

## **Amphibians in a transition region between the Cerrado and the Atlantic Forest, west-central region of the state of São Paulo, Brazil**

### **Anfíbios em uma região de transição entre o Cerrado e a Mata Atlântica, Região Centro-Oeste do estado de São Paulo, Brasil**

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#### **Abstract**

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Studies of the diversity and natural history of amphibians are extremely important and contribute with the knowledge about the patterns of geographical distribution and biology of the species, outlining the factors that influence this distribution, and contributing to the development of conservation projects of them. This study aimed to identify the richness, abundance, spatial and temporal distribution of amphibians in the Bauru region, state of São Paulo, Brazil, and compare the species composition with others regions in the São Paulo state located in the Cerrado and Atlantic Forest. Eight locations were sampled between the years 2009 and 2012. Thirty-seven amphibian species were recorded, which represents 15.61% of the species in the state of São Paulo. In comparison to other regions of the state, Bauru resemble with the north-western region of the state and with the Assis Ecological Station in species composition. The community of amphibians in the studied region is regulated to morphoclimatic conditions, environmental heterogeneity and the conservation of natural resources, which directly reflect on the composition, abundance and species' spatial and temporal distribution of the amphibians in this region. The richness of amphibians of the Bauru region is significant for the state of São Paulo and contributes with the maintenance of environments with conditions for the occurrence of *Proceratophrys moratoi*, which is considered in threat of extinction. This study contributed with the filling gap on the amphibian knowledge of the state of São Paulo.

**Keywords:** Anurans; Natural history; Diversity; Conservation.

#### **Resumo**

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Estudos sobre diversidade e história natural de anfíbios são de extrema importância para o conhecimento sobre os padrões de distribuição geográfica e biologia das espécies delineando os fatores que influenciam nessa distribuição, o que contribui para a elaboração de projetos de conservação mais realistas e efetivos. Este estudo visou identificar a riqueza, abundância, distribuição espacial e temporal das espécies de anfíbios da região de Bauru, estado de São Paulo, Brasil, e comparar a composição de espécies com outras regiões de Cerrado e Mata Atlântica do estado de São Paulo. Oito localidades foram amostradas entre os anos de 2009 e 2012. Foram registradas 37 espécies de anfíbios, as quais representam 15,61% das espécies do estado de São Paulo. Em comparação com

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outras regiões do estado, Bauru se assemelha à Região Noroeste do estado e à Estação Ecológica de Assis na composição de espécies. A comunidade de anfíbios da região estudada é regulada pelas condições morfoclimáticas, heterogeneidade ambiental e estado de conservação dos recursos naturais, que refletem diretamente na composição, na abundância e nos padrões de distribuição espacial e temporal das espécies de anfíbios presentes na região. A riqueza de anfíbios da região de Bauru é significativa para o estado de São Paulo e contribui com a manutenção de ambientes com condições para a ocorrência de *Proceratophrys moratoi*, considerada em risco de extinção. Este estudo contribui com o preenchimento de lacunas no conhecimento de anfíbios do estado de São Paulo.

**Palavras-chave:** Anuros; História natural; Diversidade; Conservação.

## Introduction

Brazil has the most diversity of amphibians in the world, with a total of 1080 species, where 1039 are Anura, 5 are Caudata and 36 are Gymnophiona.<sup>(1)</sup> The state of São Paulo represents approximately 25% of the diversity of the country, with 237 species.<sup>(2, 3)</sup> However, there are a lot of gaps in the sampling of amphibians in the state, and the Bauru region has a low level of knowledge in the sampling of these organisms.<sup>(3)</sup>

The Bauru region is situated in an area of contact between the Cerrado and the Atlantic Forest.<sup>(4)</sup> The Cerrado is the second biggest Brazilian biome in terms of extension, with more than 2,000,000 km<sup>2</sup>.<sup>(5)</sup> In the last 35 years, more than half of the Cerrado area was turned into pasture and plantations,<sup>(6)</sup> and the conservation unities cover less than 2% of its total area.<sup>(5)</sup> The state of São Paulo, which originally had circa 34,700 km<sup>2</sup> of Cerrado (14% of its total area), is in a more serious situation, since the reminiscent of this vegetation covers circa 2,100 km<sup>2</sup>, corresponding to 0.84% of the state's total area and just half of what is left is protected as conservation unity.<sup>(7)</sup> The Atlantic Forest was deforest in more than 88% and only still remains 12% of original area.<sup>(8)</sup> In the São Paulo state interior, only 7% of the Atlantic Forest fragments remaining.<sup>(8)</sup> There are at least 209 known species of amphibians in Cerrado, and approximately 52% of these species are endemic of this biome.<sup>(9)</sup> For the Atlantic Forest are know 540 amphibians species and 90% of these species are endemic of this biome.<sup>(10)</sup>

In recent years there has been a significant increase in the number of published studies on the

diversity of amphibians in the Cerrado and seasonal forest in the state of São Paulo. Few studies describe the taxocenoses of anurans of the Cerrado and its ecotone with the Semideciduous Seasonal Forest of São Paulo, with a special attention given to those conducted in Guararapes,<sup>(11)</sup> Rio Claro,<sup>(12)</sup> Itirapina and Brotas,<sup>(13)</sup> Assis,<sup>(14)</sup> Luiz Antonio,<sup>(15)</sup> Pedregulho,<sup>(16)</sup> Avaré,<sup>(17)</sup> Águas de Santa Bárbara,<sup>(18)</sup> Angatuba,<sup>(19)</sup> Anhembi,<sup>(20)</sup> Jaú and Agudos,<sup>(21)</sup> Vassununga,<sup>(22)</sup> and Bauru.<sup>(23)</sup> The strong anthropic pressure, the high level of endemism and the decline in anurans populations registered in this biome reinforce the importance of taxonomical inventories and studies about the ecology of anurans in Cerrado areas.

Therefore, amphibian inventories are extremely important and they contribute with the knowledge about the geographical distribution patterns and the biology of the species, outlining the factors that affect this distribution, which will contribute to the elaboration of conservation projects for them. This study aimed to identify the richness, abundance and spatial and temporal distribution of the amphibian species of Bauru region and to compare to studies done in other regions of the state of São Paulo located in Cerrado and Atlantic Forest.

## Material and Methods

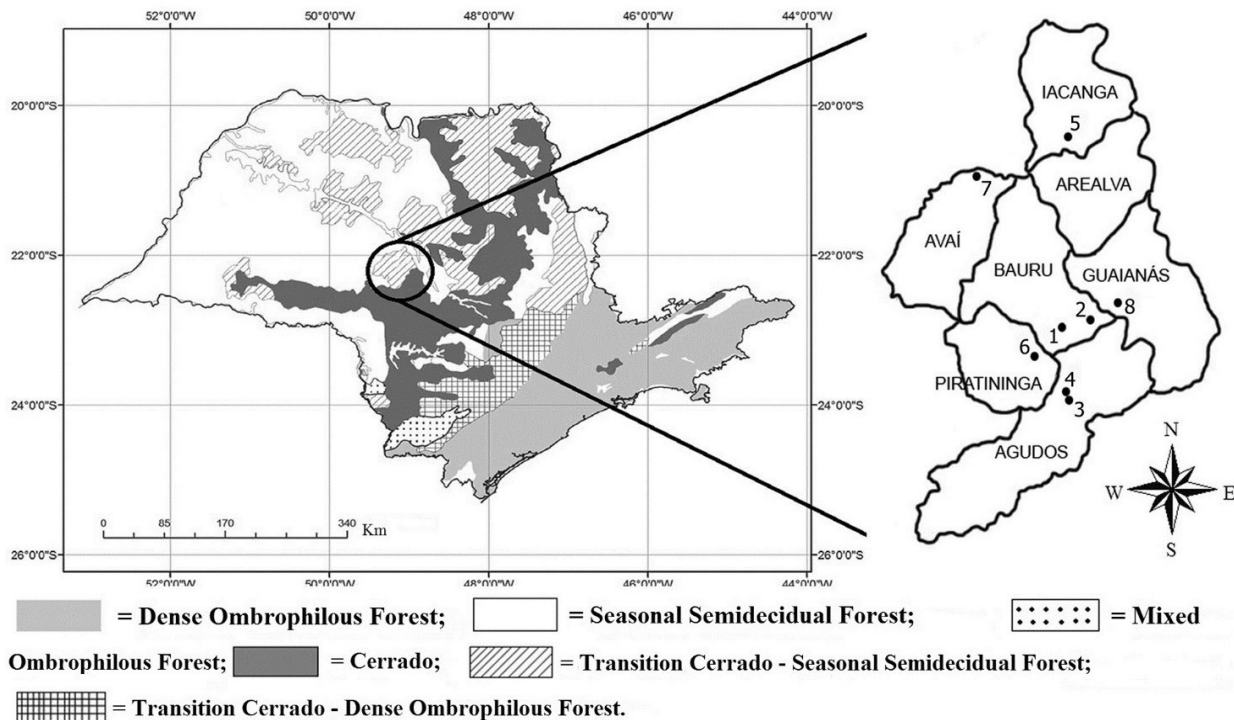
### Study area

Eight localities were sampled in the Bauru region (Figure 1), covering a radius of up to 30 km of range around the urban area of the city, contemplating six cities. The areas was: two in

the municipality of Bauru: **Localidade 1** - Jardim Botânico Municipal de Bauru (22°20'48.46"S; 49°0'56.73"W, Elevation: 550 m), **Localidade 2** - Instituto Lauro Souza Lima (22°20'29.10"S; 48°58'59.40"W, Elevation: 530 m); two in the municipality of Agudos: **Localidade 3** - Fazenda São Benedito (22°28'53.90"S; 49°2'8.80"W, Elevation: 659 m), **Localidade 4** - Pesqueiro Toca do Peixe (22°28'38.80"S; 49°2'16.10"W, Elevation: 568 m); one in the municipality of Iacanga:

**Localidade 5** - Fazenda Pindorama (21°58'46.60"S; 49°2'17.30"W, Elevation: 427 m); one in the municipality of Piratininga: **Localidade 6** - Sítio Piratininga (22°24'20.30"S; 49°6'13.90"W, Elevation: 490 m), one in the municipality of Avaí: **Localidade 7** - Fazenda Rio Batalha (22°2'34.60"S; 49°14'59.50"W, Elevation: 419 m) and one in the municipality of Pederneiras: **Localidade 8** - Reserva Legal do Horto Aimorés (22°17'55.53"S; 48°56'02.92"W, Elevation: 534 m).

**Figure 1** - Map of the state of São Paulo, showing the original vegetation distribution and in detail the 8 localities sampled in the cities of the Bauru region: 1. Jardim Botânico Municipal de Bauru; 2. Instituto Lauro Souza Lima; 3. Fazenda São Benedito; 4. Pesqueiro Toca do Peixe; 5. Fazenda Pindorama; 6. Sítio Piratininga; 7. Fazenda Rio Batalha; 8. Reserva Legal do Horto Aimorés.



Source: adaptation of Siqueira and Durigan.<sup>(4)</sup>

The region's vegetation is characterized by fragments of Forest Savannah (Cerradão) and Atlantic Forest.<sup>(4)</sup> The climate, according to the Köppen-Geiger classification is temperate, with dry winters and hot summers (Cwa).<sup>(24)</sup> And according the map of climatic division of the state of São Paulo, Bauru shows average temperatures higher than 22 °C at the hottest months and lower than 18 °C at the coldest months.<sup>(25)</sup> The area is situated in the Western

Highlands, with an average altitude of 525 m.<sup>(25)</sup> In the last ten years previous to this study, it has shown an average annual rainfall of 1,200 mm.<sup>(26)</sup>

#### *Characterization of the studied localities and water bodies*

The environments of each of the sampled localities were characterized according to their

location, elevation (meters), water body type, physiognomy (Cerrado or Atlantic Forest), water body features (duration, movement, size and soil), vegetation type that compose (arboreal and herbaceous, shrubby, macrophytes) and localization of the water bodies (open area, associated to a forest

fragment or inside the forest fragment). It was considered an open area when it was more than 50 meters away from the forest area and associated to a forest fragment when it was located at the border or at less than 50 meters from a forest fragment (Table 1).

**Table 1** - Characterization of breeding habitats, according to their location, elevation (meters), water body type, physiognomy, water body features (duration, movement, size and soil) and vegetation type that compose (arboreal and herbaceous, shrubby, macrophytes). Abbreviations: DUR = duration; MOV = movement; SIZ = size; SOI = bed soil; Per = permanent; T = temporary; Ec = exchange constant; S = standing; Cu = current; Sma = small; Med = medium; Lar = large; Roc = rocky; San = sandy; Mud = muddy; HB = herbaceous vegetation; SH = shrubby; AB = arboreal; MA = macrophytes; ++ = presence and very abundant; + = presence; - = absence.

Localities, coordinates	Water body type and physiognomy	Features				Vegetation type			
		DUR	MOV	SIZ	SOI	HB	SH	AB	MA
<b>L. 1 Jardim Botânico Municipal de Bauru</b>	Fountain in open area	T	Ec	Sma	San	++	++	+	-
	Stream on edge forest	Per	Cu	Sma	San	++	++	+	+
	Dam in open area	Per	S	Sma	Mud	+	-	-	+
	Swamp on edge forest	Per	Ec	Lar	Mud	++	++	+	++
	Dam on edge forest	Per	S	Lar	Mud	++	++	+	+
	Swamp in open area	Per	Ec	Med	Mud	++	+	+	++
	Dam on edge forest	Per	S	Sma	Mud	++	+	+	++
	Stream in gallery forest	Per	Cu	Sma	San	+	+	++	+
	Dam on edge forest	Per	S	Sma	Mud	+	+	+	+
	Stream in swampy forest	Per	Cu	Sma	San	+	++	++	+
Ponds in swampy forest	Per	Ec	Sma	Mud	+	++	++	-	
Dam in open area	Per	Ec	Med	Mud	+	-	-	+	
<b>L. 2 Instituto Lauro Souza Lima</b>	Dam on edge forest	Per	S	Med	Mud	++	++	++	+
	Dam on edge forest	Per	S	Med	Mud	++	++	++	++
<b>L. 3 Fazenda São Benedito</b>	Stream in gallery forest	P	Cu	Sma	San/Roc	+	++	++	+
	Pond in forest	T	S	Sma	San	+	+	+	-
	Pond in eucalyptus	T	S	Sma	San	++	-	-	-
	Pond on edge eucalyptus	T	S	Sma	San	+	-	+	-

*Continues*

## Continuation

<b>L. 4</b> <b>Pesqueiro</b> <b>Toca do Peixe</b>	Stream in gallery forest	Per	Cu	Sma	San/Roc	+	++	++	+
	Pond on edge forest	T	S	Med	Mud	+	-	-	+
<b>L. 5</b> <b>Fazenda</b> <b>Pindorama</b>	Dam in open area	Per	S	Lar	Mud	++	++	+	++
	Pond in open area	T	S	Med	Mud	++	++	+	+
	Pond in open area	Per	S	Sma	Mud	++	+	+	++
	Pond in open area	T	S	Sma	San	+	-	-	-
	Pond on edge forest	T	S	Sma	San	+	++	++	-
	Fountain in open area	Per	Ec	Lar	San	++	++	+	+
	Swamp in open area	Per	Ec	Lar	San/Mud	++	++	+	+
	Pond on edge eucalyptus	T	S	Sma	Mud	+	+	++	-
Pond on edge sugar cane	T	S	Sma	San	+	+	-	-	
<b>L. 6</b> <b>Sítio</b> <b>Piratininga</b>	Stream in gallery forest	Per	Cu	Sma	San	+	+	++	-
	Fountain in open area	Per	Ec	Sma	San	++	++	+	+
	Pond in open area	Per	S	Med	Mud	++	++	+	++
	Swamp in open area	Per	Ec	Lar	Mud	++	++	+	++
	Pond in open area	T	S	Sma	San	+	-	-	-
	Pond in open area	T	S	Sma	San/Mud	++	+	-	+
	Pond on edge forest	T	S	Sma	Mud	++	++	+	+
<b>L. 7</b> <b>Fazenda</b> <b>Rio Batalha</b>	Dam in open area	Per	S	Med	San/Mud	++	++	+	+
	Ponds in open area	T	Ec	Med	San	++	+	+	+
	Pond in forest	T	S	Sma	Mud	+	+	++	-
	Pond in open area	T	S	Sma	San	++	-	-	-
	Dam in open area	Per	S	Sma	Mud	++	+	+	++
	Fountain on edge forest	Per	Ec	Med	San	++	+	+	+
	Dam on edge forest	Per	S	Med	Mud	++	+	+	++
	Pond in open area	T	S	Sma	Mud	++	+	-	++
	Pond in forest	Per	S	Sma	Mud	+	++	++	+
	Pond on edge forest	T	S	Sma	San	++	+	+	+
<b>L. 8</b> <b>Horto</b> <b>Aimorés</b>	Stream in forest	Per	Ec	Sma	San	++	+	++	-
	Pond in forest	T	S	Sma	San	-	-	+	-
	Swamp in open area	Per	Ec	Lar	San/Mud	++	+	-	++
	Swamp on edge forest	Per	Ec	Lar	San/Mud	++	++	+	++
	Pond on edge forest	T	S	Sma	San	+	+	+	-

Source: the author.

### *Methods of sampling for the anuran fauna*

The eight localities were sampled between the years 2009 and 2012. All of the permanent or temporary aquatic environments were sampled, in open or forest areas, presents in the localities. There were sampled streams, marshes, dams and pools, both in open area and forest phytophysiology. The localities were sampled during daytime and nighttime, where it was registered the occurrence of adults of all the anuran species presents at the location. The methods used in the search of individuals were: active visual search, hearing search (zoophonia) and sampling at the reproduction's locations.<sup>(27)</sup>

In each visit it was made an estimation of the number of individuals of the species in activity. The monthly abundance of each species was considered equal to the higher abundance registered at each month's visit and the total abundance in each environment or locality is equal to the month with higher abundance.<sup>(28)</sup> For the abundance of each species at the Bauru region, it was used the number of individuals of the visit in which the species showed in higher abundance during the study in each locality and it was added to each locality the species was registered. These were distributed in six classes of abundance (Ca): (1): <5; (2): 5-10; (3): 11-20; (4): 21-50; (5): 50-100 and (6): >100. The temporal distribution of the species was registered along the year.

The conservation status of the species was considered according to the national and state lists of menaced species of Brazil<sup>(29-30)</sup> and in IUCN Red List of Threatened Species.<sup>(31)</sup> The nomenclature and classification presented follows Frost (2020).<sup>(32)</sup>

### *Statistical analysis*

The efficiency of the samplings was measured by accumulative curves of species (Figure 5), generated by the species abundance data in the localities and on the 108 days of sampling (one sample = one day), using the program EstimateS v. 9.1.0 with 1000 randomizations (Colwell, 2016).<sup>(33)</sup>

There were used non-parametrical estimators *Jackknife* 1, which extrapolates the number of species in function of frequency of rare species observed in each sample, using each collect locality as a sample unity and *Bootstrap*, which estimates the richness from all the registered species data (Hortal *et al.*, 2006).<sup>(34)</sup>

The similarity in the richness of anuran species between the Bauru region (initials = BUR) and nine regions of the state of São Paulo (Figure 6), dominated by Cerrado and/or Atlantic Forest, was determined through the UPGMA grouping method, applied over matrixes of qualitative similarities of the analyzed studies (Legendre and Legendre, 1998).<sup>(35)</sup> The nine regions were, with the abbreviations: northwest of the state = NWS,<sup>(2, 36)</sup> Botucatu = BTR,<sup>(37-38)</sup> Lençóis Paulista = LP,<sup>(17, 39-40)</sup> Itirapina = IT,<sup>(12-13, 41-42)</sup> Assis Ecological Station = AES,<sup>(14)</sup> Caetetus Ecological Station = CES,<sup>(43)</sup> Jataí Ecological Station = JET,<sup>(15)</sup> Morro do Diabo State Park = MDST<sup>(44)</sup> and Furnas do Bom Jesus State Park = FBJS.<sup>(16)</sup>

To make the ordination and grouping analysis, it was used the Past software (version 1.49).<sup>(45)</sup> The groupings were defined considering the minimal value of 60% of similarity.

### **Results**

There were registered 37 species of amphibians, where 36 are from the Anura Order, belonging to six families: Bufonidae (2), Odontophrynidae (2), Hylidae (16), Hylodidae (1), Leptodactylidae (13) and Microhylidae (2), and a cicely from the Siphonopidae family, *Siphonops paulensis*, from the Gymnophiona Order (Table 2; Figures 2, 3, and 4). This last one was registered by a third party, at the backyard of a house on the urban area of the city, which was included in the list of amphibians species of Bauru region, however, it was only included in the richness data, for being an important occasional registration, outside the localities sampled during the study. The Hylidae family was the most representative, corresponding to 44.45% of the total number of registered species.

**Table 2** - Species of amphibians registered at the Bauru region, São Paulo.

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**Class Amphibia** Linnaeus, 1758

**Order Anura** Fischer von Waldheim, 1813

**Family Bufonidae** Gray, 1825

*Rhinella ornata* (Spix, 1824)

*Rhinella diptycha* (Cope, 1862)

**Family Odontophrynidae** Lynch, 1969

*Odontophrynus americanus* (Duméril & Bibron, 1841)

*Proceratophrys moratoi* (Jim and Caramaschi, 1980)

**Family Hylidae** Rafinesque, 1815

*Dendropsophus elianeae* (Napoli and Caramaschi, 2000)

*Dendropsophus minutus* (Peters, 1872)

*Dendropsophus nanus* (Boulenger, 1889)

*Boana albopunctata* (Spix, 1824)

*Boana caingua* (Carrizo, 1991)

*Boana faber* (Wied-Neuwied, 1821)

*Boana lundii* (Burmeister, 1856)

*Boana raniceps* (Cope, 1862)

*Oloolygon berthae* (Barrio, 1962)

*Oloolygon hiemalis* (Haddad and Pombal, 1987)

*Phyllomedusa tetraploidea* (Pombal and Haddad, 1992)

*Pseudis platensis* (Gallardo, 1961)

*Scinax fuscmarginatus* (Lutz, 1925)

*Scinax fuscovarius* (Lutz, 1925)

*Scinax similis* (Cochran, 1952)

*Trachycephalus typhonius* (Linnaeus, 1758)

**Family Hylodidae** Günther, 1858

*Crossodactylus caramaschii* (Bastos and Pombal, 1995)

**Family Leptodactylidae** Werner, 1896

*Leptodactylus chaquensis* (Ceí, 1950)

*Leptodactylus furnarius* (Sazima and Bokermann, 1978)

*Leptodactylus fuscus* (Schneider, 1799)

*Leptodactylus labyrinthicus* (Spix, 1824)

*Leptodactylus latrans* (Steffen, 1815)

*Leptodactylus mystaceus* (Spix, 1824)

*Leptodactylus mystacinus* (Burmeister, 1861)

*Leptodactylus podicipinus* (Cope, 1862)

*Physalaemus centralis* (Bokermann, 1962)

*Physalaemus cuvieri* (Fitzinger, 1826)

*Physalaemus marmoratus* (Reinhardt and Lütken, 1862)

*Physalaemus nattereri* (Steindachner, 1863)

*Pseudopaludicola mystacalis* (Cope, 1887)

**Family Microhylidae** Günther, 1858

*Chiasmocleis albopunctata* (Boettger, 1885)

*Elachistocleis cesarii* (Miranda-Ribeiro, 1920)

**Order Gymnophiona** Müller, 1832

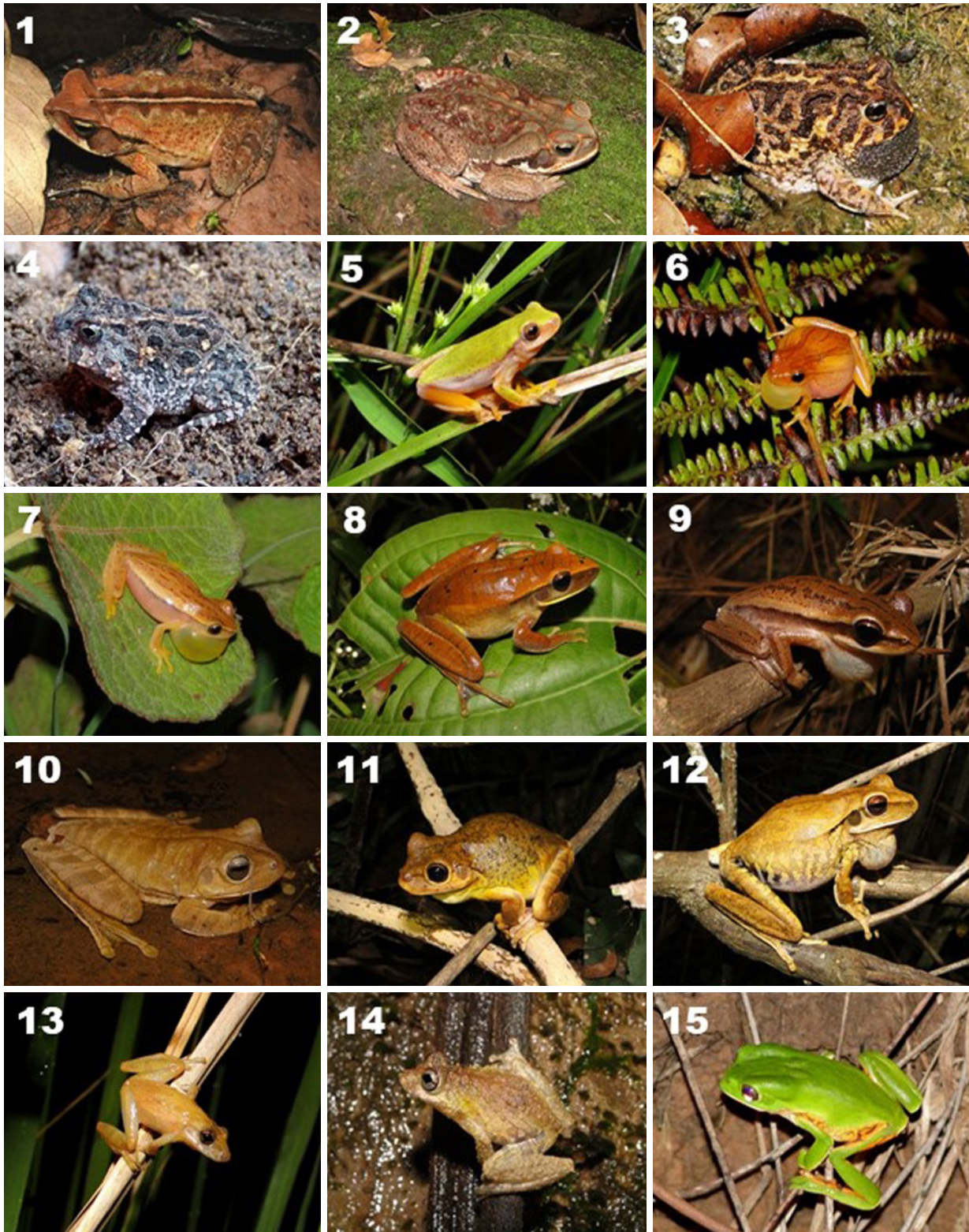
**Family Siphonopidae** Bonaparte, 1850

*Siphonops paulensis* (Boettger, 1892)

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Source: the author.

**Figure 2** - Species of amphibians registered at the Bauru region, São Paulo. 1 = *Rhinella ornata*; 2 = *R. diptycha*; 3 = *Odontophrynus americanus*; 4 = *Proceratophrys moratoii*; 5 = *Dendropsophus elianeae*; 6 = *D. minutus*; 7 = *D. nanus*; 8 = *Boana albopunctata*; 9 = *B. caingua*; 10 = *B. faber*; 11 = *B. lundii*; 12 = *B. raniceps*; 13 = *Oloolygon berthae*; 14 = *O. hiemalis*; 15 = *Phyllomedusa tetraploidea*.



Source: the author.



**Figure 3** - Species of amphibians registered at the Bauru region, São Paulo. 16 = *Pseudis platensis*; 17 = *Scinax fuscomarginatus*; 18 = *S. fuscovarius*; 19 = *S. similis*; 20 = *Trachycephalus typhonius*; 21 = *Crossodactylus caramaschii*; 22 = *Leptodactylus chaquensis*; 23 = *L. furnarius*; 24 = *L. fuscus*; 25 = *L. labyrinthicus*; 26 = *L. latrans*; 27 = *L. mystaceus*; 28 = *L. mystacinus*; 29 = *L. podicipinus*; 30 = *Physalaemus centralis*.



Source: the author.

**Figure 4** - Species of amphibians registered at the Bauru region, São Paulo. 31 = *Physalaemus cuvieri*; 32 = *P. marmoratus*; 33 = *P. nattereri*; 34 = *Pseudopaludicola mystacalis*; 35 = *Chiasmocleis albopunctata*; 36 = *Elachistocleis cesarii*; 37 = *Siphonops paulensis*.

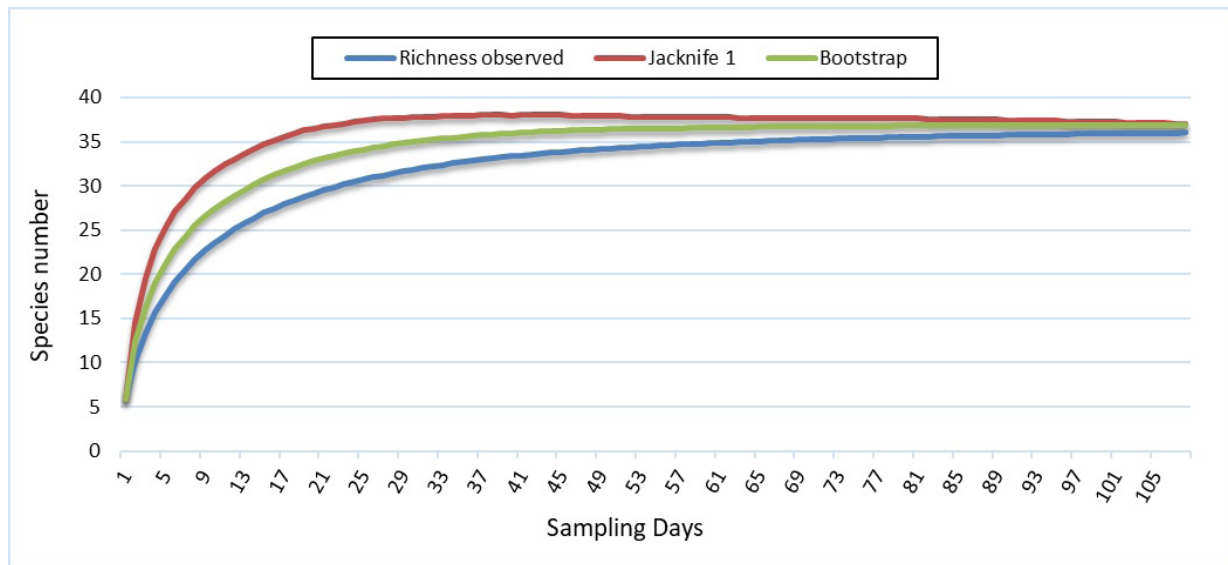


Source: the author.

The richness observed (n=36) was close to the richness pointed by the *Jackknife 1* (36.99) and *Bootstrap* (36.82) estimators (36.82) and the proximity in the results indicates that the sampling

was efficient and representative for the region. The curves of richness stabilized, forming an asymptote, indicating that the observed richness is very close to the real richness (Figure 5).

**Figure 5** - Accumulative curve of species, representing the cumulative richness of amphibians species and the richness observed for the sampling of anurans on the Bauru region, São Paulo.



Source: the author.

The species with higher abundance in the study were *Dendropsophus minutus*, *D. nanus*, *Boana albopunctatus*, *B. caingua*, *Scinax fuscumarginatus*, *S. fuscovarius*, *Physalaemus cuvieri* and *Leptodactylus podicipinus*, which represent 71.12% of the total registered individuals. With special attention to *D. nanus*, which represented

27.84% of the total registered individuals, with 800 individuals. *Odontophrynus americanus*, *Proceratophrys moratoii*, *Dendropsophus elianae*, *B. faber*, *B. raniceps*, *Crossodactylus caramaschii*, *L. chaquensis* and *L. latrans* were little abundant, with less than 11 individuals observed along the study (Table 3).

**Table 3** - Abundance of the anuran species registered at the Bauru region. CA = class of abundance: (1) <5; (2) 5-10; (3) 11-20; (4) 21-50; (5) 50-100 and (6) >100.

Species	CA	Localities								TI
		1	2	3	4	5	6	7	8	
<i>Rhinella ornata</i>	4	20	11	4	0	4	3	0	5	47
<i>Rhinella diptycha</i>	4	5	4	2	15	0	3	8	1	38
<i>Odontophrynus americanus</i>	2	0	0	0	0	0	10	0	0	10
<i>Proceratophrys moratoii</i>	2	8	0	0	0	0	0	0	0	8
<i>Dendropsophus elianae</i>	2	0	0	2	0	2	1	3	0	8
<i>Dendropsophus minutus</i>	6	21	2	66	56	20	0	53	1	219
<i>Dendropsophus nanus</i>	6	190	110	180	200	0	0	96	30	812

Continues

Continuation

<i>Boana albopunctata</i>	6	87	30	12	50	5	0	11	50	250
<i>Boana caingua</i>	6	40	0	5	5	50	0	0	40	145
<i>Boana faber</i>	2	0	1	0	0	3	4	1	0	10
<i>Boana lundii</i>	4	1	0	0	0	20	9	0	7	40
<i>Boana raniceps</i>	3	0	0	0	4	0	0	5	0	11
<i>Ololygon berthae</i>	3	0	0	10	4	0	0	0	0	16
<i>Ololygon hiemalis</i>	3	0	0	0	0	0	0	0	17	20
<i>Phyllomedusa tetraploidea</i>	4	0	0	0	0	16	0	2	1	22
<i>Pseudis platensis</i>	4	0	0	0	13	0	0	5	0	21
<i>Scinax fuscomarginatus</i>	6	0	40	10	35	0	0	65	0	155
<i>Scinax fuscovarius</i>	6	35	1	46	35	15	11	30	1	178
<i>Scinax similis</i>	5	2	0	10	61	0	0	4	0	82
<i>Trachycephalus typhonius</i>	4	0	5	0	10	0	0	20	2	40
<i>Crossodactylus caramaschii</i>	1	0	0	0	2	2	0	0	0	5
<i>Physalaemus centralis</i>	3	0	0	2	2	0	0	8	0	14
<i>Physalaemus cuvieri</i>	6	26	8	17	48	9	0	35	10	157
<i>Physalaemus marmoratus</i>	3	0	0	10	7	0	0	0	0	19
<i>Physalaemus nattereri</i>	4	1	0	9	0	5	0	10	1	28
<i>Leptodactylus chaquensis</i>	1	1	0	0	0	0	0	2	0	4
<i>Leptodactylus furnarius</i>	4	0	0	10	0	0	0	10	0	22
<i>Leptodactylus fuscus</i>	5	13	4	8	18	3	0	35	2	87
<i>Leptodactylus labyrinthicus</i>	3	1	1	1	0	0	0	8	0	13
<i>Leptodactylus latrans</i>	1	0	0	1	0	0	0	0	0	2
<i>Leptodactylus mystaceus</i>	3	0	0	0	10	1	0	4	0	17
<i>Leptodactylus mystacinus</i>	5	10	5	10	10	15	0	20	1	74
<i>Leptodactylus podicipinus</i>	6	10	30	6	101	0	0	5	0	158
<i>Pseudopaludicola mystacalis</i>	5	0	0	0	50	0	0	15	0	69
<i>Chiasmocleis albopunctata</i>	3	0	0	0	11	0	0	2	0	16
<i>Elachistocleis cesarii</i>	5	5	0	2	34	3	0	43	8	99

Source: the author.

The peak activity of anurans vocalization was concentrated during the rainy season, between the months September and February (Table 4). Only *D. minutus*, *B. caingua* and *B. lundii* showed

vocalization activity during the whole year. However, the peak activity of these species was concentrated during the rainy period. *R. ornata* and *O. hiemalis* showed peak activity during the dry season.

**Table 4** - Temporal distribution of the anuran species registered at the Bauru region. The blank spaces means that the species was not detected in the period.

■ = in vocalization activity; ■ = not in vocalization activity.

Species	J	F	M	A	M	J	J	A	S	O	N	D
<i>Rhinella ornata</i>	■	■	■	■	■	■	■	■	■	■	■	■
<i>Rhinella diptycha</i>	■		■	■		■		■	■	■	■	■
<i>Odontophrynus americanus</i>					■				■			
<i>Proceratophrys moratoi</i>	■											■
<i>Dendropsophus elianeae</i>	■			■								■
<i>Dendropsophus minutus</i>	■	■	■	■	■	■	■	■	■	■	■	■
<i>Dendropsophus nanus</i>	■	■	■	■		■	■	■	■	■	■	■
<i>Boana albopunctatus</i>	■	■	■	■		■	■	■	■	■	■	■
<i>Boana caingua</i>	■	■	■	■	■	■	■	■	■	■	■	■
<i>Boana faber</i>	■	■		■	■		■		■	■	■	■
<i>Boana lundii</i>	■	■	■	■	■	■	■	■	■	■	■	■
<i>Boana raniceps</i>	■									■	■	■
<i>Ololygon berthae</i>									■	■		■
<i>Ololygon hiemalis</i>	■	■	■	■	■	■	■	■	■		■	
<i>Phyllomedusa tetraploidea</i>	■								■	■	■	■
<i>Pseudis platensis</i>	■			■	■	■	■	■	■	■	■	■
<i>Scinax fuscomarginatus</i>	■	■	■						■	■	■	■
<i>Scinax fuscovarius</i>	■	■	■	■	■	■	■	■	■	■	■	■
<i>Scinax similis</i>	■	■							■	■	■	■
<i>Trachycephalus typhonius</i>	■									■		■
<i>Crossodactylus caramaschii</i>	■	■					■				■	■
<i>Physalaemus centralis</i>	■								■	■	■	■
<i>Physalaemus cuvieri</i>	■	■						■	■	■	■	■
<i>Physalaemus marmoratus</i>									■	■		■
<i>Physalaemus nattereri</i>				■					■	■	■	■
<i>Leptodactylus chaquensis</i>	■		■		■				■	■	■	■
<i>Leptodactylus furnarius</i>	■	■					■	■	■			
<i>Leptodactylus fuscus</i>	■	■						■	■	■	■	■
<i>Leptodactylus labyrinthicus</i>	■	■	■	■	■	■	■	■	■	■	■	■
<i>Leptodactylus latrans</i>								■				
<i>Leptodactylus mystaceus</i>		■								■	■	■
<i>Leptodactylus mystacinus</i>	■	■							■	■	■	■
<i>Leptodactylus podicipinus</i>	■	■	■	■	■	■	■	■	■	■	■	■
<i>Pseudopaludicola mystacalis</i>	■	■							■	■	■	■
<i>Chiasmocleis albopunctata</i>		■										■
<i>Elachistocleis cesarii</i>	■	■	■						■	■	■	■

Source: the author.

Among the aquatic environments occupied by the anurans at the Bauru region, only four species were exclusive to water bodies inside the forest: *B. lundii*, *O. hiemalis*, *C. caramaschii* and *L. mystaceus*, which represented 11% of the registered species. The other remained divided between species that used exclusively, during the vocalization

activity, water bodies on open areas (44.5%) and species that used water bodies inside the forest and on open areas (44.5%).

In comparison to other regions of the state, situated in areas of Cerrado and Atlantic Forest, Bauru resemble with the northwestern region of the state with 0.72% in species composition (Figure 6).

**Figure 6** - Similarity between the Bauru region and nine other regions of the state of São Paulo, based on the species composition. Abbreviations: northwest of the state = NWS; Botucatu region = BTR; Lençóis Paulista = LP; Itirapina = IT; Assis Ecological Station = AES; Caetetus Ecological Station = CES; Jataí Ecological Station = JET; Morro do Diabo State Park = MDST; Furnas do Bom Jesus State Park = FBJSP.



Source: the author.

## Discussion

The amphibians of the Bauru region represent 15.61% of the species of the state of São Paulo.<sup>(2-3)</sup> From the 14 amphibians families occurring in the state, seven were registered at the Bauru region.

Taking into consideration the occurrence of the species in the state of São Paulo, on the Bauru region there was a predominance of species that presented distribution on the center-western region, with 16 of the 37 registered species. Twelve have

occurred in all of the state, eight have occurred in the center-eastern region and only *P. moratoi* have occurred in the central area of the state. There were interesting records of *L. chachensis*, widening the species' area of occurrence to the central region of the state, and from *C. caramaschii*, that presented distribution mainly to the eastern region of the state, in areas of tropical rain forest, and it was registered in this study in a Cerrado area.

Taking into consideration the type of occupied phytophysiognomy, there was a predominance of generalist species (species with wide geographic

distribution and that occupying open and forest environments), with 23 that have been registered on the main existent vegetable formations of the state (Cerrado, Semideciduous Seasonal Forest and Tropical Rainforest). Only *P. moratoii* is endemic to the Cerrado biome. The other species registered in the study have occurred in more than one type of vegetable formation, between areas of Cerrado and Atlantic Forest.

Among the registered species, *Oloolygon hiemalis* is endemic to the state of São Paulo and *Proceratophrys moratoii* shows restricted occurrence to Cerrado dominated areas.<sup>(46-47)</sup> *Oloolygon hiemalis* occurs only on streams at Atlantic Forest areas,<sup>(37, 39, 43, 48-50)</sup> however, in this work, *Oloolygon hiemalis* was registered in a stream situated inside a Cerradão fragment, being the first register of the species to this biome.

*Proceratophrys moratoii* is cited in the National List of Brazilian Fauna Species in Threat of Extinction at the category "in danger".<sup>(29)</sup> The species was included at the List of Threatened Species of the State of São Paulo,<sup>(30)</sup> however, thanks to the new registrations of *P. moratoii* populations,<sup>(46-47)</sup> it has been removed from the list. In the IUCN Red List of Threatened Species, is appointed that Critically Endangered.<sup>(31)</sup> It is important to mention that the species disappearance from the type locality, by anthropogenic environmental changes.<sup>(51)</sup>

The abundance indexes resemble those of the Botucatu region, where the most abundant species were also *P. cuvieri*, *D. nanus*, *S. fuscovarius*, *D. minutus* and *B. albopunctatus*, differentiating regarding *B. caingua* and *L. podicipinus*, that presented the lowest abundance regarding the Bauru region.<sup>(37)</sup> Regarding the northwestern region of the state,<sup>(36)</sup> it was observed that there is also great resemblance considering the most abundant species, because *D. minutus*, *D. nanus*, *S. fuscocomarginatus*, *P. cuvieri* and *L. podicipinus* were abundant, as in the Bauru region. However, species like *D. elianeae* and *P. nattererii*, which showed high abundance to the northwestern region of the state, weren't abundant in the Bauru region.

The activity pattern of the amphibian species is also observed for all the central-western region of the state, that presents two well defined seasons, one hot and rainy and other cold and dry, as in the Bauru region (Table 4). The Bauru region showed an equal number of species as the northwestern region of the state.<sup>(2, 36)</sup> However, it showed a lower richness in comparison to the Botucatu region, which has 52 species of amphibians. It is possible to observe that the farther the region is from the east of the state of São Paulo, lower or absent is the number of species with peak activity during the dry season. The Botucatu region shows five species with reproductive peak activity during the coldest and driest period of the year.<sup>(37)</sup> In this study, there were registered only two species with peak activity during this period. But on the northwestern region, there are no registrations of species with reproductive peak activity during the driest period of the year.<sup>(28, 52)</sup> This difference occurs mainly because of the relative air humidity indexes, that get to very low levels during the driest period of the year in the central-western region of the state, and that possibly influence the occurrence of species with the activity concentrated during this period of the year.

At the Botucatu region, there is a higher number of forest exclusive species, with 6 species (*Haddadus binotatus*, *Hyalinobatrachium uranoscopum*, *Proceratophrys boiei*, *Bokermannohyla izecksohni*, *Oloolygon hiemalis* and *Crossodactylus caramaschii*).<sup>(37)</sup> But on the northwestern region there is only the registration of two species (*Boana lundii*, *Leptodactylus mystaceus*) associated to water bodies inside or at the border of the forest during the vocalization activity.<sup>(36)</sup> The Botucatu's forest exclusive species are typical to humid physiognomies of Atlantic Forest, which shows a higher influence of this biome over the Botucatu region, in comparison to the Bauru region and state's northwestern regions.

The difference and resemblance of the composition of amphibians (Figure 3) among other sampled regions of the state of São Paulo are due to the environmental heterogeneity, which is higher

at the Botucatu region,<sup>(37, 50)</sup> and similar between the northwestern<sup>(52)</sup> and Bauru region. Other factors that influence a lot on the richness difference among these regions are: climate, level of degradation and fragmentation, relief and phytophysiology. According to Ab'Sáber,<sup>(53)</sup> the temperature indexes are slightly crescents from the central-south to the north and northwest and from east to the west of the state of São Paulo. Regarding the rainfall, the west tablelands of the state presented the lowest indexes of rainfall (1,000 to 1,100 mm annually), while the other extensions of the interior highlands present precipitations that vary from 1,300 to 1,800 mm annually.

The Bauru and state's northwestern regions show higher temperatures and lower rainfall indexes, especially during the dry season,<sup>(52, 53, 55)</sup> diverging the Botucatu region, which has milder temperatures.<sup>(54)</sup> The tropical climates of humid summer and dry winter (Aw) has its dominant area in a large zone from the extreme northwest and north of the state, exactly where there is made a more direct transition to the peculiar climate types and huge areas of Central Brazil in the "Cerrado's Domain".<sup>(24)</sup> The original vegetable formation was constituted of Semideciduous Seasonal Forest in the northwestern region, which was practically substituted by areas of pasture.<sup>(52)</sup> The vegetation of Bauru and state's northwestern region's is characterized by Forest Savannah (Cerradão) and Semideciduous Seasonal Forest fragments<sup>(4)</sup> diverging the Botucatu region, that is covered by different vegetable formations, like broadleaf tropical forest, slope tropical forest, slope mesophilic semideciduous forest and different degrees of Cerrado.<sup>(54)</sup>

According to analysis made by Vasconcelos *et al.*<sup>(56)</sup> the species richness is associated to the climate and altitude, and the factor the directly influences the richness of species of a region is the annual rainfall index. The precipitation and air's relative humidity are deeply related to the amphibians' biology, which rely on these factors for reproduction and survival.<sup>(56)</sup> For regions under the dominance of the Cerrado and Semideciduous

Seasonal Forest, the species' richness is also deeply associated to the annual rainfall concentration.<sup>(56)</sup> The factors pointed out by Vasconcelos *et al.*,<sup>(56)</sup> possibly regulate the occurrence of amphibian species in the Bauru region. At the Bauru region there are those two vegetable formations, which conclude that the annual rainfall affects the presence of the amphibians' presence in the region.

These morphoclimatic differences between Bauru and the other regions influence a lot in the species' composition of each place. Especially the temperature and humidity factors, that allow or not the occurrence of a certain species in a certain region. This happens because of the differences in the adaptive conditions and environmental plasticity of each species, regarding the habitat occupied by the larva and the adult and regarding the reproductive mode and its biological needs.

The amphibians' community of the Bauru region shows its own characteristics and is adapted to the morphoclimatic conditions, the environmental heterogeneity and the conservation of the natural resources that reflect directly on the composition, abundance and spatial and temporal distribution pattern of the amphibian species present at the region.

The richness of amphibians of the Bauru region is significant for the state of São Paulo and the region contributes with the maintenance of environments with conditions for the occurrence of *Proceratophrys moratoii*, which is considered in threat of extinction. This study contributed with the filling gap on the amphibian knowledge of the state of São Paulo, because the Bauru region is situated in an area appointed by Rossa-Feres *et al.*<sup>(3)</sup> as with little knowledge of the anuran's fauna.

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