough evaluation so as to clarify their taxonomic status. However, it might also require bioacoustic data in addition to only taking a morphological approach into account, which could even reveal other cryptic species under the name *B. circumdata* among populations distributed along altitudinal riparian environments in the Cerrado of southeastern Brazil.

Recordings of *B. circumdata* from coastal Atlantic Forest in the State of São Paulo (Paranapiacaba) had only one type of note, regarded as homologous to note type B of *B. napolii* sp. nov., *B. luctuosa*, and *B. circumdata* from the southern sector of the Serra da Mantiqueira mountain range, State of Minas Gerais. We can assume that the emission of note types A and C should possibly be regulated by social context, since one of the two populations of *B. circumdata* emitted all three note types, whereas the other population only emitted one type of note.

In the original description of *Bokermannohyla ibitiguara*, Cardoso (1983) presented two distinct note types as being its advertisement call, whose audiospectrogram is difficult to interpret as the author did not exactly specify those two distinct notes. The notes named as “long notes” should probably correspond to note type A of our description. Accordingly, those notes called “short notes” should probably correspond to note type B of our description. In this context, temporal variables of *B. ibitiguara* calls presented in Cardoso (1983) and later used in Lugli and Haddad (2006) were not in accordance with our data, especially the duration of the two distinct notes. It probably seems that these variables were not measured in the same manner so that the range of values was quite different from the results obtained in our analysis. Differences in the technology available for each analysis, as well as weather and intraspecific variation might also be regarded as potential sources of variation in the results obtained.

In the original description of *Bokermannohyla sazimai*, Cardoso and Andrade (1982) presented two distinct types of notes composing its advertisement call. The first five notes in their fig. 6A were named as “multipulsed notes”, and correspond to our note type B; the remaining note of their fig. 6A and the sequence of two notes in their fig. 6B were named as “non-pulsed notes”, and correspond to our note type A.

Bokermann and Sazima (1973) defined the advertisement call of *Bokermannohyla nanuzae* as having from two to four irregularly separated notes. We believe they considered the emission of two advertisement calls consecutively (4 notes) as the advertisement call, inasmuch as we only analyzed advertisement calls with two notes. Those

authors also described the presence of frequency bands (three), whereas we could only observe two bands of emphasized frequency, the dominant frequency and sometimes the fundamental frequency (more than 1 kHz).

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References

- Bokermann, W.C.A. & Sazima, I. (1973) Anfíbios da Serra do Cipó, Minas Gerais, Brasil. 1 – Espécies novas de *Hyla* (Anura, Hylidae). *Revista Brasileira de Biologia*, 33, 329–336.
- Caramaschi, U. & Feio, R.N. (1990) A new species of *Hyla* (Anura, Hylidae) from southern Minas Gerais, Brazil. *Copeia*, 1990(2), 542–546.
- Caramaschi, U., Napoli, M.F. & Bernardes, A.T. (2001) Nova espécie do grupo de *Hyla circumdata* (Cope, 1870) do Estado de Minas Gerais, Brasil (Amphibia, Anura, Hylidae). *Boletim do Museu Nacional, N. S., Zoologia, Rio de Janeiro*, 457, 1–11.
- Cardoso, A.J. (1983) Descrição e biologia de uma nova espécie de *Hyla* Laurenti, 1768 (Amphibia, Anura, Hylidae). *Iheringia, Série Zoologia*, 62, 37–45.
- Cardoso, A.J. & Andrade, G.V. (1982) Nova espécie de *Hyla* do Parque Nacional da Serra da Canastra (Anura, Hylidae). *Revista Brasileira de Biologia*, 42, 589–593.
- Duellman, W.E. (1970) *The hylid frogs of Middle America*. Monographs of the Museum of Natural History, the University of Kansas, Lawrence, 473 pp.
- Duellman, W.E. & Trueb, L. (1994) *Biology of Amphibians*. The Johns Hopkins University Press, Baltimore, Maryland, 670 pp.
- Faivovich, J., Haddad, C.F.B., Garcia, P.C.A., Frost, D.R., Campbell, J.A. & Wheeler, W.C. (2005) Systematic Review of the frog family Hylidae, with special reference to Hylineae: phylogenetic analysis and taxonomic revision. *Bulletin of the American Museum Natural History*, 294, 1–240.
- Faivovich, J., Lugli, L., Lourenço, A.C.C. & Haddad, C.F.B. (2009) A new species of the *Bokermannohyla martinsi* group from central Bahia, Brazil with comments on *Bokermannohyla* (Anura: Hylidae). *Herpetologica*, 65, 303–310.
- Frost, D.R. (2011) *Amphibian Species of the World: an Online Reference*, v. 5.5. American Museum of Natural History, New York, USA. Available from: <http://research.amnh.org/vz/herpetology/amphibia/> (accessed on 26 May 2011).
- Griddi-Papp, M. (2007) Sound Ruler. Version 0.9.6.0. Available from <http://soundruler.sourceforge.net> (accessed 28 August 2010).
- Heyer, W.R. (1985) New species of frogs from Boracéia, São Paulo, Brazil. *Proceedings of the Biological Society of Washington*, 98, 657–671.
- Heyer, W.R., Rand, A.S., Cruz, C.A.G., Peixoto, O.L. & Nelson, C.E. (1990) Frogs of Boracéia. *Arquivos de Zoologia*, 31, 235–410.
- Jim, J. & Caramaschi, U. (1979) Uma nova espécie de *Hyla* da região de Botucatu, São Paulo, Brasil (Amphibia, Anura). *Revista Brasileira de Biologia*, 39, 717–719.
- Lugli, L. & Haddad, C.F.B. (2006) A new species of the *Bokermannohyla pseudopseudis* group from central Bahia, Brazil (Anura, Hylidae). *Herpetologica*, 62, 453–465.
- McLister, J.D., Stevens, E.D. & Bogart, J.P. (1995). Comparative contractile dynamics of calling and locomotor muscles in three hylid frogs. *The Journal of Experimental Biology*, 198, 1527–1538.
- Napoli, M.F. (2000) Taxonomia, variação morfológica e distribuição geográfica das espécies do grupo de *Hyla circumdata* (Cope, 1870) (Amphibia, Anura, Hylidae). Doctoral thesis, unpublished. Universidade Federal do Rio de Janeiro/Museu Nacional, Rio de Janeiro, 208pp. Available from http://www.amphibia.ufba.br/Public/Tese_MFNapoli.htm (accessed on 14 November 2011).
- Napoli, M.F. (2005) A new species allied to *Hyla circumdata* (Anura: Hylidae) from Serra da Mantiqueira, southeastern Brazil. *Herpetologica*, 61, 63–69.

- Napoli, M.F. & Caramaschi, U. (2004) Two new species of the *Hyla circumdata* group from Serra do Mar and Serra da Mantiqueira, Southeastern Brazil, with description of the advertisement call of *Hyla ibitipoca* (Anura, Hylidae). *Copeia*, 2004(3), 534–545.
- Napoli, M.F., Encarnação, L., Cunha, M., Abreu, F. & Herrera, J. (2011) Paradoxical geographic distributions, new record, and corrections of *Bokermannohyla circumdata* (Cope, 1870) and *B. caramaschii* (Napoli, 2005) (Amphibia: Anura: Hylidae). *Herpetology Notes*, 4, 105–109.
- Napoli, M.F. & Juncá, F.A. (2006) A new species of the *Bokermannohyla circumdata* group (Amphibia: Anura: Hylidae) from Chapada Diamantina, State of Bahia, Brazil. *Zootaxa*, 1244, 57–68.
- Napoli, M.F. & Pimenta, B.V.S. (2003) Nova espécie do grupo de *Hyla circumdata* (Cope, 1870) do sul da Bahia, Brasil (Amphibia, Anura, Hylidae). *Arquivos do Museu Nacional, Rio de Janeiro*, 61, 189–194.
- Napoli, M.F. & Pimenta, B.V.S. (2009) A new species of the *Bokermannohyla circumdata* group (Anura: Hylidae) from the coastal forests of Bahia, northeastern Brazil. *Copeia*, 2009(4), 674–683.
- Peixoto, O.L. (1981) Nova espécie de *Hyla* da Serra dos Órgãos, Estado do Rio de Janeiro, Brasil (Amphibia, Anura, Hylidae). *Revista Brasileira de Biologia*, 41, 515–520.
- Peixoto, O.L. & Cruz, C.A.G. (1992) Nova espécie de *Hyla* da Serra da Mantiqueira, Itatiaia, estado do Rio de Janeiro (Amphibia, Anura, Hylidae). *Memórias do Instituto Oswaldo Cruz*, 87, 197–200.
- Pombal, J.P. & Haddad, C.F.B. (1993) *Hyla luctuosa*, a new treefrog from southeastern Brazil (Amphibia: Hylidae). *Herpetologica*, 49, 16–21.
- R Development Core Team (2011) *R Foundation for Statistical Computing*. Vienna, Austria. Available from <http://www.R-project.org> (accessed 26 May 2011).
- Savage, J.M. & Heyer, W.R. (1997) Digital webbing formulae for anurans: a refinement. *Herpetological Review*, 28, 131.
- Sueur, J., Aubin, T. & Simonis, C. (2008) Seewave, a free modular tool for sound analysis and synthesis. *Bioacoustics*, 18, 213–226.
- Vasconcelos, E.G. & Giaretta, A.A. (2003) A new species of *Hyla* (Anura: Hylidae) from southeastern Brazil. *Revista Española de Herpetología*, 17, 21–27.
- Wells, K.D. (2007) Anuran vocal communication. In: Wells, K.D. (Eds.), *The Ecology and Behavior of Amphibians*. University of Chicago Press, Chicago & London, pp. 268–337.

Appendix 1: Additional examined specimens

See also Appendix 1 in Vasconcelos and Giaretta (2003) for a list of additional examined species.

Bokermannohyla ahenea – BRAZIL: SÃO PAULO: São José do Barreiro (CFBH 21953); *Bokermannohyla astartea* – BRAZIL: SÃO PAULO: Salesópolis (ZUEC 6401); *Bokermannohyla caramaschii* – BRAZIL: ESPÍRITO SANTO: Alegre (CFBH 25137); Domingos Martins (CFBH 10843, 22845); Santa Teresa (topotypes: CFBH 15004–05); Vargem Alta (CFBH 25088, 25581, 25583); *Bokermannohyla carvalhoi* – BRAZIL: RIO DE JANEIRO: Teresópolis (topotypes: CFBH 22010–22011, 24775); *Bokermannohyla circumdata* – BRAZIL: MINAS GERAIS: Chiador (AAG-UFU 0668–0670); RIO DE JANEIRO: Petrópolis (CFBH 13949–13950; 10121); Trajano de Moraes (AAG-UFU 0523); SÃO PAULO: Arapeí (ZUEC 6494, 6970–6972, 6980); Paranapiacaba (ZUEC 4495–96); São Luís do Paraitinga (CFBH 10776, 13783, 13788, 14651–14652, 14654, 14657–14658, 14784–14786); Serra da Bocaina (ZUEC 2027); *Bokermannohyla* cf. *circumdata* – BRAZIL: MINAS GERAIS: Congonhas (UFMG 5125, 5155); Juatuba (AAG-UFU 0326); São Gotardo (AAG-UFU 0369, 1019); São Roque de Minas (MZUFV 9944, 9946); *Bokermannohyla clepsydra* – BRAZIL: SÃO PAULO: Serra da Bocaina (topotype: ZUEC 15937); *Bokermannohyla feioi* – BRAZIL: MINAS GERAIS: Ibitipoca (topotype: ZUEC 16123); Lima Duarte (topotypes: ZUEC 7156–7157); *Bokermannohyla gouveai* – BRAZIL: MINAS GERAIS: Itamonte (CFBH 10126, 16677–16680, 16690–16691); *Bokermannohyla hylax* – BRAZIL: SÃO PAULO: Iguapé (ZUEC 9162–9163); Salesópolis (ZUEC 6421); Santo André (ZUEC 6467, 6513, 7043, 8422, 10930); *Bokermannohyla ibitiguara* – BRAZIL: MINAS GERAIS: Capitólio (AAG-UFU 4849–4852); São Roque de Minas (AAG-UFU 0060–0062, AAG-UFU 0586); *Bokermannohyla ibitipoca* – BRAZIL: MINAS GERAIS: Ibitipoca (topotypes: ZUEC 16120–16122, 16124–16125); Lima Duarte (paratopotypes ZUEC 6823–6824); *Bokermannohyla izecksohni* – BRAZIL: SÃO PAULO: Cotia (CFBH 16653–16654); *Bokermannohyla luctuosa* – BRAZIL: MINAS GERAIS: Camanducaia (CFBH 4961, 7465, 7467, 1239–1241, 11244, 11246–47, 17563–17564, 17566, 17583, 17585–17591); SÃO PAULO: Atibaia (AAG-UFU 0470–0473); Cabreúva (paratype: ZUEC 5949); Campos do Jordão (ZUEC 6938, 9793); Jundiá (topotypes: ZUEC 4540, 4543–4544; paratopotypes: ZUEC 9161, 9171; holotype: ZUEC 9159); Ribeirão Branco (ZUEC 7030); Santo Antônio do Pinhal (CFBH 7309); *Bokermannohyla nanuzae* – BRAZIL: MINAS GERAIS: Jaboticatubas (topotypes: AAG-UFU 0024–0025; paratopotypes: WCAB 47536–47537; topotypes ZUEC 3026–3027); *Bokermannohyla ravida* – BRAZIL: MINAS GERAIS: Presidente Olegário (topotype: ZUEC 9108); *Bokermannohyla sazimai* – BRAZIL: MINAS GERAIS: Araxá (CFBH 11575; AAG-UFU 0610–0611); Ibiá (CFBH 18417–18419, UFMG 3424–3429); Perdizes (AAG-UFU 2417; 2427–2429; 2615; 4789–4791; ZUEC 12063–12065); Sacramento (AAG-UFU 1034–1035); São Gotardo (AAG-UFU 0350–0366); São Roque de Minas (paratopotypes: ZUEC 4194–4196, ZUEC 4199–4200, ZUEC 4212–4213); Serra do Salitre (UFMG 844–848, UFMG 851–859); Uberaba (AAG-UFU 0553–0556, AAG-UFU 1041–1045); Vargem Bonita (topotypes: AAG-UFU 4842–4846); *Bokermannohyla vulcaniae* – BRAZIL: MINAS GERAIS: Poços de Caldas (topotype: AAG-UFU 4674).