Neotropical Biology and Conservation
11(3):122-131, september-december 2016
Unisinos - doi: 10.4013/nbc.2016.113.02

Ecology and natural history of *Hypsiboas curupi* (Anura, Hylidae): An endemic amphibian to the southern Atlantic Forest

Ecologia e história natural de *Hypsiboas curupi* (Anura, Hylidae): um anfíbio endêmico do sul da Mata Atlântica

Veluma Ialú Molinari De Bastiani[1]
veluma@unochapeco.edu.br

Inaé Ellen Cavasotto[2]
inae@unochapeco.edu.br

Fernando Ferreira[1]
ferreirafhb@gmail.com

Elaine Maria Lucas[1,3]
elaine.lucasg@gmail.com

Abstract

Data on habitat use and life history are essential for evaluation of the conservation status of species, and may direct policy for preservation of natural environments. Over the course of a year, we investigated populations of *Hypsiboas curupi* regarding (i) nighttime activity patterns; (ii) associations with climatic variables; (iii) the spatial distribution patterns of males and females with respect to microhabitat use; and (iv) variation in body size. The study was carried out from August 2010 to July 2011 in the Parque Estadual Fritz Plaumann, a seasonal deciduous forest fragment in the western region of Santa Catarina, southern Brazil. Calling activity was highest from August to November. The number of calling males was highest at 23h, and the frequency of occurrence was influenced by the air humidity. Calling males, non-calling males, and females differed in their distance from the bank and substrate type used. Females were significantly larger and heavier than males. Our results indicate that *H. curupi* is highly dependent on bank vegetation, and that changes in riparian vegetation structure due to human activity can result in the loss of sites for calling and oviposition, and may reduce availability of food and shelter.

Keywords: life history, riparian forest, stream-dwelling amphibians, seasonal deciduous forest, microhabitat use.

Resumo

Informações sobre o habitat e história de vida são essenciais para avaliar o *status* de conservação das espécies e definir ações para a preservação dos ambientes naturais. Ao longo de um ano, investigamos em populações de *Hypsiboas curupi* (i) o padrão de atividade noturna; (ii) relações com variáveis climáticas; (iii) o padrão de distribuição espacial de machos e fêmeas em termos de uso de microambientes; e (iv) variação no tamanho corporal. Conduzimos o estudo de agosto de 2010 a julho de 2011 no Parque Estadual Fritz Plaumann, um fragmento de Floresta Estacional Decidual na região oeste de Santa Catarina, sul do Brasil. O período de maior atividade foi de agosto a novembro. O maior número de machos vocalizando ocorreu às 23h e a frequência de ocorrência foi influenciada pela umidade do ar. Machos vocalizantes, não-vocalizantes e fêmeas foram discriminados pela distância da margem e tipo de substrato utilizado. Fêmeas foram significativamente maiores e mais pesadas do que machos. Os resultados indicam que *H. curupi* é altamente dependente da vegetação marginal. Assim, mudanças na estrutura da mata ciliar devido a ações humanas podem resultar na perda de sítios de canto e oviposição e reduzir a disponibilidade de alimento e abrigo.

Palavras-chave: história de vida, mata ciliar, anfíbios de riachos, floresta estacional decidual, uso de microambiente.

[1] Programa de Pós-Graduação em Ciências Ambientais. Universidade Comunitária da Região de Chapecó. Rua Senador Atílio Fontana, 591-E, Efapi, 89809-000, Chapecó, SC, Brasil.
[2] Curso de Ciências Biológicas. Área de Ciências Exatas e Ambientais. Universidade Comunitária da Região de Chapecó. Rua Senador Atílio Fontana, 591-E, Efapi, 89809-000, Chapecó, SC, Brasil.
[3] Departamento de Zootecnia e Ciências Biológicas. Universidade Federal de Santa Maria. Campus de Palmeira das Missões. Av. Independência, 3751, 98300-000, Palmeira das Missões, RS, Brasil.

Introduction

More than 40% of the world's amphibian species are threatened by extinction (Pimm *et al.*, 2014) primarily due to habitat loss and environmental degradation (Young *et al.*, 2001; Blaustein and Kiesecker, 2002; Funk *et al.*, 2003; Dixo *et al.*, 2009; Verdade *et al.*, 2010). Species responses to habitat changes vary, making it difficult to identify specific threats; this problem is magnified for species in which information on life history and ecology is lacking (Becker *et al.*, 2007, 2010). Species that are sensitive to environmental changes decline faster than more robust species (i.e., those which typically have larger populations and are less affected by habitat disturbance) (Laurance *et al.*, 2002; Henle *et al.*, 2004; Laurance, 2008).

Stream-dwelling amphibians are continuously impacted by the loss of riparian forest, pollution, and damming, and are particularly vulnerable to environmental change due to strict association with specific niches (Becker *et al.*, 2010; Almeida-Gomes *et al.*, 2014). Understanding factors that contribute to spatial and temporal variation in species composition is a central question in ecology (Dodd Jr., 2010), and this knowledge is essential for evaluation of the health of populations (Bailey and Nichols, 2010).

Hypsiboas curupi Garcia, Faivovich and Haddad, 2007 is a stream-dwelling amphibian endemic to the Atlantic Forest and distributed throughout northwestern Argentina, southeastern Paraguay and southern Brazil (Frost, 2015). *Hypsiboas curupi* belongs to the *H. pulchellus* group, which contains 35 species (Frost, 2015). Some species of this group have been recently described (Garcia *et al.*, 2007, 2008; Antunes *et al.*, 2008; Kwet, 2008), and difficulty with species identification suggests a complex taxonomy. Ecological aspects of *H. curupi* are not well described, and data are limited to descriptions of larvae, adult (male) vocalization (Garcia *et al.*, 2007), geographical distribution (Brusquetti and Lavilla, 2008; Iop *et al.*, 2009; Lucas and Garcia, 2011; Zanella *et al.*, 2012), behavior (Lipinski *et al.*, 2012) and infectious diseases (Preuss *et al.*, 2015). *Hypsiboas curupi* populations in Brazil are categorized as "vulnerable" according to the Official List of Brazilian Species Fauna Threatened by Extinction (MMA, 2014), and "endangered" by the List of Species of Threatened Fauna of Santa Catarina State (CONSEMA, 2011). They are restricted to few isolated remnants of mixed ombrophile and seasonal deciduous forest in the Atlantic Forest Biome in southern Brazil (Lucas and Garcia, 2011), where stream habitats have been altered by habitat loss and water pollution (Bonai *et al.*, 2009; Ternus *et al.*, 2011). We conducted surveys of *H. curupi*, a stream-dwelling amphibian endemic to the southern Atlantic Forest. Observations took place in the evenings over the course of a year, with the goal of increasing knowledge of *H. curupi* ecology and reproductive biology. We (i) analyzed nighttime activity patterns of *H. curupi*; (ii) evaluated *H. curupi* associations with climatic variables; (iii) examined the spatial distribution patterns of males and females with respect to microhabitat use; and (iv) investigated variation in body size of *H. curupi*.

Materials and methods

The fieldwork was conducted at the Parque Estadual Fritz Plaumann – PAEFP (27º17'36" S, 52º06'38" W, 400 m a.s.l.), in municipality of Concórdia in western of the state of Santa Catarina, southern Brazil. The PAEFP is near the Itá Hydroeletric Power Plant reservoir in the Uruguay river basin, and covers an area of 717 ha. The area is classified as seasonal deciduous forest, a formation of the Atlantic Forest Biome (Figure 1). Approximately 35% (265 ha) of the area is an island formed during the creation of the reservoir, however we only sampled the continental portion. Seasonal deciduous forest is considered one of the most endangered ecosystems in the Atlantic Forest Biome of southern Brazil (Câmara, 2003; Ribeiro *et al.*, 2009), and the PAEFP is the only protected area with this vegetation type in Santa Catarina state.

Climate in the area is humid mesothermal, with an annual temperature of approximately 17 °C (Alvares *et al.*, 2013). The mean temperature in the summer ranges between 13 °C and 30 °C, with a mean temperature of 13 °C in the winter (Braga and Ghellere, 1999). Annual rainfall is approximately 2.000 mm and is evenly distributed throughout the year, with indistinct dry seasons (Leite and Leão, 2009).

Frogs were sampled in three streams labeled R1 (Figure 2A), R2 (Figure 2B), and R3 (Figure 2C). These streams had a maximum width of 6 m, and were distanced minimally 50 m and maximally 2 km part. Streams R1 and R2 was composed of predominantly rocky bed with waterfalls and clear backwaters, and depths between 5 and 70 cm. R3 was composed of bedrock and silt, with waterfalls, clear backwaters and depth between 5 and 50 cm. Sampling transects were established spanning approximately 300 m of the stream length, and approximately 1 m beyond the stream edge on each bank. The total sample area was 1.500 m^2 for R1, and 1.200 m^2 for R2 and R3. The three streams were sampled in rotation fortnightly. The same 300 m transect was sampled each time for R2 and R3, but due to conditions limiting access and to accommodate the greater length (~1 km), three different 300 m transects were sampled alternately for R1 throughout the survey.

Fieldwork was conducted fortnightly from August 2010 to July 2011 using calling surveys at anuran breeding sites (Scott and Woodward, 1994). The surveys took place between sunset and midnight, for a total sampling effort of approximately 360 hours. Numbers of visually identified males and females were recorded for each stream.

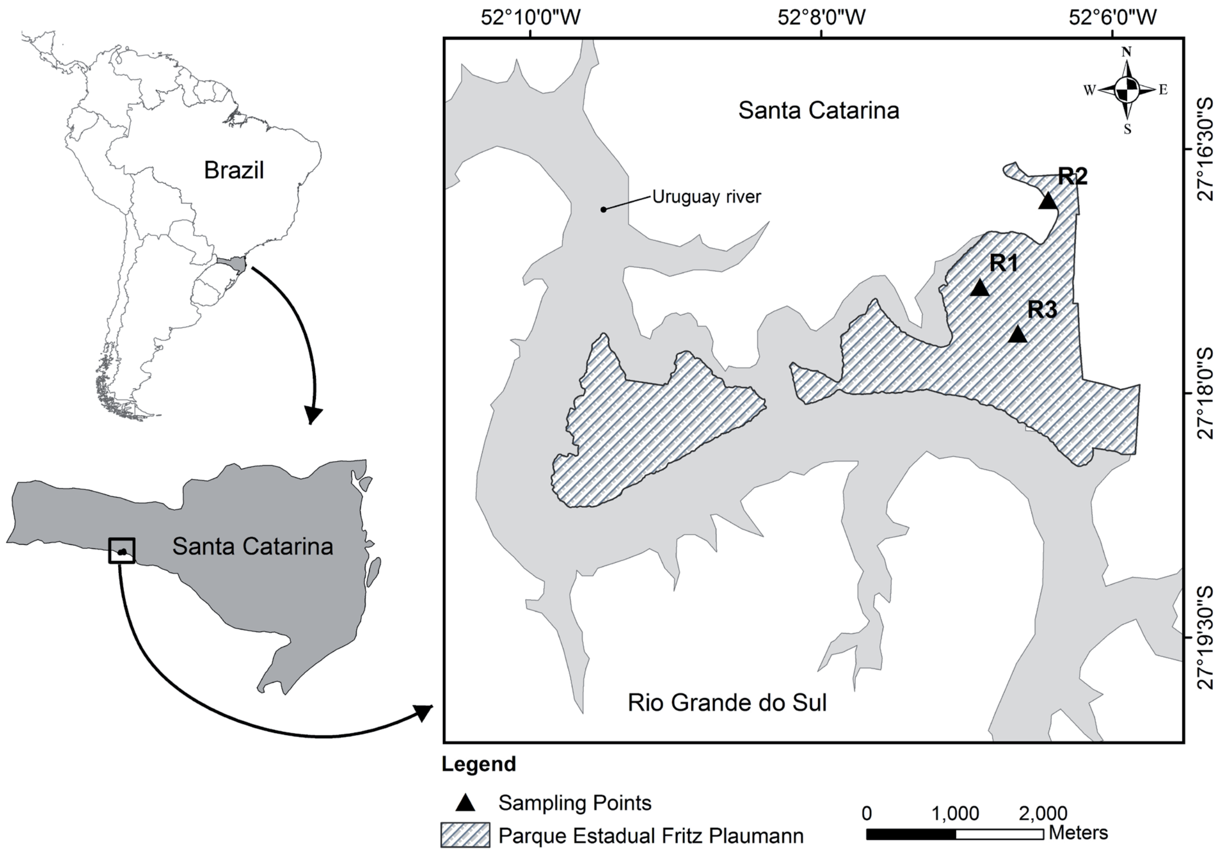

Figure 1. Location of the Parque Estadual Fritz Plaumann, Santa Catarina, southern Brazil and sampled streams.

We recorded the number of calling males at three different hours (19h, 21h, and 23h). The maximum number of calling males recorded was used as the monthly frequency of occurrence for each of these times. Mean maximum and minimum air temperatures for all sample days were used in the analysis. Mean rainfall and air humidity data were obtained from the Embrapa's Weather Station in the municipality of Concórdia, approximately 15 km from the study area. We included mean values from the data set beginning five days prior to the first sampling, and extending throughout the sample period.

Individuals were categorized according to their microhabitats as follows: 1) substrate type (water, leaves, twigs {> 3 mm}, thin branches {< 3 mm}, rocks, soil and leaf litter); 2) perch height (cm); and 3) distance from the nearest bank (cm). Distances from the bank for frogs positioned on the forest side of the bank were designated with a minus sign (-); distances from the bank into the stream were recorded as-is. Frogs were captured to obtain body measurements. Sex was determined, and snout-vent length (SVL) was measured using digital calipers (0.01 mm). Body mass was determined to the nearest 0.1 g using a dynamometer. Calling behavior at the time of capture was also recorded. After morphometric characterization frogs were returned to the location of capture. We analyzed differences in size and body mass between sexes for the month of highest overall abundance. Voucher specimens were deposited in the scientific amphibian collection of the Universidade Comunitária da Região de Chapecó, located in Chapecó, western Santa Catarina, southern Brazil (Research Permit #04/2010/PAEFP/GERUC/DPEC and #13/2011/GERUC/DPEC-FATMA).

We used a Shapiro-Wilk test (Shapiro and Wilk, 1965) to test for homogeneity of variances, a Mann-Whitney *U*-test (Statsoft, 2007) was used to examine the differences in size and body mass between males and females using individuals captured on the first sample night from each stream. We used Analysis of Variance (ANOVA) to analyze differences in the number of calling males at three observation times (19h, 21h and 23h), using the data from periods with the highest frequency of calling (August to November). We used a Tukey (Zar, 1999) *post hoc* test to identify significant differences between observation times.

We used multiple regression (Zar, 1999) to correlate frog abundance with minimum air temperature, relative humidity, and rainfall. Only the minimum temperature was used because it explained the greatest amount of variance. Simple linear regression was used to examine relationships between perch height and body mass of female, calling males and non-calling males. ANOVA and linear regression was performed using the BioEstat 5.3 package (Ayres *et al.*, 2007). Mann-Whitney tests and multiple regressions were performed using the Statistica 8.0 package (Statsoft, 2007).

We used General Discriminant Analysis (GDA) to determine which spatial variable (type of substrate, perch height, and distance from nearest bank) best predicted the distribution of females, calling males, and non-calling males. General Discriminant Analysis is a predictive analysis that combines qualitative (categorical) and quantitative (continuous) predictors (Statsoft, 2007). The recent approach of GDA applies the methods of the general linear model to Discriminant Analysis (DA) problem (Statsoft, 2007). Traditional DA is very similar to analysis of variance (ANOVA/MANOVA), but allows identification of explanatory quantitative variables (descriptors) that best describe differences between two or more pre-established groups (Legendre and Legendre, 1998). F-tests can then (Valentin, 1995) be used to determine distance among objects and their significance (the Mahalanobis Distance). DA also generates discriminant functions that represent the linear combination of original predictors, discriminating groups in a multidimensional space (Nelson and Marler, 1990). General Discriminate Analysis was performed using the 'best selection' function of Statistica 8.0 (Statsoft, 2007). This method allowed us to value-test the selection criteria for all possible combinations of predictor variables. We also used the Wilk's lambda value ($p<0.05$) as the selection criterion for interpreting the 'best selection', because the default coefficient range is from 1.0 (no discriminatory power) to 0.0 (perfect discriminatory power) (Statsoft, 2007).

Figure 2. Stream locations for *Hypsiboas curupi* sampling in the Parque Estadual Fritz Plaumann, Santa Catarina, southern Brazil. (A) R1, (B) R2, and (C) R3.

Results

The highest overall abundance of *H. curupi* was found at stream R1 (Figure 3). The maximum number of males recorded in a single nightly observation was 10 (R1-R3). The maximum number of females recorded in a single nightly observation was seven at R1, two at R2, three at R3.

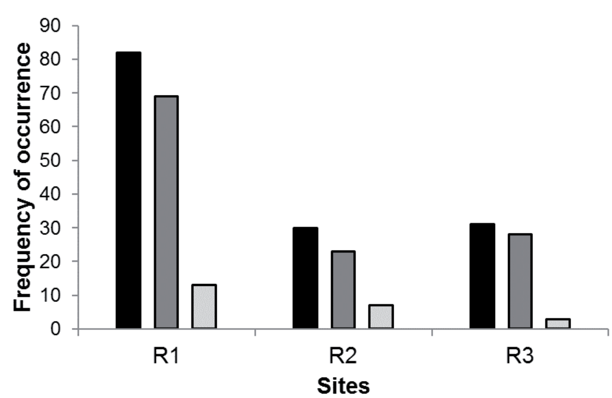

Figure 3. *Hypsiboas curupi* occurrence in three streams located in the Parque Estadual Fritz Plaumann, Santa Catarina, southern Brazil, from August 2010 to July 2011. Black bars represent the total number of individuals observed, dark grey bars indicate males, and light grey bars indicate females.

Males vocalized over an eight-month period, with most calling activity from August to November and a decrease in the coldest months (April to June, Figures 4 and 5). During the highest period of activity, the number of calling males differed throughout the night ($F_{(2,9)}=4.40$ and $p=0.04$, Figure 5), with a significant increase in activity at 23h (Tukey's $q=4.0$, $p<0.05$). The frequency of vocalization was influenced ($R^2=0.45$, adjusted $R^2=0.35$, $F_{(3,17)}=4.69$, $p<0.01$) by relative humidity ($\beta=-0.74$, $p<0.01$) but not by the absolute minimum temperature ($\beta=-0.35$, $p=0.11$) or rainfall ($\beta=0.29$, $p=0.25$, Figure 4).

Hypsiboas curupi used microhabitats close to the stream banks. Most calling males were found using twigs or leaves as a perch (Table 1). Thin branches of vegetation and dry soil were also utilized as substrate, but less commonly. Non-calling males typically used leaves or twigs,

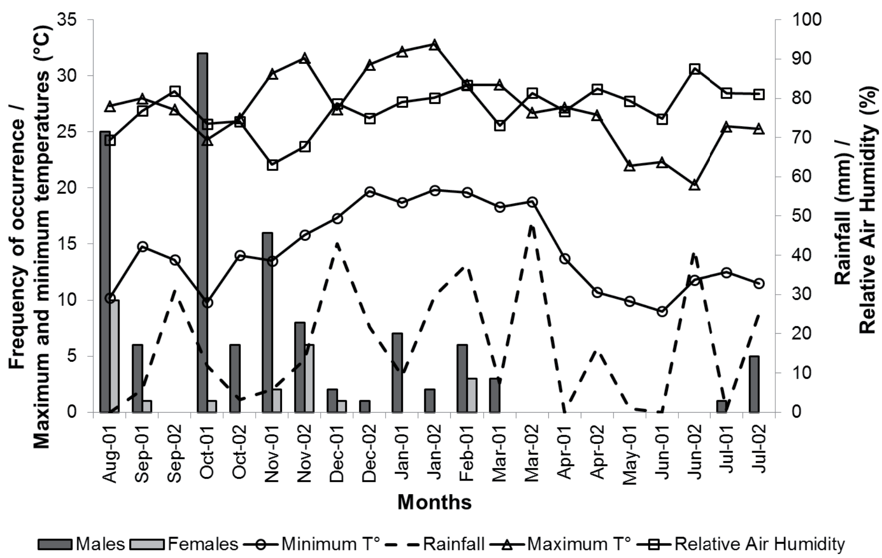

Figure 4. The frequency of occurrence of *Hypsiboas curupi* and climatic variables from August 2010 to July 2011 in the Parque Estadual Fritz Plaumann, Santa Catarina, southern Brazil. Males are represented by dark grey bars, and females by light grey bars.

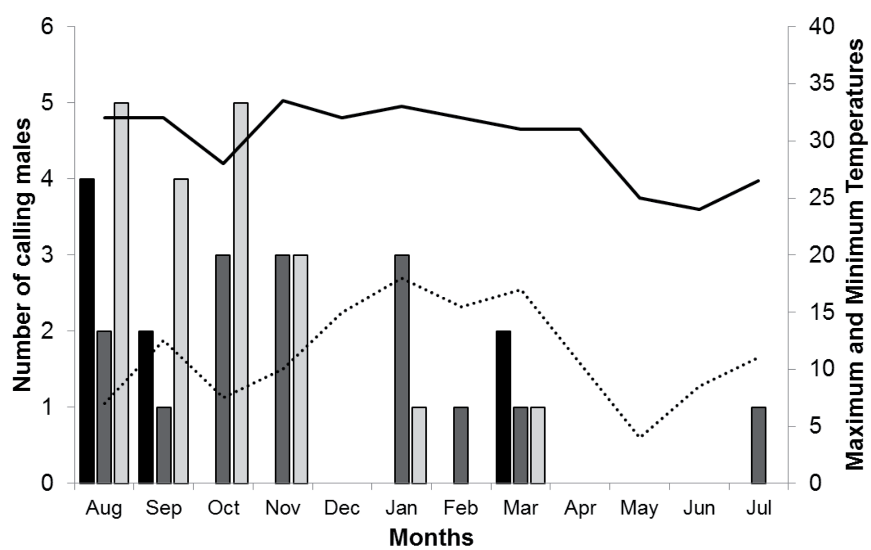

Figure 5. The maximum number of *Hypsiboas curupi* calling males at 19h (black bars); 21h (dark grey bars) and 23h (light grey bars) from August 2010 to July 2011 in the Parque Estadual Fritz Plaumann, Santa Catarina, southern Brazil. The dotted line indicates the mean of the absolute minimum air temperature, and the solid line indicates the mean for the absolute maximum air temperature over the sampling period.

Table 1. Microhabitats used by *Hypsiboas curupi* females, calling males, and non-calling males from August 2010 to July 2011 in the Parque Estadual Fritz Plaumann, Santa Catarina, Southern Brazil. N=number of individuals.

Individuals	Microhabitat						
	Leaves	Twigs	Thin branches	Rocks	Dry soil	Wet soil	Leaf litter
Females	50% (N=12)	12,5% (N=3)	25% (N=6)	8,3% (N=2)	-	-	4,1% (N=1)
Calling males	33,3% (N=16)	43,7% (N=21)	16,6% (N=8)	-	6,2% (N=3)	-	-
Non-calling males	61,5% (N=40)	18,4% (N=12)	7,6% (N=5)	7,6% (N=5)	-	4,6% (N=3)	-

Table 2. Mean±standard deviation (SD) and range of snout-vent length (SVL) and body mass for *Hypsiboas curupi* in the Parque Estadual Fritz Plaumann, Santa Catarina, southern Brazil. N=number of individuals.

	Females			Males			*U*	p
	N	Mean± SD	Range	N	Mean± SD	Range		
SVL (mm)	9	43.39 ± 4.95	33.98 – 48.46	22	41.58 ± 2.09	38.11 – 45.61	52.00	0.04
Mass (g)	9	7.20 ± 2.18	3.00 – 10.25	22	5.30 ± 0.80	4.00 – 7.60	35.50	<0,01

thin branches of vegetation, rocks, or wet soil. Females used leaves and thin branches of vegetation. Rarely were females observed on twigs, rock, or leaf litter (Table 1).

Females were significantly larger and heavier than males (Table 2). Calling males, non-calling males and females used perches with a mean height of 47.4±26.3 cm (range: 0-150 cm, N=98), 46.5±24.8 cm (range: 0-100 cm, N=57) and 46.4±39.8 cm (range: 0-120 cm, N=21), respectively. There were no significant relationships between body mass and perch height.

For animals positioned on the stream side of the bank, non-calling males were generally furthest from the bank (mean: 51.9±54 cm, range: 0–200 cm, N=43), while calling males were positioned closer to the bank (mean: 35.8±43 cm, range: 0–115 cm, N=32). Females were intermediate in distance from the bank compared to males (mean: 46.8±55.1 cm, range: 0–150 cm, N=11).

For animals positioned on the forest side, calling males occupied microhabitats closer to bank (mean: 39.2±25.9 cm, range: 0–80 cm, N=10) while non-calling males were further from the bank (near the forest) (mean: 52.5±56.4 cm, range: 0–150 cm, N=12). Females were positioned furthest from the banks (mean: 191±156.3 cm, range: 40–450 cm, N=10).

Axis 1 from GDA analysis accounted for 30.9% of the total data dispersion, whereas the Axis 2 accounted for 18.8%. In this analysis, *H. curupi* groups were differentiated by the distance from the bank and substrate type. Females were grouped by distance from the banks (F=3.65, p<0.01), calling males were grouped by the type of substrate (F=3.53, p<0.01) and non-calling males were grouped by distance from the bank (F=10.55, p<0.01) and substrate type (F=2.55, p=0.03). *Post hoc* testing showed that habitat use differed between females and non-calling males (F=4.09, p<0.01), between females and calling males (F=3.43, p<0.01) and between calling and non-calling males (F=2.61, p<0.01). We were not able to discriminate groups based on perch height.

Discussion

The *H. curupi* population in this study had an intermediate reproductive pattern (*sensu* Wells, 2007), with activity mainly in the warmer months of the year (September to March) and diminishing in the colder months (April to June). This trait is typical of amphibian assemblages in southern Brazil (Both *et al.*, 2008). Although no significant correlations were observed among temperature, rainfall, and reproductive activity, we did detect a decrease in activity during the colder months; this pattern is supported by many studies showing positive influence of climatic variables on the reproductive activity of anurans (Guix, 1996; Pombal, 1997; Camargo *et al.*, 2005; Conte and Rossa-Feres, 2007; Santos *et al.*, 2007; Both *et al.*, 2008; Vasconcelos *et al.*, 2011; Bastiani and Lucas, 2013). The study area is located on the shoreline of a lake that houses a hydroelectric plant, which in conjunction with air humidity, may have influenced the positive correlation of temperature with individual activity. For amphibians which use vegetation as perch for calling, variation in air humidity may result this species susceptible to hydric stress (Pough *et al.*, 1983; Caramaschi and Cruz, 2002).

Our results indicate that *H. curupi* is highly dependent on bank vegetation. Changes in the structure of riparian vegetation due to human activity may result in the loss of calling sites, egg-laying sites, shelter, and food availability for this species (Toledo *et al.*, 2010). This use of vegetation is a common trait within the genus, and has been a source of concern for other species, such as *H. beckeri* (Caramaschi and Cruz, 2004), *H. caipora* Antunes, Faivovich and Haddad, 2008 and *H. joaquini* (Lutz, 1968), which also use the shrub vegetation on the stream banks in preserved habitats (Garcia *et al.*, 2003; Acioli and Toledo, 2008; Antunes *et al.*, 2008). In addition to the direct loss of breeding habitat, the reduction of riparian vegetation might result in changes in microclimate conditions (Saunders *et al.*, 1991), affecting both adults and development of aquatic larvae, which are dependent on streams (Duarte *et al.*, 2012).

The use of vegetation as calling sites is common in Hylidae species (Giasson and Haddad, 2006). The preference of *H. curupi* males for twigs and leaves may be due to favorable sound propagation (Bastos and Haddad, 1999) and increased visual communication (Lipinski *et al.*, 2012) associated with this type of substrate. Such choices may reflect the evolutionary history of the species and their success in attracting females and defending territory (Greer and Wells, 1980; Martins *et al.*, 1998; Bastos and Haddad, 1999; Giasson and Haddad, 2006). While this study shows that the substrate type utilized by *H. curupi* was not related to body mass, morphological characteristics such as weight and size remain as important factors in amphibian habitat use (Hödl *et al.*, 1997).

The degree of sexual dimorphism observed in *H. curupi* is similar to other species in the *H. pulchellus* group, such as *H. beckeri* (Acioli and Toledo, 2008), *H. caipora* (Antunes *et al.*, 2008), *H. joaquini* (Garcia *et al.*, 2003) and *H. semiguttatus* (A. Lutz, 1925) (Garcia *et al.*, 2007). Females larger than males are usually associated with the production of larger and/or more ovules (Crump and Kaplan, 1979; Prado *et al.*, 2000). Dimorphism in *H. curupi* is likely related to different energy investments between the sexes (Freitas *et al.*, 2008). For species with intermediate or prolonged reproductive periods, males may be smaller than females because of energy constraints associated with reproduction, a result of trade-offs involving calling activity, territorial defense, differences in diet, or higher predation pressure (Woolbright, 1983, 1989). As with other species, namely *H. caipora*, *H. ericae* (Caramaschi and Cruz, 2000) and *H. joaquini* (Garcia *et al.*, 2003; Antunes *et al.*, 2008; Garcia and Haddad, 2008), *H. curupi* physically engage in territorial disputes, a trait that is detectable due to scarring on the backs of males. Our study, however, did not observe "satellite male" behavior, which is often reported in Hylidae species (Pombal and Haddad, 2005; Oliveira *et al.*, 2007; Miranda *et al.*, 2008; Muniz *et al.*, 2008). Such behavior might have exacerbated differences in perch height between calling and non-calling males.

The relatively low numbers of individuals observed in this study suggests that the *H. curupi* population is small in this area. Small population sizes are apparently more common in stream-dwelling amphibians in the Atlantic Forest (Almeida-Gomes *et al.*, 2014) than in species in lentic habitat. The population in this study is one of the few currently known in Brazil (see Iop *et al.*, 2009; Lucas and Marocco, 2011; Lucas and Garcia, 2011; Lipinski *et al.*, 2012; Bastiani and Lucas, 2013). Fragmentation and isolation of the interior Atlantic Forest, expansion of hydroelectric projects in the region, and land and soil conversion for agricultural (Câmara, 2003; Bonai *et al.*, 2009; Ternus *et al.*, 2011) and silvicultural projects (Machado *et al.*, 2012) may promote isolation of *H. curupi* populations. Such isolation increases the risk of extinction from inbreeding, genetic and demographic stochasticity, and vulnerability to diseases such as chytridiomycosis (Toledo *et al.*, 2006).

This study contributes to our understanding of *H. curupi* life history, and expands the current knowledge of this species and other amphibians in the Neotropical region. This information is essential for the development of further ecological and evolutionary studies of amphibians (Greene, 1994). Effective conservation strategies aimed to prevent local extinctions can only be formulated with thorough knowledge of the distributions, sizes and vulnerabilities of these populations, and this information must come from field studies (Silvano and Segalla, 2005; Colombo *et al.*, 2008). Future policy and research efforts could focus on predicting the likely geographic distribution of *H. curupi* in southern Brazil. Conservation goals should include a better understanding of the structure and dynamics of populations at a landscape scale, and implementation of plans for riparian zone restoration and reconnection of forest fragments (Becker *et al.*, 2010; Toledo *et al.*, 2010; Almeida-Gomes *et al.*, 2014). Further knowledge of *H. curupi* biology and habitat requirements may aid the design of enhanced conservation strategies for this species in the study region. Further field studies may inform conservation of other groups as well as the lack of effective legislation in riparian habitat is a serious problem for many species that compose the regional biodiversity.

Acknowledgements

We are grateful to the Fundação do Meio Ambiente do Estado de Santa Catarina – FATMA and the Co-Management Team of the Parque Estadual Fritz Plaumann – ECOPEF for logistic support, especially to Murilo A. Nichele and Adelar Otowski for assistance in the field. We thank the anonymous reviewers for their valuable suggestions for improvement of this work and Tiago Gomes dos Santos for statistical analysis.

References

ACIOLI, E.C.S.; TOLEDO, L.F. 2008. Amphibia, Anura, Hylidae, *Hypsiboas beckeri*: filling gap and description of its advertisement call. *Check List*, **4**(2):182-184. https://doi.org/10.15560/4.2.182

ALMEIDA-GOMES, M.; LORINI, M.L.; ROCHA, C.F.D.; VIEIRA, M.V. 2014. Underestimation of extinction threat to stream-dwelling amphibians due to lack of consideration of narrow area of occupancy. *Conservation Biology*, **28**(2):616–619. https://doi.org/10.1111/cobi.12196

ALVARES, C.A.; STAPE, J.L.; SENTELHAS, P.C.; GONÇALVES, J.L.M.; SPAROVEK, G. 2013. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, **22**(6):711–728. https://doi.org/10.1127/0941-2948/2013/0507

ANTUNES, A.P.; FAIVOVICH, J.; HADDAD, C.F.B. 2008. A new species of *Hypsiboas* from Atlantic Forest of Southeastern Brazil (Amphibia: Anura: Hylidae). *Copeia*, **2008**(1):179-190. https://doi.org/10.1643/CH-06-163

AYRES, M.; AYRES JR., M.; AYRES, D.L.; SANTOS, A.S. 2007. *BioEstat 5.3.* Aplicações estatísticas nas áreas das Ciências Biológicas e Médicas. Belém, Sociedade Civil de Mamirauá, 364 p.

BAILEY, L.L.; NICHOLS, J.D. 2010. Capture-mark-recapture, removal sampling and occupancy models. *In*: C.K. DODD Jr. (ed.), A*mphibian Ecology and Conservation: A Handbook of Techniques.* New York, Oxford University Press, p. 447-459.

BASTIANI, V.I.M.; LUCAS, E.M. 2013. Anuran diversity (Amphibia, Anura) in a Seasonal Forest fragment in southern Brazil. *Biota Neotropica*, **13**(1):1-10. https://doi.org/10.1590/S1676-06032013000100025

BASTOS, R.P.; HADDAD, C.F.B. 1999. Atividade reprodutiva de *Scinax rizibilis* (Bokermann) (Anura, Hylidae) na Floresta Atlântica, sudeste do Brasil. *Revista Brasileira de Zoologia*, **16**(2):409-421. https://doi.org/10.1590/S0101-81751999000200007

BECKER, C.G.; FONSECA, C.R.; HADDAD, C.F.B.; BATISTA, R.F.; PRADO, P.I. 2007. Habitat split and the global decline of amphibians. *Science*, **318**(5857):1775-1777. https://doi.org/10.1126/science.1149374

BECKER, C.G.; LOYOLA, R.D.; HADDAD, C.F.B.; ZAMUDIO, K.R. 2010. Integrating species life-history traits and patterns of deforestation in amphibian conservation planning. *Diversity and Distributions*, **16**(1):10–19. https://doi.org/10.1111/j.1472-4642.2009.00625.x

BLAUSTEIN, A.R.; KIESECKER, J.M. 2002. Complexity in conservation: lessons from the global decline of amphibian populations. *Ecology Letters*, **5**(4):597–608. https://doi.org/10.1046/j.1461-0248.2002.00352.x

BONAI, N.; SOUZA-FRANCO, G.M.; FOGOLARI, O.; MOCELLIN, D.J.C.; DAL MAGRO, J. 2009. Distribution of metals in the sediment of in the Itá Reservoir, Brazil. *Acta Limnologica Brasiliensis*, **21**(2):245-250.

BOTH, C.; KAEFER, I.L.; SANTOS, T.G.; CECHIN, S.T.Z. 2008. An austral anuran assemblage in the Neotropics: seasonal occurrence correlated with photoperiod. *Journal of Natural History*, **42**(3-4):205-222. https://doi.org/10.1080/00222930701847923

BRAGA, H.J.; GHELLERE, R. 1999. Proposta de diferenciação climática para o Estado de Santa Catarina. *In*: Congresso Brasileiro de Agrometeorologia, 11º e Reunião Latino-Americana de Agrometeorologia, 2ª, Florianópolis, 1999. *Anais*..., CD-ROM.

BRUSQUETTI, F.; LAVILLA, E.O. 2008. Amphibia, Anura, Hylidae, *Hypsiboas curupi*: first record for Paraguay. *Check List*, **4**(2):145. https://doi.org/10.15560/4.2.145

CÂMARA, I.G. 2003. Brief history of conservation in the Atlantic Forest. *In*: C. GALINDO-LEAL; I.G. CÂMARA (eds). *The Atlantic Forest of South America: Biodiversity Status, Threats, and Outlook*. Center for Applied Biodiversity Science and Island Press, Washington, D. C., p. 31-42.

CAMARGO, A.; NAYA, D.E.; CANAVERO, A.; ROSA, I.; MANEYRO, R. 2005. Seasonal activity and the body size-fecundity relationship in a population of *Physalaemus gracilis* (Boulenger, 1883) (Anura, Leptodactylidae) from Uruguay. *Annales Zoologici Fennici*, **42**(5):513-521.

CARAMASCHI, C.; CRUZ, C.A.G. 2002. *Phyllomedusa*: posição taxonômica, hábitos e biologia (Amphibia, Anura, Hylidae). *Phyllomedusa*, **1**(1):5-10. https://doi.org/10.11606/issn.2316-9079.v1i1p05-10

COLOMBO, P.; KINDEL, A.; VINCIPROVA, G.; KRAUSE, L. 2008. Composição e ameaças à conservação dos anfíbios anuros do Parque Estadual de Itapeva, município de Torres, Rio Grande do Sul, Brasil. *Biota Neotropica*, **8**(3):229-240. https://doi.org/10.1590/S1676-06032008000300020

CONSELHO ESTADUAL DO MEIO AMBIENTE (CONSEMA). 2011. Lista de Espécies da Fauna Ameaçadas de Extinção no Estado de Santa Catarina. Available at: http://ignis.org.br/lista/. Accessed on: 20/12/2011.

CONTE, C.E.; ROSSA-FERES, D.C. 2007. Riqueza e distribuição espaço-temporal de anuros em um remanescente de Floresta de Araucária no sudeste do Paraná. *Revista Brasileira de Zoologia*, **24**(4):1025-1037. https://doi.org/10.1590/S0101-81752007000400020

CRUMP, M.L.; KAPLAN, R.H. 1979. Clutch energy portioning of tropical tree frogs (Hylidae). *Copeia*, **1979**(4):626-635. https://doi.org/10.2307/1443869

DIXO, M.; METZGER, J.P.; MORGANTE, J.S.; ZAMUDIO, K.R. 2009. Habitat fragmentation reduces genetic diversity and connectivity among toad populations in the Brazilian Atlantic Coastal Forest. *Biological Conservation*, **142**(8):1560-1569. https://doi.org/10.1016/j.biocon.2008.11.016

DODD JR., C.K. 2010. *Amphibian Ecology and Conservation: A Handbook of Techniques*. New York, Oxford University Press, 556 p.

DUARTE, H.; TEJEDO, M.; KATZENBERGER, M.; MARANGONI, F.; BALDO, D.; BELTRÁN, J.F.; MARTÍ, D.A.; RICHTER-BOIX, A.; GONZALEZ-VOYER, A. 2012. Can amphibians take the heat? Vulnerability to climate warming in subtropical and temperate larval amphibian communities. *Global Change Biology*, **18**(2):412-421. https://doi.org/10.1111/j.1365-2486.2011.02518.x

FREITAS, E.B.; DE-CARVALHO, C.B.; FARIA, R.G.; BATISTA, R.C.; BATISTA, C.C.; COELHO, W.A.; BOCCHIGLIERI, A. 2008. Nicho ecológico e aspectos da história natural de *Phyllomedusa azurea* (Anura: Hylidae, Phyllomedusinae) no Cerrado do Brasil Central. *Biota Neotropica*, **8**(4):101-110. http://dx.doi.org/10.1590/S1676-06032008000400009

FROST, D.R. 2015. Amphibian Species of the World: an Online Reference. Version 6 (20 December, 2015). American Museum of Natural History, New York, New York, U.S.A. Available at: http://research.amnh.org/herpetology/amphibia/index.html. Accessed on: 20/12/2015.

FUNK, W.C.; ALMEIDA-REINOSO, D.; NOGALES-SORNOSA, F.; BUSTAMANTE, M.R. 2003. Monitoring population trends of *Eleutherodactylus* frogs. *Journal of Herpetology*, **37**(2):245-256. https://doi.org/10.1670/0022-1511(2003)037[0245:MPTOEF]2.0.CO;2

GARCIA, P.C.A.; VINCIPROVA, G.; HADDAD, C.F.B. 2003. The taxonomic status of *Hyla pulchella joaquini* (Anura: Hylidae) with description of its tadpole and vocalization. *Herpetologica*, **59**(3):350-363. https://doi.org/10.1655/01-54

GARCIA, P.C.A.; FAIVOVICH, J.; HADDAD, C.F.B. 2007. Redescription of *Hypsiboas semiguttatus*, with the description of a new species of the *Hypsiboas pulchellus* group. *Copeia*, **2007**(4):933-951. https://doi.org/10.1643/0045-8511(2007)7[933:ROHSWT]2.0.CO;2

GARCIA, P.C.A.; HADDAD, C.F.B. 2008. Vocalizations and comments on the relationships of *Hypsiboas ericae* (Amphibia, Hylidae). *Iheringia Série Zoologia*, **98**(1):161-166. https://doi.org/10.1590/S0073-47212008000100021

GARCIA P.C.A.; PEIXOTO, O.L.; HADDAD, C.F.B. 2008. A new species of *Hypsiboas* (Anura: Hylidae) from the Atlantic Forest of Santa Catarina, Southern Brazil, with comments on its conservation status. *South American Journal of Herpetology*, **3**(1):27-35. https://doi.org/10.2994/1808-9798(2008)3[27:ANSOHA]2.0.CO;2

GIASSON, L.O.M.; HADDAD, C.F.B. 2006. Social interactions in *Hypsiboas albomarginatus* (Anura: Hylidae) and the significance of acoustic and visual signals. *Journal of Herpetology*, **40**(2):171-180. https://doi.org/10.1670/205-05A.1

GREER, B.J.; WELLS, K.D. 1980. Territorial and reproductive behavior of the tropical American frog *Centrolenella fleischmanni*. *Herpetologica*, **36**(4):318-326.
GREENE, H.W. 1994. Systematics and natural history foundations for understanding and conserving biodiversity. *American Zoologist*, **34**(1):48-56. https://doi.org/10.1093/icb/34.1.48
GUIX, J.C. 1996. Actividad invernal de anuros en tres sierras del sudeste de Brasil. *Boletín de La Asociacion Herpetologica Española*, **7**:31-34.
HENLE, K.; DAVIES, K.F.; KLEYER, M.; MARGULES, C.; SETTELE, J. 2004. Predictors of species sensitivity to fragmentation. *Biodiversity and Conservation*, **13**(1):207-251.
https://doi.org/10.1023/B:BIOC.0000004319.91643.9e
HÖDL, W.; RODRIGUES, M.T.; ACCACIO, G.M.; LARA, P.H.; PAVAN, D.; SCHIESARI, L.C.; SKUK, G. 1997. Foot flagging behavior in *Hylodes asper* (Leptodactilydae). Scientif film, Ctf 2444 ÖWF, Vienna, Austria.
IOP, S.; CALDART, V.M.; ROCHA, M.C.; PAIM, P.M.; CECHIN, S.Z. 2009. Amphibia, Anura, Hylidae, *Hypsiboas curupi* Garcia, Faivovich and Haddad, 2007: First record for the state of Rio Grande do Sul, Brazil. *Check List*, **5**(4):860-862. https://doi.org/10.15560/5.4.860
KWET, A. 2008. New species of *Hypsiboas* (Anura: Hylidae) in the *pulchellus* group from southern Brazil. *Salamandra*, **44**(1):1-14.
LAURANCE, W.F.; LOVEJOY, T.E.; VASCONCELOS, H.; BRUNA, E.; DIDHAM, R.; STOUFFER, P.; GASCON, C.; BIERREGAARD, R.O.; LAURANCE, S.G.; SAMPAIO, E. 2002. Ecosystem decay of Amazonian forest fragments: a 22-year investigation. *Conservation Biology*, **16**(3):605–618. https://doi.org/10.1046/j.1523-1739.2002.01025.x
LAURANCE, W.F. 2008. Theory meets reality: How habitat fragmentation research has transcended island biogeographic theory. *Biological Conservation*, **141**(7):1731-1744.
https://doi.org/10.1016/j.biocon.2008.05.011
LEGENDRE, P.; LEGENDRE, L. 1998. *Numerical Ecology (Developments in Environmental Modelling: 20)*. Elsevier Science, Amsterdam, 853 p.
LEITE, M.A.S.; LEÃO, R. 2009. *Diagnóstico e caracterização da subbacia do Rio dos Queimados*. Concórdia: Consórcio Lambari: Comitê do Rio Jacutinga e Contíguos. 210 p.
LIPINSKI, V.M.; CALDART, V.M.; IOP, S. 2012. Visual communication in *Hypsiboas curupi* (Anura: Hylidae) at Parque Estadual do Turvo, southern Brazil. *Phyllomedusa*, **11**(1):71-74.
https://doi.org/10.11606/issn.2316-9079.v11i1p71-74
LUCAS, E.M.; GARCIA, P.C.A. 2011. Amphibia, Anura, Hylidae Rafinesque, 1815 and Hylodidae Günther, 1858: Distribution extension and new records for Santa Catarina, southern Brazil. *Check List*, **7**(1):13-16.
LUCAS, E.M.; MAROCCO, J.C. 2011. Anurofauna (Amphibia, Anura) em um remanescente de Floresta Ombrófila Mista no Estado de Santa Catarina, Sul do Brasil. *Biota Neotropica*, **11**(1):1-8.
https://doi.org/10.1590/S1676-06032011000100035
MACHADO, I.F.; MOREIRA, L.F.B.; MALTCHIK, L. 2012. Effects of pine invasion on anurans assemblage in southern Brazil coastal ponds. *Amphibia-Reptilia*, **33**(2):227-237.
https://doi.org/10.1163/156853812X638518
MARTINS, M.; POMBAL, J.P.J.; HADDAD, C.F.B. 1998. Escalated aggressive behaviour and facultative parental care in the nest building gladiator frog, *Hyla faber*. *Amphibia-Reptilia*, **19**(1):65-73.
https://doi.org/10.1163/156853898X00331
MINISTÉRIO DO MEIO AMBIENTE (MMA). 2014. *Lista Nacional Oficial das Espécies da Fauna Brasileira Ameaçadas de Extinção*. Portaria n. 444, de 17 de dezembro de 2014. Diário Oficial da República Federativa do Brasil, Brasília, DF. Seção 1, 245, p. 121-126.
MIRANDA, D.B.; GAREY, M.V.; MONTEIRO-FILHO, E.L.A.; HARTMANN, M. T. 2008. Sinalização visual e biologia reprodutiva de *Dendropsophus werneri* (Anura: Hylidae) em área de Mata Atlântica no Estado do Paraná, Brasil. *Papéis Avulsos de Zoologia*, **48**(29):335-343.
https://doi.org/10.1590/s0031-10492008002900001
MUNIZ, K.P.R.; GIARETTA, A.A.; SILVA, W.R.; FACURE, K.G. 2008. Auto-ecologia de *Hypsiboas albopunctatus* (Anura, Hylidae) em área de Cerrado no sudeste do Brasil. *Iheringia Série Zoologia*, **98**(2):254-259.
https://doi.org/10.1590/S0073-47212008000200014
NELSON, D.A.; MARLER, P. 1990. The perception of bird song and an ecological concept of signal space. *In*: W.C. STEBBINS; M.A. BERKLEY. (eds). *Comparative Perception*: *complex signals*. Wiley, New York, p. 443-478.
OLIVEIRA, E.F.; FEIO, R.N.; MATTA, S.L.P. 2007. Aspectos reprodutivos de *Dendropsophus minutus* (Peters, 1872) no município de Viçosa, Minas Gerais. *Revista Ceres*, **54**(313):230-238.
PIMM, S.L.; JENKINS, C.N.; ABELL, R.; BROOKS, T.M.; GITTLEMAN, J.L.; JOPPA, L.N.; RAVEN, P.H.; ROBERTS, C.M.; SEXTON, J.A. 2014. The biodiversity of species and their of extinction, distribution and protection. *Science*, **344**(6187):1246752.
https://doi.org/10.1126/science.1246752
POMBAL, J.P.; HADDAD, C.F.B. 2005. Estratégias e modos reprodutivos de anuros (Amphibia) em uma poça permanente na Serra de Paranapiacaba, Sudeste do Brasil. *Papéis Avulsos de Zoologia*, **45**(15):201-213.
https://doi.org/10.1590/S0031-10492005001500001
POMBAL, J.P. 1997. Distribuição espacial e temporal de anuros (Amphibia) em uma poça permanente na Serra de Paranapiacaba, Sudeste do Brasil. *Revista Brasileira de Biologia*, **57**(4):583-594.
POUGH, F.H.; TAIGEN, T.L.; STEWART, M.M.; BROUSSARD, P.F. 1983. Behavioral modification of evaporative water loss by a Puerto Rican frog. *Ecology*, **64**(2):244-252.
https://doi.org/10.2307/1937072
PRADO, C.P.A.; UETANABARO, M.; LOPES, F.S. 2000. Reproductive strategies of *Leptodactylus chaquensis* and *L. podicipinus* in the Pantanal, Brasil. *Journal of Herpetology*, **34**(1):135-139.
https://doi.org/10.2307/1565249
PREUSS, J.F.; LAMBERTINI, C.; LEITE, D.S.; TOLEDO, L.F.; LUCAS, E.M. 2015. *Batrachochytrium dendrobatidis* in near threatened and endangered amphibians in the southern Brazilian Atlantic Forest. *North-Western Journal of Zoology*, **11**(2): 360-362.
RIBEIRO, M.C.; METZGER, J.P.; MARTENSEN, A.C.; PONZONI, F.J.; HIROTA, M.M. 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation*, **142**(6):1141-1153.
https://doi.org/10.1016/j.biocon.2009.02.021
SANTOS, T.G.; ROSSA-FERES, D.C.; CASATTI, L. 2007. Diversidade e distribuição espaço-temporal de anuros em região com pronunciada estação seca no sudeste do Brasil. *Iheringia, Série Zoologia*, **97**(1):37-49.
https://doi.org/10.1590/S0073-47212007000100007
SAUNDERS, D.A.; HOBBS, R.J.; MARGULES, C.R. 1991. Biological consequences of ecosystem fragmentation: a review. *Conservation Biology*, **5**(1):18-32. https://doi.org/10.1111/j.1523-1739.1991.tb00384.x
SCOTT JR., N.J.; WOODWARD, B.D. 1994. Revielamentos de lugares de reprodución. *In*: W.R. HEYER; M.A. DONNELLY; R.W. MCDIARMID; L.A.C. HAYEK; M.S. FOSTER (eds). *Measuring and Monitoring Biological Diversity: standard methods for amphibians*. Washington, Smithsonian Institution Press, p.113-120.
SHAPIRO, S.S.; WILK, M.B. 1965. An analysis of variance test for normality. *Biometrika*, **52**(3-4): 591-611.
http://dx.doi.org/10.1093/biomet/52.3-4.591
SILVANO, D.L.; SEGALLA, M.V. 2005. Conservation of Brazilian amphibians. *Conservation Biology*, **19**(3):653-658.
https://doi.org/10.1111/j.1523-1739.2005.00681.x
STATSOFT, INC. 2007. *Statistica* (data analysis software system), version 6. Available at: www.statsoft.com. Accessed on: 12/12/2014.
TERNUS, R.Z.; SOUZA-FRANCO, G.M.; ANSELMINI, M.E.K.; MOCELLIN, D.J.C.; DAL MAGRO, J. 2011. Influence of urbanisation on water quality in the basin of the upper Uruguay River in western Santa Catarina, Brazil. *Acta Limnologica Brasiliensis*, **23**(2):189-199.
https://doi.org/10.1590/S2179-975X2011000200009

TOLEDO, L.F.; BRITTO, F.B.; ARAÚJO, O.G.S.; GIASSON, L.O.M.; HADDAD, C.F.B. 2006. The occurrence of *Batrachochytrium dendrobatidis* in Brazil and the inclusion of 17 new cases of infection. *South American Journal of Herpetology*, **1**(3):185-191. https://doi.org/10.2994/1808-9798(2006)1[185:TOOBDI]2.0.CO;2

TOLEDO, L.F.; CARVALHO-E-SILVA, S.P.; SÁNCHEZ, C.; ALMEIDA, M.A.; HADDAD, C.F.B. 2010. The review of the Brazilian Forest Act: harmful effects on amphibian conservation. *Biota Neotropica*, **10**(4):35-38. https://doi.org/10.1590/S1676-06032010000400003

VALENTIN, J.L. 1995. Agrupamento e ordenação. *In*: P.R.P. PERES-NETO; J.L. VALENTIN; F. FERNANDEZ (eds.), *Tópicos em tratamentos de dados biológicos*. Rio de Janeiro, Oecologia Brasiliensis, p. 27-55. https://doi.org/10.4257/oeco.1995.0201.02

VASCONCELOS, T.S.; SANTOS, T.G.; ROSSA-FERES, D.C.; HADDAD, C.F.B. 2011. Spatio-temporal distribution of calling male frogs in Morro do Diabo State Park (Southeastern Brazil): implications for conservation and management in a seasonally dry tropical Forest. *South American Journal of Herpetology*, **6**(2):107-118. https://doi.org/10.2994/057.006.0201

VERDADE, V.K.; DIXO, M.; CURCIO, F.F. 2010. Os riscos de extinção de sapos, rãs e pererecas em decorrência das alterações ambientais. *Estudos Avançados*, **24**(68):161-172. https://doi.org/10.1590/S0103-40142010000100014

WELLS, K.D. 2007. *The ecology and behavior of amphibians*. Chicago, The University of Chicago Press, 1148 p. https://doi.org/10.7208/chicago/9780226893334.001.0001

WOOLBRIGHT, L.L. 1983. Sexual selection and size dimorphism in anuran amphibia. *The American Naturalist*, **121**(1):110-119. https://doi.org/10.1086/284042

WOOLBRIGHT, L.L. 1989. Sexual dimorphism in *Eleutherodactylus coqui*: selection pressures and growth rates. *Herpetologica*, **45**(1):68-74. https://doi.org/10.1111/j.1523-1739.2001.00218.x

YOUNG, B.; LIPS, K.R.; REHACER, J.K.; IBÁÑEZ, R.; SALAS, A.W.; CEDEÑO, J.R.; COLOMA, L.A.; RON, S.; LA MARCA, E.; MEYER, J.R.; MUÑOZ, A.; BOLAÑOS, F.; CHAVES, G.; ROMO, D. 2001. Population declines and priorities for amphibian conservation in Latin America. *Conservation Biology*, **15**(5):1213-1223. https://doi.org/10.1046/j.1523-1739.2001.00218.x

ZANELLA, N.; MACHADO, L.S.; BUSIN, C.S. 2012. Geographic distribution: *Hypsiboas curupi*. *Herpetological Review*, **43**:440.

ZAR, J.H. 1999. *Biostatistical analyses*. New Jersey, Prentice Hall, 944 p.

Submitted on March 8, 2016
Accepted on July 18, 2016