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# The Advertisement Calls and Distribution of Two Sympatric Species of *Chiasmocleis* (Méhely 1904) (Anura, Microhylidae, Gastrophryinae) from the Atlantic Forest

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**Abstract.** The advertisement calls of *Chiasmocleis cordeiroi* and *C. crucis* are described for populations from the municipalities of Igrapiúna and Camacan, respectively, state of Bahia, Brazil. Both calls consist of multipulsed notes produced in series. Differences between the two calls are: dominant frequency, higher in *C. cordeiroi* (range 4500–4898 Hz; *C. crucis* range 4069–4435 Hz); note rate, higher in *C. cordeiroi* (range 6.20–7.46 s/note; *C. crucis* range 5.17–5.59 s/note); pulse rate, higher in *C. cordeiroi* (151.82–194.83 s/note; *C. crucis* range 125.30–142.12 s/note); and the structure of the modulation patterns of the notes. Moreover, the advertisement calls of *C. crucis* and *C. cordeiroi* are more similar than the calls of all syntopic congeners. Furthermore, the current distribution of both species was extended.

**Keywords.** Bioacoustics; Sympatry; Southern Bahia; *Chiasmocleis cordeiroi*; *Chiasmocleis crucis*.

**Resumo.** O canto de anúncio de *Chiasmocleis cordeiroi* e *C. crucis* é descrito para os municípios de Igrapiúna e Camacan, Bahia, Brasil, respectivamente. A vocalização de ambas espécies consistem em notas multipulsionadas produzidas em série. As diferenças entre os dois cantos de anúncio estão relacionadas com a maior frequência dominante em *C. cordeiroi* (variando 4500–4898 Hz; *C. crucis* variando 4069–4435 Hz), maior taxa de emissão de notas em *C. cordeiroi* (variando 6.20–7.46 s/nota; *C. crucis* variando 5.17–5.59 s/nota), maior taxa de emissão de pulsos em *C. cordeiroi* (variando 151.82–194.83 s/nota; *C. crucis* variando 125.30–142.12 s/nota), e a estrutura dos padrões de modulação das notas. As diferenças encontradas entre os cantos de *C. cordeiroi* e *C. crucis* são menos evidentes que outras espécies sintópicas do gênero. Adicionalmente ampliamos a atual distribuição de ambas as espécies.

## INTRODUCTION

Advertisement calls of anurans have been used to diagnose species (e.g., Gerhardt, 1988; Duellman and Trueb, 1994) and they play a role as behavioral isolating mechanisms (Blair, 1964; Wells, 1977). These calls have distinct measurements related with the physical and/or biological environment (Blair, 1955). A comparative analysis of advertisement calls in New World microhylids revealed three patterns: bleats, single whistles, and trilled calls (Nelson, 1973). The latter pattern has been reported for most of the genus *Chiasmocleis*, consisting of multipulsed notes produced in series (Nelson, 1973; Zimmerman and Bognart, 1988; De La Riva *et al.*, 1996; Harmman *et al.*, 2002; Wogel *et al.*, 2004; Schluter, 2005; Oliveira Filho and Giarretta, 2006; Rodrigues *et al.*, 2008, 2011; Barros *et al.*, 2010). However, among 25 species currently described (Frost, 2012), only *C. mantiqueira* has a non-pulsed call (Santana *et al.*, 2012).

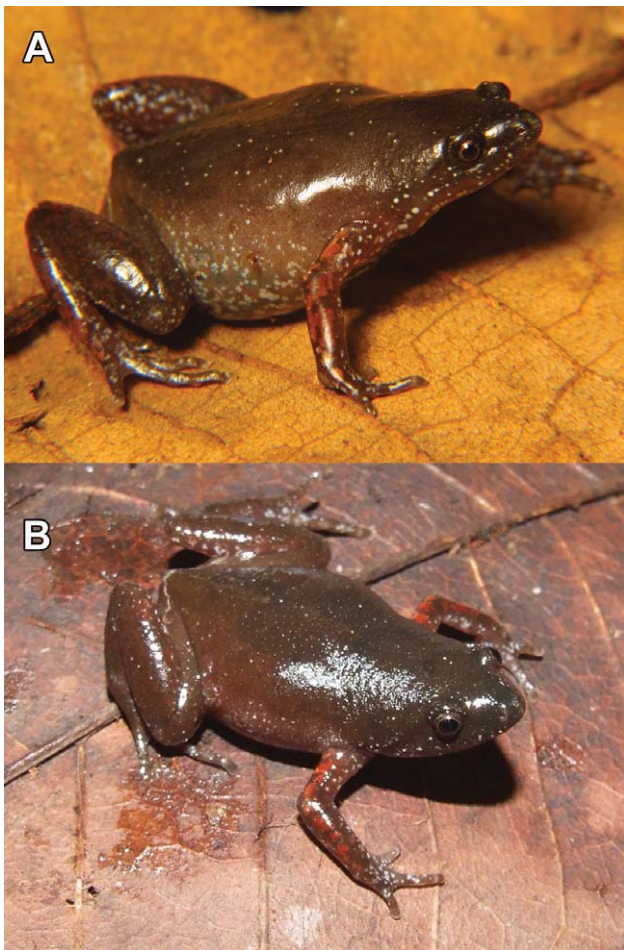
Herein, we describe for the first time the advertisement calls of *Chiasmocleis cordeiroi* Caramaschi and Pimenta, 2004 (Fig. 1A) and *C. crucis* Caramaschi and Pimenta, 2004 (Fig. 1B), and extend the known range of both species (Fig. 2). We compare the advertisement calls

of all known species of *Chiasmocleis* and compare the level of differences present in others sympatric species.

## MATERIALS AND METHODS

We found *Chiasmocleis cordeiroi* breeding in a temporary pond inside a rubber plantation located in a fragment adjacent to Atlantic Forest on 24 January 2011, at Reserva Ecológica Michelin (Michelin Ecological Reserve; 13°49'S, 39°08'W), Municipality of Igrapiúna, state of Bahia, northeastern Brazil. The advertisement calls of two males were recorded using a Marantz PMD 660 digital recorder coupled with a Sennheiser ME45 directional microphone, between 23:00 h and 01:00 h, air temperature 25°C. Recorded specimens were deposited at the Coleção de anfíbios do Museu de Zoologia da Universidade Estadual de Santa Cruz (MZUESC), under catalog numbers MZUESC 9086–87.

We found *Chiasmocleis crucis* breeding in a temporary pond inside a fragment of Atlantic Forest on November 14, 2010, at Reserva Particular Serra Bonita (RPPN; Private Natural Heritage Reserve Serra Bonita, 15°25'31.4"S; 39°32'39.2"W), Municipality of Camacan, state of Bahia,

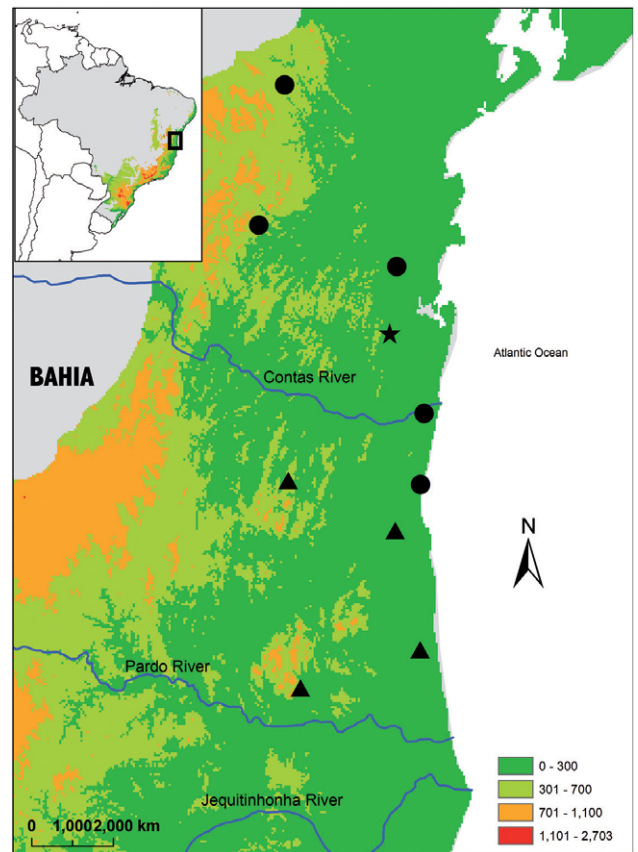


**Figure 1.** (A) Live female of *Chiasmocleis cordeiroi* from the municipality of Wenceslau Guimarães, state of Bahia, Brazil; (B) live male of *Chiasmocleis crucis* from the RPPN Serra Bonita, municipality of Camacan, state of Bahia, Brazil.

northeastern Brazil. The advertisement call of a male was recorded using a Tascam DR1 digital recorder with an internal microphone. Voucher specimens are deposited at the Coleção de anfíbios do Museu de Zoologia da Universidade Estadual de Santa Cruz (MZUESC), under catalog numbers MZUESC 9028–29, 9031–34, 9036 (one of these specimens was recorded while specimens were kept in a plastic bag). Recordings are deposited at the Museu Nacional Rio de Janeiro (MNRJ), under catalog numbers MNVOC 039/1, MNVOC 039/2 (*C. cordeiroi*) and MNVOC 039/3 (*C. crucis*). Replicas of the recordings are deposited at the Coleção de Anfíbios, Departamento de Zoologia, Universidade Estadual Paulista, campus Rio Claro (CFBH), under catalog numbers MF01, MF02 (*C. cordeiroi*) and MF03 (*C. crucis*).

Vocalizations were analyzed and edited with Raven v. 1.2.1, using default parameters (DFT or FFT size 512; overlap at 50%; Hop Size 256; Gris spacing 93.9; 3dB filter Bandwidth 124; Hann filter); terminology follows Duellman and Trueb (1994).

Identification of the recorded specimens as *Chiasmocleis cordeiroi* and *C. crucis* was determined through



**Figure 2.** Distribution map of *Chiasmocleis cordeiroi* (circles) and *Chiasmocleis crucis* (triangle). Star represents the type locality of both species.

examination of the type series and specimens deposited in the following collections: Coleção de Anfíbios, Departamento de Zoologia, Universidade Estadual Paulista, campus Rio Claro (CFBH); Museu Nacional, Rio de Janeiro (MNRJ); Museu de Zoologia, Universidade de São Paulo (MZUSP); Museu de Zoologia, Universidade Estadual de Santa Cruz (MZUESC); and Museu de Zoologia, Universidade Federal da Bahia (UFBA); data on specimens examined is provided in Appendix I.

## RESULTS

### Advertisement call of *Chiasmocleis cordeiroi*

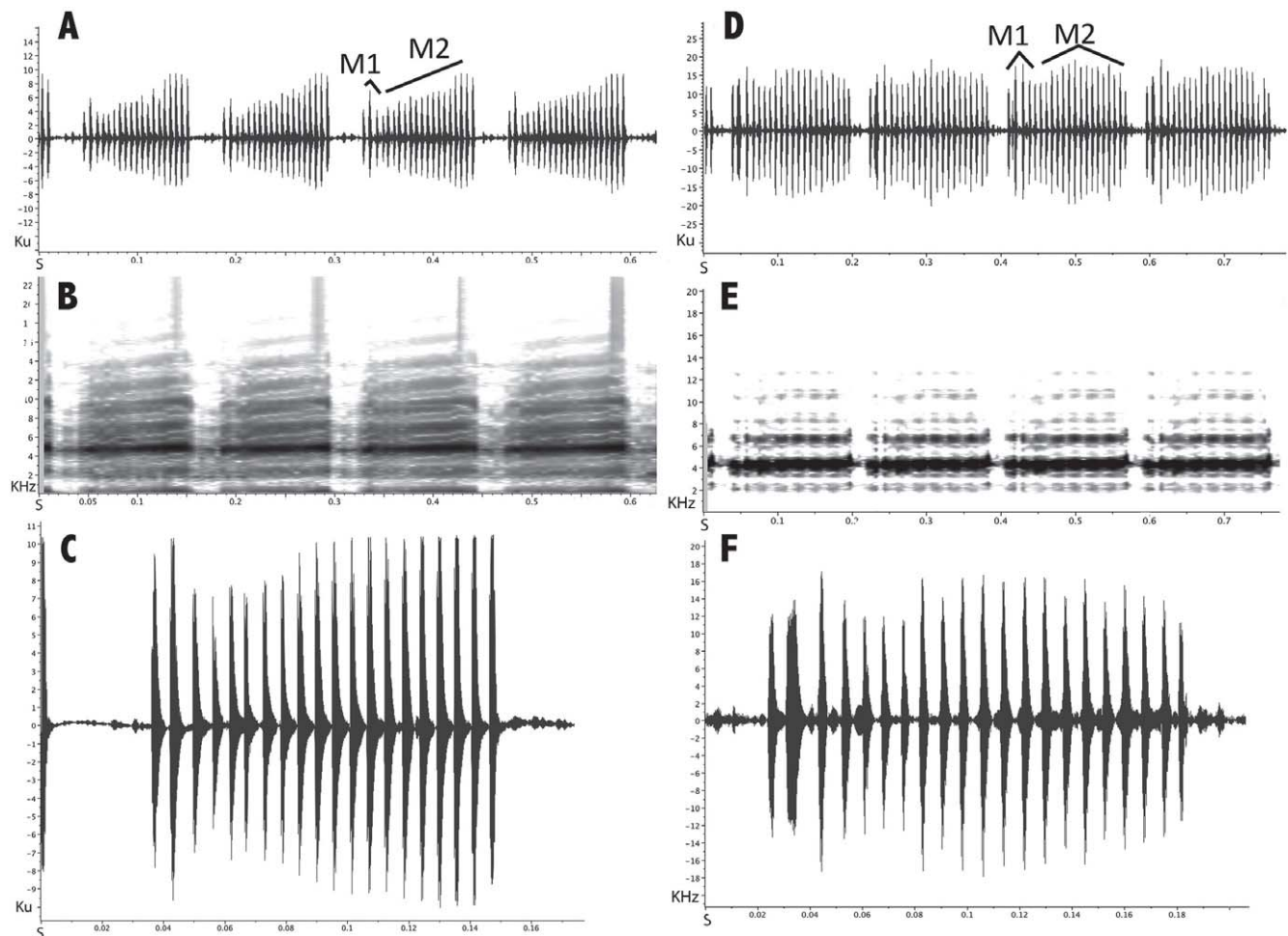
*Chiasmocleis cordeiroi* was found inside a rubber plantation located beside of a forest fragment in a temporary pond (about 40 cm deep) after two days of heavy rains. At night, hundreds of specimens were heard and breeding activity was observed. Calling males were observed vocalizing on the edge as well in deeper areas of the pond, floating on the water or on top of vegetation and debris. The recorded individuals were vocalizing on the edge of a puddle close to the water.

The advertisement call of *Chiasmocleis cordeiroi* consists of multi-pulsed notes produced in series with duration range 1.31–26.86 s ( $\bar{x} = 7.22 \pm 7.80$  s,  $n = 9$  calls; Fig. 3). The notes showed a distinct harmonic structure visible in the spectrogram (Fig. 3B). The number of notes per call varied from 9 to 182 ( $\bar{x} = 48.56 \pm 52.93$ ,  $n = 9$  calls) with interval between notes ranging from 0.03–0.04 s ( $\bar{x} = 0.031 \pm 0.001$  s,  $n = 365$ ). Note rates were emitted from 6.20 to 7.46 s per call ( $\bar{x} = 6.76 \pm 0.37$  s/call,  $n = 9$  calls) and consisted of 13–24 pulses ( $\bar{x} = 20.13 \pm 1.59$ ,  $n = 372$  notes), with pulse rate range from 151.82–194.83 s per note ( $\bar{x} = 172.75 \pm 3.61$  s/note,  $n = 372$  notes); note duration ranging from 0.07–0.14 s ( $\bar{x} = 0.12 \pm 0.01$  s,  $n = 372$  notes); and dominant frequency ranging from 4500–4898 Hz ( $\bar{x} = 4761.48 \pm 62.34$  Hz). Descriptive statistics of the advertisement call parameters in Table 1. The modulation of each note has a pattern consisting of descending and ascending intensities (Fig. 3A, C). The first modulation consists of 2–4 pulses, with the first

ones having the highest intensity and the last one having the lowest intensity. The second modulation is longer than the first, consisting of more than 15 pulses, all with approximately the same length and with the first few pulses having lower intensity and gradually increasing. Moreover, the second modulation pulses consist of higher maximum amplitude (~10272–10570 Ku) than the first one (~77738–10306 Ku). In one of the recorded males, the second modulation consists of fewer pulses with the highest amplitude, resulting in a more gradual modulation pattern. One of the recorded calls consists of 182 notes with long duration (26.85 s).

### Advertisement call of *Chiasmocleis crucis*

Individuals of *Chiasmocleis crucis* were found after heavy rains (about 24.5 mm) in two temporary ponds: a small pond inside a forest fragment and a larger pond



**Figure 3.** (A–C) Advertisement call of *Chiasmocleis cordeiroi* from the municipality of Igrapiúna, state of Bahia, Brazil: (A) oscillogram showing four notes of an advertisement call; (B) spectrogram showing four note of an advertisement call; (C) oscillogram showing one note of advertisement call; (D–F) Advertisement call of *Chiasmocleis crucis* from municipality of Camacan, state of Bahia, Brazil: (D) oscillogram showing four notes of an advertisement call; (E) spectrogram showing four notes of an advertisement call; (F) oscillogram showing one note of an advertisement call. M1, first modulation pattern; M2, second modulation pattern.

**Table 1.** Summary of acoustic parameters of the advertisement call of *Chiasmocleis crucis* and *C. cordeiroi*. Values are presented as arithmetic mean  $\pm$  standard deviation; n = number of samples.

Parameters	<i>Chiasmocleis crucis</i>	<i>Chiasmocleis cordeiroi</i>
Call duration (s)	$\bar{X} = 3.54 \pm 19.55$ (5.97–13.89) n = 7	$\bar{X} = 7.22 \pm 7.80$ (1.31–26.86) n = 9
Number of notes per call	$\bar{X} = 59.50 \pm 19.55$ (33–77) n = 4	$\bar{X} = 48.56 \pm 52.93$ (9–182) n = 9
Interval between notes (s)	$\bar{X} = 0.02 \pm 0.003$ (0.01–0.03) n = 108	$\bar{X} = 0.031 \pm 0.001$ (0.03–0.04) n = 365
Note rate (notes/s)	$\bar{X} = 5.39 \pm 0.21$ (5.17–5.59) n = 4	$\bar{X} = 6.76 \pm 0.37$ (6.20–7.46) n = 9
Note duration (s)	$\bar{X} = 0.15 \pm 0.01$ (0.105–0.179) n = 109	$\bar{X} = 0.12 \pm 0.01$ (0.07–0.14) n = 372
Number of pulses per note	$\bar{X} = 20.78 \pm 1.70$ (14–23) n = 73	$\bar{X} = 20.13 \pm 1.59$ (13–24) n = 372
Pulse rate (pulses/s)	$\bar{X} = 131.33 \pm 2.92$ (125.30–142.12) n = 73	$\bar{X} = 172.75 \pm 3.61$ (151.82–194.83) n = 372
Dominant frequency (Hz)	$\bar{X} = 4324 \pm 61$ (4069–4435) n = 109	$\bar{X} = 4761 \pm 62$ (4500–4898) n = 372

on the banks of a dirt road across an agroforestry system locally named “cabruças” (*i.e.*, managed forest with “Cocoa” plantations shaded by native trees). At night, a large number of specimens were observed in breeding activity in these ponds. Calling males vocalized at the edge of the ponds as well as floating on the water surface with just the head above the water surface.

The advertisement call of *Chiasmocleis crucis* consists of multi-pulsed notes produced in series with duration ranging from 5.97–13.89 s ( $\bar{x} = 3.54 \pm 19.55$  s, n = 7). The notes showed a structure with distinct harmonics visible in the spectrogram; the second harmonic is the strongest (Fig. 3E). Number of notes per call ranged from 33–77 ( $\bar{x} = 59.50 \pm 19.55$ , n = 4 calls) with interval between notes lasting from 0.01–0.03 s ( $\bar{x} = 0.02 \pm 0.003$  s, n = 108). The rate note varied from 5.17–5.59 s per call ( $\bar{x} = 5.39 \pm 0.21$  s/call, n = 4 calls) and consisted of 14–23 pulses ( $\bar{x} = 20.78 \pm 1.70$ , n = 73 notes), emitted at a pulse rate ranging from 125.30–142.12 s per note ( $\bar{x} = 131.33 \pm 2.92$  s/note, n = 73 notes); note duration ranging from 0.105–0.179 s ( $\bar{x} = 0.159 \pm 0.01$  s, n = 109 notes), and dominant frequency ranging from 4069–4435 Hz ( $\bar{x} = 4324 \pm 61$  Hz, n = 109). Descriptive statistics of the advertisement call are show in Table 1. The notes have two clear intensity modulation patterns, each with

ascending and descending intensity parts (‘wave pattern’ Fig. 3D, F). The first modulation consists of three to six pulses, with the first and last pulses having lower intensity than the intermediate ones. Usually the second pulse is longer than others. The second modulation is longer than the first one and consists of more than 10 pulses, all of approximately the same length and with the first and last pulses having lower intensity. Moreover, both modulations present similar maximum amplitude, ranging from 15295–19121 Ku in the first one, and 16174–19779 Ku on the second. Was observed, with longer notes having more distinct ascendant and descendent patterns. In short notes the second descending amplitude is less evident.

## DISCUSSION

The advertisement calls of *Chiasmocleis cordeiroi* and *C. crucis* are distinct (Fig. 3). Differences include: higher mean dominant frequency in *C. cordeiroi* (4761.48 Hz; *C. crucis* 4324.37 Hz), higher note rate in *C. cordeiroi* (6.20–7.46 s/note; *C. crucis* 5.17–5.59 s/note), higher pulse rate in *C. cordeiroi* (151.82–194.83 s/note; *C. crucis* 125.30–142.12 s/note), and note with different modulation patterns (one ascendant and one descendent in *C. cordeiroi*; two ascendant and two descendent in *C. crucis*); also, there are slight differences in call duration and number of notes per call, but these differences could represent differences related to social interactions (Table 1).

An intensity modulation pattern formed by two groups of pulses within a note was previously reported for *C. albopunctata* (Oliveira Filho and Giaretta, 2006). However, it can also be observed in the call description of *C. mehelyi* (Harmman *et al.*, 2002: fig. 1b). In these two species the advertisement call clearly displays two groups of pulses: the first one with lower number of pulses than the second; and the second group of pulses with a distinct ascending modulation (Oliveira Filho and Giaretta, 2006: fig. 2a-c; Hartmann *et al.*, 2002: fig. 1b). Also, the modulation patterns found in *C. cordeiroi* and *C. crucis* do not show a clear space between the groups of pulses as seen in *C. albopunctata* and *C. mehelyi*.

The general structure of the advertisement calls of *Chiasmocleis cordeiroi* and *C. crucis* is consistent with most species of the genus (summary in Santana *et al.*, 2009), consisting of multi-pulsed notes produced in series (Nelson, 1973; Zimmerman and Bogart, 1988; De La Riva *et al.*, 1996; Hartmann *et al.*, 2002; Oliveira Filho and Giaretta, 2006; Rodrigues *et al.*, 2008; Santana *et al.*, 2009; Barros *et al.*, 2010; Rodrigues *et al.*, 2010). The call of *C. mantiqueira* is distinguished from the rest of the genus by its non-pulsed structure (Santana *et al.*, 2012). The range number of pulses per note in *C. cordeiroi* and

*C. crucis* (13–24 and 14–23, respectively) is higher than most of the calls known for other *Chiasmocleis* species (3–13 pulses per note; Santana *et al.*, 2009; Barros *et al.*, 2010). Furthermore, the calls describe here are similar to those of *C. atlantica* (7–22; Wogel *et al.*, 2004) and *C. leucosticta* (14–17; unpublished data).

The mean dominant frequency found in *Chiasmocleis cordeiroi* and *C. crucis* is similar to that in *C. albopunctata* (4431.5 Hz, De La Riva *et al.*, 1996; 4306 Hz, Oliveira Filho and Giaretta, 2006), *C. capixaba* and *C. carvalhoi* (4750 Hz and 4840 Hz respectively, Wogel *et al.*, 2004), higher than *C. avilapiresae* (3368.2 Hz, Barros *et al.*, 2010), *C. atlantica* (3540 Hz, Wogel *et al.*, 2004), *C. bassleri* (3268.67 Hz, Santana *et al.*, 2009), *C. leucosticta* (3647 Hz, Nelson, 1973), *C. schubarti* (3886 Hz, Nelson, 1973), *C. shudikarensis* (3380–3570 Hz, Lescure and Marty, 2000), and *C. ventrimaculata* (3562 Hz, Zimmerman and Bogart, 1988), and lower than *C. mehelyi* (4700–5400 Hz, Hartmann *et al.*, 2002), *C. panamensis* (4800–5500 Hz, Nelson, 1973), *C. shudikarensis* (5530–7460 Hz, Zimmerman and Bogart, 1988), and *C. ventrimaculata* (5000–7000 Hz, Schluter, 2005). Moreover, *C. crucis* and *C. cordeiroi* are more similar to each other concerning call characteristics, as well as morphology features, than to other syntopic species, *i.e.*, *C. atlantica* and *C. carvalhoi* (Cruz *et al.*, 1997; Wogel *et al.* 2004).

Several authors reported great differences in the dominant frequency among populations of *Chiasmocleis ventrimaculata* and *C. shudikarensis* (Peloso and Sturaro 2008; Santana *et al.*, 2009; Barros *et al.*, 2010). Such distinction has not been stated in any other species of the genus and, in fact, recent analysis confirmed that the advertisement call of *C. ventrimaculata*, described by Schluter (2005) from Peru, represent a new unnamed species (P. Peloso, *pers. comm.*). According to the current knowledge on advertisement calls of *Chiasmocleis*, closely related species show small variation in call patterns, reinforcing the possibility of more than one taxon under the name *C. shudikarensis*.

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## APPENDIX I

*Chiasmocleis cordeiroi*: **Brazil:** Bahia: Amargosa (13°01'37.62"S, 39°06'22.01"W; UFBA 2328); Projeto de Assentamento Zumbi dos Palmares, Camamu (MNRJ 29931 Holotype); Igrapiúna (MZUESC 9086–87, 9286–89); Ilhéus (MZUESC 10930); Itacaré (MNRJ 35364, 35382–83); E.E. Wenceslau Guimarães (Field number MRT 22117–25).

*Chiasmocleis crucis*: **Brazil:** Bahia: Projeto de Assentamento Zumbi dos Palmares, Camamu (MNRJ 2993 Holotype; MNRJ 29936–37 paratypes); RPPN Serra Bonita, Camaçan (15°25'28.60"S, 39°32'47.66"W; MZUESC 9028–29, 9031–34, 9036, MZUSP 147408; Field number MRT 15920, 15935, 15940, 16069–71, 16106, 16118, 16198, 16987); Ilhéus, Mata UESC (14°36'49.68"S, 39°04'01.52"W; MZUSP 147403–04), Ponta da Tulha (MZUSP 147405–07); Una (MRT 5831).