

Vocalizations of *Crossodactylus schmidti* Gallardo, 1961 (Anura, Hylodidae): advertisement call and aggressive call

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Abstract. We describe the advertisement and aggressive calls of *Crossodactylus schmidti* based on recordings made in the Parque Estadual do Turvo, located in northwest Rio Grande do Sul, Brazil. Compared to the advertisement calls described for other species of the genus, the advertisement call of *C. schmidti* differs in the temporal structure by having fewer notes per call and longer intervals between notes, and in the spectral structure by having lower values of dominant frequency. The aggressive call of *C. schmidti* is a variation of the advertisement call, which is similar to this in the note duration and dominant frequency values, but is a longer call, having fewer notes with longer intervals between them. The advertisement and aggressive calls of *C. schmidti* may be emitted separately, or the aggressive call may be followed by the advertisement call.

Key words: Hylodidae, *Crossodactylus*, advertisement call, aggressive call.

Introduction

Most anuran species have well-developed vocal structures used to produce a variety of sounds that serve to attract mates, defend territories, or avoid predators (Duellmann & Trueb 1994). The advertisement call is the most common call emitted by male frogs, serving to identify individuals of the same species, sex, reproductive status, and location, and often has the dual function of attracting females and establishing territories (Stebbins & Cohen 1995). This call is an important mechanism of reproductive isolation (Wells 1977).

Aggressive calls emitted by conspecific males are also common in anurans, and may be transmitted in different contexts. These calls can be divided into signals of short or long range, though the two functions can be combined in the same call. Due to some confusion in the use of call terminology, the use of the general term "aggressive call" is more appropriate to classify calls made in any kind of aggressive context (Wells 2007).

Crossodactylus is the second-largest genus of the family Hylodidae. Its members are distributed from northeastern to southern Brazil, southern Paraguay, and northern Argentina (Frost 2010). Caramaschi & Sazima (1985) recognized three groups of species in the genus. The *Crossodactylus gaudichaudii* group is the richest, with seven recognized species, followed by the *C. trachystomus* group, with three species, and the monospecific group *C. schmidti*, consisting of the nominal spe-

cies. The vocalizations are described for only four species, all in the *C. gaudichaudii* group: *C. caramaschii* Bastos & Pombal 1995, *C. gaudichaudii* Duméril & Bibron 1841 (description of the call by Weygoldt & Carvalho-e-Silva 1992), *C. cyclospinus* Nascimento, Cruz & Feio 2005, and *C. bokermanni* Caramaschi & Sazima 1985 (description of the call by Pimenta et al. 2008).

Crossodactylus schmidti Gallardo 1961 is known only from localities in the Mesophytic Semideciduous Forest (*sensu* Prado 2000) in southern Paraguay, northern Argentina, and the southern Brazilian states of Paraná, Santa Catarina, and Rio Grande do Sul (Caldart et al. 2010). Since the description of the species by Gallardo (1961), the only additional studies were done by Faivovich (1998), who redescribed the tadpole, and Caldart et al. (2010), who discussed the geographical distribution and characterized the calling site.

In this study, we provide a description of the advertisement and aggressive calls of *C. schmidti*, based on vocalizations recorded in streams in the Parque Estadual do Turvo, in the northwest region of Rio Grande do Sul, Brazil. We also compare the temporal and spectral characteristics of the advertisement calls among *Crossodactylus* species.

Material and Methods

Vocalizations of seven individuals of *C. schmidti* were recorded in October 2009 and January and February 2010, in streams in the Parque Estadual do Turvo (27° 14'34.08

"S, 53° 57'13.74" W), located in the municipality of Derrubadas, northwest Rio Grande do Sul. The park covers an area of 17,491.4 ha of Mesophytic Semideciduous Forest, and is one of the last large remnants of this type of vegetation in southern Brazil (SEMA 2005). The local climate is subtropical sub-humid with dry summer (ST SB v type of Maluf 2000), with temperatures above 22° C in the warmest month (January) and ranging from -3° C to 28° C in the coldest month (July). Rainfall is evenly distributed throughout the year, with an annual mean of 1665 mm (SEMA 2005).

Recordings of vocalizations were made between 19:30 and 05:00 h, in air temperatures from 18.8° C to 24.2° C. The vocalizations were recorded at a distance of about 50 cm from the individuals, with a Marantz PMD671 digital recorder coupled to a Sennheiser ME66 directional microphone, and with a Panasonic RR-US450 digital recorder.

The recorded vocalizations were classified as advertisement call and aggressive call, and the specific functions of the vocalizations were determined by observations of the social context in which each call was emitted, including observations of many calls not recorded. Therefore, we considered the advertisement call as emitted by males in an attempt to attract conspecific females (Heyer et al. 1990, Duellmann & Trueb 1994) and the aggressive call as emitted in short-or long-distance interactions between conspecific males (Wells 2007). The parameters of the calls analyzed were the following: number of notes per call, note duration, time interval between notes, call duration, fundamental frequency, and dominant frequency. These parameters were chosen to enable comparison between the descriptions of other calls of the genus *Crossodactylus*. The terminology used for call parame-

ters follows Heyer et al. (1990) and Duellman & Trueb (1994).

The vocalizations were analyzed using the SoundRuler software (Gridi-Papp 2004; version 0.9.6.0) at a sampling frequency of 22050 Hz and a resolution of 16 bits. The sonograms were also produced with the SoundRuler software, including the following parameters: Fast Fourier Transformation (FFT) with 256 points, 100% frame, Hanning window type, and 90% overlap.

The advertisement call of *C. schmidtii* was compared to other advertisement calls described for congeners: *C. caramaschii* (Bastos & Pombal 1995), *C. gaudichaudii* (Weygoldt & Carvalho-e-Silva 1992), *C. cyclospinus* (Nascimento et al. 2005), and *C. bokermanni* (Pimenta et al. 2008). In describing the call of *C. gaudichaudii*, Weygoldt & Carvalho-e-Silva (1992) presented four types of calls. Only the fourth call (described as "The long range advertisement call") is compared here with the advertisement call of *C. schmidtii*, because it is the most similar. Individuals whose vocalizations were recorded were collected and deposited in the Herpetological Collection of the Universidade Federal de Santa Maria (Voucher specimens: ZUFSM 4669, 4670, 4672, 4677, 4678, 4695, 4696).

Results

The advertisement and aggressive calls of *C. schmidtii* may be emitted alone, or the aggressive call may be emitted followed by the advertisement call. The advertisement call (Figs 1–2) of *C. schmidtii* is a long call (mean= 4.14 s, SD= 1.06, range= 2.23–5.75 s, n= 11 calls) and consists of

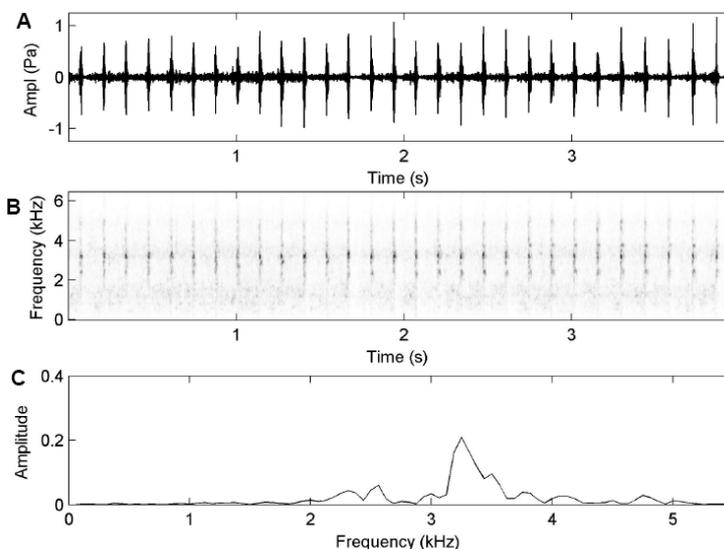


Figure 1. Advertisement call of *Crossodactylus schmidtii*: oscillogram (A), audiospectrogram (B), and power spectrum (C). Call recorded in the municipality of Derrubadas, Rio Grande do Sul, Brazil, on 10 January 2010; 20:00 h; air temperature 23.4°C; SVL 28.33 mm. Voucher specimen: ZUFSM 4677.

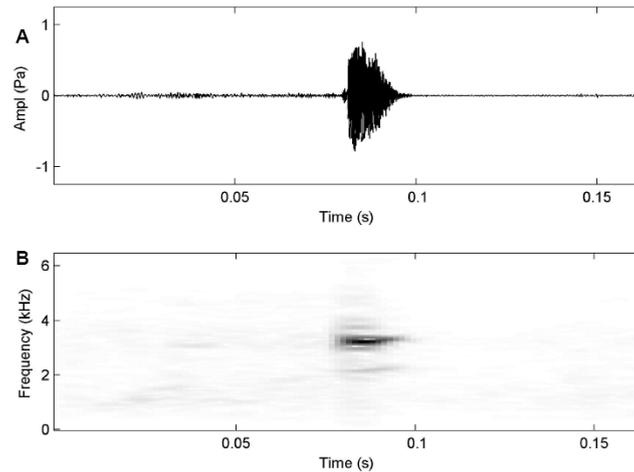


Figure 2. Isolated note of the advertisement call of *Crossodactylus schmidtii*: oscillogram (A) and audiospectrogram (B). Call recorded in the municipality of Derrubadas, Rio Grande do Sul, Brazil, on 10 January, 2010; 20:00 h; air temperature 23.4°C; SVL 28.33 mm. Voucher specimen: ZUFMS 4677.

several notes in harmonic structure (mean= 35, SD= 6.64, range= 13–45; n= 289 notes) and of short duration (mean= 0.022 s, SD= 0.007, range= 0.009–0.061 s, n= 289 notes). Mean note interval was 0.100 s (SD= 0.029, range= 0.017–0.249 s, n= 279 intervals) and mean dominant frequency was 3306 Hz (SD= 649, range= 2017–4280, n= 11 calls). The dominant frequency is located in the second or third harmonic. The fundamental frequency ranges from 1008 to 2071 Hz (Table 1).

The advertisement call was emitted at varying distances from the receiver female (30 cm to about

2 m), and some individuals were observed vocalizing with no female nearby. In this circumstance, the male emitted the call in several directions, constantly changing the position of his body.

The aggressive call (Figs 3–4) is longer than the advertisement call (mean= 11.31 sec, SD= 5.36, range= 6.78–24.42 s, n= 10 calls) and consists of fewer notes (mean= 26, SD= 9.81, range= 13–41, n= 211 notes). The duration of the note is similar to that found for the advertisement call (mean= 0.024 s, SD= 0.008, range= 0.011–0.041 s, n= 211 notes), however, the interval between notes is higher

Table 1. Temporal and spectral characteristics of the advertisement call among species of *Crossodactylus*. Values are presented as mean, standard deviation (SD), and range. References: *C. schmidtii* (present study); *C. bokermanni* (Pimenta et al. 2008); *C. cyclopinus* (Nascimento et al. 2005); *C. caramaschii* (Bastos & Pombal 1995); *C. gaudichaudii* (Weygoldt & Carvalho-e-Silva 1992).

Species	Dominant frequency (Hz)	Fundamental frequency (Hz)	Notes per call	Note duration (s)	Internote interval (s)	Call duration (s)	Air temperature
<i>C. schmidtii</i>	3306 SD= 649 (2017–4280)	1565 SD= 354 (1008–2071)	35 SD= 6.64 (13–45)	0.022 SD= 0.007 (0.009–0.061)	0.100 SD= 0.029 (0.017–0.249)	4.14 SD= 1.06 (2.23–5.75)	18.8° C to 24.2° C
<i>C. bokermanni</i>	3894 SD= 525 (1802–4826)	–	58.8 SD= 26.2 (13–121)	0.014 SD= 0.005 (0.001–0.033)	0.092 SD= 0.021 (0.056–0.265)	4.95 SD= 1.9 (1.4–10.1)	23.9° C
<i>C. cyclopinus</i>	4981 SD= 626.6 (3488–5447)	(700–1200)	63.3 SD= 11.9 (35–98)	0.028 SD= 0.004 (0.003–0.04)	0.04 SD= 0.003 (0.029–0.065)	4.33 SD= 0.74 (3.57–6.25)	30° C
<i>C. caramaschii</i>	5000	1600	56.83 SD= 5.41 (49–69)	–	–	5.50 SD= 0.54 (4.71–6.09)	24° C
<i>C. gaudichaudii</i>	–	(2000–5500)	(25–130)	(0.04–0.05)	(0.04–0.05)	(2.0–13.0)	22° C

(mean= 0.507 s, SD= 0.127, range= 0.032–1.211 s, n= 199 intervals). The dominant frequency is similar to that found for the advertisement call (mean= 3394 Hz, SD= 768, range= 1998–4143, n= 10 calls) and, similarly to the advertisement call, may be located in the second or third harmonic. The fundamental frequency has a range between 999 and 2071 Hz.

The emission of the aggressive call was observed in interactions between nearby or distant males. While the aggressive call was emitted, the calling male was in a vigilant position and vocalizing toward another male. We also recorded vocalizations of individuals who emitted an aggressive call followed by the advertisement call (Fig. 5).

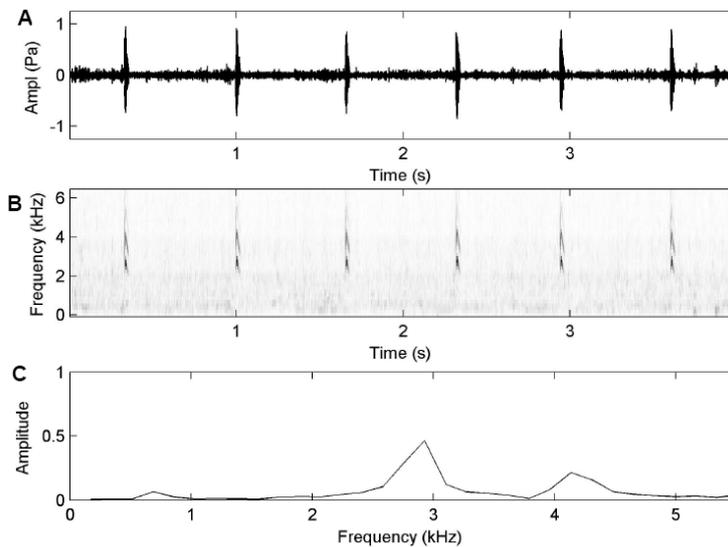


Figure 3. Aggressive call of *Crossodactylus schmidti*: oscillogram (A), audiospectrogram (B), and power spectrum (C). Call recorded in the municipality of Derrubadas, Rio Grande do Sul, Brazil, on 20 October 2009; 20:00 h; air temperature 18.8 °C; SVL 28.72 mm. Voucher specimen: ZUFMS 4695.

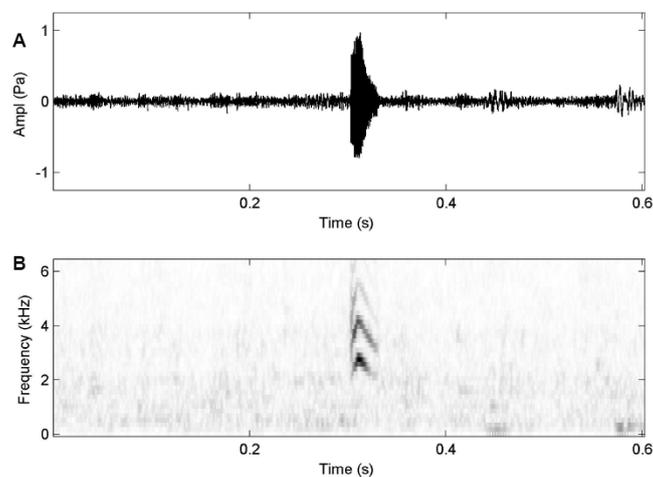


Figure 4. Isolated note of the aggressive call of *Crossodactylus schmidti*: oscillogram (A) and audiospectrogram (B). Call recorded in the municipality of Derrubadas, Rio Grande do Sul, Brazil, on 20 October 2009; 20:00 h; air temperature 18.8 °C; SVL 28.72 mm. Voucher specimen: ZUFMS 4695.

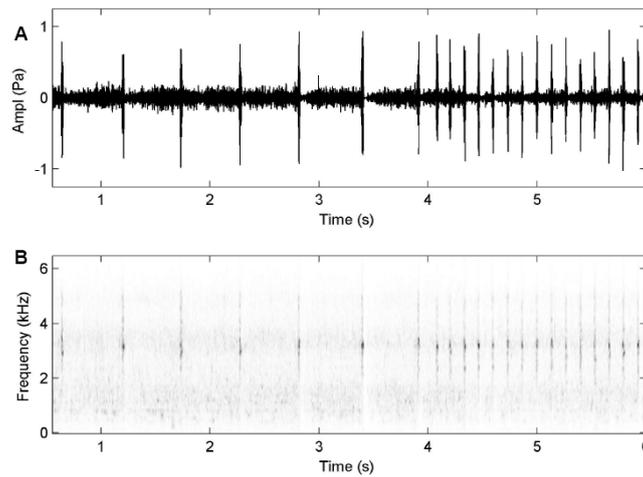


Figure 5. Aggressive call of *Crossodactylus schmidtii* followed by the advertisement call: oscillogram (A) and audiospectrogram (B). Call recorded in the municipality of Derrubadas, Rio Grande do Sul, Brazil, on 10 January 2010; 20:00 h; air temperature 23.4°C; SVL 28.33 mm. Voucher specimen: ZUFMS 4677.

Discussion

The advertisement call of *Crossodactylus schmidtii* differs from other known advertisement calls for the genus, in its temporal structure, by having fewer notes per call and longer intervals between notes. The spectral structure differs by having lower values in the dominant frequency. The dominant frequency may be located in the second or third harmonic, as in the advertisement calls of *C. cyclopinus* (Nascimento et al. 2005) and *C. bokermanni* (Pimenta et al. 2008). In the advertisement call of *C. caramaschii* (Bastos & Pombal 1995), the dominant frequency is located in the third harmonic. In relation to note duration and call duration, the advertisement call of *C. schmidtii* shows intermediate values to those found for other *Crossodactylus* species.

Crossodactylus species have advertisement calls that are structurally similar to calls of several species of *Hylodes*, composed of several short harmonic notes. In all species of *Hylodes* whose advertisement call is known, the dominant frequency is located in the third harmonic (Lingnau & Bastos 2007), although in some calls of *H. cardosoi* Lingnau, Canedo & Pombal 2008 it is difficult to discern whether it is in the second or third harmonic (Lingnau et al. 2008). In *Crossodactylus* species, the dominant frequency may be located in the second (Nascimento et al. 2005, Pimenta et al. 2008, present study), third (Bastos & Pombal 1995, Nasci-

mento et al. 2005; Pimenta et al. 2008; present study), or both harmonics (Pimenta et al. 2008). Several studies suggest that the dominant frequency located in the third harmonic provides better propagation of the acoustic signal in environments with flowing water (Bastos & Pombal 1995; Wogel et al. 2004; Lingnau & Bastos 2007), and the higher the dominant frequency, the better the contrast with the low-frequency-dominated sound produced by running water in streams (Hödl & Amézquita 2001). The similarities between the location of the dominant frequency in calls of *Crossodactylus* and *Hylodes* may be evidence of a phylogenetic relationship between these genera (Bastos & Pombal 1995, Nascimento et al. 2005). Indeed, their relationship was reinforced in the phylogenetic analysis done by Grant et al. (2006). These similarities can also result from ecological characteristics of these species, which are predominantly diurnal and inhabit streams, and therefore must have their calls shaped by similar selective pressures that aim to minimize acoustic interference from the environment (Vielliard & Cardoso 1996).

While recording the vocalizations, we did not observe overlapping in the emission of the advertisement call among relatively close individuals, so the advertisement call must also serve to maintain a minimum spacing between males, reducing interference in the emission of the call and making it easier for the females to find individual males

(Wells 1977). The behavior of constant vigilance and changes in position observed in calling males probably contributes to maintain the spacing between males and to increase the possibility to be heard by females. Similar behavior was observed for *Oophaga granulifera* Taylor, 1958 (Goodman 1971), *Anomaloglossus stepheni* Martins, 1989, *Allobates marchesianus* Melin, 1941 (Juncá 1998), and *Hypsiboas raniceps* Cope, 1862 (Guimarães & Bastos 2003).

Prior to this study, the emission of aggressive calls by species of the genus *Crossodactylus* was described only for *C. gaudichaudii* (Weygoldt & Carvalho-e-Silva 1992). The aggressive call of *C. schmidti* was emitted by both nearby and distant males, while the aggressive call of *C. gaudichaudii* was emitted only in interactions between nearby males. In the temporal structure, the aggressive call of *C. schmidti* differs from *C. gaudichaudii* basically in having more notes. Data on dominant frequency were not supplied for the aggressive call of *C. gaudichaudii*, making it difficult to compare the spectral characteristics.

Aggressive calls of most anurans are often variations of the advertisement call, with similar dominant frequencies, but differ in temporal structure (Wells 2007). The aggressive call of *C. schmidti* is indeed similar to the advertisement call, differing only in the more spaced and fewer notes and the longer duration of the call, which gives the aggressive call a long and slow aspect. When individually analyzed, the notes that make up the advertisement and aggressive calls of *C. schmidti* show very similar temporal and spectral structures, and the human ear can only distinguish between the two calls by their temporal characteristics. Although the maximum amplitude of the length of the aggressive call was 24.42 seconds, this appears to be a quite variable call in duration, as we observed several males emitting longer calls (vocalizations not recorded).

The advertisement and aggressive calls were regularly interspersed, but we also noted the emission of an aggressive call followed by the advertisement call. Even when an aggressive call followed by the advertisement call occurs, the functions of the two calls are clearly distinct: to keep conspecific males away and to attract females, respectively. The combination of two calls with distinct functions is reported in several species, such as *C. cyclopinus* (Nascimento et al. 2005) and *Hypsiboas ericae* Caramaschi & Cruz, 2000 (Garcia & Haddad 2008). For males of *C. schmidti*, who spend

much time in agonistic interactions (authors, pers. obs.), the combination of aggressive and advertisement calls should serve as a strategy to increase efficiency in the emission of the calls.

Although *C. schmidti* belongs to another group of species, some characteristics of its advertisement call are very similar to the calls known for the species of the *C. gaudichaudii* group. However we recorded some differences in the advertisement call of *C. schmidti* in contrast to the advertisement calls of species of the *C. gaudichaudii* group: fewer notes per call, the longest interval between the notes, and lower values of dominant frequency. Descriptions of the calls of species from the *C. trachystomus* group (*C. trachystomus* Lütken & Reinhardt, 1862, *C. grandis* Lutz, 1951, and *C. dispar* Lutz, 1925) are necessary in order to make a better comparative assessment of the acoustical characteristics of the calls of the genus *Crossodactylus*. Future studies should also focus on the occurrence of aggressive calls in *Crossodactylus* species.

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References

- Bastos, R.P., Pombal Jr., J.P. (1995): New species of *Crossodactylus* (Anura: Leptodactylidae) from the Atlantic rain forest of southeastern Brazil. *Copeia* 2: 436-439.
- Caldart, V.M., Iop, S., Santos, T.G. dos, Cechin, S.T.Z. (2010): Extension of the geographical distribution of two anuran species for Rio Grande do Sul state, Brazil, with comments on natural history. *Biota Neotropica* 10: 143-147.
- Caramaschi, U., Sazima, I. (1985): Uma nova espécie de *Crossodactylus* da Serra do Cipó, Minas Gerais, Brasil (Amphibia, Leptodactylidae). *Revista Brasileira de Zoologia* 3: 43-49.
- Duellman, W.E., Trueb, L. (1994): *Biology of Amphibians*. McGraw-Hill, Baltimore and London.
- Faivovich, J. (1998): Comments on the larvae of the Argentine species of the genus *Crossodactylus* (Leptodactylidae, Hylodinae). *Alytes* 16: 61-67.
- Frost, D.R. (2010): *Amphibian Species of the World: an Online Reference*. Version 5.4 (8 April, 2010). American Museum of Natural History, New York, USA. <http://research.amnh.org/vz/herpetology/amphibia>, accessed on: 2010.07.20.
- Gallardo, J.M. (1961): Anfíbios anuros de Misiones con la descripción de una nueva especie de *Crossodactylus*. *Neotropica* 7: 33-38.

- García, P.C.A., Haddad, C.F.B. (2008): Vocalizations and comments on the relationship of *Hypsibous ericae* (Amphibia, Hylidae). *Iheringia Série Zoologia* 98: 161-166.
- Goodman, D.E. (1971): Territorial behavior in a neotropical frog, *Dendrobates granuliferus*. *Copeia* 1971: 365-379.
- Grant, T., Frost, D.R., Caldwell, J.P., Gagliardo, R., Haddad, C.F.B., Kok, P.J.R., Means, B.D., Noonan, B.P., Schargel, W.E., Wheeler, W.C. (2006): Phylogenetic systematics of dart-poison frogs and their relatives (Amphibia: Athesphatanura: Dendrobatidae). *Bulletin of the American Museum of Natural History* 299: 1-262.
- Gridi-Papp, M. (2004): SoundRuler, version 0.9.6.0: Acoustic Analysis for Research and Teaching (ed.). 2003 - 2007. Accessible at: <http://soundruler.sourceforge.net>.
- Guimarães, L.D., Bastos, R.P. (2003): Vocalizações e interações acústicas em *Hyla raniceps* (Anura, Hylidae) durante a atividade reprodutiva. *Iheringia Série Zoologia* 93: 149-158.
- Heyer, W.R., Rand, A.S., Cruz, C.A.G. da., Peixoto, O.L., Nelson, C.E. (1990): Frogs of Boracéia. *Arquivos de Zoologia* 31: 231-410.
- Hödl, W., Amézquita, A. (2001): Visual signalling in anuran amphibians. pp 121-141. In: Ryan, M.J. (ed.), *Anuran Communication*. Smithsonian Institution Press, Washington, DC.
- Juncá, F.A. (1998): Reproductive biology of *Colostethus stepheni* and *Colostethus marchesianus* (Dendrobatidae), with the description of a new anuran mating behavior. *Herpetologica* 54: 377-387.
- Lingnau, R., Bastos, R.P. (2007): Vocalizations of the Brazilian torrent frog *Hylodes heyeri* (Anura: Hylodidae): repertoire and influence of air temperature on advertisement call variation. *Journal of Natural History* 41: 1227-1235.
- Lingnau, R., Canedo, C.C., Pombal Jr., J.P. (2008): A new species of *Hylodes* (Anura: Hylodidae) from the Brazilian Atlantic Forest. *Copeia* 2008: 595-602.
- Maluf, J.R.T. (2000): Nova classificação climática do Estado do Rio Grande do Sul. *Revista Brasileira de Agrometeorologia* 8: 141-150.
- Nascimento, L.B., Feio, R.N., Cruz, C.A.G. (2005): A new species of diurnal frog in the genus *Crossodactylus* Duméril and Bibron, 1841 (Anura, Leptodactylidae) from southeastern Brazil. *Amphibia-Reptilia* 26: 497-505.
- Pimenta, B.V.S., Wachlewski, M., Cruz, C.A.G. (2008): Morphological and Acoustical Variation, Geographic Distribution, and Conservation Status of the Spinythumb Frog *Crossodactylus bokermanni* Caramaschi and Sazima, 1985 (Anura, Hylodidae). *Journal of Herpetology* 42: 481-492.
- Prado, D.E. (2000): Seasonally dry forests of tropical South America: from forgotten ecosystems to a new phytogeographic unit. *Edinburgh Journal of Botany* 57: 437-461.
- SEMA - Secretaria Estadual do Meio Ambiente. (2005): Plano de Manejo do Parque Estadual do Turvo. Estado do Rio Grande do Sul: [s.n.], 348 p.
- Stebbins, R.C., Cohen, N.W. (1995): *A Natural History of Amphibians*. Princeton University Press, New Jersey.
- Vielliard, J.M.E., Cardoso, A.J. (1996): Adaptação de sinais sonoros de anfíbios e aves a ambientes de riachos com corredeiras. In *Herpetologia neotropical*. Acta Del II Congresso Latino Americano de Herpetologia, Universidad de Los Andes (J.E. Pefaur, ed.). Consejo de Desarrollo, Humanístico y Tecnológico, Mérida, Venezuela 2:97-119.
- Wells, K.D. (1977): The social behaviour of anuran amphibians. *Animal Behaviour* 25: 666-693.
- Wells, K.D. (2007): *The Ecology and Behavior of Amphibians*. The University of Chicago Press, Chicago and London.
- Weygoldt, P., Carvalho-e-Silva, S.P. (1992): Mating and oviposition in the Hylodine frog *Crossodactylus gaudichaudii* (Anura: Leptodactylidae). *Amphibia-Reptilia* 13: 35-45.
- Wogel, H., Abruñhosa, P.A., Weber, L.N. (2004): The tadpole, vocalizations and visual displays of *Hylodes nasus* (Anura, Leptodactylidae). *Amphibia-Reptilia* 25: 219-117.
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