

How riparian forest integrity influences anuran species composition: a case study in the Southern Brazil Atlantic Forest

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Abstract

How riparian forest integrity influences anuran species composition: a case study in the Southern Brazil Atlantic Forest. Riparian forests are under legal protection in Brazil and provide essential ecosystem services yet have been historically degraded and reduced by deforestation. Consequently, the fauna of these riparian forests and associated ecosystems can be strongly affected, as is the case with amphibians. In this study we identify how anuran species composition varies in riparian forests with various levels of environmental integrity. The study took place in the Fritz Plaumann State Park (FPSP), a protected area with forest formations typical of the Southern Atlantic Forest. Our results suggest that the environmental integrity of the sampling sites influenced where each species was found. The most preserved habitats, with large areas of riparian forest and fewer anthropic impacts, promoted greater species diversity and allowed for the maintenance of species with specific environmental requirements. Two species registered are on the list of endangered amphibians (*Boana curupi* and *Vitreorana uranoscopa*) and one is an exotic invasive species (*Lithobates catesbeianus*). Because it preys on native amphibians and may act as a pathogen vector, this species is a potential threat to the native amphibian populations inside the park. Even though large portions of the FPSP consist of forests in a secondary stage of succession, the connection with better-preserved areas of primary forest allows for the general occurrence of more demanding species that are usually associated with well-preserved habitats. On a regional level, these habitats occur only inside the park and in their absence, these species will most likely become locally or regionally extinct.

Key words: Conservation, Protected area, Environmental integrity, Richness, Invasive species

Resumen

Cómo influye la integridad de los bosques ribereños en la composición de especies de anuros: un estudio práctico en el bosque Atlántico del sur del Brasil. Los bosques ribereños, que en Brasil están protegidos por la ley, proporcionan servicios ecosistémicos esenciales, a pesar de que, tradicionalmente, la deforestación ha conllevado su degradación y reducción. En consecuencia, la fauna de estos bosques ribereños y los ecosistemas asociados puede verse gravemente afectada, como en el caso de los anfibios. En este estudio, determinamos la composición de especies de anuros en bosques ribereños con varios grados de integridad ambiental. El estudio se llevó a cabo en el Parque Estatal Fritz Plaumann, un área protegida con formaciones forestales típicas del bosque atlántico meridional. Nuestros resultados sugieren que la integridad ambiental de los sitios de muestreo influyó en el lugar en que se encontró cada especie. Los hábitats más conservados, con grandes superficies de bosque ribereño y un impacto antrópico escaso, propiciaron la presencia de una mayor diversidad de especies y permitieron mantener especies con necesidades ambientales específicas. Dos de las especies registradas figuran en la lista de anfibios en peligro de extinción (*Boana curupi* y *Vitreorana uranoscopa*) y otra es una especie invasora exótica (*Lithobates catesbeianus*). Debido a que se alimenta de anfibios autóctonos y puede actuar como un vector de patógenos, esta especie representa una amenaza potencial para las poblaciones de anfibios autóctonos dentro del parque. Incluso aunque grandes extensiones del Parque Estatal Fritz Plaumann estén cubiertas por bosques en el segundo estadio de sucesión, la conexión



con áreas mejor conservadas de bosque primario permite la presencia general de especies más exigentes, que se suelen asociar a hábitats bien conservados. A escala regional, estos hábitats solo se encuentran dentro del parque y, en su ausencia, lo más probable es que estas especies se extingan a escala local o regional.

Palabras clave: Conservación, Área protegida, Integridad ambiental, Riqueza, Especie invasora

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Introduction

As a consequence of intense deforestation and fragmentation, over 70 % of its original area of the Atlantic Forest biome is degraded, and approximately 65 % was affected by anthropic activities (Almeida, 2016; Rezende et al., 2018). The intensity of this degradation, when considered along with the high biodiversity and endemism levels of the Atlantic Forest, make it a priority ecosystem for conservation (Myers et al., 2000). In the southern portion of the Atlantic Forest, and more specifically in western Santa Catarina and northern Rio Grande do Sul, habitat deforestation and fragmentation has increased because of logging, agricultural and livestock activities (Santa Catarina, 2014). Because of the historical conditions of soil use, there was a sharp reduction in forest cover including those forests associated with water bodies, the riparian forests (Durigan and Engel, 2012; Santa Catarina, 2014).

Riparian forests provide ecological protection for lotic water bodies like streams and rivers, promoting the structuring of firm soil and decreasing erosion (Silva et al., 2017). The preservation of riparian forests is also related to increased water quality and environmental complexity of aquatic habitats (Cabette et al., 2017). In regions where the landscape is highly fragmented, riparian forests also function as faunal refuges or ecological corridors between forest fragments (Tanaka et al., 2016). In Brazil, riparian forests are protected by law. The width of the Permanent Preservation Areas (PPAs) around water bodies ranges from 30 to 600 m. However, the Native Vegetation Protection Law of Brazil (Brasil, 2012) includes exceptional cases that allow for riparian forests as small as 5 m around water bodies.

Despite the fact that they are under legal protection and provide essential ecosystem services, riparian forests nevertheless have been historically degraded and reduced by deforestation (Ricci, 2013). Because of anthropic influences and reduction of the riparian forests, watercourses become prone to contamination and siltation (Parron et al., 2015). Consequently, the fauna of these riparian forests and associated ecosystems can be strongly affected, as is the case with amphibians (Toledo et al., 2010).

The structure of the riparian forest influences the reproduction and conservation of many species of anurans that use these areas for reproduction and shelter (Ricci, 2013). In the context of degradation and contamination of water bodies, anuran dependence on water for reproduction may result in rapid declines of population sizes, or even in local species extinctions (Antonini and Martins, 2016). Furthermore, factors such as changes in forest size, presence of ponds and canopy cover may also influence the distribution of anurans in these riparian forests (Crema et al., 2014; Toledo, 2009).

Anurans often exhibit fidelity to a reproductive site and have life cycles restricted to aquatic environments (Toledo et al., 2010). Because they respond to changes in the structure of water bodies and the landscape associated with them, anurans are considered good biological indicators of environmental quality (Toledo,

2009; Ribeiro et al., 2012; Gonçalves et al., 2015). It is therefore important to understand how species richness and composition vary in habitats with various degrees of environmental integrity, because this understanding allows for the identification of priority areas for conservation and restoration (Harper et al., 2005).

The preservation of biodiversity in the Atlantic Forest is strongly dependent on the number and size of the remaining forest fragments (Colombo et al., 2008; Toledo et al., 2010) and on the anthropic activities in the areas surrounding these fragments. In southern Brazil, large forest areas with little anthropic activity are usually restricted to protected areas (PA). However, only 9% of the remaining areas of Atlantic Forest are situated within fully-protected areas (Rezende et al., 2018), and most of these areas are strongly influenced by surrounding anthropic activities.

Given this scenario, the goal of this study was to identify how anuran species composition, diversity and richness varies in areas of riparian forest with various levels of environmental integrity, in a region of subtropical forest in Southern Brazil. We addressed the following question: is there variation in species composition, diversity and richness among riparian forest with various levels of environmental integrity? We predicted that species composition and diversity would be different among levels of environmental integrity, with most disturbed habitats occupied by more generalist species and the least disturbed habitats having the most specific species. Based on predictions of the intermediate disturbance hypothesis, and considering the levels of environmental integrity, we also predicted that species richness would be greatest at an intermediate level of landscape complexity (Connell, 1978).

Material and methods

Study site

The study was developed in the Fritz Plaumann State Park (27° 17' 26" S, 52° 06' 51" W) and its surrounding regions, comprising an area referred to as the Buffer Zone in the park's management plan (Santa Catarina, 2014). The FPSP is a protected area located in western Santa Catarina state, at the border with the state of Rio Grande do Sul, from which it is separated by the Uruguay River (fig. 1). The park was created as a compensatory measure for the area flooded by the Itá Hydroelectric Plant reservoir and its main goal is to protect an important remnant of the Deciduous Seasonal Forest of the Atlantic Forest.

The FPSP has a crucial role in connecting other protected areas of the Santa Catarina (the National Forest of Chapecó and the Araucarias National Park) and Rio Grande do Sul states (Teixeira Soares Municipal Park). The area surrounding the FPSP is mostly occupied by farmers, whose economic activities rely importantly on small-scale and/or subsistence agriculture, with various types of soil use (Santa Catarina, 2014). These characteristics make the FPSP a high-priority site for studies regarding regional

biodiversity, and the impacts of anthropic activities in species conservation. The park has an area of de 717.48 ha, including an insular environment of 260 ha. The vegetation is composed of subtropical Atlantic semi-deciduous forests (Oliveira-Filho et al., 2013). The mosaic of forest fragments in the FPSP comprises areas in the early, intermediate and advanced successional stages, as well as fragments of primary forest (Santa Catarina, 2014)

The buffer zone surrounding the park has an area of 1,778 ha. It is considered a strategic area for sustainable rural development, where agricultural and livestock activities occupy approximately 58% of its total area, including pastures, forestry, pig farming, temporary and/or permanent crops, and yerba mate plantations. As the result of agricultural activities and land use, the Permanent Preservation Areas (PPAs) of the streams in the buffer zone include riparian forests of various sizes and levels of environmental integrity (Santa Catarina, 2014). The region has a humid mesothermal climate, without a well-defined dry season. The average yearly rainfall is of approximately 1,800 mm (Wrege et al., 2012).

Data sampling

We established four sampling areas representing the structures of the riparian forests associated with regional streams, two inside the FPSP and two in the surrounding buffer zone area (fig. 1). We chose the following factors in the selection process: riparian forest width, recuperation efforts for the riparian forest and land use/occupation in the area surrounding the stream, according to the information available in the park management plan (Santa Catarina, 2014).

Area 1 (A1) and Area 2 (A2) are located along the Lajeado Cruzeiro stream, in the buffer zone of the park. Area 3 (A3) and Area 4 (A4) are located inside the FPSP, A3 along the Lajeado Cruzeiro stream, and A4 along the Canafístula stream in the most well-preserved area of the park (fig. 1; Santa Catarina, 2014). The Lajeado Cruzeiro stream is a second order stream that runs through the park. It is approximately 5 km long, with a width ranging from 2 m near its source to 10 m near its mouth at the Queimados River, in the wetlands around the Itá HPP. The Canafístula stream is a first order stream that originates inside the FPSP and is an affluent of the Lajeado Cruzeiro stream. It is approximately 3 km long with a width ranging between 1 and 5 m (Santa Catarina, 2014).

Regarding the sampling sites, A1 (27° 17' 21" S, 52° 05' 28" W) has a riparian forest of approximately 10 m on each side of the stream. It supports agricultural and livestock activities, with pig farming waste being dumped directly into the stream. The only recuperation effort in this area has been the presence of fences, installed in 2013 to protect the stream margins from trampling and grazing by cattle. The A2 site (27° 7' 24" S, 52° 06' 09" W) exhibits a riparian forest of approximately 20 m on each side of the stream, with a fence similar to that of A1 installed in 2015. In addition to fencing, other actions were undertaken to accelerate recuperation of the area, including the

planting of native trees. The A3 site (27° 17' 21" S, 52° 06' 58" W) is characterized by a riparian forest of approximately 50 m on each side of the stream. This forest is in an intermediate succession stage, because anthropic activities ceased after the park was created in 2003. Finally, the A4 site (27° 17' 38" S, 52° 06' 40" W) consists of more than 100 m of riparian forest, mostly comprised of forest in advanced succession stages, with patches of primary forest in between. This area has been subjected to very little exploration and alteration, and occasional low-intensity logging. All sampling sites are situated at least 700 m away from one another (Santa Catarina, 2014).

Samplings were carried out from November 2017 to April 2018, including the reproductive season of most anuran species that occur in the region (Bastiani and Lucas, 2013). To quantify species richness and the number of anuran individuals, we established linear transects of 150 m in each sampling site along the streams. The transects were traversed from twilight (~20:00 h) until approximately 24:00 h. Each site was sampled at least eight times: A1, N = 10 (total of 22 h); A2, N = 9 (21 h); A3 (19 h) and A4, N = 8 (20 h). Whenever possible, we sampled two sites per night, always alternating the order in which they were sampled.

We recorded all individuals sighted and heard, in a distance of up to five meters from the stream margins, and photographed them whenever possible. The limit of five meters was established to exclude the recording of species that are not ecologically associated with streams. For each individual, we recorded the species and the substrate used (Hartmann et al., 2010). Species were identified at the sampling site, whenever possible, or via the photographs taken (Research Authorization n° 60637-1-SISBIO and AUA n°14/2017 GERUC/DPEC-FATMA). The taxonomic nomenclature and classification followed the List of Brazilian Species, organized by the Brazilian Society of Herpetology (Segalla et al., 2019).

To evaluate the level of environmental integrity of the streams at each sampling site (A1, A2, A3 and A4), we applied the rapid river assessment protocol (RAP). This protocol was modified from the RAP proposed by Callisto et al. (2002), combined with information from the protocols of Minatti-Ferreira and Beaumord (2006); Rodrigues and Castro (2008); and Rodrigues et al. (2012). The RAP uses categories of habitat alterations such as anthropic alterations, presence of aquatic plants, type of stream bank occupation, presence and size of riparian forest, water and sediment traits, erosion and siltation, plant cover, stream width, and number of riffle/pool areas in the stream. Higher scores reflect better levels of environmental integrity, whereas lower scores suggest degradation. The classification regarding environmental integrity of the streams evaluated used the following score values: 0–40 points = impacted; 41–60 = altered; 60 or more = natural (Callisto et al., 2002). The RAP results were used for analysis considering the various environmental integrities of the sampling sites.

We classified the anuran species according to habitat use and conservation status. To determine the

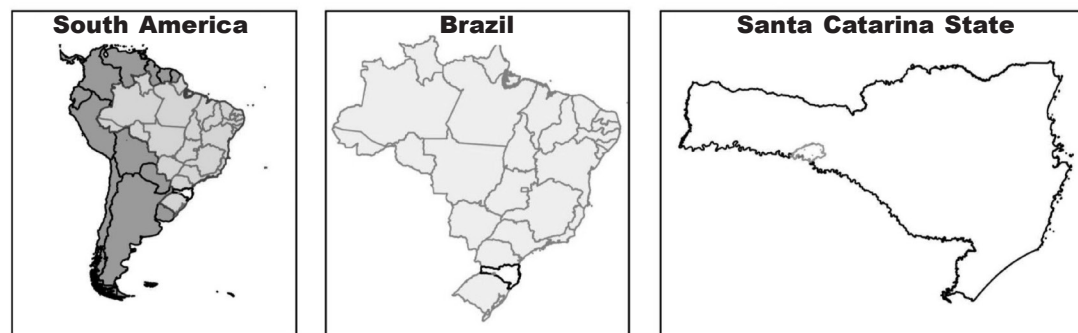
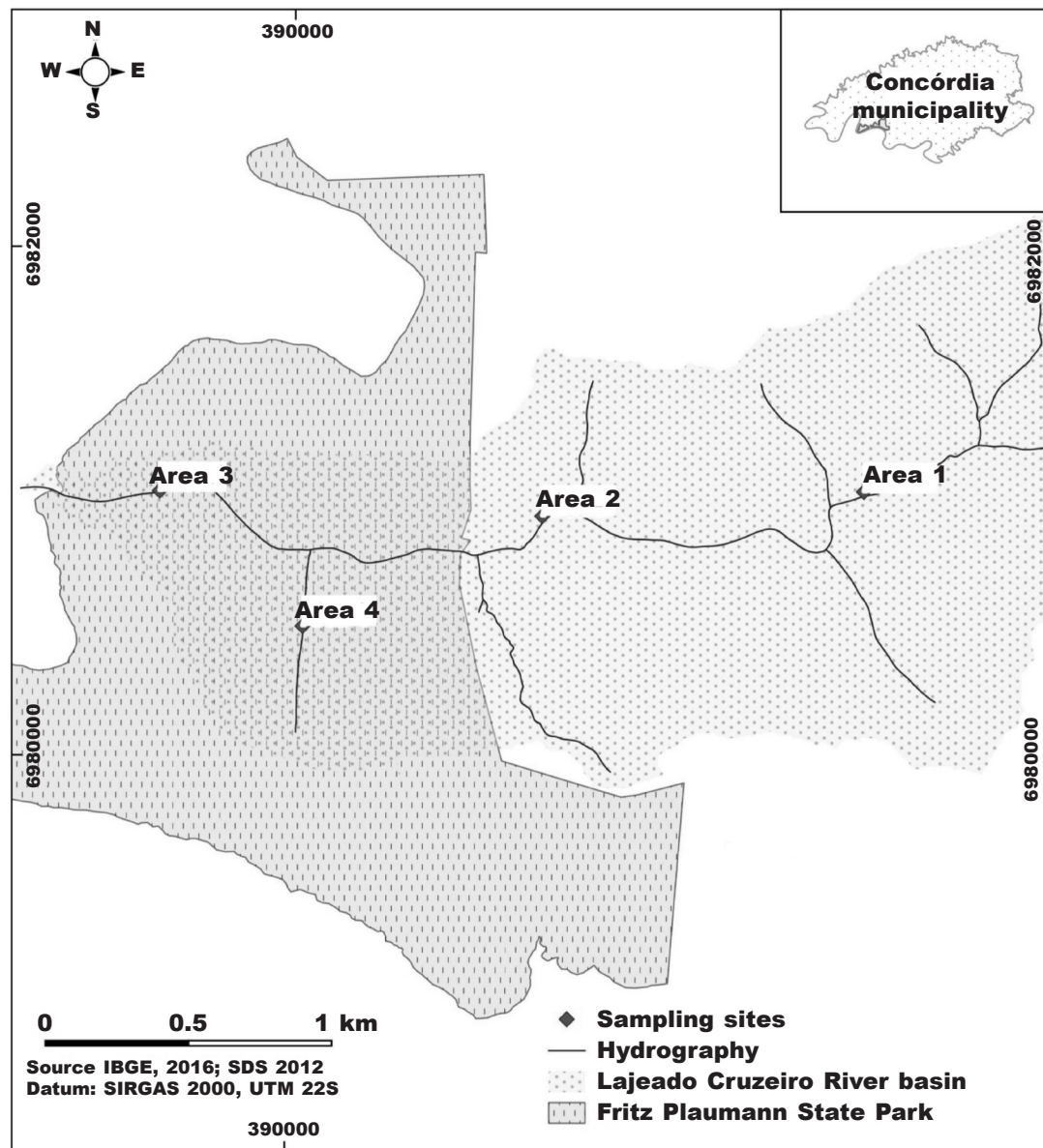


Fig. 1. Map of the study area showing the four sampling sites, two along the Lajeado Cruzeiro stream, into the buffer zone, and two inside the Fritz Plaumann State Park (FPSP), Southern Brazil Atlantic Forest.

Fig. 1. Mapa de la zona del estudio en el que se muestran los cuatro sitios de muestreo: dos a lo largo del arroyo Lajeado Cruzeiro, en la zona de transición, y dos dentro del Parque Estatal Fritz Plaumann (FPSP), en el bosque atlántico del sur del Brasil.

habitat use categories, we used data from the literature (specifically: Haddad, 1998; Heyer et al., 1998; Hartmann et al., 2010; Bastiani and Lucas, 2013). Regarding habitat use, we considered the following categories: broad (Br, uses a variety of different habitats, including anthropic areas), forest (Fo, typical of inside the forest), forest edge (FE; uses primarily forest borders), permanent ponds (PP, uses water bodies that hold water all year round), and temporary ponds (TP, typical of annual water bodies with dry phase of variable timing and duration). For conservation status, we consulted the IUCN Red List of Threatened Species (IUCN, 2019), The Red Book of the Endangered Brazilian Fauna: Volume V: Amphibians (Brazilian list; ICMBIO, 2018), and the CONSEMA Resolution number 002, from December 6th 2011 (Santa Catarina State list; CONSEMA, 2011).

Data analysis

To estimate species richness and determine sample sufficiency, we used the Jack1 and Chao1 richness estimators (Chao et al., 2015), with the sampling days used as sampling units (Magurran, 2011).

The comparisons between the sites with respect to richness (number of species recorded per site at each sampling), number of individuals (number of individuals recorder per site at each sampling) were made using one-way ANOVA, followed by a Tukey post-hoc test with a significance threshold of $P < 0.05$. We performed these analyses using Past 3.15 software (Hammer et al., 2001). We evaluated data normality and homogeneity using the Shapiro-Wilk and Bartlett tests, respectively. To assess similarity between sites, we use Jaccard's similarity coefficient (SJij). Whenever appropriate, the analyses were performed either among the four sampling sites (A1, A2, A3 and A4), or between the areas in the buffer zone (A1 and A2) and those inside the park (A3 and A4).

We compared the diversity among the sites using Shannon's H' index. To test if the H' values differed between sites, we used a t -test with a significance threshold of $P < 0.05$, performed using Past 3.15 software (Hammer et al., 2001). Finally, to test for differences in the RAP core between areas in the buffer zone and those inside the FPSP, we used a Chi-squared (χ^2) test.

Results

We recorded a total of ten anuran species belonging to seven families (table 1). Two of these species are on the list of endangered amphibians. *Boana curupi* is considered Endangered (EN) on the list for the Santa Catarina State (CONSEMA, 2011), and Vulnerable (VU) is on the Brazilian list (ICMBIO, 2018). *Vitreorana uranoscopa*, is listed as Vulnerable (VU) for the Santa Catarina State (CONSEMA, 2011). One of the species found (*Lithobates catesbeianus*) is exotic (Segalla et al., 2019).

The two richness estimators showed that over 80% of the richness estimated for the sampling sites was registered ($N_{(J1)} = 12.38 \pm 1.52$ species; Chao1 =

10 ± 0.16 species). The total number of anuran species registered corresponds to 45% of the anuran species known for the FPSP, considering all habitats ($N = 22$), and more than 90% of the stream species recorded for the park ($N = 11$; Bastiani and Lucas, 2013; Santa Catarina, 2014).

The RAP score was lowest in the buffer zone (A1 and A2) and highest inside the FPSP (A3 and A4; table 1). The two sites located in the buffer zone had scores that corresponded to altered habitats, while the two sites located inside the FPSP had scores corresponding to natural habitats. There was a significant difference between the RAP scores of areas in the buffer zone and those inside the FPSP ($\chi^2 = 9.04$, g.l. = 1, $p < 0.01$).

We registered seven species occurring inside the FPSP, and five in the buffer zone (fig. 2). There was a significant difference regarding the number of species found inside the FPSP and those found in the buffer zone ($F_{1,33} = 4.24$; $p = 0.04$). When considering all four sampling sites separately, we found that A2 had the highest number of species, followed by A4 and A3, and A1 (table 1). The difference in the number of species registered was only significant between A1 and A4 ($F_{3,31} = 3.62$; $p = 0.02$; Tukey test $p < 0.05$).

We registered 31 individuals inside the FPSP, and 19 in the buffer zone. There was no significant difference between the number of individuals recorded in the buffer zone and those inside the FPSP ($F_{1,33} = 3.76$; $p = 0.06$). The stream in A4 had the highest number of individuals reported, followed by A2, A3 and A1 (table 1). A significant difference for the number of individuals encountered was found only between sites A1 and A4 ($F_{3,31} = 2.83$; $p = 0.05$; Tukey test $p < 0.05$).

Species diversity was significantly higher inside the FPSP ($H' = 1.80$) than in the buffer zone ($H' = 1.39$; $p = 0.01$). The diversity index among the four sampling sites was highest for A4, followed by A2, A3 and A1 (table 1). All the comparisons between sites revealed significant differences (A1 x A3, $p = 0.02$; A1 x A4, $p = 0.01$; A2 x A3, $p = 0.02$; A2 x A4, $p = 0.01$), with the exception of the comparison between A1 and A2 ($p = 0.05$).

Of the ten species encountered, four occurred primarily in forest habitats, three in both forests and open areas, and another three in open habitats (table 1). The exotic species, *L. catesbeianus*, occurred in both the buffer zone and the FPSP. Nevertheless, the number of *L. catesbeianus* individuals found was higher in the altered habitats (A1 and A2, $N = 9$) than inside the FPSP (A3, $N = 1$).

Discussion

The highest values of species richness, number of individuals and species diversity reported for the most well-preserved streams, as well as the differences in species composition, support the hypothesis that well-preserved riparian forests harbor more diverse anurans communities than do impacted areas with reduced forest cover (Moraes et al., 2007; Crema

Table 1. Anuran species recorded at each sampling site in the Fritz Plaumann State Park (FPSP, A1 and A2) and in the buffer zone (A3 and A4), from November 2017 to April 2018. Habitat use: Br, broad; Fo, forest; FE, forest edge; PP, permanent ponds; TP, temporary ponds; * exotic species.

Tabla 1. Especies de anuros registradas por sitio de muestreo en el Parque Estatal Fritz Plaumann (A1 y A2) y en la zona de transición (A3 y A4), entre noviembre de 2017 y abril de 2018. Utilización del hábitat: Br, general; Fo, forestal; FE, márgenes de bosques; PP, embalses permanentes; TP, embalses temporales; * especie exótica.

Family / species	A1	A2	A3	A4	Habitat use
F. Brachycephalidae					
<i>Ischnocnema henselii</i> (Peters, 1872)				4	Fo, FE
F. Bufonidae					
<i>Melanophryniscus</i> sp.		1			Br, Fo
F. Centrolenidae					
<i>Vitreorana uranoscopa</i> (Müller, 1924)			5		Fo, FE
F. Hylidae					
<i>Boana curupi</i> (Garcia, Faivovich, Haddad, 2007)	4	1		6	Fo, FE
<i>Boana faber</i> (Wied, 1821)	1	1			Fo, FE, Br
<i>Dendropsophus minutus</i> (Peters, 1872)			5		Fo, FE, PP, TP, Br
<i>Oolygon aromothyella</i> (Faivovich, 2005)				2	Fo, FE, TP
F. Leiuperidae					
<i>Physalaemus</i> aff. <i>gracilis</i>		2			Br, FE, PP
F. Odontophrynidae					
<i>Proceratophrys bigibbosa</i> (Peters, 1872)				8	Fo, FE
F. Ranidae					
<i>Lithobates catesbeianus</i> (Shaw, 1802)*	1	8	1		PP, Br
Number of species	3	5	3	4	-
Number of individuals	6	13	11	20	-
RAP value	44	52	73	91	-
Diversity index (H')	0.50	1.25	0.93	1.27	-
Number of site-specific species	0	2	2	3	-

et al., 2014; Almeida–Gomes et al., 2014). Likewise, the difference regarding the number of species and number of individuals between the extremes (A1 and A4) appears to be related to the environmental integrity of each site. The extremes demonstrate a high level of structural differences, while the intermediate areas demonstrate transitional characteristics. Similarly to findings in other studies (Heyer et al., 1998; Moraes et al., 2007; Gonçalves et al., 2015), the species reported from the transition areas have the ability to occupy a wide range of habitats and are able to tolerate a moderate degree of environmental alterations.

The RAP provided a measure of disturbance intensity and allowed us to test the influence of the intermediate–disturbance hypothesis (Connell, 1978;

Shea et al., 2004). As predicted by the hypothesis, we found the most disturbed habitats were occupied by more generalist species (no single exclusive species in A1) whereas the least disturbed habitats had the most specific species (N = 3 in A4). Even so, the highest absolute number of species among the four sampling sites was found in A2 where some transitional characteristics between altered and well-preserved habitats were observed. A similar situation was reported in other studies, demonstrating that transition habitats, between forest and open habitats, often exhibit high environmental complexity, offering a variety of resources and physical conditions that may favor increased species richness levels for anurans (Conte and Rossa–Feres, 2007; Babbitt et al., 2009; Gonçalves et al., 2015). The intermediate

successional stages of secondary forests represent a similar context to that described above because they combine landscape elements typical of habitats in both early and late successional stages (Fox, 2013).

On the other hand, and not predicted by an intermediate–disturbance hypothesis, the number of species recorded showed a significant difference only between A1 and A4. That is, the sampling sites with intermediate values of disturbance intensity (A2 and A3) did not show a significant difference in number of species compared to the other sites. We found no clear gradient between the sampling sites regarding environmental integrity, thus reducing the effects of intermediate disturbance and increasing the characteristic of the extremes.

The difference in species composition that can be perceived in the low similarity between the sampling sites and by the higher number of species occurring inside the FPSP (compared to the buffer zone) suggests that the environmental integrity of the sampling sites played a role in areas where each species was found. Most species encountered inside the FPSP prefer forest habitats and often require specific habitat characteristics (Haddad, 1998; Bastiani and Lucas, 2013). Of the seven species reported inside the FPSP, four (*V. uranoscopa*, *B. curupi*, *Ischnocnema henseli* and *Proceratophrys bigibbosa*) are considered typical of forest areas (Bastiani and Lucas, 2013). Two other species (*Dendropsophus minutus* and *Ololygon aromothyella*) were found in forest habitats, but they may also occur in other habitats such as temporary or permanent ponds (Bastiani and Lucas, 2013; Haddad, 1998). Of the five species found in the buffer zone, four may occur in forest edges and permanent or temporary ponds (*L. catesbeianus*, *Melanophryniscus* sp. and *Physalaemus aff. gracilis* and *Boana faber*). These findings suggest that anuran species typical of forests appear to depend on environmentally preserved areas. In contrast, most species found in the surrounding buffer zone exhibit greater environmental plasticity, or are typical of open areas, and are more tolerant to altered habitats (Oliveira et al., 2007).

Interestingly, although *B. curupi* is usually associated with forest habitats (Bastiani and Lucas, 2013; Bastiani et al., 2016), it occurred in three of the four sampling sites, including A1, despite this being the most altered site. This demonstrates that although this species prefers forest areas it can potentially occur in locations with different environmental integrity (Bastiani and Lucas, 2013) as long as the vegetation cover is not completely altered. The A4 site exhibited the best habitat conditions for anurans, and was the place where *B. curupi* was most often found. Populations of *B. curupi* are currently in decline because of continuous reduction in habitat area, extension, and quality (CONSEMA, 2011; ICMBIO, 2018).

The exotic invasive species, *L. catesbeianus*, was found in an area considered a natural habitat, despite being usually associated with lentic waters and open areas (Descamps and Vocht, 2016). *Lithobates catesbeianus* can be associated with A3 due to dispersion along the Lajeado Cruzeiro stream. It is not present in the A4 (Canafistula stream), probably

due to the lack of connection of this stream with the environments outside the park. Because it preys on native amphibians and may act as a pathogen vector, this species is a potential threat to the local amphibian fauna (Madalozzo et al., 2016). This amphibian currently occurs in approximately 136 municipalities in Brazil, mostly in the south and southeastern regions of the Atlantic Forest biome. The broad distribution of this species represents a conservation challenge, especially if we consider that invasive anurans might be related to the decline of the native anuran fauna (Both et al., 2011). Furthermore, *L. catesbeianus* may occupy permanent water bodies in the cropland–border–forest gradients that may increase the potential of this species to spread through the forest matrix, allowing it to invade protected areas (Madalozzo et al., 2016). It is estimated that 87.5% of the protected Atlantic Forest areas might be subject to invasion by *L. catesbeianus* (Barbosa et al., 2017). The occurrence of this species inside the FPSP may represent a risk to the maintenance of native amphibian populations inside the park.

According to the Native Vegetation Protection Law of Brazil (Brasil, 2012) all marginal bands of any natural watercourse from the channel edge of the regular bed are considered as Permanent Preservation Areas (PPAs). The mandatory width of natural marginal bands ranges from 30 to 600 m, depending of the width of the watercourse. However, in consolidated areas (i.e. with anthropic occupation pre-existing July 22nd, 2008) the same law permits marginal bands ranging 5 m, according to the size of the rural property in Fiscal Modules. As most properties in the buffer zone are smallholdings or rural family holdings, almost all riparian forest along the Lajeado Cruzeiro stream had widths of less than 30 m on each side of the stream.

If the minimum width of natural marginal bands, such as riparian forests (30 m; Brasil, 2012), appears to be insufficient to maintain anuran diversity (Toledo et al., 2010; this study), this will clearly be a major concern in cases that allow for riparian forests as small as 5 m around water bodies. Furthermore, not only the width, but also too low levels of environmental integrity of the riparian forest, as we demonstrate here, can reduce the overall number of species and determine which species will occur in streams and surroundings.

This study shows the importance of the preserving riparian forests for the maintenance of amphibian populations, both inside and outside the FPSP. The most preserved habitats, with large areas of riparian forest and less anthropic impact, promote higher species diversity and allow for the maintenance of species with specific environmental requirements. Smaller riparian forests with more anthropic impacts were occupied by species with fewer habitat requirements and broader ecological tolerances.

Because FPSP is located in a region with intensive agricultural and livestock activities, it is an important remnant of the Deciduous Seasonal Forest, and is of paramount importance for its conservation. Even though large portions of the FPSP consist of forests in a secondary stage of succession, the connection with better–preserved areas of primary forest allows for the

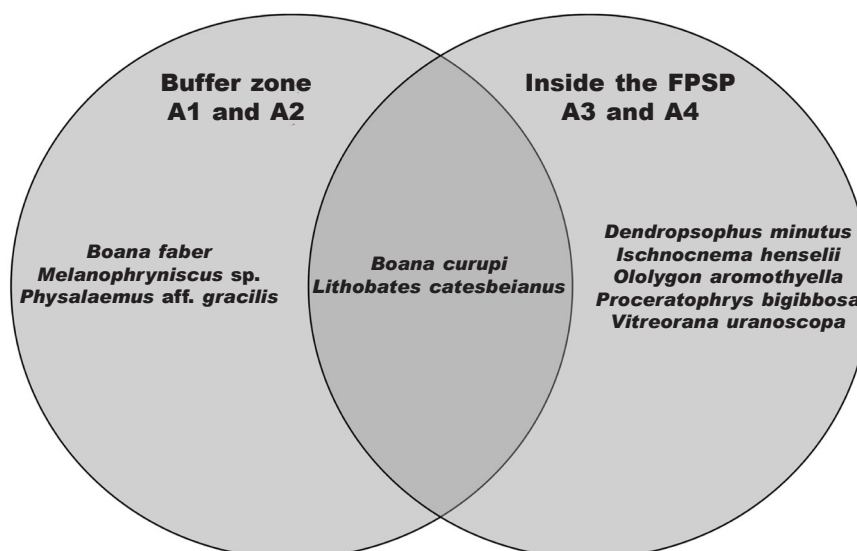


Fig. 2. Species recorded in the buffer zone and inside the Fritz Plaumann State Park (FPSP), Southern Brazil Atlantic Forest. A1, Area 1; A2, Area 2; A3, Area 3; A4, Area 4.

Fig. 2. Especies registradas en la zona de transición y dentro del Parque Estatal Fritz Plaumann, en el bosque atlántico del sur del Brasil. A1, Sitio de muestreo 1; A2, Sitio de muestreo 2; A3, Sitio de muestreo 3; A4, Sitio de muestreo 4.

general occurrence of more demanding species that are usually associated with well-preserved habitats. On a regional level, these habitats occur only inside the park and in their absence, these species would most likely become locally or regionally extinct.

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