UNIVERSIDADE ESTADUAL DE CAMPINAS
INSTITUTO DE BIOLOGIA

MARIANE DE OLIVEIRA FREITAS

TREEFROGS WITH DISTINCT ADVERTISEMENT CALLS PRODUCE SIMILAR TERRITORIAL SIGNALS

ESPÉCIES DE *SCINAX* (ANURA, HYLIDAE) COM CANTOS DE ANÚNCIO DISTINTOS PRODUZEM CANTOS TERRITORIAIS SIMILARES

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Dissertation presented to the Institute of Biology of the University of Campinas in partial fulfillment of the requirements for the degree of Master of Science in the area of Animal Biology, specific area of Animal Biodiversity

Dissertação apresentada ao Instituto de Biologia da Universidade Estadual de Campinas como parte dos requisitos exigidos para a obtenção do Título de Mestra em Biologia Animal na área de Biodiversidade Animal.

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Prof. Dr. Luis Felipe de Toledo Ramos Pereira

Prof. Dr.Emygdio Leite de Araujo de Monteiro Filho

Prof. Dr. Ivan Sérgio Nunes Silva Filho

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"Quando as aves falam com as pedras

e as rãs com as águas

é de poesia que estão falando."

Manoel de Barros

RESUMO

O canto de anúncio contém informações espectrais e temporais importantes para o reconhecimento espécie-específico e geralmente está relacionado à atração sexual. Por outro lado, o canto territorial é emitido para defesa de um território específico entre coespecíficos ou heteroespecíficos. Portanto, hipotetizamos que os cantos territoriais de espécies simpátricas, são mais semelhantes entre si (como resultado da convergência ou ausência de divergência) do que seu canto de anúncio, já que essas diferenças seriam resultantes de pressões seletivas diferentes. Para testar essa hipótese, examinamos os cantos territoriais e de anúncio de cinco espécies simpátricas de anuros do gênero *Scinax* (Hylidae). Duas dessas espécies foram previamente observadas exibindo comunicação territorial heteroespecífica. Descrevemos o canto de anúncio e territorial dessas cinco espécies, comparando-as com uma análise de agrupamento, e descobrimos que as características acústicas dos cantos territoriais eram mais semelhantes entre si do que os cantos de anúncio. Esses resultados poderiam ser um indicativo de uma pressão seletiva convergente para o canto territorial, em oposição a uma pressão seletiva divergente para o anúncio. Esse padrão pode ser mais difundido do que o relatado e direções futuras são propostas.

Palavras-chave: Competição interespecífica, comunicação acústica, pressão evolutiva, simpatria

ABSTRACT

The advertisement call contains important spectral and temporal information for species-specific recognition and is generally related to sexual attraction. On the other hand, the territorial call is emitted to defending a specific territory from conspecifics or heterospecifics. Therefore, we hypothesized that the territorial call of sympatric and close related species is more similar to each other (as a result of convergence or lack of divergence), than their advertisement calls, as these differences result from different selective pressures. In order to test this hypothesis, we examined the territorial and advertisement calls of five anuran species of the genus *Scinax*. These species are sympatric and two of them were previously observed displaying heterospecific territorial communication. We described the advertisement and territorial calls of these five species, compared them with cluster analyses and found that acoustic characteristics of the territorial calls were more similar to each other than their advertisement calls. These results could be an indicative of a convergent selective pressure for the territorial call in opposite to a divergent selective pressure for the advertisement call. This pattern may be more widespread than reported and future directions are proposed.

Keywords: Acoustic communication, evolutionary pressure, interspecific competition, sympatry

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Abstract

The advertisement call contains important spectral and temporal information for species-specific recognition and is generally related to sexual attraction. On the other hand, the territorial call is emitted to defending a specific territory from conspecifics or heterospecifics. Therefore, we hypothesized that the territorial call of sympatric and close related species is more similar to each other (as a result of convergence or lack of divergence), than their advertisement calls, as these differences result from different selective pressures. In order to test this hypothesis, we examined the territorial and advertisement calls of five anuran species of the genus *Scinax*. These species are sympatric and two of them were previously observed displaying heterospecific territorial communication. We described the advertisement and territorial calls of these five species, compared them with cluster analyses and found that acoustic characteristics of the territorial calls were more similar to each other than their advertisement calls. These results could be an indicative of a convergent selective pressure for the territorial call in opposite to a divergent selective pressure for the advertisement call. This pattern may be more widespread than reported and future directions are proposed.

Keywords: Acoustic communication, evolutionary pressure, interspecific competition, sympatry

Introduction

Among the several types of communication (visual, chemical, tactile and seismic, for example), acoustic (mainly by means of vocalization) is the most widely used and studied anuran communication (Duellman & Trueb 1994). This type of communication plays an important role in many contexts, such as reproductive (Wells 1977, Alonso & Rodríguez 2003, Toledo *et al*. 2015), territorial conflicts (Stewart & Rand 1992, Stewart & Bishop 1994, Bastos & Haddad 2002, Toledo *et al*. 2015), and defense against predators (Capranica 1968, Leary & Razafindratsita 1998, Toledo & Haddad 2009). The different types of anuran calls have been classified in four major categories: reproductive, aggressive, defensive (Toledo *et al*. 2015) and feeding (Köhler *et al*. 2017). Among these, the most common anuran vocalization is the advertisement call, classified as a reproductive type of call. (Wells 1977, 2007, Duellman & Trueb 1994, Ryan 2001, Narins *et al*. 2007), which is exhibited by most species of frogs (Toledo *et al*. 2015). This call is related to two main functions: to attract the opposite sex for breeding and to transmit territorial information for conspecifics rivals (Köhler *et al*. 2017). Hence, this call contains important spectral and temporal information for species-specific recognition (Ryan 1985, Cocroft & Ryan 1995, Gerhardt & Huber 2002, Köhler *et al*. 2017), acting as a valuable premating isolation mechanism and mediating social interactions (Wells 2007).

The territorial call is the most common aggressive call type, often emitted by males who are defending specific resources within a territory, such as calling, breading or feeding sites (Martins & Haddad 1988, Toledo & Haddad 2005a, 2005b, Wells 2007). This type of aggressive call is exclusive to territorial species (Toledo *et al*. 2015). Competition between conspecifics is common (Peiman & Robinson 2010), and examples of heterospecific competition have also been reported (e.g., Orians & Wilson 1964, Ebersole 1977, Mikami & Kawata 2004). Furthermore, it is widespread among vertebrates, and there are some reports including anurans (see Wells 1980, Brzoska, 1982, Schwartz & Wells 1984, 1985, Given 1990, Gerhardt & Schwartz 1995, Shimoyama 1999). Nonetheless, emitting calls in a multispecies context, such as calling in a pond during the breeding season of many anuran species, may cause acoustic interference, in both conspecific and heterospecific individuals

(Gerhardt & Schwartz 1995, Gerhardt & Huber 2002). Such interference may reduce the individual reproductive fitness (Marshall *et al*. 2006).

From an evolutionary perspective, the acoustic divergence of the advertisement calls of sympatric species is adaptive (Blair 1974, Schwartz 1987, Duellman & Trueb 1994, Gerhardt 1994). These differences may avoid misidentification of the conspecifics (Gerhardt 1994, Höbel & Gerhardt 2003, Gröning & Hochkirch 2008), serving as a premating isolation mechanism and preventing hybridization (Dobzhansky 1940, 1951, Blair 1955, Brown & Wilson, 1956, Lemmon 2009, Abrunhosa *et al*. 2014). On the other hand, the occurrence of a territorial dispute between a pair of heterospecific sympatric species may be related to a convergent selection of the aggressive signals, as this convergence may be beneficial to both species (Moynihan 1968, Cody 1969, 1973, Cody & Brown 1970, Grant 1972, Vadas 1990, Grether *et al*. 2013). For example, in a playback experiment with *Dryophytes versicolor* and *Dryophytes chrysoscelis*, the two species showed positive response for the territorial call of each other (Reichert & Gerhardt 2014). However, the similarity between calls of phylogenetically close related species can be associated to a common ancestry, probably as the result of neutral selection (Gerhardt & Schwartz 1995).

Therefore, we hypothesized that territorial calls of pairs of sympatric and close related species are more similar to each other, than their advertisement calls. Although interspecific communication is rarely reported in anurans, there is a sporadic observation reporting an aggressive interaction between *Scinax fuscovarius* and *Scinax x-signatus* in the field. In that case one species responded to the territorial call of the other (Toledo *et al*. 2015).

Methods

Species and sound files

We analyzed advertisement and territorial calls from males of five species of the genus *Scinax* included in the *Scinax ruber* clade (*sensu* Faivovich 2005, Nunes *et al*. 2012): *Scinax alter, S. fuscovarius, S. hayii, S. tymbamirim,* and *S. x-signatus*. These species were selected based on previous observations of heterospecific communication (Toledo *et al*.

2015) and their overlapped distribution (Figure 1). The audiofiles we analyzed are available in the sound archive Fonoteca Neotropical Jacques Vielliard (FNJV, Museu de Zoologia “Prof. Adão José Cardoso”, Universidade Estadual de Campinas, Brazil), Coleção de Anfíbios Célio F. B. Haddad (CFBH, MTH, VLMG) and Arquivo Sonoro da Coleção de Anuros da Universidade Federal de Uberlândia at UFU, Minas Gerais, Brazil. These samples are from 44 municipalities of Brazil (Figure 1; Appendix I) and included 93 recordings (Appendix I).

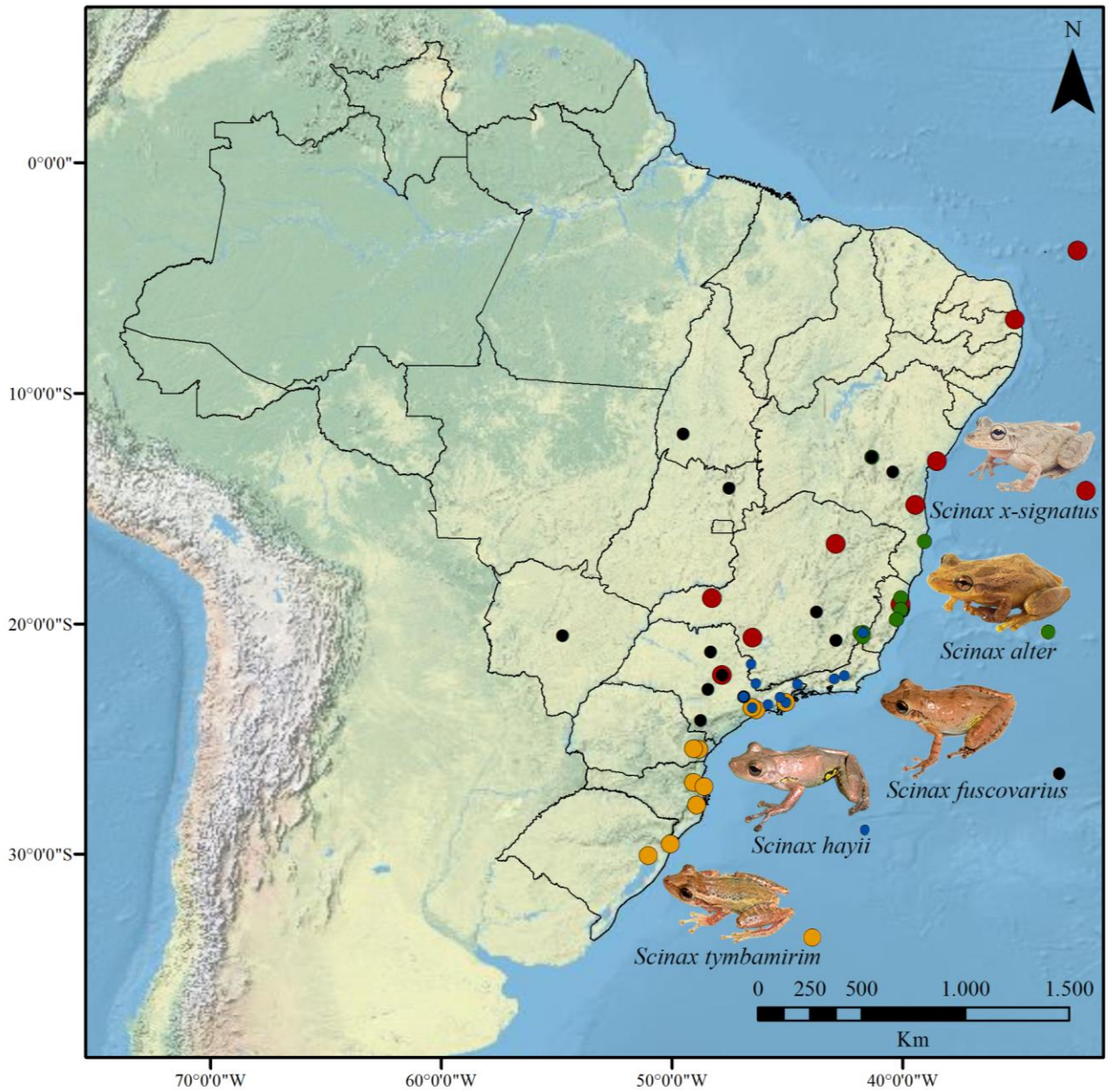

Figure 1. Geographic distribution of the populations of five species of *Scinax* for which we analyzed advertisement and territorial calls.

Sound analysis

We standardized all sound files to a sample rate of 44.1 kHz and 16-bit of resolution and normalized all files (peak -1.0 dB) in Audacity 2.1.1. We analyzed the calls in Raven Pro 64 1.5 (Cornell Laboratory of Ornithology). We used a Fast Fourier Transformation

(FFT) of 296 or 512, depending on the recording. From 93 recordings (1387 advertisement calls and 354 territorial calls) we measured 7 quantitative acoustic parameters of the advertisement call and 5 of the territorial call. Temporal traits were measured on oscillograms and spectral traits were measured on spectrograms. The spectral parameters were: i) minimum frequency; ii) maximum frequency (for these measurements we used automatic measurements of Raven: Frequency 5% and Frequency 95% below and above the total energy contained in the call); iii) dominant frequency (using the function Peak frequency of Raven); iv) frequency bandwidth (using the function BW90% in Raven); and v) call duration (using the function Delta time in Raven). Besides these, we also measured the vi) number of pulses (as defined by Köhler et al. 2017) and vi) pulse rate (number of pulses/call duration) only for the advertisement call (the territorial calls pulses were not always distinguishable).

Statistical analyses

We calculated the Euclidean distance to compare the similarity of the advertisement and territorial calls between the species of *Scinax*. We then performed a *t*-test to compare whether the similarity indexes were different between these types of calls. Statistical analyses were made in Past 2.17 (Hammer *et al.* 2001) and R- 3.5.3. (R Core Team 2013).

Results

Advertisement call

The advertisement call of the five analyzed species consists of a multipulsed note. The differences between them consists that *Scinax alter* has no frequency modulation; *Scinax fuscovarius* reaches lower dominant frequencies when compared with the other species; for *Scinax hayii* the initial pulse begins at a slightly lower frequency and amplitude and ascends during the call; *Scinax tymbamirim* call presents amplitude and frequency with ascendant modulation and *Scinax x-signatus* has no modulation in peak of frequency and amplitude across the call (Table 1; Figure 2).

Territorial call

We found similarity between the acoustic characteristics of the territorial calls of these five species of *Scinax*. These calls have shorter duration than the advertisement call, present frequency bands, parts of the call have no frequency modulation and parts present slight ascending and descending amplitude modulation (Table 1; Figure 2).

For *S. alter* and *S. tymbamirim* the territorial call has the higher-pitched dominant frequency, in opposition to *S. x-signatus* that has generally a low-pitched dominant frequency in comparison with the others species. *Scinax tymbamirim* also presents the higher call duration, and *S. x-signatus* presented the lower duration.

Table 1. Acoustic characteristics of advertisement and territorial calls of five species of the genus *Scinax*. Values presented as mean ± standard deviation (range), number of calls analyzed of each of the seven measured call characteristics for the advertisement call and five measured characteristics for the territorial call.

Species	***Scinax alter***		***Scinax fuscovarius***		***Scinax hayii***		***Scinax tymbamirim***		***Scinax x-signatus***	
Type call	Advertisement	Territorial	Advertisement	Territorial	Advertisement	Territorial	Advertisement	Territorial	Advertisement	Territorial
Recordings	16	11	16	3	20	10	21	14	18	8
Number of calls	245	66	315	25	245	71	327	131	255	61
Number of Pulse	15.32 ± 11.34 (4-79)	n/a	10.11 ± 3.91 (3 – 46)	n/a	14.67 ± 2.49 (9 – 21)	n/a	16.74 ± 5.61 (9 – 36)	n/a	11.57 ± 14.40 (5 – 104)	n/a
Pulse rate	42.08 ± 11.50 (23.53 – 77.67)	n/a	43.84 ± 13.47 (0.19 – 79.44)	n/a	62.32 ± 10.90 (45.14 – 89.89)	n/a	34.48 ± 8.58 (0.02 – 47.37)	n/a	34.33 ± 11.46 (0.04 – 60.24)	n/a
Call duration (ms)	364.05 ± 234.24 (131 – 1630)	109.02 ± 22.78 (53-145)	226.42 ± 79.61 (118– 1079)	96.93 ± 18.31 (68-125)	239.58 ± 44.75 (141 – 373)	113.45 ± 33.82 (67-312)	484.54 ± 181.90 (113 – 1195)	132.11± 32.72 (56-270)	305.44 ± 328.31 (133 – 2432)	89.25 ± 25.94 (47-148)
Minimum frequency (kHz)	1.50 ± 0.34 (0.95 – 2.24)	1.77 ± 0.42 (1.29-2.76)	0.9 ± 0.25 (0.34 – 1.38)	0.99 ± 0.31 (0.6-1.46)	1.4 ± 0.16 (1.21 – 1.89)	1.40 ± 0.2 (1.21-2.15)	1.86 ± 0.48 (0.95 – 3.27	2.03 ± 0.45 (0.95-2.93)	0.99 ± 0.09 (0.86 – 1.21)	0.9 ± 0.1 (0.78-1.21)
Maximum frequency (kHz)	3.83 ± 1.02 (1.64 – 5.77)	4.05 ± 0.57 (2.671-5.17)	2.85 ± 0.80 (1.21 – 4.31)	2.78 ± 0.8 (1.72-3.96)	3.48 ± 0.55 (1.64 – 4.39)	3.96 ± 0.37 (2.07-4.05)	4.15 ± 0.77 (2.67 – 6.89)	4.05 ± 0.58 (2.93-6.29)	3.55 ± 0.75 (1.64 – 6.03)	3.38 ± 0.3 (2.58-3.79)
Dominant frequency (kHz)	2.28 ± 1.04 (1.12 – 5.25)	3.39 ± 0.68 (1.46-4.57)	1.32 ± 0.81 (0.78 – 3.79)	2.14 ± 1.02 (0.78-3.7)	2.55 ± 0.90 (1.29 – 3.79)	2.44 ± 0.49 (1.29-3.19)	3.19 ± 0.87 (1.21 – 4.82)	3.19 ± 0.61 (1.29-4.5)	2.25 ± 1.10 (0.95 – 4.05)	1.75 ± 0.98 (0.86-3.45);
Frequency bandwidth 90 (kHz)	2.34 ± 0.93 (0.26 – 3.96)	2.27 ± 0.57 (1.29-3.27)	1.89 ± 0.68 (0.43 – 3.01)	1.79 ± 0.49 (1.03-2.58)	2.08 ± 0.50 (0.26 – 2.84)	1.66 ± 0.32 (0.86-2.58)	2.35 ± 0.80 (0.86 – 5)	2.10 ± 0.68 (0.69-4.91)	2.56 ± 0.72 (0.69 – 4.91)	2.48 ± 0.33 (1.46 - 3.01)

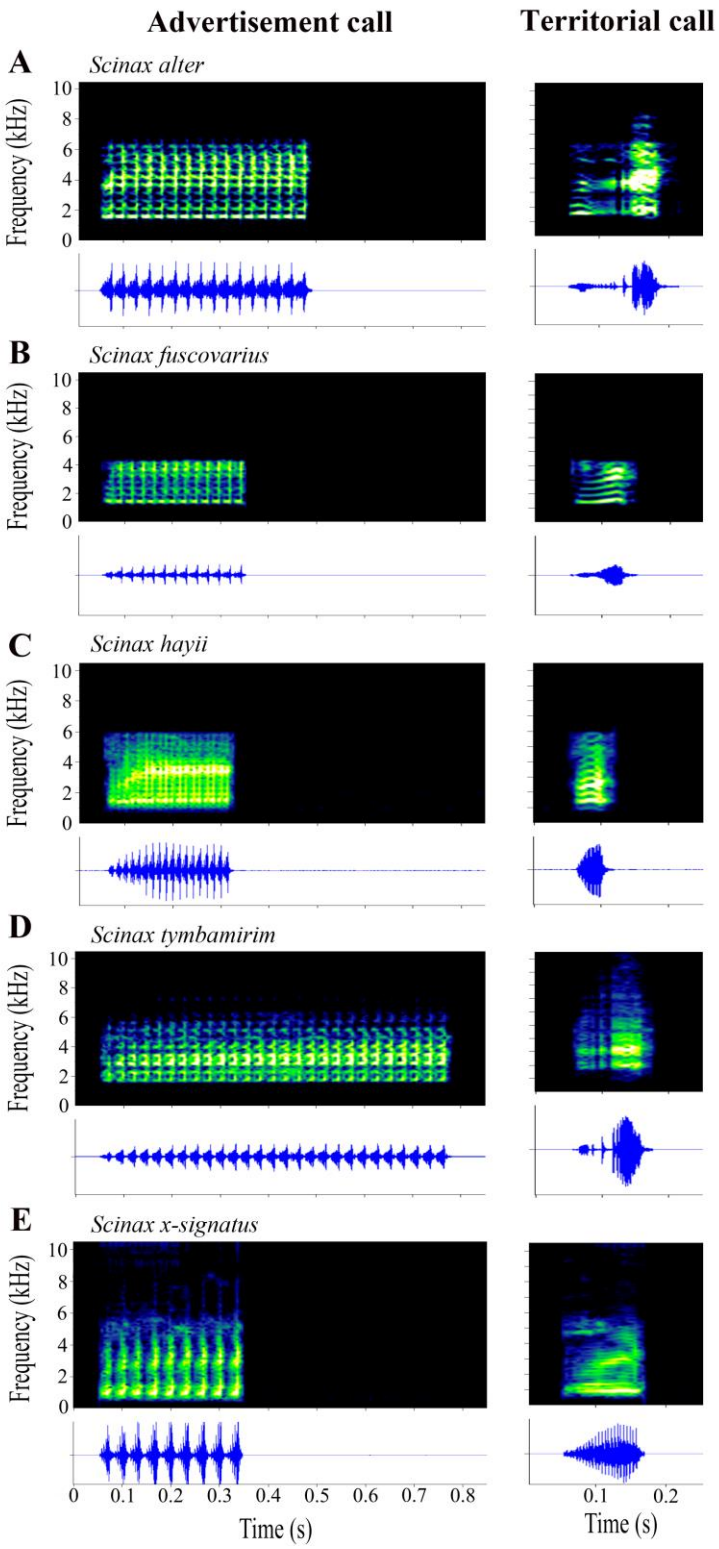

Figure 2. Spectrogram and waveform of the advertisement (left) and territorial (right) calls of *Scinax alter* (A)*; Scinax fuscovarius* (B)*; Scinax hayii* (C)*; Scinax tymbamirim* (D), and *Scinax x-signatus* (E).

We detected more similarity among territorial calls than among advertisement calls between pairs of sympatric species of *Scinax* (t = -3.11; P = 0.003; n = 10; Figure 3).

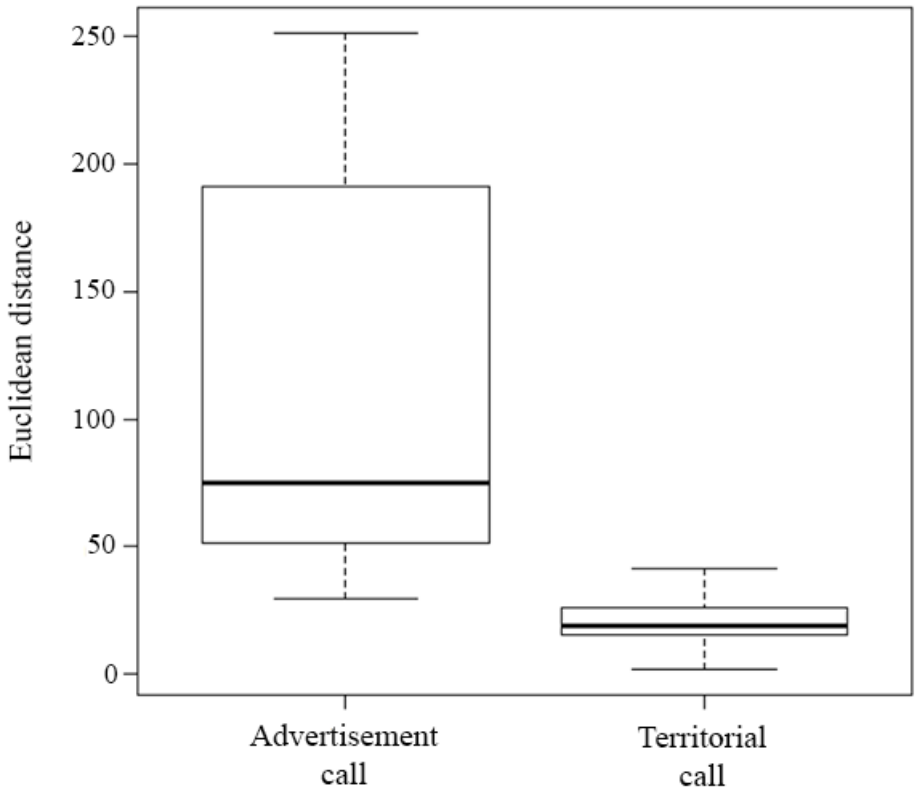

Figure 3. Euclidean distance between advertisement and territorial calls of the species of *Scinax*. The box-plot represents the mean, standard error, 90% confidence interval.

Discussion

The similarity between the acoustic characteristics of the territorial calls of these five species of *Scinax* allow the interspecific communication in multispecies aggressive encounters. This finding is in agreement with the similar evolutionary history of these species, the occurrence in sympatry (syntopy eventually), and the call frequency overlap during calling activity. The similarity among territorial calls could be the result of one of this two distinct processes: convergence or neutral selection. Convergence would occur favoring interspecific communication (i.e., territorial calls) if it is adaptive, for example avoiding hybridization (Haddad *et al.* 1994, Drillon *et al.* 2019) and sound masking when

synchronotopically advertisement calling (Martins & Jim 2003, Forti *et al.* 2017, Medeiros *et al.* 2017, Lima *et al.* 2018). Alternatively, neutral selection could be implied in the conservation of the similar signals, due to common ancestry (Gerhardt & Schwartz 1995). i.e., the pair of species evolved, but their territorial calls didn't, as a result of lack of selective pressures.

Although not all these *Scinax* species occur simultaneously in sympatry, the distribution of each species overlaps with at least one other species. This way, all species are connected to each other. Therefore, despite of the distribution of some species does not overlap directly, the possible convergent selective pressure may be the same, even in regions of allopatry. Besides that, the past distributions could be different, implying in different combinations of sympatric pairs of species.

Alternatively, the advertisement call contains spectral and temporal information for species-specific recognition (Ryan 1985, Cocroft & Ryan 1995, Gerhardt & Huber 2002, Köhler *et al.* 2017). Therefore, it also acts as a prezygotic isolation mechanism (Wells 2007) and is also a target of sexual selection (mate choice) (Ryan & Rand 1993). Hence, as the advertisement call is driven by sexual selection, and assuming that ecological differences have a small or no role in causing acoustic signal divergence (Wilkins *et al*. 2013), sexual selection has a primary role in acoustic divergence (Boul *et al.* 2007), favoring optimized signal transmission and reproductive success (Wilkins *et al*. 2013). On the other hand, aggressive calls are probably not used for species recognition. Thus, it can be less stereotyped when compared with the advertisement call (Wells 2007).

The multipulsed note structure, with pulses regularly spaced, for the advertisement call is frequent in the genus *Scinax* (Pombal Jr. *et al.* 1995a, 1995b, Magrini *et al.* 2011, Abrunhosa *et al*. 2014) and is in accordance with our analyses. Furthermore, the call parameters we describe here are in agreement with previous reports for the advertisement call of *S. fuscovarius* (De la Riva *et al.* 1994; Pombal Jr. *et al*. 1995a), *S. hayii* (Lutz 1973, Heyer *et al.* 1990, Cardoso & Andrade 1991, Pombal Jr. *et al.* 1995a, Magrini *et al.* 2011, Abrunhosa *et al*. 2014, Santos & Martin 2017), and *S. tymbamirim* (Bokermann 1967, Kwet 2001, Nunes *et al.* 2012). However, we found different values for call duration and number of pulses when comparing the advertisement call of *S. alter* with previous descriptions (Pombal *et al.* 1995a, Nunes *et al.* 2012). Also, the call duration, number of pulses and

dominant frequency of the advertisement call of *S. x-signatus* we presently report is different from that reported previously (Rivero 1969, Novaes & Zina 2016). These differences could be an indicative of species complexes (Pombal Jr. *et al*.1995b; Rodrigues *et al.* 2010) and that further taxonomic revisions are necessary.

As there are only few studies with anuran interspecific communication (e.g., Schwartz & Wells 1984, Gerhardt & Schwartz 1995, Shimoyama 1999, Reichert & Gerhardt 2014), we provide some insights for future studies. Firstly, experimental trials will confirm whether the similarity between territorial calls is enough for different species to respond to each other species' signals. Also, comparative methods could be applied to test the convergent *vs*. neutral selective pressure, non-exclusive, hypotheses. Finally, it is possible that the observed pattern is also present in other species groups, being therefore generalized among anurans.

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Supplementary Material

Appendix I. Audio files information for the advertisement and territorial call of the *Scinax* species analyzed: recordings number, recordist, data, hour, localities (municipalities, states), and air temperature in °C.

Recording	Call type	Recordist	Date	Hour	Locality	Temperature
Scinax alter						
FNJV_0011420	advertisement	Werner C. A. Bokermann	11/21/1968	19:30	Andarai, BA	
FNJV_0012257	advertisement	Luís Felipe Toledo	08/21/2006	22:30	Jaguaré, ES	
FNJV_0031334	advertisement	Adão José Cardoso	02/15/1990	22:00	Linhares, ES	
FNJV_0031335	advertisement territorial	Adão José Cardoso	07/22/1995	19:30	Linhares, ES	
FNJV_0031336	advertisement territorial	Adão José Cardoso	07/22/1995	19:30	Linhares, ES	
FNJV_0032260	advertisement territorial	Célio F. B. Haddad	10/25/1996		Aracruz, ES	
FNJV_0032458	advertisement	Luís Felipe Toledo	108/5/2006		Caraíva, BA	
FNJV_0033217	advertisement territorial	Luís Felipe Toledo	12/08/2016		Ibitirama, ES	
FNJV_0034654	advertisement	Camila Zornosa Torres	10/07/2017	20:45	Alto Caparaó, MG	
FNJV_0036481	advertisement territorial	Luís Felipe Toledo	12/09/2017		Linhares, ES	
FNJV_0036591	advertisement territorial	Camila Zornosa Torres	12/11/2017		Divino de São Lourenço, ES	
FNJV_0036595	advertisement territorial	Camila Zornosa Torres	12/11/2017	23:59	Divino de São Lourenço, ES	
FNJV_0036597	advertisement territorial	Camila Zornosa Torres	12/12/2017	0:15	Divino de São Lourenço, ES	
FNJV_0036598	advertisement territorial	Camila Zornosa Torres	12/12/2017	0:20	Divino de São Lourenço, ES	
FNJV_0036676	advertisement	Camila Zornosa Torres	01/16/2018	22:00	Divino de São Lourenço, ES	
FNJV_0036677	territorial	Camila Zornosa Torres	01/22/2018	20:32	Divino de São Lourenço, ES	
FNJV_0036678	territorial	Camila Zornosa Torres	01/22/2018		Divino de São Lourenço, ES	
CFBH48-11	advertisement territorial	Célio F. B. Haddad	10/25/1996	21:30	Aracruz, ES	23.5
Scinax fuscovarius						
FNJV_0007708	advertisement	Adão José Cardoso	11/14/1983	20:00	Vicosa, MG	
FNJV_0012356	advertisement	Werner C. A. Bokermann	11/21/1968	19:30	Andarai, BA	
FNJV_0012982	advertisement	Luís Felipe Toledo	11/13/2002	20:00	Itirapina, SP	19

	territorial					
FNJV_0037498	advertisement	Matheus Moroti	03/02/2018		Campo Grande, MS	
FNJV_0033918	advertisement	Luis Felipe Toledo	10/05/2005		Jaboticabal, SP	
FNJV_0031376	advertisement	Célio F. B. Haddad	12/12/1988	20:00	Jundiaí, SP	
FNJV_0031378	advertisement		11/13/1983	20:00	Vicosa, MG	23
FNJV_0031379	advertisement	Adão José Cardoso	12/08/1992	0:00	Formoso do Araguaia, TO	
FNJV_0031633	advertisement	Adão José Cardoso	01/12/1996	21:15	Jaboticatubas, MG	24,5
FNJV_0031828	advertisement	Werner C. A. Bokermann	01/26/1963		Botucatu, SP	
FNJV_0031944	advertisement	Werner C. A. Bokermann	11/24/1965	22:00	Maracas, BA	20
FNJV_0032080	advertisement	Werner C. A. Bokermann	01/10/1974	20:00	Chapada dos Veadeiros, GO	20
FNJV_0032086	advertisement	Werner C. A. Bokermann	02/24/1974	21:00	Chapada dos Veadeiros, GO	21
FNJV_0031375	territorial	José Peres Pombal Junior	11/13/1988		Campinas, SP	
FNJV_0031377	advertisement territorial	Célio F. B. Haddad	12/12/1988	22:00	Jundiai, SP	20
JGRG01-17	advertisement	João G. R. Giovanelli			Corupa, SC	22.8
CFBH40-10	advertisement	Célio F. B. Haddad	10/31/1993	19:40	Ribeirão Branco, SP	19.5

Scinax hayii

FNJV_0031389	advertisement territorial	Adão José Cardoso	01/07/1981	20:30	Poços de Caldas, MG	18
FNJV_0031390	advertisement	Adão José Cardoso	11/08/1981	21:00	Munhoz, MG	19
FNJV_0031391	advertisement	Adão José Cardoso	11/19/1981	23:00	Santo André, SP	20
FNJV_0031392	advertisement	Adão José Cardoso	11/20/1981	21:30	Santo André, SP	20
FNJV_0031394	advertisement	Célio F. B. Haddad	12/30/1988		Jundiaí, SP	21
FNJV_0031395	advertisement territorial	Célio F. B. Haddad	12/30/1988		Jundiaí, SP	21
FNJV_0031396	advertisement territorial	Adão José Cardoso	11/20/1982	19:30	Santo André, SP	23
FNJV_0031397	advertisement territorial	Adão José Cardoso	12/08/1982	20:30	Nova Friburgo, RJ	21
FNJV_0031398	advertisement territorial	Adão José Cardoso	01/17/1987	22:10	Teresópolis, RJ	19
FNJV_0031399	advertisement	Adão José Cardoso	02/12/1987	18:50	São José Barreiro, SP	19
FNJV_0032239	advertisement	Luís Felipe Toledo	10/24/2015		Teresópolis, RJ	
FNJV_0032240	advertisement	Luís Felipe Toledo	10/24/2016		Teresópolis, RJ	
FNJV_0032268	advertisement territorial	Célio F. B. Haddad	07/29/1992	18:30	Ubatuba, SP	17
FNJV_0033219	advertisement	Luís Felipe Toledo	12/09/2016		Ibitirama, ES	
FNJV_0033220	advertisement territorial	Luís Felipe Toledo	12/09/2016		Ibitirama, ES	
FNJV_0033752	advertisement territorial	Frogs of Boracéia	11/10/1983	19:45	Salesópolis, SP	20
CFBH41-04	advertisement	Célio F. B. Haddad	11/19/1993	19:45	Ubatuba, SP	

MTH04-03	advertisement territorial	Maria Teresa Hartimann	01/18/2001	21:00	Ubatuba, SP	23
VLMG01-45	advertisement territorial	Luís O. M. Giasson	10/15/2004	23:10	Santa Virgínia, SP	
VLMG01-46	advertisement	Luís O. M. Giasson	10/15/2004	23:10	Santa Virgínia, SP	
Scinax Tymbamirim						
FNJV_0031870	advertisement	Jacques Vielliard	09/18/1985		Piraquara, PR	
FNJV_0033866	advertisement	Leandro O. Drummond	02/25/2015		São Bonifácio, SC	
FNJV_0033867	advertisement territorial	Leandro O. Drummond	11/10/2015		São Bonifácio, SC	
FNJV_0033868	advertisement territorial	Leandro O. Drummond	11/10/2015		São Bonifácio, SC	
FNJV_0033869	advertisement territorial	Leandro O. Drummond	11/10/2015		São Bonifácio, SC	
FNJV_0034216	advertisement	Leandro O. Drummond	11/05/2015		São Bonifácio, SC	20
FNJV_0031323	advertisement territorial	Ivan Sazima	10/28/1970		Ubatuba, SP	
FNJV_0031326	advertisement territorial	Adão José Cardoso	11/21/1981	19:00	Santo André, SP	19
FNJV_0031329	advertisement territorial	Adão José Cardoso	02/03/1982	22:30	Morretes, PR	22
FNJV_0031331	advertisement territorial	Adão José Cardoso	12/05/1982	20:30	Ubatuba, SP	21
FNJV_0031332	advertisement territorial	Adão José Cardoso	12/17/1982	21:30	Viamão, RS	25
FNJV_0031333	advertisement	Adão José Cardoso	11/01/1986	23:30	Santo André, SP	21
FNJV_0034030	advertisement territorial	Adão José Cardoso	02/03/1982	23:00	Morretes, PR	21
FNJV_0033064	advertisement	Paulo C. de A. Garcia	02/23/1999	23:18	Ubatuba, SP	22.5
FNJV_0031327	advertisement territorial	Adão José Cardoso	02/05/1982	20:00	Blumenau, SC	22
FNJV_0031330	advertisement territorial	Adão José Cardoso	02/03/1982	23:00	Morretes, PR	21
FNJV_0031493	advertisement territorial	Adão José Cardoso	10/06/1993	19:50	Morretes, PR	13
FNJV_0031325	advertisement	Ivan Sazima	02/11/1981		Itapema, SC	27
FNJV_0008702	advertisement	Jacques Vielliard	09/18/1985		Piraquara, PR	
FNJV_0008701	advertisement	Jacques Vielliard	09/18/1985		Piraquara, PR	15.5
FNJV_0033870	territorial					
CFBH30-08	advertisement territorial	Célio F. B. Haddad	07/31/1992	20:00	Ubatuba, SP	15.5
Scinax x-signatus						
FNJV_0031485	advertisement	Luís Felipe Toledo	12/02/2005	22:30	Grão Mogol, MG	21

	territorial					
FNJV_0031474	advertisement	Luís Felipe Toledo	11/29/2005	22:43	Grão Mogol, MG	22
FNJV_0012994	advertisement territorial	Luís Felipe Toledo	11/27/2002	20:00	Itirapina, SP	
FNJV_0012995	advertisement	Luís Felipe Toledo	11/27/2002	20:00	Itirapina, SP	
FNJV_0012997	advertisement	Luís Felipe Toledo	11/27/2002	20:05	Itirapina, SP	
FNJV_0012998	advertisement territorial	Luís Felipe Toledo	11/27/2002	20:05	Itirapina, SP	
FNJV_0012999	advertisement	Luís Felipe Toledo	11/27/2002	20:05	Itirapina, SP	
FNJV_0013010	advertisement territorial	Luís Felipe Toledo	11/27/2002	21:55	Itirapina, SP	18
FNJV_0012252	advertisement	Luís Felipe Toledo	11/27/2002	20:45	Itirapina, SP	18
FNJV_0012989	advertisement territorial	Luís Felipe Toledo	11/14/2002		Itirapina, SP	16
FNJV_0012987	advertisement territorial	Luís Felipe Toledo	11/14/2002	21:35	Itirapina, SP	16
FNJV_0012918	advertisement territorial	Luís Felipe Toledo	01/25/2009	22:00	Fernando de Noronha, PE	28
FNJV_0013063	advertisement	Luís Felipe Toledo	08/18/2006		Salvador, BA	
FNJV_0030711	advertisement	Luís Felipe Toledo	01/31/2004	20:30	Itape, SP	
FNJV_0031576	advertisement	Adão José Cardoso	07/14/1995	18:05	Sooretama, ES	23
FNJV_0034086	advertisement	Diego José Santana	01/19/2009		Glória, MG	23
FNJV_0034232	advertisement	Diego José Santana	02/24/2015		Mamanguape, PB	
FNJV_0034233	advertisement	Diego José Santana	02/24/2015		Mamanguape, PB	
MG14aAAGm671	advertisement territorial	Ariovaldo Giaretta	10/08/2011		Uberlândia, MG	

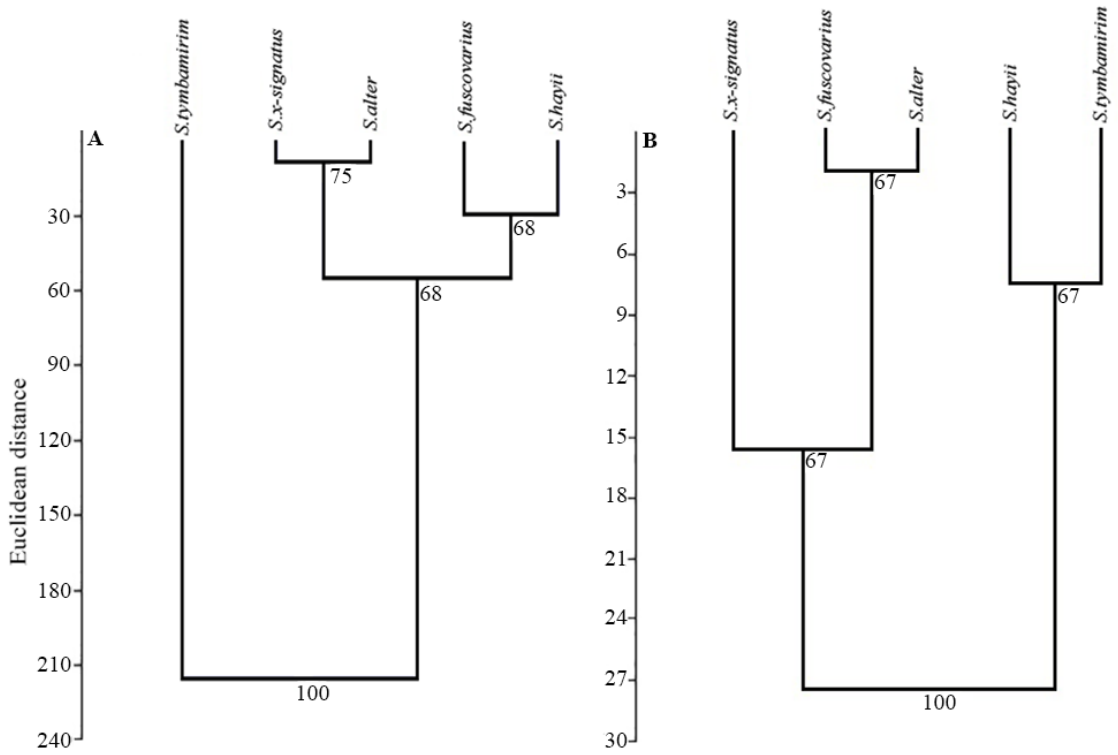

Figure S1. Dendrograms of acoustic similarity (Euclidean distance; paired group linkage) of the advertisement (A) and territorial (B) calls between the species of *Scinax*. The results were randomized 1000 times for bootstrap values and the cophenetic correlation index was 0.979 for the advertisement calls (A) and 0.825 for the territorial calls (B).

Anexos

1. Declaração de Bioética e Biossegurança

COORDENADORIA DE PÓS-GRADUAÇÃO
INSTITUTO DE BIOLOGIA
Universidade Estadual de Campinas
Caixa Postal 6109. 13083-970, Campinas, SP, Brasil
Fone (19) 3521-6378. email: cpgib@unicamp.br

DECLARAÇÃO

Em observância ao **§5º do Artigo 1º da Informação CCPG-UNICAMP/001/15**, referente a Bioética e Biossegurança, declaro que o conteúdo de minha Dissertação de Mestrado, intitulada " ***Similaridade e divergência entre o canto territorial e de anúncio de espécies de Scinax (Anura, Hylidae)*** ", desenvolvida no Programa de Pós-Graduação em Biologia Animal do Instituto de Biologia da Unicamp, não versa sobre pesquisa envolvendo seres humanos, animais ou temas afetos a Biossegurança.

Assinatura: _____
Nome do(a) aluno(a): Mariane de Oliveira Freitas

Assinatura: _____
Nome do(a) orientador(a): Luís Felipe de Toledo Ramos Pereira

Data: 30/05/2019

2. Declaração

Declaração

As cópias de artigos de minha autoria ou de minha co-autoria, já publicados ou submetidos para publicação em revistas científicas ou anais de congressos sujeitos a arbitragem, que constam da minha Dissertação/Tese de Mestrado/Doutorado, intitulada **ESPÉCIES DE SCINAX (ANURA, HYLIDAE) COM CANTOS DE ANÚNCIO DISTINTOS PRODUZEM CANTOS TERRITORIAIS SIMILARES**, não infringem os dispositivos da Lei n.° 9.610/98, nem o direito autoral de qualquer editora.

Campinas, 11 de Novembro de 2019

Assinatura : _____
Nome do(a) autor(a): **Mariane de Oliveira Freitas**
RG n.° 52.943.645-0

Assinatura : _____
Nome do(a) orientador(a): **Prof. Dr. Luís Felipe de Toledo Ramos Pereira**
RG n.° 28.465.361-5