Biota Neotropica 15(4): e0095, 2015
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
article

Spatial and temporal distribution of stream macroalgae in a tropical river basin

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TONETTO, A.F., PERES, C.K., HIRATA, R.T., BRANCO, C.C.Z. **Spatial and temporal distribution of stream macroalgae in a tropical river basin.** Biota Neotropica. 15(4): e0095. http://dx.doi.org/10.1590/1676-0611-BN-2015-0095

Abstract: Spatial and temporal distribution of stream macroalgae in streams from southeastern Brazil were assessed for one year. The fluctuations in macroalgal species composition and environmental factors were monitored monthly. The region exhibit a tropical climate, with defined rainy and dry seasons. Nineteen species were found, with a predominance of Chlorophyta (52.7% of the species), followed by Cyanobacteria (26.3%), Ochrophyta and Rhodophyta (10.5% each). *Scytonema arcangeli* had the highest number of records (63.6%), while *Mougeotia capucina* occurred in all sampling sites. Community structure had low similarity (20-26%) and the environmental factors showed a weak contribution to the distribution pattern observed. Despite this, the light availability at the stream-bed seems to be a major influence on the macroalgal seasonal dynamics. We suggest that macroalgae communities are predominantly composed of rare species, and this could explain the lack of a clear spatial and temporal variation pattern of these organisms.
Keywords: *species distribution, spatial variation, temporal dynamics, stream macroalgae, rarity*

TONETTO, A.F., PERES, C.K., HIRATA, R.T., BRANCO, C.C.Z. **Distribuição espacial e temporal de macroalgas de riachos em uma bacia tropical.** Biota Neotropica. 15(4): e0095. http://dx.doi.org/10.1590/1676-0611-BN-2015-0095

Resumo: A distribuição espacial e temporal das macroalgas lóticas em riachos do sudeste do Brasil foram avaliadas por um ano. As flutuações na composição de espécies de macroalgas e fatores ambientais foram monitorados mensalmente. A região apresenta um clima tropical, com estações chuvosas e secas definidas. Dezenove espécies foram encontradas, com predomínio de Chlorophyta (52,7% das espécies), seguido por Cianobactérias (26,3%), Ochrophyta e Rhodophyta (10,5% cada). *Scytonema arcangeli* teve o maior número de registros (63,6%), enquanto *Mougeotia capucina* ocorreu em todos os pontos de amostragem. A estrutura da comunidade teve baixa similaridade (20-26%) e os fatores ambientais mostraram uma fraca contribuição para o padrão de distribuição observado. Apesar disso, a disponibilidade de luz no leito do riacho parece ser de grande influência sobre a dinâmica sazonal de macroalgas. Nós sugerimos que as comunidades de macroalgas são predominantemente compostas por espécies raras, e isso poderia explicar a falta de um padrão claro de variação espacial e temporal desses organismos.
Palavras-chave: *distribuição de espécies, variação espacial, dinâmica temporal, macroalgas de riacho, raridade*

Introduction

Stream macroalgae are important primary producers in many lotic environments and numerous investigations have focused on these organisms (Sheath & Cole 1992, Branco & Necchi Júnior 1996, Branco et al. 2009, Necchi Júnior et al. 2000, 2003, 2008, Peres et al. 2008). Their ecological distribution is influenced by oscillations in environmental factors. Rivers and streams can be characterized by a set of habitat descriptors, which can be divided into physicochemical variables (e.g. pH, dissolved oxygen, temperature) and structural variables (e.g. marginal vegetation and substrate), both of which vary over time (Allan & Castillo 2007).

The majority of studies on ecological distribution of macroalgal communities suggests several habitat variables that could be relevant to temporal variation including: temperature (DeNicola 1996, Branco et al. 2008, Bojorge-Garcia et al. 2010), current velocity (Uehlinger 1991, Stevenson 1996), nutrients (Borchardt 1996), day length, precipitation, turbidity and dissolved oxygen (Necchi Júnior & Pascoaloto 1993,

Table 1. Descriptions of sampling sites in the Cervo River Basin.

Streams	Description
Site 1 – Barro Preto stream (22°35′33,8″S, 50°25′22,5″W)	Unshaded stream with substrate composed of clay and sand with a portion of dead plant material and macrophytes.
Site 2 – Água do Cervo stream (22°36′25,1″S, 50°25′52,7″W)	Shaded stream with substrate composed of sand and dead plant material
Site 3 – Água da Porca stream (22°36′54,4″S, 50°25′00,5″W)	Partially shaded stream with substrate composed mainly of pebbles, gravel and sand.

Branco & Necchi Júnior 1997). Branco et al. (2008) proposed that, despite the relevance of regional variables, particular features of each stream can strongly influence the seasonal tendencies at a local scale. Branco et al. (2009) extended this concept and suggested that differences in diversity and distribution of macroalgal communities among streams could be explained by the combination of specific features in small sections (i.e., microhabitat scale) of each stream.

Therefore, the aim of the present study was to carry out comparisons among the structure of macroalgal communities over an entire year in three tropical streams in the Cervo River Basin, southeastern Brazil. Samples were taken monthly to assess the species richness and abundance of macroalgal communities and their relationships with environmental factors. We hypothesized, that differences in environmental variables at the local scale are important in controlling the distribution of lotic communities (Branco et al. 2008, 2009). We also expected that differences would be found for macroalgal seasonal fluctuations in each stream, since they have particular features, especially of light availability.

Materials and methods

Study area

The study was carried out in three streams (Table 1) belonging to the Cervo River Basin, a tropical drainage basin located in São Paulo State, southeastern Brazil. The region is broad and flattened, with straight sides, and altitudes ranging from 500 to 588 meters (Max et al. 2003). The climate condition is characterized as tropical with rainy summer and dry winter (Max et al. 2003). The original flora was Brazilian savanna, but the deterioration has replaced the original vegetation by sugarcane and reforestation of *Pinus* sp. and *Eucalyptus* sp.

Sampling procedures and analysis

The streams were sampled monthly from December 2005 to November 2006. Samples were taken by using the cross-transect technique (Branco et al. 2009). We divided the stream transect in 10 equal parts (1 m each) (Branco et al. 2009). Percent cover on the stream bottom was calculated by visual analysis for each 1 m interval and averaged for the whole 10 m transect (Branco et al. 2009). The specimens found throughout the study period were preserved in formaldehyde 4% (Peres et al. 2008). We adopted the concept of macroalgae and respective morphological types as defined by Sheath & Cole (1992).

At each sampling occasion, the water temperature, pH, dissolved oxygen, turbidity and electric conductivity were measured in each site using a Horiba U-10 equipped with a multiparameter probe (Horiba®, Kyoto, Japan). Irradiance was measured using a quantometer LI-250 (Li-Cor®, Lincoln, USA). The current velocity was recorded using an electronic flowmeter Swoffer 3000 (Swoffer Instruments®, Seattle, USA), while depth was measured by a ruler. To obtain the nutrients concentration, a sample of water was collected and frozen immediately. Table 2 summarizes all environmental factors collected in each stream.

Table 2. Environmental variables measured at each sampling sites at the River Cervo Basin.

Variables	Site 1	Site 2	Site 3
Temperature (°C)	17.6 – 28.8	16.3 – 27.9	15.6 – 26.0
	23.9 ± 3.9	22.2 ± 4.1	21.5 ± 3.8
Conductivity (μS.cm^{-1}.s^{-1})	4.0 – 310.0	4.0 – 28.0	4.0 – 9.0
	46.6 ± 90.3	7.3 ± 6.9	5.6 ± 1.9
Turbidity (NTU)	5 – 24	2 – 15	7 – 15
	9.2 ± 9.0	6.0 ± 3.6	10.1 ± 2.3
Dissolved Oxygen (mg.L^{-1})	4.6 – 6.6	4.7 – 7.0	4.9 – 7.7
	5.6 ± 0.7	5.7 ± 0.7	6.2 ± 0.8
pH	5.0 – 6.6	5.5 – 6.1	5.4 – 6.1
	6.0 ± 0.5	5.8 ± 0.2	5.7 ± 0.2
Depth (cm)	18.6 – 27.6	24.9 – 35.1	29.8 – 38.0
	21.9 ± 2.9	29.0 ± 3.6	32.6 ± 2.8
Current Velocity (cm.s^{-1})	22.0 – 71.0	16.7 – 40.9	39.0 – 65.0
	39.0 ± 16.1	24.7 ± 6.9	52.3 ± 7.8
Irradiance (μmol.m^{-2}.s^{-1})	104.4 – 1391.2	5.6 – 210.7	30.4 – 420.8
	701.9 ± 436.4	43.1 ± 57.6	175.5 ± 129.6
Total Nitrogen (mg.L^{-1})	0.1 – 0.7	0.1 – 0.7	0.1 – 0.5
	0.38 ± 0.32	0.16 ± 0.30	0.28 ± 0.21
Total Phosporus (mg.L^{-1})	0.11 – 0.21	0.10 – 0.22	0.13 – 0.23
	0.16 ± 0.04	0.16 ± 0.04	0.16 ± 0.03

Values represent minimum and maximum range, average, and standard deviation ($n = 12$)

Table 3. Distribution, seasonality, morphological types (gelatinous colonies GC, gelatinous filaments GF, free filaments FF, mats M and tufts T of macroalgal communities in study sites of Cervo River Basin.

Species	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Chlorophyta												
1. Chaetophora elegans (Roth) C. Agardh (GC)			S3	S3	S1, S3	S3	S3	S3	S3	S3	S3	S3
2. Closterium rostratum var *rostratum* Ehr. ex Ralfs (GC)					S1							
3. Geminella sp. (GF)	S3				S3	S3	S3	S3	S3	S3	S3	S3
4. Microspora floccosa (Vaucher) Thuret (FF)	S3	S3	S3	S3		S3		S3	S3	S3	S3	
5. Mougeotia capucina (Bory) C. Agardh (FF)	S3		S1	S1	S1	S1, S3	S3	S2, S3		S1		S1
6. Oedogonium sp. (FF)		S1	S3	S1								
7. Palmodictyon sp. (GF)		S3	S3	S3	S3	S3	S3				S3	
8. Spirogyra sp. (FF)		S1	S1	S1	S1	S1	S1					
9. Zygogonium sp. (FF)	S1, S3	S1				S1						
10. Zygnema sp. (FF)						S1	S1	S1			S1	S1
Cyanobacteria												
11. Cilindrospermum minutissimum Collins (M)		S1			S1					S1	S1	S1
12. Geitlerinema splendidum (Gomont) Anagnostidis (M)			S1			S1	S1	S1	S1		S1, S2	S1, S2
13. Phormidium aerogineo-caeruleum (Gomont) Anagnostidis et Komárek (M)	S2		S2, S3		S3	S2, S3	S2	S3		S3		
14. Phormidium retzii (C. Agardh) Gomont (M)								S1	S1	S1	S1	
15. Scytonema arcangeli Bornet et Flahault (T)	S1, S3	S1, S3	S1, S3	S1, S2, S3	S1, S3	S1, S3	S1, S3	S1	S1	S1	S1, S3	S1, S3
Rhodophyta												
16. 'Chantrasia' Stage (T)	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
17. Sirodotia delicatula Skuja (GF) Ochrophyta	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3
18. Eunotia camelus Ehrenberg (GC)					S1	S1	S1					
19. Eunotia sp.(FF)			S3	S3			S3	S3	S3	S3		

Species number corresponds to the following Figures

Microscopic observations and morphometric analysis of specimens were performed using an optical microscopy, Leica DM-1000 (Leica Microsystems GmbH, Wetzlar, Germany), coupled with an image capture system for species identification in laboratory. To quantify nutrients (total nitrogen and total phosphorus) we used a spectrophotometer, Merck, model Spectroquant Nova 60, with specific kits for each nutrient. Finally, rainfall data were obtained from the pluviometric station of Assis, the closest weather station from the sampling sites.

Data analyses

Dominance-diversity curves were constructed based on abundance (i.e., percent cover) of macroalgae to analyze differences in richness and abundance among sampling sites and among sampling dates. The relationship among spatial and temporal distribution of macroalgal abundance with environmental factors was assessed using CCA (Canonical Correspondence Analysis), followed by Monte Carlo test (999 permutation, $\alpha = 0.05$) to determine the results significance. These statistical analyses were performed using PC-ORD version 5.31. In addition, we applied a cluster analysis to verify the similarity of the species composition among the studied streams using the statistical software NTSYS, version 2.1.

Results

Analysis of macroalgal communities

A total of 19 taxa were recorded from the three streams (Table 3), of which eight were identified only to generic level (including sterile green algae, three possibly new species and the sporophytic stage of *Sirodotia*, the 'Chantransia' stage) and 11 to infrageneric level. Chlorophyta had greatest representation with 10 taxa (52.7% of total), followed by Cyanobacteria with five (26.3%), and Ochrophyta and Rhodophyta with two each (10.5%). The proportion of macroalgal morphological types was as follows: free filaments (7 taxa – 36.8% of total), mats (4 – 21%), gelatinous filaments (3 – 15.8%), gelatinous colonies (3 – 15.8%) and tufts (2 – 10.5%). Among the taxa identified, 13 (68.4% of total) were collected in a single sampling site. *Closterium rostratum* was reported once in one sampling site, while *Scytonema arcangeli* and *Mougeotia capucina* were recorded several times in all sampling sites. *S. arcangeli* had the highest number of records, totalizing 23 occurrences (63.6% of the sampling dates).

Species richness, abundance and morphological types showed pronounced differences among sites and sampling dates (Table 3, Figures 1-3). In the sampling site 1 (S1), we recorded a relative richness varying from two to seven species per sampling dates associated with the highest mean value of macroalgal percent cover (12%) among the studied streams. In turn, the sampling site 3 (S3) had the highest relative richness of species per date (4-8) and intermediate mean value of percent cover (5.9%). In sampling site 2 (S2), on the other hand, were found the lowest relative richness (1-3) and the lowest mean percent cover value (0.8%).

Dominance-curves (Figures 1-3) showed the dominance of one or few species in all sampling sites and sampling dates, with dominant species varying among sampling sites and sampling

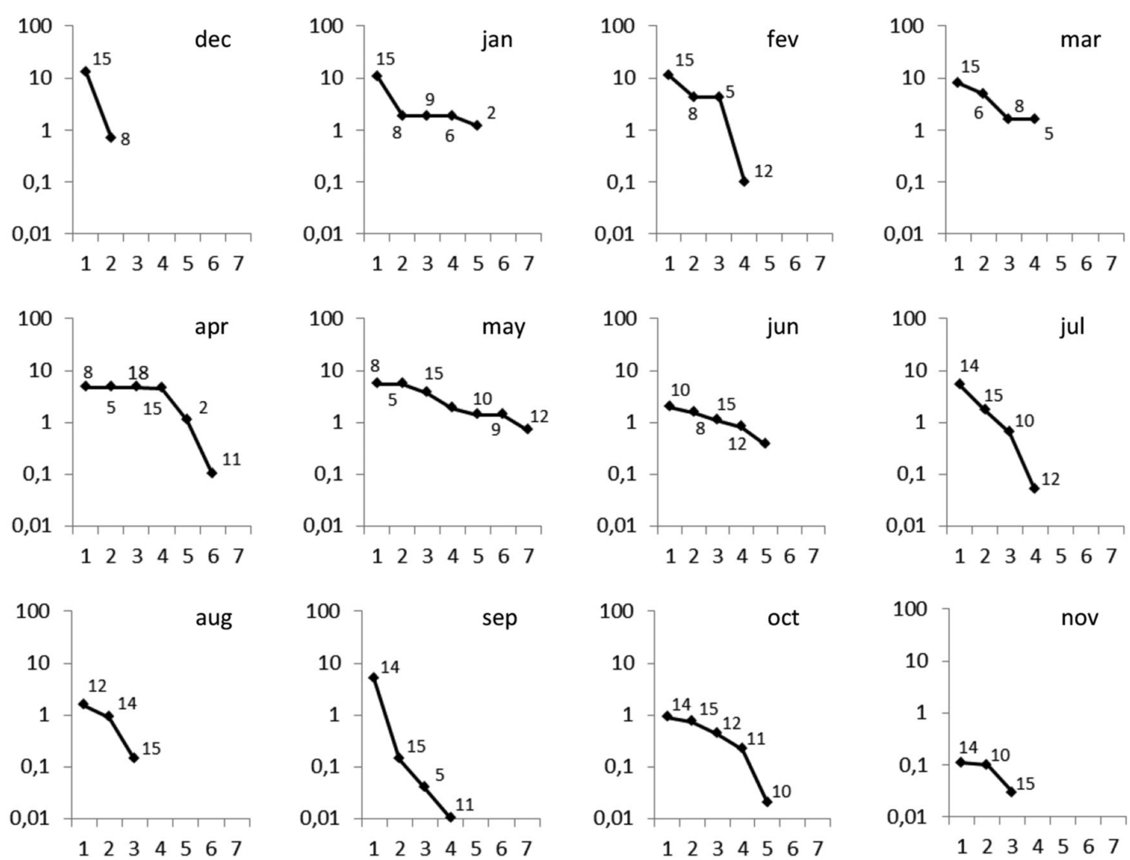

Figure 1. Dominance-diversity curves based on macroalgal percent cover between months in Site 1. The horizontal axis represent the percent cover and the vertical axis the number of species.

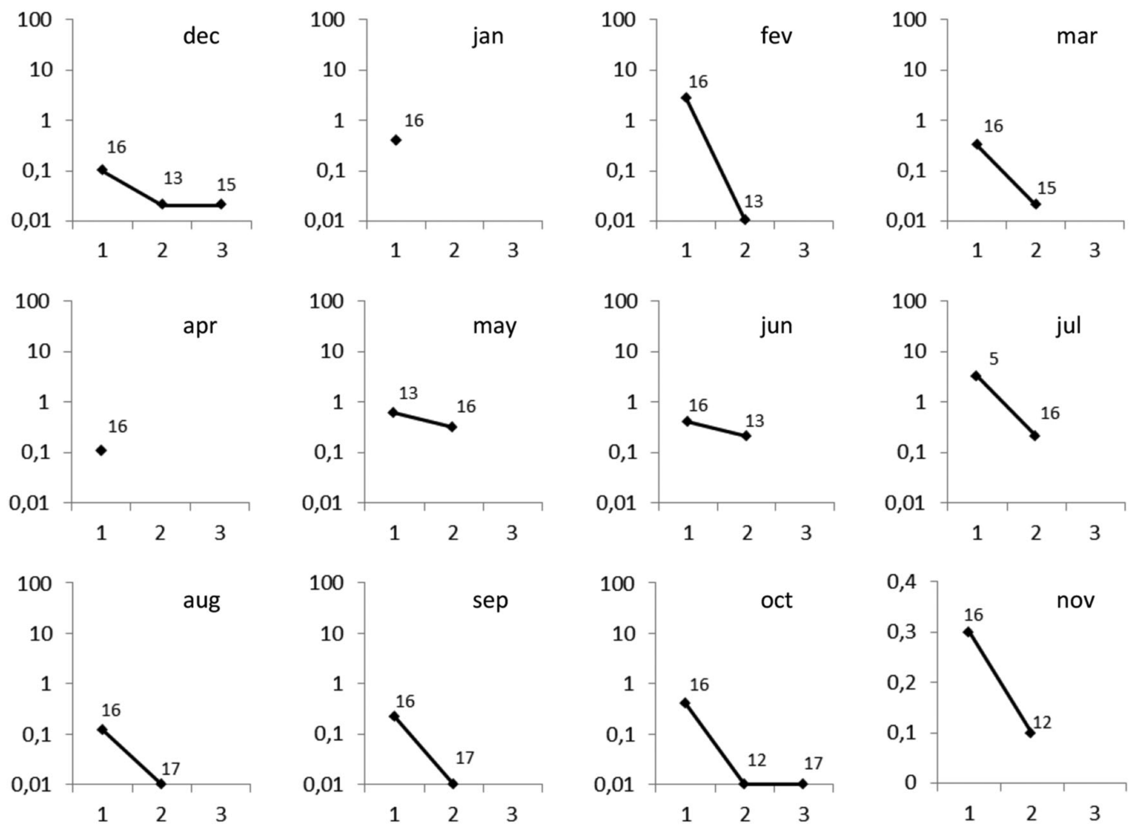

Figure 2. Dominance-diversity curves based on macroalgal percent cover between months in Site 2. The horizontal axis represent the percent cover and the vertical axis the number of species.

dates. In S1 (Figure 1), the dominant specie varied through time, with predominance of *Scytonema arcangeli* at the beginning of the samplings (December/2005 to March/2006), but the dominance changed to *Spyrogyra* sp. in the intermediate sampling dates (April to June/2006) and changed again to *Phormidium retzii* from July until the end of the samplings (July to November/2006). In the S2 (Figure 2), 'Chantransia' stage was the predominant species in ten of the twelve sampling dates (83.3%). In the S3 (Figure 3), after April/2006, *Sirodotia delicatula* was definitively established as the dominant species and remained so until the end of the sampling period.

Differences in specific composition among sampling dates were recorded for all sampling sites, however, despite the dominance observed, associations of few species were registered for the three streams year around. Thus, for S1, *S. arcangeli* and *Spirogyra* sp. were frequently associated, while for S2, 'Chantransia' and *Phormidium aerogineo-caeruleum* varied their abundance in relative synchrony and for S3, the same situation was observed but with *Sirodotia delicatula* and *Microspora floccosa.*

Considering species composition similarity among sampling sites, the cluster analysis revealed small similarity among them (20-26% of similarity), reflecting the fact that only 2 species have been recorded in all three sampling sites. The seasonal fluctuation of macroalgal communities abundances varied from stream to stream. Thus, in S1 was observed higher macroalgal percent cover from December to May (summer-spring), a period with higher occurrence of rains in tropical regions, while, in S2 and S3 no evident seasonal variation pattern was identified.

Relationship among macroalgal distribution and environmental factors

In the CCA, the first two axes explained 37.8% of the total variation in macroalgal distribution, with first axis being significant ($P = 0.001$) (Figure 4). The relationship between species and environmental factors was significant to axis one ($P = 0.001$), showing that irradiance, current velocity, substrate and depth were the variables that more contributed to explain the spatial distribution of macroalgal species and the grouping of streams. Moreover, this analysis revealed that sampling sites were grouped mainly by spatial features (including the particularity in species composition and environmental variables), rather than by temporal characteristics. Thus, Figure 4 showed the formation of three groups, representing the complete set of the sampling dates of S1, S2 and S3. The CCA analysis also showed that sampling dates of the S2 group had a more pronounced scattering along the environmental gradient than the sampling dates of the other two groups, S1 and S3 (Figure 4).

Considering streams individually, CCA revealed that the first axis was significant for S1 ($P = 0.013$), and the two first axes explained 48.4% of the total variation in macroalgal abundance. In this sampling site, species distribution was mainly determined by irradiance, dissolved oxygen, temperature, water velocity and precipitation (Figure 5, S1). The CCA analysis of the sampling sites S2 and S3 revealed no significant relationships ($P > 0.05$) among axes and species distribution for these streams (Figure 5, S2 and S3).

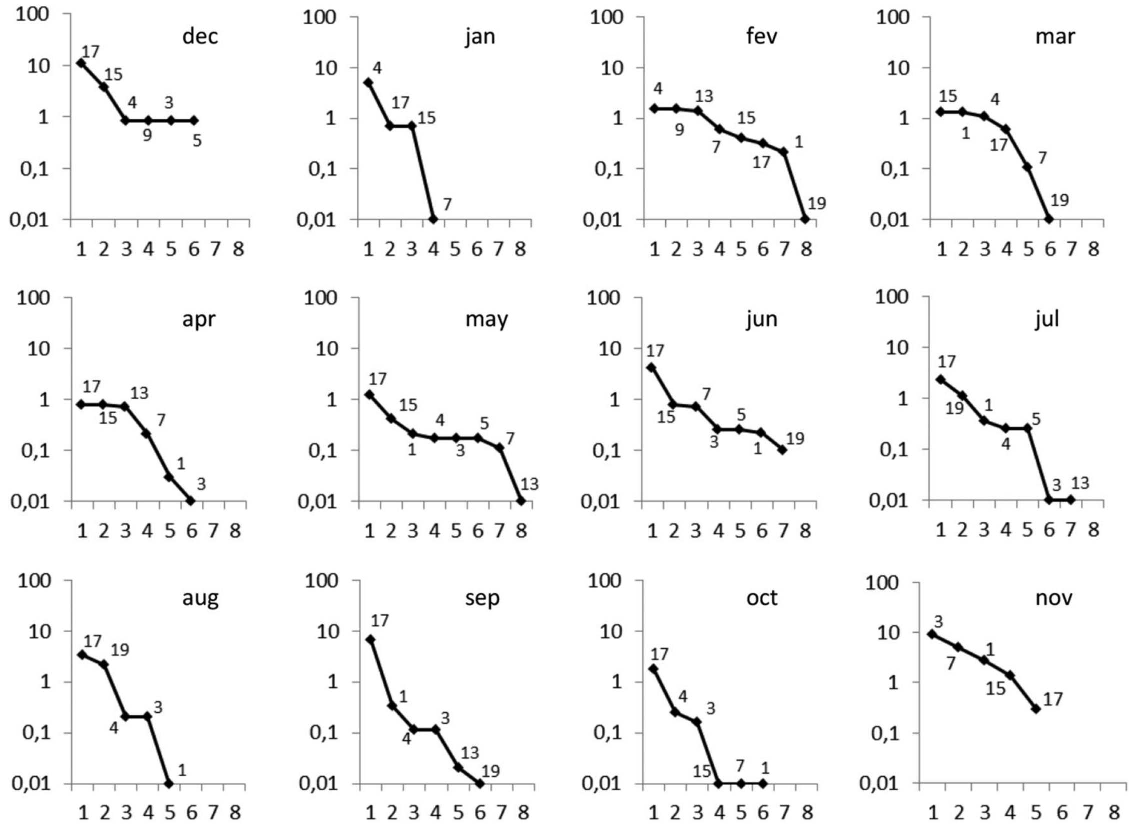

Figure 3. Dominance-diversity curves based on macroalgal percent cover between months in Site 3. The horizontal axis represent the percent cover and the vertical axis the number of species.

Discussion

The mean species richness per sampling site ranged from five to 11 taxa, what is expected for tropical streams (Necchi Júnior et al. 1991, Branco & Necchi Júnior 1996, Branco et al. 2008). In each sampling site, the absolute number of species ranged between one and eight (mean = 4.0 ± 2.2) and also is in accordance with the pattern frequently found in similar studies conducted in tropical regions (2.5 ± 1.6 – Branco & Necchi Júnior 1996, 2.6 ± 1.5 – Krupek et al. 2007, 2.6 ± 1.6 – Branco et al. 2008, 4.2 ± 2.3 – Necchi Júnior et al. 2008, and 6.7 ± 2.7 – Necchi Júnior et al. 2003). Likewise, the macroalgal abundance (in terms of percent cover) of each sampling site varied from 0.11 to 20.4% (6.4% ± 6.8), which is similar to other previous studies (e.g. 5.2 ± 8.4 – Krupek et al. 2007, 5.7 ± 7.4 – Branco et al. 2008, 13.5 ± 11.9 – Necchi Júnior et al. 2008, and 15.4 ± 21.0 – Branco & Necchi Júnior 1996).

Chlorophyta was the algal group that showed the highest total number of species. However, members of Cyanobacteria (*S. arcangeli* and *Phormidim retzii*, in S1) and Rhodophyta ('Chantransia' in S2 and *Sirodotia delicatula* in S3) were dominant in terms of percent cover in the three streams investigated. DeNicola et al. (1992) states that the lack of pigment diversity in Chlorophyta limits their establishment and distribution to stream sections with high irradiance. Some of our results seem to confirm this hypothesis. For instance, *Mougeotia capucina* was widely recorded in streams with higher light availability (sampling sites S1 and S3) in Cervo River Basin, while this species was registered only once in the heavily shaded stream (sampling site S2). Cyanobacteria and Rhodophyta, on the other hand, have a pigment complex that allows them to tolerate low irradiances. Necchi Júnior et al. (2008) reported the presence, sometimes predominant, of Cyanobacteria species in lotic environments with varying degree of shading, ranging from open to heavily shaded streams. Nonetheless, Branco & Necchi Júnior (1996) reported a relative predominance of red algae in shaded and heavily shaded streams from the Brazilian Atlantic Forest. Hence, we believe that the pigment content of cyanobacteria and red algae may have favored these algal phyla, what could explain their greater abundance in the studied streams.

The stream environmental features had a relative influence in temporal and spatial distribution of macroalgal communities. However, considering present and previous studies (see Introduction section), it is difficult to precisely identify what stream variable is more important for macroalgae because numerous variables have been considered as relevant for their distribution. Indeed, several researchers have suggested that the relationship between the ecological distribution of these organisms and environmental characteristics must be examined carefully (Krupek et al. 2007, Branco et al. 2009). Despite this difficulty, in our study, the availability of light in each stream seemed to affect macroalgal communities variability (as showed by CCA groups), followed by physical and chemical characteristics of each sampling site. Thus, we suggest that the primary environmental filter is the type of riparian vegetation, what determines the initial establishment of stream macroalgal communities. Secondarily, other stream variables could be relevant for the development and maintenance of these organisms. For instance, in S2 and S3, where availability of light was reduced, irradiance was so limiting for macroalgal growth (low values of macroalgal percent cover) that no other local environmental factors had significant influence on the macroalgal distribution (Krupek et al. 2007, Peres et al. 2009),

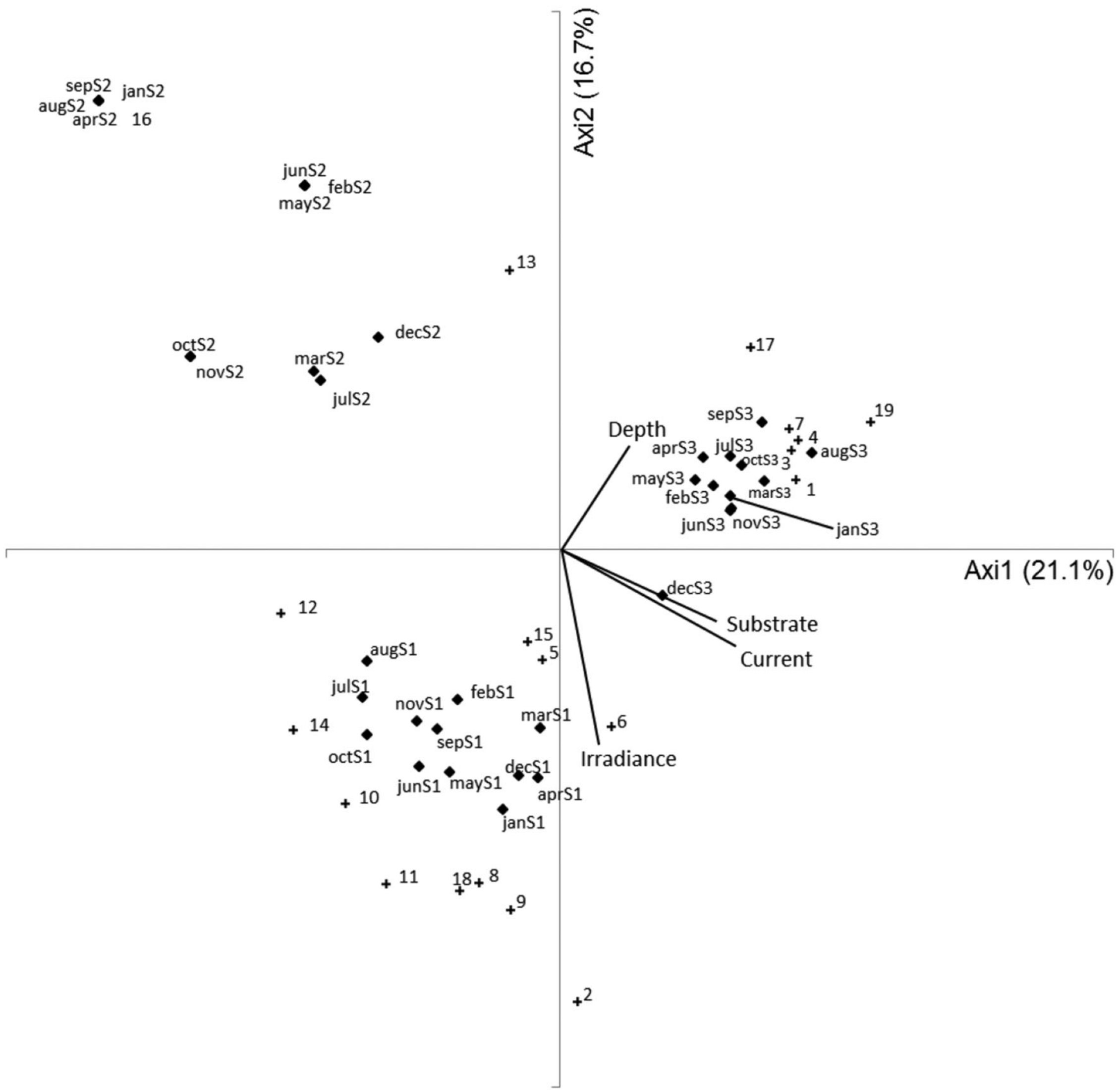

Figure 4. CCA biplot of the general distribution of sites and macroalgae with regard to environmental factors recorded in all study. Cross corresponds to species, S1, S2 and S3 is site abbreviation.

as showed by CCA analyses. On the other hand, in S1 where irradiance registered higher values, the macroalgal development was also significantly higher than the other two streams investigated (as showed by higher values of macroalgal percent cover). In this condition of light availability, other local environmental variables (e.g., dissolved oxygen and temperature) have gained significant influence on the communities distribution (Branco et al. 2009, Costa & Mello 2008).

Considering macroalgal flora, we observed a clear distinction in community composition among the streams. This difference seems to be a consequence of variances in light availability at each sampling site. According to CCA (Figure 4), the sampling site with lower irradiance (S2) showed a much more dissimilar community than those sampling sites with higher light availability (S1 and S3). Considering that light limitation on algal growth has been extensively documented (e.g., Tonetto et al. 2012) and, that different species have distinct ecophysiological abilities to absorb light, we believe that community composition found in S2 was basically influenced by a pool of species adapted to habitats with lower levels of irradiance (Stevenson 1996). Indeed, in S2 we reported a few number of species per sampling date and, individually, the species showed low reoccurrence, being recorded only in one or few samples (e.g., *Mougeotia capucina* that appeared only in July, *Sirodotia delicatula* in August, and *Geitlerinema splendidum* in October. For this reason, S2 exhibited a higher variation in species composition through time. In addition, we suggest that this site is composed by macroalgal species that require more specific conditions and, therefore, they suffer great impact from abiotic oscillations (Pandit et al. 2009) providing this variability in community composition.

On the other hand, S1 and S3 had a higher and intermediate light condition and, consequently supported a higher percent cover and number of species. Due to high availability of irradiance, communities can reach higher abundance and maintain themselves in a more stable condition through time. Seasonality, gain and loss of species would provide few changes in community composition. Thus, in general, streams with low supply of light will present a lower number of species, and a more unstable community through time than communities from streams with higher availability of light.

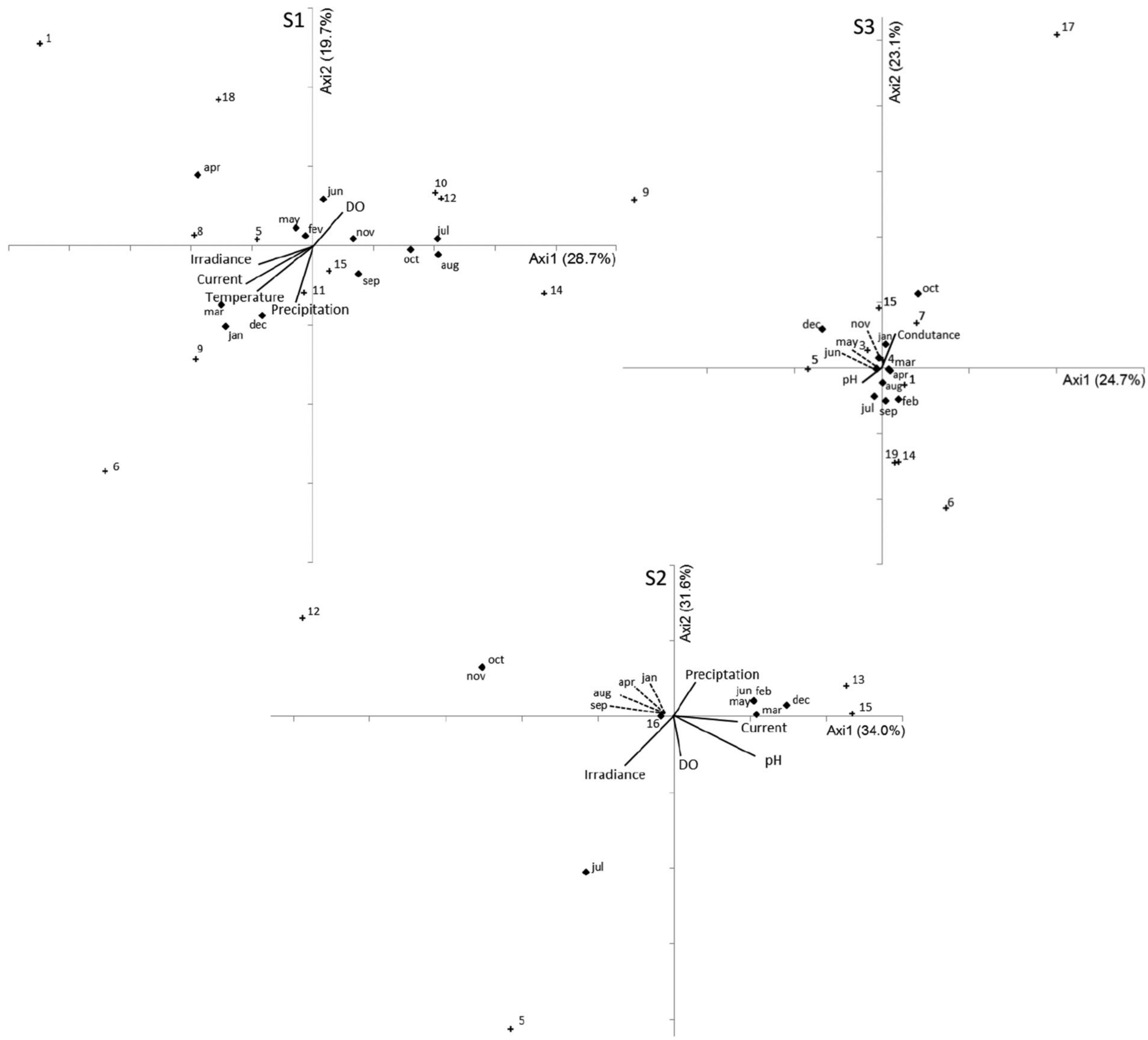

Figure 5. CCA biplot of the general distribution of macroalgae according to environmental factors registered in each site. Cross corresponds to species, Black diamond corresponds to months.

The three sampling sites showed strong dominance of few species with common species being reported throughout year (e.g. *Scytonema arcangeli* at S1, 'Chantransia' at S2, and *Sirodotia delicatula* at S3). Indeed, these results are in agreement with one of the most important ecological observations in nature which states that most natural communities are composed by few common species and many rare species (Siqueira et al. 2012). In addition, we reported only two species occurring in all three sampling sites (*Scytonema arcangeli* and *Mougeotia capucina*). Indeed, this type of species occurrence is very common in ecological studies focusing on lotic macroalgal communities (Branco et al. 2009, Hu & Xie 2006, Peres et al. 2010), where one species is frequently reported in only one stream, even under broad geographical bases. Because of this particular pattern of ecological distribution, the spatial and temporal variations in the macroalgal communities become difficult to describe, since the species sampling may not represent the real community composition because of rarity.

In conclusion, our results showed that the light availability has a central role in spatial and temporal variations of lotic macroalgal communities. Even with this information, a precise description of seasonal pattern of macroalgae in relation to environmental factors remains very difficult to be described, especially for tropical streams where rare species represent an important part of the communities' composition. Furthermore, our data support the hypothesis that local characteristics of each stream segment influence the ecological distribution of macroalgae (Branco et al. 2008, Costa & Melo 2008, Branco et al. 2009). We finally suggest that studies on micro and/or mesohabitat scales of analysis can be fundamental to better understand the ecological distribution of these communities.

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Received 24/07/2015
Revised 23/09/2015
Accepted 5/10/2015

Biota Neotropica 15(4): e0033, 2015
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
inventory

Mammal richness and diversity in Serra do Facão region, Southeastern Goiás state, central Brazil

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GOMES, L.P., ROCHA, C.R., BRANDÃO, R.A., MARINHO FILHO, J. **Mammal richness and diversity in Serra do Facão region, Southeastern Goiás state, central Brazil.** Biota Neotropica. 15(4): e0033. http://dx.doi.org/10.1590/1676-0611-BN-2015-0033

Abstract: At least 251 mammal species are recorded for the Brazilan cerrado, which, therefore, is the third richest Brazilian biome. Most mammal surveys in Brazilian cerrado result from studies performed opportunistically and in short time periods. The aims of the present study were (1) provide a checklist for the mammalian fauna based on a five-year sampling in Serra do Facão region, Southeastern Goiás state; (2) compare small non-flying mammals diversity in open and forest areas and (3) compare species diversity before and after the flood caused by a hydroelectric reservoir filling. The data was gathered in 19 sampling periods, from May 2008 to September 2013. We sampled open and forest habitats and captured non-flying small mammals with Sherman and Tomahawk live traps and pitfalls; bats were sampled with mist-nets; large mammals were recorded with camera traps, and by direct observations and track surveys in field. We found 20 species of small non-flying mammals, 10 species of bats and 33 species of larger mammals. Species diversity was greater for forest than open habitats, and was also greater before than after the complete reservoir filling. About 10% of the recorded species are included in the Brazilian official list of threatened species. The total richness represents 25% of all cerrado mammal fauna, highlighting the importance of this area for regional mammal fauna conservation.

Keywords: *cerrado, mammal survey, non-flying mammals, bats, large mammals, hydroelectric reservoir.*

GOMES, L.P., ROCHA, C.R., BRANDÃO, R.A., MARINHO FILHO, J. **Riqueza e diversidade de mamíferos na Região da Serra do Facão, sudeste do estado de Goiás, Brasil central.** Biota Neotropica. 15(4): e0033. http://dx.doi.org/10.1590/1676-0611-BN-2015-0033

Resumo: Há 251 espécies de mamíferos de ocorrência confirmada no cerrado, o terceiro bioma brasileiro em riqueza de espécies. A maioria dos inventários da mastofauna do cerrado é resultado de estudos oportunísticos, com curta duração. Os objetivos do presente estudo foram (1) inventariar a mastofauna durante cinco anos de amostragens na região do Aproveitamento Hidrelétrico da Serra do Facão, no sudeste do estado de Goiás; (2) Comparar a diversidade de pequenos mamíferos em áreas abertas e florestais e (3) comparar a diversidade da mastofauna antes e depois da inundação causada pelo enchimento do reservatório do empreendimento hidrelétrico. A coleta de dados foi realizada em 19 campanhas de amostragem, entre maio de 2008 e setembro de 2013. Os pequenos mamíferos não voadores foram amostrados com armadilhas *Sherman* e *Tomahawk*, e armadilhas de queda; morcegos foram amostrados com redes de neblina; e os mamíferos de maior porte foram amostrados com armadilhas-fotográficas, observações diretas e observações de vestígios. Foram registradas 20 espécies de pequenos mamíferos não-voadores, 10 espécies de morcegos e 33 de mamíferos de maior porte. A diversidade de pequenos mamíferos não voadores foi maior em ambientes florestais que em abertos, e foi também maior antes do que depois do enchimento do reservatório da hidroelétrica. Cerca de 10% das espécies registradas estão incluídas na lista oficial dos mamíferos ameaçados de extinção. O total de espécies representa 25% da fauna de mamíferos do cerrado, o que demonstra a importância da área para conservação da mastofauna regional.

Palavras-chave: *cerrado, inventário, pequenos mamíferos não voadores, morcegos, mamíferos de grande porte, reservatório hidrelétrico.*

Introduction

Currently, 701 species of mammals are known in Brazil (Paglia et al. 2012). The mammal richness reported for the cerrado varies from 227 (Carmignotto et al. 2012) to 251 species (Paglia et al. 2012). About 40% cerrado mammals are bats (Chiroptera), 31% are rodents (Rodentia), and 10% are marsupials (Didelphimorphia) (Paglia et al. 2012). This diversity places the cerrado biome as the third richest for Brazilian mammals. The number of endemic cerrado mammals varies from 25 to 32 species depending on the authors (Carmignotto et al. 2012, Paglia et al. 2012). The distribution of mammal fauna in cerrado is affected by habitat heterogeneity, being approximately 16% of species exclusive to open areas, and about 29% occur exclusively in forest environments (Marinho-Filho et al. 2002). However, the endemism rate is slightly larger for open areas (56%), highlighting the relevance of both open and forested habitats for cerrado mammals conservation (Marinho-Filho et al. 2002).

The original cerrado covered approximately 2 million km^2. However, about half of its area was already removed by human activities, and the actual deforestation persist at rates varies between 22,000 to 30,000 km^2/year (Klink & Machado 2005). Processes of habitat loss and fragmentation, as well as hunting pressure, are among the main threats to mammalian diversity conservation (Rodrigues et al. 2002, Costa et al. 2005, Trolle et al. 2007). Changes in the environment occur in an accelerated rate, causing loss of irreplaceable habitats at local and regional scale, and even resulting in local extinctions (Whitmore & Sayer 1992, Myers et al. 2000).

In this context, inventories are essential because they provide basic information on biological diversity composition of determined areas and regions, providing arguments and justification for the conservation of remnant areas. However, the majority of fauna surveys on cerrado's mammalian fauna are performed punctually and in short time periods.

Herein we present a mammalian inventory based on five years sampling an area affected by the flooding of the reservoir of Serra do Facão Hydroelectric Plant, in southeastern Goiás state. Other aims of this study are to evaluate differences in richness and diversity for small non-flying mammals between (1) environments (open areas and forests) and (2) sampling periods (before and after the hydroelectric plant construction). We also provide reproductive ecological observations for small non-flying mammals.

Material and Methods

1. Area of study

The study was carried out in Serra do Facão region, southeastern Goiás state (Figure 1). The Serra do Facão region is crossed by São Marcos River, which belongs to Rio de la Plata Basin, the second largest river basin in South America (ANA 2007). In November 2009, a dam on the São Marcos River was built to form the reservoir of the hydroelectric plant of Serra do Facão. This reservoir floods ca. 20,000 ha, encompassing five municipalities in the state of Goiás: Catalão, Campo Alegre de Goiás, Davinópolis, Ipameri, and Cristalina - and the municipality of Paracatu, in the state of Minas Gerais.

In the region the climate is tropical (Köppen Aw), with temperatures between 23 and 24°C and mean annual rainfall between 1600 and 1800 mm, and two well-defined seasons, one hot and rainy (October to Match) and other colder and dry (April to September) (Cardoso et al. 2015). The landscape consists of large tracts of plantation areas and pastures, in which there is a mosaic of remnant patches of native habitats,

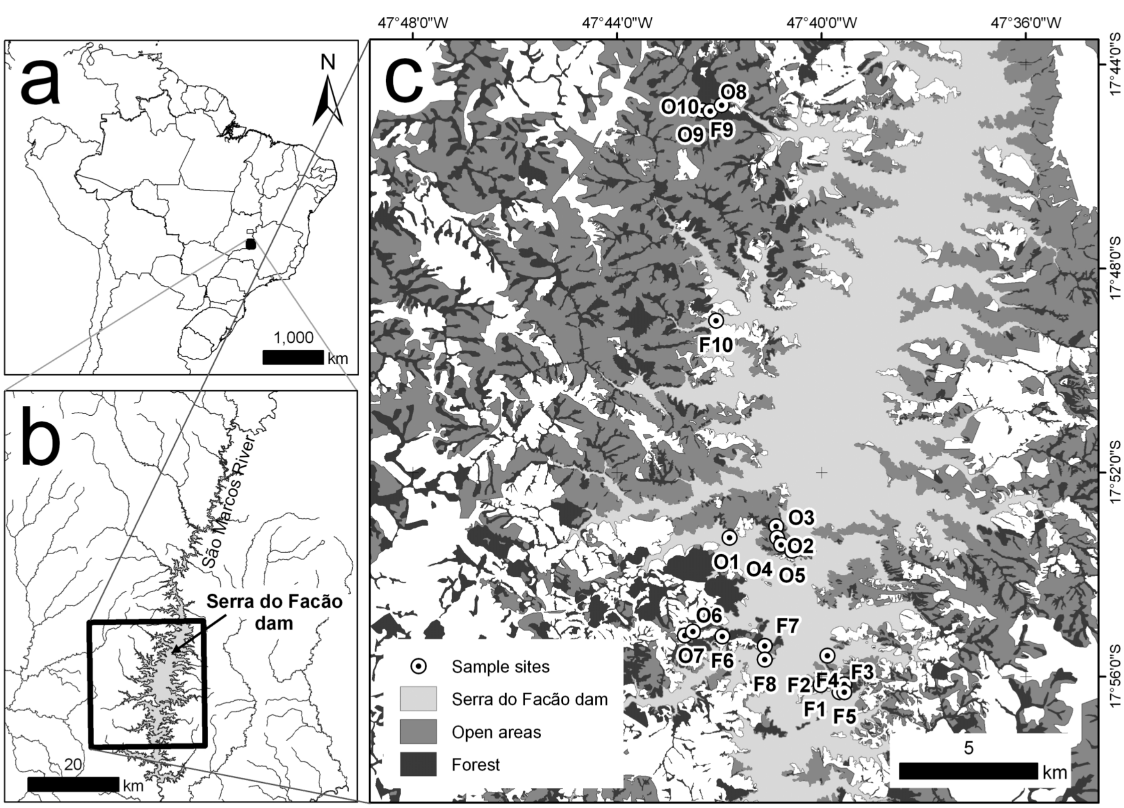

Figure 1. Serra do Facão state of Goiás, and location of sample sites a) Brazil; b) River system in the area; c) Sample Sites. O – Open areas; F – Forest. Description of sampling points and coordinates are on Supplement 1.

including several open cerrado physiognomies as *campo limpo*, *campo sujo*, *vereda* (palm swamps) , and "cerrado *sensu stricto*", and forest habitats, such as semi-deciduous forest, *mata ciliar* (riparian forest), and gallery forest. Phytophysiognomies were identified according to Oliveira-Filho & Ratter (2002). Grassland without shrubs or trees is called *campo limpo*, and grassland with scattered shrubs and small trees is called *campo sujo*. Open cerrado physiognomies over rock soil and scattered rock outcrops – *cerrado rupestre* (Lenza et al. 2011) was present in some places. The cerrado *sensu stricto* have trees covering more than 30% of canopy, and presents an herbaceous/grassy layer. *Veredas* are valley marshes where the water table reaches the surface and palms *Mauritia flexuosa* are common. Semi-deciduous forest (mesophytic seasonal forest) generally grow on spots of calcareous fertile soils; gallery forests are placed along river banks, and the tree branches cover the water course, forming a “gallery”. Riparian forests are also placed along river banks, but the water course is not covered by trees. The sampling sites included both open areas (grassland and "cerrado *sensu stricto*") and forest habitats (gallery forest and semi-deciduous forest).

2. Data Collection

We collected data on 19 field expeditions, with quarterly intervals, from May 2008 to February 2012. In 2013, we done three complementary expeditions in March, June and September. Initially, we gathered data in 10 sampling sites placed in open areas and 10 sampling sites placed in forest habitats (Figure 1, Supplement 1). However, after the impoundment in 2009, three forest sites were flooded. The study was carried out in areas located in the municipalities of Catalão and Campo Alegre de Goiás, state of Goiás (Supplement 1).

We considered small mammals all species of small rodents and marsupials with less than 2 kg (e.g. Bennett 1990, Eisenberg & Redford 1999). This group was sampled using Sherman and Tomahawk traps, and some additional data came from pitfall traps. In every sample sites (Supplement 2), we set up 21 Sherman traps (250 x 80 x 90 mm) and seven Tomahawk traps (300 x 160 x 160 mm), which remained open during three consecutive nights in each field expedition. Traps were placed on soil level and on trees and shrubs, up to 2m high as well, in order to access the greatest number of micro-habitats. Baits consisted of a mixture of peanut butter, banana, canned sardines and cornmeal. All traps were monitored every day at dawn. The sampling effort was 31,496 traps*night.

Pitfall traps consisted by stations composed by four 35-litre plastic buckets arranged in a Y-shaped disposition. All buckets were buried in the ground, placed 4m away from each other, and connected by a plastic fence (0.5m height). Five pitfall trap stations were set at each sample site (Supplement 2). Pitfall traps were kept open for ten consecutive days in each expedition. Although pitfall traps are commonly used for herpetological sampling, they often capture small terrestrial mammals (Mengak & Guynn Jr 1987, Santos Filho et al. 2008), being able to sample species that are rarely captured by more traditional methods (Monteiro-Filho & Graipel 2006, Cáceres et al. 2010). During sampling periods all traps were checked every day and we performed a total sampling effort of 49,600 pitfalls*night.

Bats were recorded only in forest environments (Supplement 2). We used five to ten mist-nets (12 m length x 3 m height) in each sampling site, for a few nights (usually 1-2) per field expedition. The nets were set on forest edges, or inside them, near food sources and shelters, and/or on trails potentially used as flight route. Nets were opened at 18:00 h and closed at midnight. The total bat sampling effort, following Straube & Bianconi (2002), was of 18,144 hours*m^2.

We identified, measured, and weighted all animals captured. We also recorded the reproductive status of all animals. We considered as reproductive all perforated, lactating, or pregnant females. Small non-flying mammals were marked with numbered earrings (National Band & Tags – Mod. 1005 – 1). After data collection, we released all animals at the same place they were captured. Some specimens were collected for further confirmation of identification. All collected animals were deposited in the Mammal Collection of the University of Brasília (Supplement 3). All procedures (capture, handling and marking) followed the guidelines of animal care and use by the American Society of Mammalogists (Sikes & Gannon 2011). All captures and collections were made upon authorization issued by the Brazilian Institute for the Environment (IBAMA ACCTMB No. 198/2010). We used the specific literature for taxonomic identifications (Vizotto & Taddei 1973, Emmons & Feer 1997, Weksler & Bonvicino 2005, Carmignotto & Monfort 2006, Bonvicino et al. 2008, Gardner 2008, Reis et al. 2013). Confirmation of the identifications were done by comparison with material (skins and skulls) housed in the mammal collections of the Zoology Department of the Universidade de Brasília and the Museu Nacional da Universidade Federal do Rio de Janeiro.

We sampled larger mammals opportunistically by tracking them while collecting or setting traps for small mammals sampling. Additionally we set a total of six to ten camera traps (Tigrinus Analog 6.0C), at some sampling site per expedition (Supplement 2). Camera traps were set in open and forest areas, and remained in operation for about ten consecutive days in each expedition. Some were set in trails, others not, but in any case they were set apart at least 1.5 km from each other. In 2013 we changed all camera traps by another digital model (Bushnell Trophy Cam HD). We also took into account direct sights, animals hit by cars and/or carcasses found, as well as indirect observations, such as tracks and feces, obtained during active diurnal and nightly surveys. The total effort performed with camera traps was 14,508 traps*hours. We did not consider photos of the same species taken in less than one hour interval for abundance counting. All species, including carcasses, tracks, and photos were identified using pertinent literature (Becker & Dalponte 1991, Oliveira & Cassaro 1999, Borges & Tomás 2004, Mamede & Alho 2006, Carvalho Jr & Luz 2008, De Angelo et al. 2008).

3. Data Analysis

We used collector’s curve based on effort by expedition for checking the reliability of our mammal survey, including all species obtained by all methods. For the analysis of diversity we used the number of individuals and not total captures of small mammals. We used rarefaction curves based on abundance for compare non-flying small mammal diversity between (1) open and forest areas, (2) before and after the reservoir filling in open areas, and (3) before and after flooding in forest habitats. All comparisons were done using Coleman index on EstimateS Version 9.1.0 (Colwell 2013) and tested differences using Z tests (Zar 1999).

Table 1. Mammalian species recorded at Serra do Facão region from 2008 to 2013. Families richness is displayed at parenthesis. Habitat of record and sampling methods are: O = open areas, F= forest, Cap = capture, Vs = visually, Ct = camera trap, Ts = track surveys.

Taxa	Habitat	Sampling method
DIDELPHIMORPHIA		
Didelphidae (8)		
Caluromys lanatus (Olfers, 1818)	F	Cap
Cryptonanus agricolai (Moojen, 1943)	O	Cap
Didelphis albiventris Lund, 1840	O, F	Cap
Gracilinanus agilis (Burmeister, 1854)	O, F	Cap
Micoureus demerarae (Thomas, 1905)	F	Cap
Monodelphis domestica (Wagner, 1842)	O, F	Cap
Monodelphis kunsi Pine, 1975	O, F	Cap
Thylamys karimii (Petter, 1968)	O	Cap
CINGULATA		
Dasypodidae (5)		
Cabassous unicinctus (Linnaeus, 1758)	O	Vs
Dasypus novemcinctus Linnaeus, 1758	F	Ct
Dasypus septemcinctus Linnaeus, 1758	F	Vs
Euphractus sexcinctus (Linnaeus, 1758)	O	Vs
Priodontes maximus (Kerr, 1792)*	F	Ct, Vs, Ts
PILOSA		
Myrmecophagidae (2)		
Myrmecophaga tridactyla Linnaeus, 1758*	F, O	Ct, Ts, Vs
Tamandua tetradactyla (Linnaeus, 1758)	F	Ct, Ts
CHIROPTERA		
Phyllostomidae (10)		
Anoura caudifer (E. Geoffroy, 1818)	F	Cap
Artibeus lituratus (Olfers, 1818)	F	Cap
Carollia perspicillata (Linnaeus, 1758)	F	Cap
Dermanura cinerea (Gervais 1855)	F	Cap
Desmodus rotundus (E. Geoffroy, 1810)	F	Cap
Glossophaga soricina (Pallas, 1766)	F	Cap
Mimon bennettii (Gray, 1838)	F	Cap
Phyllostomus hastatus (Pallas, 1767)	F	Cap
Platyrrhinus lineatus (E. Geoffroy, 1810)	F	Cap
Sturnira lilium (E. Geoffroy, 1810)	F	Cap
PRIMATES		
Atelidae (1)		
Alouatta caraya (Humboldt, 1812)	F	Vs
Callithrichidae (1)		
Callithrix penicillata (E. Geoffroy, 1812)	F	Vs
Cebidae (1)		
Sapajus libidinosus (Spix, 1823)	F	Ct, Vs, Cap
CARNIVORA		
Canidae (3)		
Cerdocyon thous (Linnaeus, 1766)	O	Ct,Vs, Cap
Chrysocyon brachyurus (Illiger, 1815)*	O	Ct, Vs
Lycalopex vetulus (Lund, 1842)*	O	Ct, Vs
Procyonidae (2)		
Nasua nasua (Linnaeus, 1766)	F, O	Ct, Vs, Cap
Procyon cancrivorus (G. Cuvier, 1798)	F, O	Ct, Vs
Mustelidae (4)		
Conepatus semistriatus (Boddaert, 1785)	O	Vs
Eira barbara (Linnaeus, 1758)	F	Ct, Vs
Galictis cuja (Molina, 1782)	O, F	Vs
Lontra longicaudis (Olfers, 1818)	F	Vs, Ts
Felidae (5)		
Leopardus pardalis (Linnaeus, 1758)	F	Ct, Cap, Ts
Leopardus tigrinus (Schreber, 1775)*	F	Ts, Vs

Continued on next page

Table 1. Continued.

Taxa	Habitat	Sampling method
Leopardus wiedii (Schinz, 1821)*	F	Ct
Puma concolor (Linnaeus, 1771)*	F	Ct, Ts
Puma yagouaroundi (E. Geoffroy, 1803)*	F	Vs
PERISSODACTYLA		
Tapiridae (1)		
Tapirus terrestris (Linnaeus, 1758)	F, O	Ts
ARTIODACTYLA		
Tayassuidae (1)		
Pecari tajacu (Linnaeus, 1758)	F	Ct, Vs, Ts
Cervidae (2)		
Mazama americana (Erxleben, 1777)	F	Ct, Vs
Mazama gouazoubira (G. Fischer, 1814)	O, F	Ct, Vs
RODENTIA		
Cricetidae (10)		
Calomys expulsus (Lund, 1841)	O, F	Cap
Calomys tener (Winge, 1887)	O, F	Cap
Cerradomys scotti (Langguth & Bonvicino, 2002)	O, F	Cap
Hylaeamys megacephalus (G. Fischer, 1814)	O, F	Cap
Necromys lasiurus (Lund, 1841)	O	Cap
Oecomys cleberi Locks 1981	F	Cap
Oligoryzomys fornesi (Massoia, 1973)	F	
Oligoryzomys moojeni Weksler & Bonvicino 2005	F	Cap
Oligoryzomys nigripes (Olfers, 1818)	O, F	Cap
Rhipidomys macrurus (Gervais, 1855)	O, F	Cap
Erethizontidae (1)		
Coendou prehensilis (Linnaeus, 1758)	F	Vs
Caviidae (1)		
Hydrochoerus hydrochaeris	F	Ts
Cuniculidae (1)		
Cuniculus paca (Linnaeus, 1766)	F	Ct
Dasyproctidae (1)		
Dasyprocta azarae Lichtenstein, 1823	F	Vs
Echimyidae (2)		
Proechimys roberti Thomas, 1901	F	Cap
Thrichomys apereoides (Lund, 1839)	O	Cap
LAGOMORPHA		
Leporidae (1)		
Sylvilagus brasiliensis (Linnaeus, 1758)	F	Ct, Vs

* Threatened species (MMA 2014).

Reproductive patterns were roughly designed by the percentage of reproductive females in dry and wet seasons. Our sampling of larger mammals with camera traps did not allow the recognition of individuals and abundance estimates. However the number of records may provide an idea of abundance or activity of a given species in the area or specific habitat type.

Results

We recorded 63 species of mammals in the study area: 33 larger mammals, 20 small non-flying mammals and 10 bats (all belonging to the Phyllostomidae family) (Table 1). The collector's curve based on sampling effort by expedition for all species stabilized on the 13^{th} expedition (Figure 2), indicating we performed an adequate effort to sample the local richness. We recorded eight species considered as threatened with extinction (MMA 2014), such as *Puma concolor* and *Priodontes maximus* (Table 1).

The sampling effort with camera traps was equivalent to 14,508 traps*hour, which yielded 231 records of 22 species of large mammals. Photographic records of some species are presented on Supplement 4. Data from direct and indirect observations resulted in 11 additional species that were not recorded by camera traps, totaling 33 species of large mammals observed with all thechniques combined. The most speciose large mammals families were Dasypodidae (n = 5) and Felidae (n = 5). More than half large species (51%) were recorded exclusively in forest environments, 24.5% were recorded only in open areas and 24.5% in both environments. The species with greater number of records were *Mymercophaga tridactyla* (n = 54) and *Sylvilagus brasiliensis* (n = 30). The smallest number of records were obtained for *Lycalopex vetulus* (n = 4) and *Mazama americana* (n = 2).

The sampling effort of 18,144 hour*m^2 with mist nets in forest habitats resulted in capture of 107 individuals of 10 species of bats. The most frequently captured bat species were *Carollia perspicillata* (n = 26) and *Artibeus lituratus* (19), and

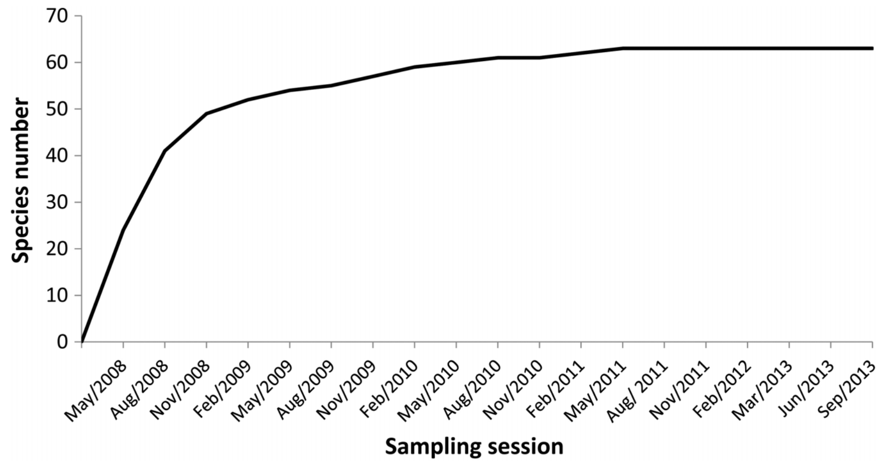

Figure 2. Species accumulation curve (collector's curve) based on effort for all mammalian species recorded in the Serra do Facão hydroelectric plant from May 2008 to September 2013.

Mimon benetti was recorded only once. For small non-flying mammals, the capture success with live traps (Sherman and Tomahawk) was approximately 2%, with 20 species recorded. Pitfall traps did not resulted in exclusive additional records of species. However, two species of rodents (*O. cleberi* and *P. roberti*), and two species of marsupials (*C. lanatus* and *M. demararae*) were recorded exclusively with live traps.

The Cricetidae family was the most representative, with 10 species, followed by Didelphidae (n = 8). Five species were captured only in forest environments, three of them were restricted to open areas, and eleven were captured in both environments. *Gracilinanus agilis* was the most frequently captured small mammal (N = 255), followed by *Calomys tener* (N = 200). These two species were more abundant in dry season (*C. tener* – n = 141 e *G. agilis* – n = 209). Marsupials were reproductive during wet season, whereas rodents were reproductive during all year (Figure 3). About 24% of all *G. agilis* females captured on wet season were reproductive, whereas only 4% of them were reproductive during all dry season. The species *C. tener* was found reproductive throughout the year (Figure 3). The rodents *Oecomys cleberi*, *Proechymys roberti*, and *Rhipidomys macrurus* and the marsupials *Caluromys lanatus* and *Thylamys karimii* were the rarest small mammal species, with only one to three records each. Since field expeditions, we used this group to assess local populational and diversity parameters.

Forest habitats were more diverse in small terrestrial mammals than open areas ($Z = -8.115$; $p < 0.001$; Figure 4). The diversity was higher before flooding for both open ($Z = -8.956$; $p < 0.001$; Figure 5) and forest habitats ($Z = -2.530$; $p = 0.005$; Figure 6)

Discussion

We found mammal richness similar to those reported in long sampling period studies conducted in cerrado Protected Areas (Table 2). Despite our larger sampling effort, we recorded 73% of mammals recorded for Emas National Park,

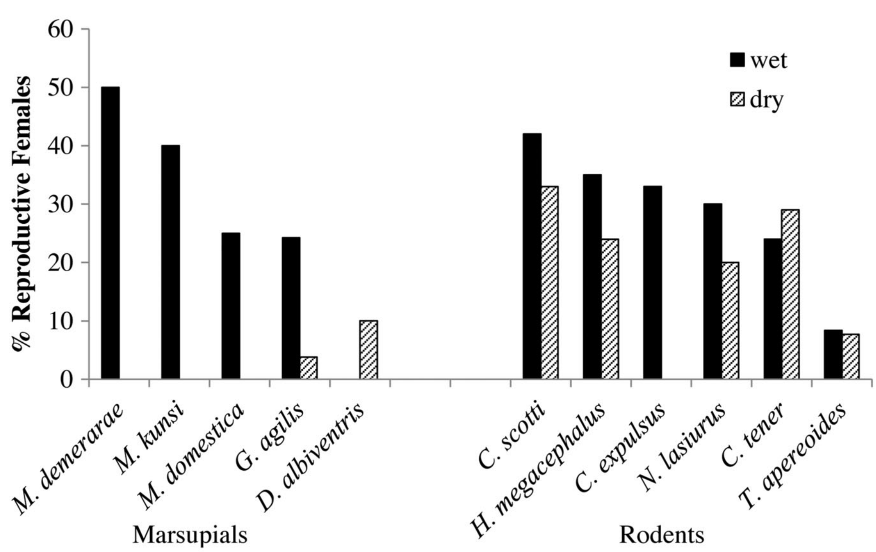

Figure 3. Percentage of reproductive females of marsupials and rodents captured during dry and wet seasons at Serra do Facão region, Goiás state, from May 2008 to September 2013.

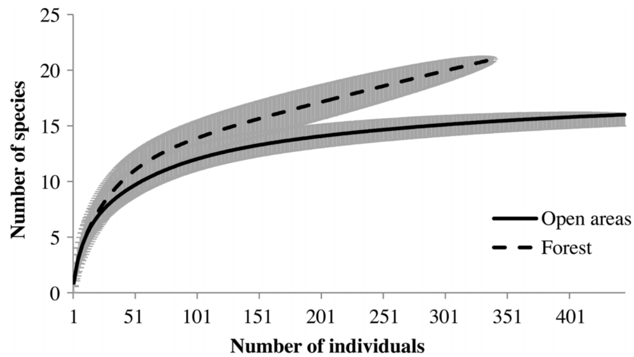

Figure 4. Rarefaction curves (Cole estimator) for small non-volant mammals captured in open and forest environments at Serra do Facão, Goiás state, from May 2008 to September 2013.

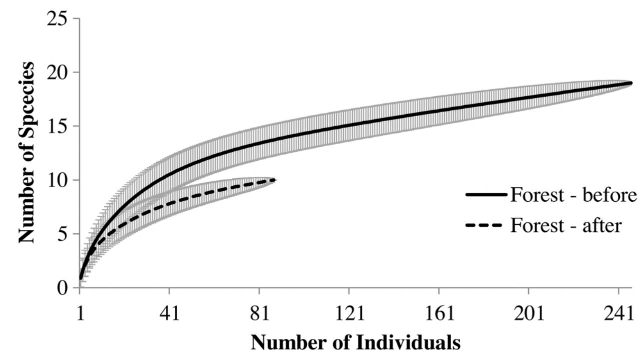

Figure 6. Rarefaction curves for small non-volant mammals in forest enviroments before (May 2008 to November 2009) and after (February 2010 to September 2013) the reservoir flooding of the Hydroeletric Power Plant of Serra do Facão.

with about 132,000 ha (Rodrigues et al. 2002). Águas Emendadas Ecological Station, in the Federal District, with 11,000 ha, shows similar species richness (Marinho-Filho et al. 1998) to Serra do Facão region. Other studies found between 24 and 93 species for areas of different sizes and locations in the Brazilian cerrado (Mares et al. 1989, Schneider 2000, Moreira et al. 2008, Pereira & Geise 2009) (Table 2).

Small Mammals – We recorded 20 species of small non-flying mammals. About 25% of them were exclusive to forest environments and 15% were recorded only in open areas. This pattern is expected for the cerrado biome (Marinho-Filho et al. 2002). Considering studies in Protected Areas of cerrado and those that make use of pitfalls in addition to conventional traps, the richness of small non-flying mammals ranged from 19 to 29 species (Schneider 2000, Marinho-Filho et al. 2002, Pereira & Geise 2009, Carmignotto & Aires 2011, Bonvicino et al. 2012). This richness is similar (or even large) than our study, despite our larger sample effort (Table 2). The region of Serra do Facão has been greatly altered by human activity over the last 300 years, and now is also impacted by the fragmentation and reduction of natural habitats imposed by São Marcos river dams and by the infrastructure projects associated to Serra do Facão Hydroelectric Plant (Chaul 1997). However, the richness observed in the region of Serra do Facão is comparable to some Protected Areas in the cerrado domain, and other cerrado localities. We recorded some cerrado rare species (Marinho-Filho et al. 2002) as *Oecomys cleberi*, *Micoureus demerarae, Caluromys lanatus*, and *Thylamys karimii*, and their records were also rare throughout the study. The higher richness of forests when compared to open areas are also an expected finding for cerrado small non-flying mastofauna (Marinho-Filho et al. 2002).

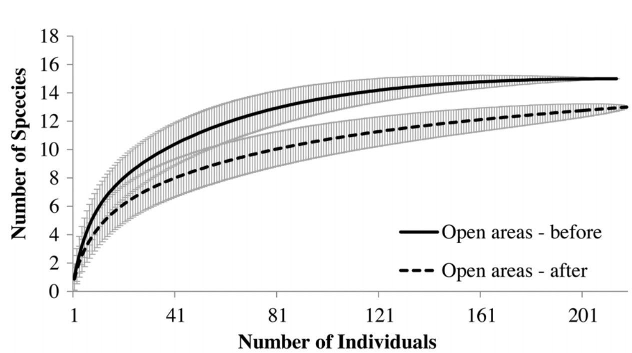

Figure 5. Rarefaction curves for small non-volant mammals in open areas before (May 2008 to November 2009) and after (February 2010 to September 2013) the reservoir flooding of the Hydroeletric Power Plant of Serra do Facão.

The reservoir formation for the hydroelectric enterprise on Serra do Facão seemingly affected the small mammal diversity in open and forest habitats. The impacts of hydroelectric power plants on mammal communities were investigated by several other studies, and species loss is a common effect of reservoir filling (Cosson et al. 1999, Fournier-Chambrillon et al. 2000, Alho 2011, Andriolo et al. 2013). Besides habitat (and area) loss, the increase of predation and competition intensity are possible as factors affecting small non-flying mammals diversity loss in this kind of environmental change (Lemos de Sá 1995, Alho 2011, Andriolo et al. 2013, Passamani & Cerboncini 2013).

Marsupials presented seasonal reproduction, whereas rodents were reproductive year round (Figure 3). The marsupial *Gracilinanus agilis* showed marked seasonal reproduction, confirming previous studies (Mares et al. 1989, Mares & Ernest 1995) but the rodent *Calomys tener*, was reproductive in both rainy and dry seasons (Figure 3). Studies carried out in central cerrado showed that the reproduction in *C. tener* females is significantly greater during the rainy season, with reproductive individuals recorded year round, but in lower proportions during the dry season (Mares et al. 1989, Rocha 2011).

Bats – Bat richness in Serra do Facão is lower when compared to other areas in cerrado, which presented a richness ranging from 16 to 25 species (Marinho-Filho et al. 1998, Aguiar 2000, Rodrigues et al. 2002, Bezerra & Marinho-Filho 2010). We recorded 10 species of bats, which represents only 10% of the richness known to the cerrado (Paglia et al. 2012). Although some other studies report equally modest numbers of bat species found in some cerrado areas (see Table 2 e.g. (Moreira et al. 2008) such low richness seems to be more an effect of relatively small sampling effort. The fact that we also only captured phyllostomid bats is expected with mist nets. The bat community from Serra do Facão is clearly undestimated and more species will be added with further sampling. However, there are some interesting records such as an individual of *Mimon benetti* a gleaning animalivore, not so common in inventories and collections. Although *Anoura caudifer* presents a wide distribution in South America,

Table 2. Mammalian richness from different Cerrado localities, including Protected Areas (PA).

Richness	PA	Methodology	Year	Sampling effort	References
Small non-flying mammals					
18	yes	Sherman/Wire traps	1986-1998	not available	Marinho-Filho et al. 1998
19	yes	Sherman/Wire traps Pitfall	2002-2004	10,897 traps*night 2,671pifalls*night	Pereira & Geise 2009
19	no	Sherman/Wire traps	1998; 1999; 2010	7,651 traps*night	Bonvicino et al. 2012
20	**no**	**Sherman/Wire traps** **Pitfall**	**2008-2013**	**31,496 traps*night** **49,600 pitfalls*night**	**This study**
21	yes	Sherman/Wire traps	1999-2000	13,200 traps*night	Santos-Filho et al. 2012
23	yes	Sherman/Wire traps Pitfall	1998-1999	10,664 traps*night 2,898 traps*night	Carmignotto et al. 2014
24	yes	Sherman/Wire traps Pitfall	1998-1999	10,664 traps*night 2,898 pifalls*night	Rodrigues et al. 2002
24	yes	Sherman/Wire traps Pitfall	2003; 2008	5,396 traps*night 5,300 pifalls*night	Carmignotto & Aires 2011
29	no	Sherman/Wire traps Pitfall	1988-1989; 1998-1999; 1997	not available not available	Schneider 2000
Bats					
9	no	Mist net	2003-2004	2,520 m2*hour	Moreira et al. 2008
10	**no**	**Mist net**	**2008-2013**	**18,144 m2*hour**	**This study**
16	yes	Mist net	1986-1998	not available	Marinho-Filho et al. 1998
17	Both	Mist net	1983-1984	not available	Mares et al. 1989
22	yes	Mist net	1998-1999	388,800 m2*hour	Aguiar 2000
23	no	Mist net	2004	16,650 m2*hour	Bezerra & Marinho-Filho 2010
24	yes	Mist net	1998-1999	26,838 m2*hour	Rodrigues et al. 2002
25	no	Mist net	1997; 1998 - 1999	not available	Schneider 2000
Large mammals					
10	no	Observations	2003-2004	80 hours	Moreira et al. 2008
10	yes	Observations	2002-2004	not available	Pereira & Geise 2009
17	yes	Observations	2003; 2008	not available	Carmignotto & Aires 2011
18	no	Observations	2008-2009	143.51 km - 320 hours	Alves et al. 2014
23	no	Observations	2008-2009	7,200 km	Bocchiglieri et al. 2010
26	yes	Track stations Census	2001-2002	1,518 track stations*night 309 km - 207 hours	Oliveira et al. 2009
29	Both	Observations	1983-1984	not available	Mares et al. 1989
32	yes	Observations	1986-1998	not available	Marinho-Filho et al. 1998
33	**no**	**Observations** **Camera trap**	**2008-2013**	**not available** **14,508 traps.hour**	**This study**
38	no	Observations	1999-2000	not available	Brito et al. 2001
39	no	Observations	1988-1989; 1998-1999; 1997	not available	Schneider 2000
37	yes	Observations/Census	1994-1999	not available	Rodrigues et al. 2002
All mammals					
24	no		2003-2004		Moreira et al. 2008
58	yes		2002-2004		Pereira & Geise 2009
63	**no**		**2008-2013**		**This study**
66	yes		1986-1998		Marinho-Filho et al. 1998
85	yes		1994-1999		Rodrigues et al. 2002
86	Both		1983-1984		Mares et al. 1989
93	no		1997; 1998-1999		Schneider 2000

occurring in several Brazilian states, there are few localities in the Brazilian cerrado with formal records in the literature (Oprea et al. 2009), and the species was recorded only in northeastern Goiás (Zortéa & Alho 2008, Bezerra & Marinho-Filho 2010, Peracchi et al. 2010). The present record of *A. caudifer* indicates this species presents a wider distribution across the cerrado. The small bat species richness verified at Serra do Facão may have been caused by a number of causes as well as their combination. 1) We used only mist nets to sample bats and no bat detectors that help to find and identify species that fly high above the canopy of forests and are not easily captured with nets. 2) Bat sampling was conducted in the period between

18:00 and 24:00 h, and consequently; 3) not all bat activity periods were covered and not all areas were explored as well as collection did not take place in all field trips. Thus, the assemblage of bats in Serra do Facão is clearly underestimated and further studies remain be done.

Large mammals – We recorded 33 large mammals species (Table 1, Supplement 4), a richness higher than the sum of richness found in three Protected Areas in Brasília (n = 25) (Juarez 2008). Other studies also carried out in other cerrado regions, including Protected Areas (Marinho-Filho et al. 1998, Schneider 2000, Brito et al. 2001, Rodrigues et al. 2002, Moreira et al. 2008, Oliveira et al. 2009, Bocchiglieri et al. 2010, Carmignotto & Aires 2011, Alves et al. 2014), recorded 10 to 39 species of large mammals (Table 2). However, any comparison on large mammal richness between areas is limited because there is not a standard methodology used in different studies and the sampling efforts performed for this group in different studies are also very different. Indeed, most large mammals checklists are based on opportunistic data.

Eigth species of larger mammals surveyed are threatened with extinction (MMA 2014): *Priodontes maximus*, *Mymercophaga tridactyla*, *Chrysocyon brachyurus*, *Lycalopex vetulus, Leopardus tigrinus, L. wiedii*, *Puma concolor,* and *P. yagouaroundi.* The giant armadillo, *Priodontes maximus,* occurs in nearly all Brazilian biomes (Medri et al. 2010). This species, as well as their characteristic burrows, were found in both open and forest areas by direct observation and camera trapping. The fact that this species is considered extinct in various localities of southern Brazil (Marinho-Filho & Medri 2008) and is currently declining in other Brazilian regions, reinforces the importance of Serra do Facão for the conservation of its wild populations. Another threatened species found was the giant anteater, *Mymercophaga tridactyla*, which originally occurred in all Brazilian biomes, but is currently considered extinct in eastern states of Rio de Janeiro and Espírito Santo, and its populations are declining in southern, southeastern and northeastern Brazil (Medri & Mourão 2008). In the present study, the giant anteater was the most frequently recorded species among large mammals, using both open and forest areas - where most records were made.

The maned wolf, *Chrysocyon brachyurus*, a species associated with central Brazilian cerrados (Cheida & Santos 2010) was one of the rarest species in the present study, and the few records were obtained in open vegetation areas. Furthermore, we recorded the occurrence of some felines threatened with extinction. The margay, *Leopardus wiedii*, was spotted only in forest environments. *Puma concolor*, another feline threatened with extinction was the largest predator, with few photo records in the region. We did not detect jaguar, *Panthera onca*, which could explain the considerable abundance of mesopredators, such as *L. wiedii* in the area. The oncilla, *Leopardus tigrinus*, was one of the rarest species among larger mammals and this may be explained by the relatively high frequency of *L. pardalis,* one of the largest predators found, and capable of excluding smaller spotted cats in areas where it is dominant (Oliveira 2004).

Despite the fact that Serra do Facão region has been altered for centuries by several kinds of natural resources exploitation that resulted in a quite fragmented landscape, and the area that we sampled is not included in or near to any protected area, the present study reveals that it still shelters a mammalian fauna corresponding to at least 25% of the total mammalian fauna of the whole cerrado biome. This richness, in addition to the presence of rare and threatened species, reinforces the importance of natural remnants of cerrado for the conservation of regional mammalian fauna. It also calls attention for the importance of enforcing the protection of natural areas that may be affected by many large infrastructure projects.

Acknowledgments

We are grateful to Serra do Facão Energia S.A. for financial and logistic support and to Fundação Pró-Natureza for logistic and administrative support; to CAPES for the fellowships to LPG, CRR and JMF; to CNPq for fellowship and financial support to JMF; to all those who helped in the fieldwork; to Danielle Palhares for translating the text into English; to Pedro de Podestá for the map and edition of the pictures; to Alexandra Bezerra, Raquel Ribeiro and Alexandre Portella for help with species identification.

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Received 06/05/2015
Revised 23/07/2015
Accepted 10/09/2015

Biota Neotropica 15(4): e0155, 2015
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
inventory

Birds at Santa Bárbara Ecological Station, one of the last Cerrado remnants in the state of São Paulo, Brazil

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LUCINDO, A.S., ANTUNES, A.Z., KANASHIRO, M.M, DIAS, M.M. **Birds at Santa Bárbara Ecological Station, one of the last Cerrado remnants in the state of São Paulo, Brazil.** Biota Neotropica. 15(4): e0155. http://dx.doi.org/10.1590/1676-06032015015514

Abstract: In the state of São Paulo, southeastern Brazil, the phytophysiognomy known as Cerrado takes less than 1% of its original cover. Thus, the establishment and management of protected areas are essential to save a significant sample of biodiversity of this environment in the region. The Santa Bárbara Ecological Station is one of the largest protected areas in São Paulo, and one of the few ones to cover a mosaic with most of the vegetation types of Cerrado. This article aims to increase the knowledge of avifauna in the reserve, showing new bird records and evaluating the association of species to their physiognomies. We carried out surveys from 2008 to 2013, which resulted in the record of 226 species, or 246 when in regard to Willis & Oniki's works (1981, 2003). Twenty-two are regionally threatened, and five globally threatened. Despite showing lower species richness, grasslands stood out because of the number of species of conservation concern. Preventing the densification of woody vegetation and controlling the invasion of alien plants are important management actions for the conservation of the bird assemblages at Santa Bárbara reserve, one of the last open Cerrado remnants in São Paulo.
Keywords: *conservation, protected area, management, savanna*

LUCINDO, A.S., ANTUNES, A.Z., KANASHIRO, M.M, DIAS, M.M. **Aves da Estação Ecológica de Santa Bárbara, um dos últimos remanescentes de Cerrado no Estado de São Paulo, Brasil.** Biota Neotropica. 15(4): e0155. http://dx.doi.org/10.1590/1676-06032015015514

Resumo: Atualmente no estado de São Paulo, o Cerrado ocupa menos de um por cento de sua cobertura original. O estabelecimento e o manejo de unidades de conservação de proteção integral são fundamentais para resguardar uma amostra significativa da biodiversidade deste domínio fitogeográfico em território paulista. A Estação Ecológica de Santa Bárbara está entre as maiores áreas protegidas em São Paulo, e é uma das poucas a contemplar um mosaico dos diferentes tipos de vegetação de Cerrado. Os objetivos do presente trabalho foram ampliar o conhecimento sobre a avifauna da estação e avaliar a associação das espécies com as diferentes fitofisionomias. A amostragem ocorreu entre 2008 e 2013. Foram registradas 226 espécies de aves, ou 246 considerando os primeiros estudos na área (Willis & Oniki 1981, 2003). Vinte e duas encontram-se regionalmente ameaçadas de extinção e cinco ameaçadas globalmente. Apesar da menor riqueza específica, as formações campestres destacaram-se pelo número de espécies ameaçadas. Evitar o adensamento da vegetação arbórea e controlar a invasão por plantas exóticas são práticas de manejo fundamentais para a conservação das assembléias de aves na estação ecológica, um dos últimos remanescentes de Cerrado aberto em São Paulo.
Palavras-chave: *conservação, área protegida, manejo, savana.*

Introduction

In the Brazilian states of São Paulo and Paraná, Cerrado phytophysiognomies appear as open vegetation enclaves immersed in a forest matrix, establishing the southern boundary of this domain (Durigan et al. 2006). In São Paulo, where the Cerrado took nearly 14% of the area, today less than 1% of its original cover remains (Kronka et al. 2005), and only 0.5% is protected area, including ecotones with the Atlantic Forest domain (Durigan et al. 2006).

Regarded as the most biodiverse tropical Savanna, Cerrado is among the 34 areas with higher conservation priorities, also known as hotspots of biodiversity of the world (Mittermeier et al. 2004). In this context, the birds constitute the animal group best known from both taxonomic and ecological viewpoints. The avifauna inventory in Cerrado remnants may contribute to select areas aimed for the creation of reserves, as well as to monitor ecological restoration actions within the already implemented ones.

There are 856 known bird species in the Cerrado domain, within which 30 (3.5%) are considered endemic (Silva & Santos

2005). In comprehensive analyses of Cerrado avifauna, Silva (1995a, b, 1996) excluded the Cerrado in São Paulo and Paraná, which he designated as enclaves within the Atlantic forest. Nonetheless, among the endemic species (Silva 1995b, Silva & Santos 2005), 16 (53%) of them still occur in patches located within São Paulo (Willis & Oniki 2003). For this reason, many authors believe an analysis of these bird species makes more sense when they are regarded as part of the Cerrado (Willis 2004, Motta-Júnior et al. 2008, Batalha et al. 2010, Fieker et al. 2013).

Willis & Oniki (1981) were pioneers in bird censuses in São Paulo protected areas, especially in Cerrado and semideciduous forests of interior plateaus. In their studies, they included three Cerrado areas, named ecological stations of Assis, Mogi Guaçu (formerly Fazenda Campininha), and Santa Bárbara (formerly Santa Bárbara do Rio Pardo), the latter highlighted for the occurrence of endemic and threatened species of Cerrado, as happens at the Itirapina Ecological Station (Motta-Júnior et al. 2008).

Santa Bárbara Ecological Station currently harbors up to 330 vertebrate species (São Paulo 2011, Araújo et al. 2010, 2013) and 530 vascular plants species (Meira-Neto et al. 2007, São Paulo 2011). It is one of the few protected areas to cover a mosaic with most vegetation types in Cerrado. A comparison with other Cerrado bird assemblages within São Paulo could clarify the understanding of the patterns of avian species richness and species-physiognomy relation in the Ecological Station. Published bird surveys encompass forest physiognomies of Cerrado (Telles & Dias 2010, Cavarzere et al. 2011); shrubby ones (Willis 2006); forest and shrubby ones (Motta-Júnior 1990, Dias 2000, Manica et al. 2011); forest, shrubby and grassland ones (Motta-Júnior et al. 2008), and Atlantic forest-savanna bondaries (Develey et al. 2005).

This article aims to increase knowledge of the birds at Santa Bárbara Ecological Station, showing new bird records; evaluating species richness and its relation to the local physiognomies, and examining the relevance of maintaining this reserve for the conservation of birds in the Cerrado of São Paulo.

Material and Methods

1. Study area

Santa Bárbara Ecological Station (headquarters at 22° 48'54"S and 49°14'12"W) takes an area of 2,712 ha in the county of Águas de Santa Bárbara. The altitude ranges between 600-680 m and climate is classified as Köppen's Cwa, with warm summer and dry winter. Based on field observations and literature (Stotz et al. 1996), we classified the vegetation into three main phytophysiognomies, namely: open grass savanna, which consists of wet grassland remnants and *campo cerrado*; shrubby savanna (cerrado *sensu stricto*); and woody savanna (forest-like vegetation), formed by dense *cerrado*, *cerradão* woodland, semideciduous seasonal forest, riparian vegetation and marsh-like vegetation. There are also *capoeiras*, plots of *Pinus* spp. and *Eucalyptus* spp., anthropic fields (pastures with invasive alien grasses), and aquatic vegetation associated with streams and water reservoirs. The Management Plan for the reserve shows a map with the distribution of local physiognomies (São Paulo 2011).

The local avifauna was previously surveyed by Willis & Oniki (1981, 2003), who visited the area between 1976 and 1989, and recorded 131 bird species in 17 transect hours.

2. Bird census

Birds were surveyed with transect counts (Bibby et al. 1993), which consist of walking slowly at a speed of about 1 km/h on trails, firebreaks and roads, registering each individual bird contacted. We visited excerpts of all environments at Santa Bárbara Ecological Station between October 2008 and August 2013, for 380 hours of sampling effort.

Observations of birds were aided with 8 x 42 binoculars. For documentation purposes, we used professional recorders Sony PCM-D50 and Marantz PMD222, with a Sennheiser ME66/K6C Shotgun microphone, and a camera Canon SX30 IS. Sound recordings have been deposited at Xeno-Canto database (http://www.xeno-canto.org). Geographic coordinates of the main sampled areas were obtained with GPS Garmin e-Trex Summit, with geodetic system in SAD 69 Datum.

The scientific nomenclature adopted comes from the Comitê Brasileiro de Registros Ornitológicos (CBRO 2014). When defining threatened species, we followed the official list of São Paulo (Silveira et al. 2009), the Brazilian list (Silveira & Straube 2008), and the global list (IUCN red list) (BirdLife International 2014). For defining species endemic to the Cerrado, we relied on Silva & Santos (2005), Motta-Júnior et al. (2008), and Vasconcelos (2008).

Species composition was compared to other areas of Cerrado within São Paulo, namely: Botanical Garden/UNESP Reserve in Bauru (Cavarzere et al. 2011), Canchim Farm in São Carlos (Manica et al. 2010), UNESP Reserve in Corumbataí (Willis 2006), Itirapina Ecological Station (Willis 2004, Motta-Júnior et al. 2008, Fieker et al. 2013), Itirapina Experimental Station (Telles & Dias 2010), Jataí Ecological Station (Dias 2000), Cerrado Pé-de-Gigante/Vassununga State Park (Willis & Oniki 2003, Develey et al. 2005), and UFSCar, campus São Carlos (Motta-Júnior 1990) (Figure 1). Similarities (Jaccard's index) between areas were evaluated through the UPGMA clustering analysis with Euclidean distance matrix, using the R stats package (R Development Core Team 2008).

Results and Discussion

We found 226 avian species, of which 128 were tape-recorded and 79 photographed, counting upon 69% of the avifauna. Along with Willis and Oniki's transect counts, Santa Bárbara Ecological Station reaches 246 species (Table 1). The two studies had 111 species in common, reaching 45% of similarity at different times. Twenty species were found only in the 1980s, and 115 species found in this study had not been previously reported for the area, an increase of the local species list by 87%. The bird list of the ecological station can possibly be expanded with more surveys. However, the nuclear avifauna for each phytophysiognomy, i.e. the set of resident and regular migratory species (Remsen 1994), was determined. Therefore, we believe data showed here constitute a strong basis for local assemblages.

We observed 90 species in open grass savannas, 81 in shrubby savannas, and 124 in woody savannas (Figure 2). The number of exclusive species was significantly higher in the forest environments than in the savanna ones. Sick (1966) and Silva & Santos (2005) described the avifauna in Cerrado as a predominantly forest group living in a biome mainly covered by savannas, since 72% of species use forest physiognomies. Besides, several species from open formations require the

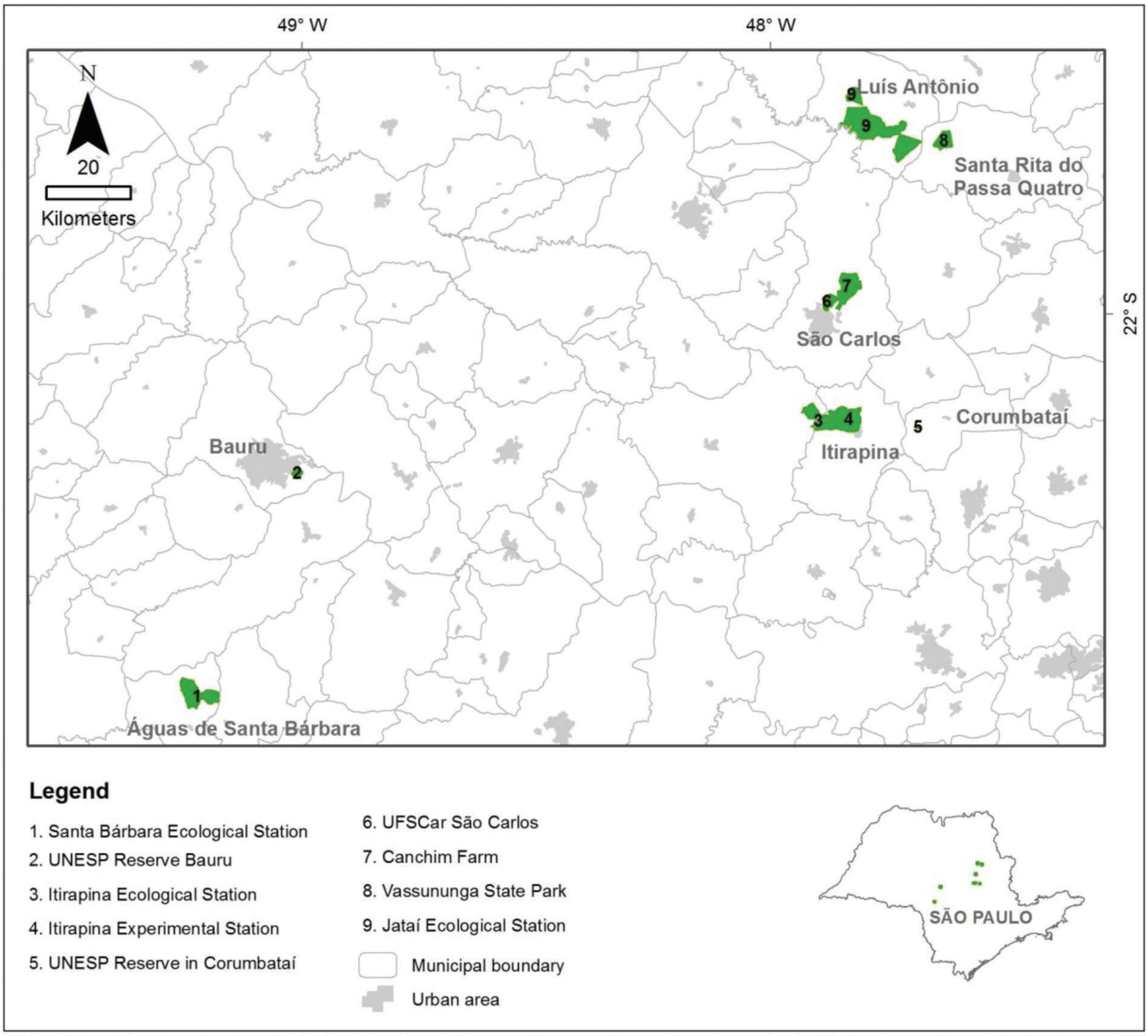

Figure 1. Cerrado locations within São Paulo state with published bird surveys.

vegetation mosaic to keep their population, because they obtain resources in savanna spots and forest edges (Piratelli & Blake 2006). On the other hand, the records of threatened species were more frequent in environments with open vegetation, such as *campo cerrado* and wet grassland. Ignoring anthropogenic habitats and individual birds flying over, grasslands had the highest proportion of species of conservation concern (14%).

In general, Santa Bárbara assemblages correspond to 29% of the known Cerrado avifauna (Silva & Santos 2005), with six species restricted to this domain: *Melanopareia torquata* (Wied, 1831), *Antilophia galeata* (Lichtenstein, 1823), *Cyanocorax cristatellus* (Temminck, 1823), *Saltatricula atricollis* (Vieillot, 1817), *Cypsnagra hirundinacea* (Lesson, 1831), and *Neothraupis fasciata* (Lichtenstein, 1823). Seven local species are nearly threatened and twenty-two are threatened in São Paulo, within which four are in the Brazilian list and five in the global list. Among the species threatened in São Paulo, eight (38%) are in the critically endangered category, i.e. with extremely high risk of regional extinction; three were found only by Willis & Oniki (1981, 2003): *Cistothorus platensis* (Latham, 1790), *Anthus nattereri* Sclater, 1878, and *Coryphaspiza melanotis* (Temminck, 1822).

When compared to other Cerrado sampled areas in São Paulo, Santa Bárbara is among those richer in bird

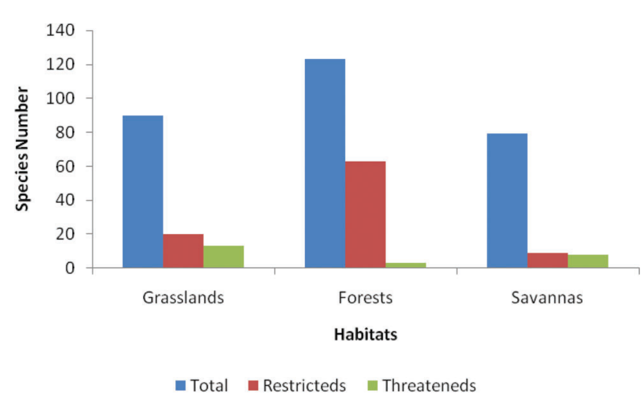

Figure 2. Bird species richness in three sets of habitats observed at Santa Bárbara Ecological Station, São Paulo, Brazil.

Table 1. Birds recorded at Santa Bárbara Ecological Station, São Paulo, Brazil. Types of documentation: T = tape-record; P = photograph. *Status*: NT = near threatened; CR = critically endangered; EN = endangered; VU = vulnerable. SP = local list of threatened species; BR = Brazilian list; red list = global list. N = number of contacts. Ecosystems: RS = reservoirs and swamps; AF = anthropic field (pasture); CC = *campo cerrado*; DC = dense *cerrado*; CW = *cerradão* woodland; WG = wet grassland; SS = cerrado *sensu stricto*; RV = riparian vegetation; SF = semideciduous seasonal forest; and MV = marsh-like vegetation. [lak]: species reported in this study; [wo]: species exclusively reported by Willis & Oniki (1981, 2003).

Species	Popular Name	SP	BR	red list	N	Ecosystems
Rheiformes						
Rheidae						
Rhea americana (Linnaeus, 1758) P	Greater Rhea	CR		NT	1	WG
Tinamiformes						
Tinamidae						
Crypturellus parvirostris (Wagler, 1827) T	Small-billed Tinamou				12	CC, SS
Crypturellus tataupa (Temminck, 1815)[wo]	Tataupa Tinamou					
Rhynchotus rufescens (Temminck, 1815) T	Red-winged Tinamou	VU			20	CC, WG, SS
Nothura maculosa (Temminck, 1815)	Spotted Nothura				2	AF, CC
Anseriformes						
Anatidae						
Cairina moschata (Linnaeus, 1758)[lak]	Muscovy Duck				5	RS
Amazonetta brasiliensis (Gmelin, 1789) P	Brazilian Teal				5	RS
Galliformes						
Cracidae						
Penelope superciliaris Temminck, 1815[lak] T	Rusty-margined Guan	NT			8	DC, CW, SS, RV, SF
Podicipediformes						
Podicipedidae						
Podilymbus podiceps (Linnaeus, 1758)[lak]	Pied-billed Grebe				1	RS
Suliformes						
Phalacrocoracidae						
Phalacrocorax brasilianus (Gmelin, 1789)[lak]	Neotropic Cormorant				1	RS
Anhingidae						
Anhinga anhinga (Linnaeus, 1766)	Anhinga				1	RS
Pelecaniformes						
Ardeidae						
Butorides striata (Linnaeus, 1758)[wo]	Striated Heron					
Bubulcus ibis (Linnaeus, 1758)[lak]	Cattle Egret				15	AF
Ardea alba Linnaeus, 1758[lak]	Great Egret				1	RS
Syrigma sibilatrix (Temminck, 1824) T	Whistling Heron				3	CC, WG
Threskiornithidae						
Mesembrinibis cayennensis (Gmelin, 1789)[lak] T	Green Ibis				4	RV, SF
Theristicus caudatus (Boddaert, 1783)[lak] T	Buff-necked Ibis				4	AF
Platalea ajaja Linnaeus, 1758[lak]	Roseate Spoonbill				1	RS
Cathartiformes						
Cathartidae						
Cathartes aura (Linnaeus, 1758) P	Turkey Vulture				4	DC
Coragyps atratus (Bechstein, 1793) P	Black Vulture				15	ALL
Sarcoramphus papa (Linnaeus, 1758)	King Vulture	VU			1	SF
Accipitriformes						
Accipitridae						
Gampsonyx swainsonii Vigors, 1825[lak] P	Pearl Kite				1	SS
Elanus leucurus (Vieillot, 1818)	White-tailed Kite				1	flying over CC
Accipiter bicolor (Vieillot, 1817)[wo]	Bicolored Hawk					
Ictinia plumbea (Gmelin, 1788)[lak]	Plumbeous Kite				3	DC
Rostrhamus sociabilis (Vieillot, 1817)[wo]	Snail Kite					
Heterospizias meridionalis (Latham, 1790) P	Savanna Hawk				3	SS
Rupornis magnirostris (Gmelin, 1788) T, P	Roadside Hawk				6	CC, DC, SS, RV, SF
Geranoaetus albicaudatus (Vieillot, 1816)	White-tailed Hawk				4	WG, SS, *Eucalyptus*
Buteo brachyurus Vieillot, 1816 T[lak]	Short-tailed Hawk				2	SF, flying over CC
Gruiformes						

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Table 1. Continued.

Species	Popular Name	SP	BR	red list	N	Ecosystems
Rallidae						
Micropygia schomburgkii (Schomburgk, 1848)[lak]	Ocellated Crake	CR			3	CC
Aramides cajaneus (Statius Muller, 1776)[lak] T	Gray-necked Wood-Rail				2	RS
Laterallus xenopterus Conover, 1934 T	Rufous-faced Crake	CR		VU	2	WG, RV
Porzana albicollis (Vieillot, 1819)[lak] T	Ash-throated Crake				18	CC, WG, SS
Pardirallus nigricans (Vieillot, 1819)[lak] T	Blackish Rail				2	RS
Gallinula galeata (Lichtenstein,1818)[lak]	Common Gallinule				2	RS
Charadriiformes						
Charadriidae						
Vanellus chilensis (Molina, 1782) P	Southern Lapwing				13	AF, CC
Scolopacidae						
Gallinago undulata (Boddaert, 1783)[lak] T	Giant Snipe				2	WG
Tringa flavipes (Gmelin, 1789)[wo]	Lesser Yellowlegs					
Jacanidae						
Jacana jacana (Linnaeus, 1766)[lak]	Wattled Jacana				4	WG
Columbiformes						
Columbidae						
Columbina talpacoti (Temminck, 1811) T, P	Ruddy Ground-dove				11	AF, CC
Columbina squammata (Lesson, 1831)[lak] T, P	Scaled Dove				9	AF, CC
Claravis pretiosa (Ferrari-Perez, 1886)[lak]	Blue Ground-dove				1	SS
Patagioenas picazuro (Temminck, 1813)[lak] T	Picazuro Pigeon				31	AF, CC, DC, CW, SS, RV, SF
Patagioenas cayennensis (Bonnaterre, 1792) T	Pale-vented Pigeon				7	CW, RV, SF
Zenaida auriculata (Des Murs, 1847) T, P	Eared Dove				19	CC, SS
Leptotila verreauxi Bonaparte, 1855 T, P	White-tipped Dove				10	CW, SS, RV, SF
Cuculiformes						
Cuculidae						
Piaya cayana (Linnaeus, 1766) T	Squirrel Cuckoo				5	SS, RV, SF
Coccyzus melacoryphus Vieillot, 1817	Dark-billed Cuckoo				2	CC
Crotophaga ani Linnaeus, 1758 T	Smooth-billed Ani				11	AF, CC, SS
Guira guira (Gmelin, 1788) T, P	Guira Cuckoo				23	AF, CC
Tapera naevia (Linnaeus, 1766) T, P	Striped Cuckoo				9	RS, CC, SS, RV
Dromococcyx pavoninus Pelzeln, 1870[lak]	Pavonine Cuckoo				2	SS
Strigiformes						
Tytonidae						
Tyto furcata (Scopoli, 1769)	Barn Owl				1	flying over SS
Strigidae						
Megascops choliba (Vieillot, 1817)[lak] T	Tropical Screech-Owl				2	RV
Athene cunicularia (Molina, 1782) P	Burrowing Owl				6	AF, CC, WG
Asio stygius (Wagler, 1832)[lak] T	Stygian Owl				1	RV
Asio flammeus (Pontoppidan, 1763)[lak]	Short-eared Owl	EN			1	WG
Nyctibiiformes						
Nyctibiidae						
Nyctibius griseus (Gmelin, 1789)[lak]	Common Potoo				2	RV, MV
Caprimulgiformes						
Caprimulgidae						
Antrostomus rufus (Boddaert, 1783)[lak] T	Rufous Nightjar				6	RV, SF, on firebreaks
Lurocalis semitorquatus (Gmelin, 1789)[lak]	Short-tailed Nighthawk				1	RV
Hydropsalis albicollis (Gmelin, 1789)[lak]	Pauraque				9	DC, RV, on firebreaks
Hydropsalis parvula (Gould, 1837)[lak]	Little Nightjar				4	RV, on firebreaks
Hydropsalis torquata (Gmelin, 1789)[lak]	Scissor-tailed Nightjar				2	DC, SS, on firebreaks
Apodiformes						

Continued on next page

Table 1. Continued.

Species	Popular Name	SP	BR	red list	N	Ecosystems
Apodidae						
Cypseloides fumigatus (Streubel, 1848)T	Sooty Swift				200	flying over AF
Cypseloides senex (Temminck, 1826)[wo]	Great Dusky Swift	NT				
Streptoprocne zonaris (Shaw, 1796)[lak]	White-collared Swift				1	flying over SS
Trochilidae						
Phaethornis pretrei (Lesson & Delattre, 1839)[lak]	Planalto Hermit				4	CW, RV, SF
Eupetomena macroura (Gmelin, 1788)[lak]	Swallow-tailed Hummingbird				5	CC, SS
Colibri serrirostris (Vieillot, 1816) P	White-vented Violetear				9	CC, WG, SS
Anthracothorax nigricollis (Vieillot, 1817)[lak]	Black-throated Mango				1	SF
Chlorostilbon lucidus (Shaw, 1812)[lak]	Glittering-bellied Emerald				3	SS
Thalurania glaucopis (Gmelin, 1788)[lak]	Violet-capped Woodnymph				1	CW, SF
Hylocharis chrysura (Shaw, 1812)[lak] P	Gilded Hummingbird				15	CC, DC, SS
Polytmus guainumbi (Pallas, 1764)[wo]	White-tailed Goldenthroat	VU				
Amazilia versicolor (Vieillot, 1818)	Versicolored Emerald				1	SF
Amazilia lactea (Lesson, 1832)[lak] P	Sapphire-spangled Emerald				4	RV, SF
Coraciiformes						
Alcedinidae						
Megaceryle torquata (Linnaeus, 1766)[lak]	Ringed Kingfisher				1	RS
Galbuliformes						
Galbulidae						
Galbula ruficauda Cuvier, 1816[lak] T, P	Rufous-tailed Jacamar				2	RV, SF
Bucconidae						
Nystalus chacuru (Vieillot, 1816) T, P	White-eared Puffbird				5	CC, SS
Piciformes						
Ramphastidae						
Ramphastos toco Statius Muller, 1776[lak] T, P	Toco Toucan				15	AF, DC, SS, RV
Picidae						
Picumnus temminckii Lafresnaye, 1845[wo]	Ochre-collared Piculet					
Picumnus albosquamatus d'Orbigny, 1840	White-wedged Piculet				3	SS, RV, SF
Melanerpes candidus (Otto, 1796)[lak] P	White Woodpecker				11	AF, CC, SS
Veniliornis passerinus (Linnaeus, 1766)[lak] T	Little Woodpecker				6	CC, SF
Colaptes melanochloros (Gmelin, 1788) T	Green-barred Woodpecker				2	RV
Colaptes campestris (Vieillot, 1818) T, P	Campo Flicker				17	AF, CC, SS
Celeus flavescens (Gmelin, 1788)[wo]	Blond-crested Woodpecker					
Dryocopus lineatus (Linnaeus, 1766)[lak] P	Lineated Woodpecker				5	CC, RV, SF
Cariamiformes						
Cariamidae						
Cariama cristata (Linnaeus, 1766)[lak] T, P	Red-legged Seriema				8	AF, CC, SS
Falconiformes						
Falconidae						
Caracara plancus (Miller, 1777) T, P	Southern Caracara				7	AF, CC
Milvago chimachima (Vieillot, 1816) T, P	Yellow-headed Caracara				7	AF, CC, SS, RV
Herpetotheres cachinnans (Linnaeus, 1758)[lak] T, P	Laughing Falcon				4	CC, DC, SS
Micrastur semitorquatus (Vieillot, 1817)[lak] T	Collared Forest-falcon				2	RV, *Pinus* plantation
Falco sparverius Linnaeus, 1758 P	American Kestrel				2	AF, SS
Falco femoralis Temminck, 1822 P	Aplomado Falcon				4	WG, CC, SS
Psittaciformes						

Continued on next page

Table 1. Continued.

Species	Popular Name	SP	BR	red list	N	Ecosystems
Psittacidae						
Psittacara leucophthalmus (Statius Muller, 1776) T	White-eyed Parakeet				23	DC, CW, RV, SF
Brotogeris chiriri (Vieillot, 1818)[lak] T	Yellow-chevroned Parakeet				17	CC, DC, CW, RV, SF
Amazona aestiva (Linnaeus, 1758)[lak]	Blue-fronted Parrot	NT			2	flying over SS
Passeriformes						
Thamnophilidae						
Formicivora rufa (Wied, 1831)[lak] T, P	Rusty-backed Antwren				9	CC
Dysithamnus mentalis (Temminck, 1823)[lak] T	Plain Antvireo				6	SF
Thamnophilus doliatus (Linnaeus, 1764)[lak] T, P	Barred Antshrike				6	CC, RV, SF
Thamnophilus ruficapillus Vieillot, 1816 T	Rufous-capped Antshrike				20	CC, WG
Thamnophilus pelzelni Hellmayr, 1924 T	Planalto Slaty-Antshrike				13	DC, CW, SS, RV
Thamnophilus caerulescens Vieillot, 1816	Variable Antshrike				4	DC, CW, RV, SF
Taraba major (Vieillot, 1816)[lak] T	Great Antshrike				4	RV, SF
Melanopareiidae						
Melanopareia torquata (Wied, 1831)[lak] T, P	Collared Crescentchest	EN			8	CC, WG
Conopophagidae						
Conopophaga lineata (Wied, 1831) T	Rufous Gnateater				3	SF, MV
Dendrocolaptidae						
Campylorhamphus falcularius (Vieillot, 1822)[lak]	Black-billed Scythebill				1	SF
Lepidocolaptes angustirostris (Vieillot, 1818) T, P	Narrow-billed Woodcreeper				11	AF, CC, SS
Furnariidae						
Furnarius rufus (Gmelin, 1788) T	Rufous Hornero				2	AF
Automolus leucophthalmus (Wied, 1821)[lak] T	White-eyed Foliage-gleaner				3	SF, MV
Phacellodomus ferrugineigula (Pelzeln, 1858)[lak] T	Orange-breasted Thornbird				2	SF, MV
Certhiaxis cinnamomeus (Gmelin, 1788)[lak] T	Yellow-chinned Spinetail				2	RS
Synallaxis ruficapilla Vieillot, 1819 T	Rufous-capped Spinetail				2	WG, SF
Synallaxis frontalis Pelzeln, 1859	Sooty-fronted Spinetail				2	CC, SS, RV
Synallaxis albescens Temminck, 1823 T, P	Pale-breasted Spinetail	NT			16	CC, WG, SS
Synallaxis spixi Sclater, 1856 T, P	Spix's Spinetail				6	CC, RV
Pipridae						
Chiroxiphia caudata (Shaw & Nodder, 1793) T	Swallow-tailed Manakin				4	SF
Antilophia galeata (Lichtenstein, 1823)[lak] T	Helmeted Manakin	NT			14	RV, SF
Tityridae						
Pachyramphus polychopterus (Vieillot, 1818)	White-winged Becard				1	CW
Pachyramphus validus (Lichtenstein, 1823)[lak]	Crested Becard				3	RV
Platyrinchidae						
Platyrinchus mystaceus Vieillot, 1818[lak] T	White-throated Spadebill				8	SF
Rhynchocyclidae						
Leptopogon amaurocephalus Tschudi, 1846[lak]	Sepia-capped Flycatcher				2	SF
Corythopis delalandi (Lesson, 1830)[lak]	Southern Antpipit				1	SF
Tolmomyias sulphurescens (Spix, 1825)[lak] T	Yellow-olive Flycatcher				1	SF
Todirostrum poliocephalum (Wied, 1831)[lak] T	Yellow-lored Tody-Flycatcher				1	SF
Todirostrum cinereum (Linnaeus, 1766)	Common Tody-Flycatcher				2	CW, RV

Continued on next page

Table 1. Continued.

Species	Popular Name	SP	BR	red list	N	Ecosystems
Poecilotriccus plumbeiceps (Lafresnaye, 1846)[lak] T	Ochre-faced Tody-Flycatcher				2	SF
Myiornis auricularis (Vieillot, 1818)[wo]	Eared Pygmy-Tyrant					
Hemitriccus diops (Temminck, 1822)[wo]	Drab-breasted Pygmy-Tyrant					
Hemitriccus nidipendulus (Wied, 1831)[lak]	Hangnest Tody-Tyrant				2	SF
Hemitriccus margaritaceiventer (d'Orbigny & Lafresnaye, 1837)[lak] T Tyrannidae	Pearly-vented Tody-Tyrant				11	CC, SS
Euscarthmus meloryphus Wied, 1831	Tawny-crowned Pygmy-Tyrant				2	CC, SS
Camptostoma obsoletum (Temminck, 1824) T	Southern Beardless-Tyrannulet				5	CC, DC, SS, RV, SF
Elaenia flavogaster (Thunberg, 1822) T, P	Yellow-bellied Elaenia				18	CC, DC, SS, RV
Elaenia parvirostris Pelzeln, 1868	Small-billed Elaenia				1	SF
Elaenia mesoleuca (Deppe, 1830)[lak] T	Olivaceous Elaenia				1	SF
Elaenia cristata Pelzeln, 1868[lak] T	Plain-crested Elaenia	VU			8	SS
Elaenia chiriquensis Lawrence, 1865 T, P	Lesser Elaenia				39	CC, WG, SS, RV
Elaenia obscura (d'Orbigny & Lafresnaye, 1837) T, P	Highland Elaenia				16	DC, CW, RV, SF, MV
Suiriri suiriri (Vieillot, 1818) T	Suiriri Flycatcher	EN			2	CC, SS
Phaeomyias murina (Spix, 1825) T	Mouse-colored Tyrannulet				11	CC, DC, CW, RV, SF
Culicivora caudacuta (Vieillot, 1818)[lak] T, P	Sharp-tailed Tyrant	CR	VU	VU	7	CC, WG
Serpophaga subcristata (Vieillot, 1817) T, P	White-crested Tyrannulet				3	CC, SS, RV
Myiarchus swainsoni Cabanis & Heine, 1859[lak] T	Swainson's Flycatcher				6	RV, SF
Myiarchus ferox (Gmelin, 1789) T, P	Short-crested Flycatcher				8	CC, DC, CW, SS, RV
Myiarchus tyrannulus (Statius Muller, 1776) T, P	Brown-crested Flycatcher				2	CC, CW, SS, RV
Sirystes sibilator (Vieillot, 1818)[wo]	Sirystes					
Casiornis rufus (Vieillot, 1816)[lak]	Rufous Casiornis	NT			5	CD, CW, SS
Pitangus sulphuratus (Linnaeus, 1766) T	Great Kiskadee				10	AF, CW, SS, RV
Machetornis rixosa (Vieillot, 1819) T	Cattle Tyrant				2	AF
Myiodynastes maculatus (Statius Muller, 1776)[lak] T	Streaked Flycatcher				16	DC, CW, RV, SF
Megarynchus pitangua (Linnaeus, 1766)[lak] T	Boat-billed Flycatcher				9	CW, RV, SF
Myiozetetes similis (Spix, 1825) T	Social Flycatcher				2	CW, RV
Tyrannus melancholicus Vieillot, 1819 T, P	Tropical Kingbird				16	AF, DC, SS, RV
Tyrannus savana Vieillot, 1808 T, P	Fork-tailed Flycatcher				42	AF, CC, WG, SS
Empidonomus varius (Vieillot, 1818)[lak]	Variegated Flycatcher				2	CW, RV
Colonia colonus (Vieillot, 1818)[lak] T	Long-tailed Tyrant				2	SF
Myiophobus fasciatus (Statius Muller, 1776) T	Bran-colored Flycatcher				6	CC, SS, RV
Pyrocephalus rubinus (Boddaert, 1783) P	Vermilion Flycatcher				1	CC
Fluvicola nengeta (Linnaeus, 1766)[lak] P	Masked Water-Tyrant				2	AF
Arundinicola leucocephala (Linnaeus, 1764)[lak] P	White-headed Marsh Tyrant				1	RS
Gubernetes yetapa (Vieillot, 1818) T	Streamer-tailed Tyrant				2	CC, WG
Alectrurus tricolor (Vieillot, 1816) T	Cock-tailed Tyrant	CR	VU	VU	4	CC
Cnemotriccus fuscatus (Wied, 1831)[lak] T	Fuscous Flycatcher				9	DC, CW, SS, RV, SF
Lathrotriccus euleri (Cabanis, 1868)	Euler's Flycatcher				4	SF
Satrapa icterophrys (Vieillot, 1818)	Yellow-browed Tyrant				1	AF
Xolmis cinereus (Vieillot, 1816) T	Gray Monjita				5	CC, WG
Xolmis velatus (Lichtenstein, 1823) P	White-rumped Monjita				3	AF, CC
Vireonidae						

Continued on next page

Table 1. Continued.

Species	Popular Name	SP	BR	red list	N	Ecosystems
Cyclarhis gujanensis (Gmelin, 1789) T	Rufous-browed Peppershrike				8	DC, CW, RV, SF
Vireo chivi (Linnaeus, 1766) T	Chivi Vireo				14	DC, CW, RV, SF
Hylophilus amaurocephalus (Nordmann, 1835) T	Gray-eyed Greenlet				2	CW, SS
Corvidae						
Cyanocorax cristatellus (Temminck, 1823) T, P	Curl-crested Jay				23	AF, CC, DC, SS
Cyanocorax chrysops (Vieillot, 1818)[lak] T, P	Plush-crested Jay				35	AF, DC, CW, SS, RV, SF
Hirundinidae						
Pygochelidon cyanoleuca (Vieillot, 1817)[lak]	Blue-and-white Swallow				9	AF
Alopochelidon fucata (Temminck, 1822)[wo]	Tawny-headed Swallow					
Stelgidopteryx ruficollis (Vieillot, 1817)	Southern Rough-winged Swallow				6	AF, RV
Progne tapera (Vieillot, 1817)[lak]	Brown-chested Martin				2	AF
Progne subis (Linnaeus, 1758)[wo]	Purple Martin	NT				
Progne chalybea (Gmelin, 1789)[lak] T	Gray-breasted Martin				4	AF
Tachycineta albiventer (Boddaert, 1783)[lak]	White-winged Swallow				4	RS
Tachycineta leucorrhoa (Vieillot, 1817)	White-rumped Swallow				10	RS, AF, CC
Troglodytidae						
Troglodytes musculus Naumann, 1823 T, P	Southern House Wren				6	AF, CC, SS
Cistothorus platensis (Latham, 1790)[wo]	Sedge Wren	CR				
Turdidae						
Catharus fuscescens (Stephens, 1817)[wo]	Veery					
Turdus leucomelas Vieillot, 1818 T	Rufous-bellied Thrush				27	AF, CC, DC, CW, SS, RV, SF
Turdus rufiventris Vieillot, 1818[lak] P	Pale-breasted Thrush				1	AF
Turdus amaurochalinus Cabanis, 1850 T	Creamy-bellied Thrush				13	AF, CW, SS, RV, SF
Turdus subalaris (Seebohm, 1887)[lak] T	Eastern Slaty Thrush				2	RV
Turdus albicollis Vieillot, 1818[lak] P	White-necked Thrush				2	SS
Mimidae						
Mimus saturninus (Lichtenstein, 1823) T, P	Chalk-browed Mockingbird				22	AF, CC, WG, SS
Motacillidae						
Anthus lutescens Pucheran, 1855[lak]	Yellowish Pipit				1	AF
Anthus nattereri Sclater, 1878[wo]	Ochre-breasted Pipit	CR	VU	VU		
Passerellidae						
Zonotrichia capensis (Statius Muller, 1776) T, P	Rufous-collared Sparrow				26	AF, CC, SS
Ammodramus humeralis (Bosc, 1792)[lak] T, P	Grassland Sparrow				48	CC, WG, SS
Arremon flavirostris Swainson, 1838[lak] P	Saffron-billed Sparrow				1	SF
Parulidae						
Setophaga pitiayumi (Vieillot, 1817) T	Tropical Parula				8	DC, CW, RV, SF
Geothlypis aequinoctialis (Gmelin, 1789)[lak] T, P	Masked Yellowthroat				9	RS, CC, WG, SS, RV
Basileuterus culicivorus (Deppe, 1830) T	Golden-crowned Warbler				10	DC, CW, RV, SF
Myiothlypis flaveola (Baird, 1865) T	Flavescent Warbler				14	DC, CW, RV, SF
Icteridae						
Psarocolius decumanus (Pallas, 1769)[lak] P	Crested Oropendola				10	AF, RV
Gnorimopsar chopi (Vieillot, 1819)	Chopi Blackbird				1	CC
Chrysomus ruficapillus (Vieillot, 1819)[lak] P	Chestnut-capped Blackbird				2	RS
Pseudoleistes guirahuro (Vieillot, 1819)	Yellow-rumped Marshbird				9	AF, WG
Molothrus rufoaxillaris Cassin, 1866[wo]	Screaming Cowbird					

Continued on next page

Table 1. Continued.

Species	Popular Name	SP	BR	red list	N	Ecosystems
Molothrus bonariensis (Gmelin, 1789)	Shiny Cowbird				18	AF, SS
Sturnella superciliaris (Bonaparte, 1850) T, P	White-browed Blackbird				21	AF
Thraupidae						
Coereba flaveola (Linnaeus, 1758)[lak]	Bananaquit				2	RV
Saltatricula atricollis (Vieillot, 1817) T, P	Black-throated Saltator	VU			23	AF, CC, WG, SS
Saltator similis d'Orbigny & Lafresnaye, 1837 T	Green-winged Saltator				6	RV, SF
Saltator fuliginosus (Daudin, 1800)[lak] T, P	Black-throated Grosbeak				1	SF
Nemosia pileata (Boddaert, 1783)[lak] P	Hooded Tanager				1	SS
Thlypopsis sordida (d'Orbigny & Lafresnaye, 1837)	Orange-headed Tanager				3	RV, SF
Cypsnagra hirundinacea (Lesson, 1831)[lak] P	White-rumped Tanager	EN			14	CC, SS
Tachyphonus coronatus (Vieillot, 1822)	Ruby-crowned Tanager				2	SF
Ramphocelus carbo (Pallas, 1764)[lak] T	Silver-beaked Tanager				2	SF
Lanio cucullatus (Statius Muller, 1776) P	Red-crested Finch				62	CC, SS
Lanio melanops (Vieillot, 1818)[lak]	Black-goggled Tanager				1	SF
Tangara sayaca (Linnaeus, 1766) T	Sayaca Tanager				10	AF, CC, DC, CW, SS, RV, SF
Tangara cayana (Linnaeus, 1766) T, P	Burnished-buff Tanager				16	AF, DC, CW, SS, RV, SF
Neothraupis fasciata (Lichtenstein, 1823) T, P	White-banded Tanager	EN			10	CC, SS
Schistochlamys melanopis (Latham, 1790)[lak] T, P	Black-faced Tanager	VU			3	SS, RV
Schistochlamys ruficapillus (Vieillot, 1817) T, P	Cinnamon Tanager				17	CC, DC, SS, RV
Pipraeidea melanonota (Vieillot, 1819)[lak] P	Fawn-breasted Tanager				1	SF
Tersina viridis (Illiger, 1811)[lak] T	Swallow Tanager				6	CW, RV
Dacnis cayana (Linnaeus, 1766)[lak] P	Blue Dacnis				2	CW, SS
Hemithraupis guira (Linnaeus, 1766)[lak]	Guira Tanager				2	CC
Conirostrum speciosum (Temminck, 1824)[lak]	Chestnut-vented Conebill				2	SS
Sicalis citrina Pelzeln, 1870[lak] T, P	Stripe-tailed Yellow-Finch				2	AF
Sicalis flaveola (Linnaeus, 1766)	Saffron Finch				2	CC
Sicalis luteola (Sparrman, 1789)[lak] T, P	Grassland Yellow-Finch				22	CC
Emberizoides herbicola (Vieillot, 1817) T, P	Wedge-tailed Grass-Finch				46	CC, WG, SS
Volatinia jacarina (Linnaeus, 1766) T, P	Blue-black Grassquit				52	AF, CC, SS
Sporophila plumbea (Wied, 1830) T, P	Plumbeous Seedeater	EN			23	CC, WG, SS
Sporophila caerulescens (Vieillot, 1823) T, P	Double-collared Seedeater				3	CC
Sporophila pileata (Sclater 1864)[lak] T	Capped Seedeater	VU			8	CC, WG
Sporophila angolensis (Linnaeus, 1766)[lak] T	Chestnut-bellied Seed-finch	VU			2	RS
Tiaris fuliginosus (Wied, 1830)[wo]	Sooty Grassquit					
Coryphaspiza melanotis (Temminck, 1822)[wo]	Black-masked Finch	CR	VU	VU		
Cardinalidae						
Piranga flava (Vieillot, 1822)[lak]	Hepatic Tanager				3	CC, RV
Habia rubica (Vieillot, 1817)[lak]	Red-crowned Ant-Tanager				4	SF
Fringillidae						
Sporagra magellanica (Vieillot, 1805) T, P	Hooded Siskin				34	AF, CC, WG, SS
Euphonia chlorotica (Linnaeus, 1766) T	Purple-throated Euphonia				4	DC, CW, RV, SF
Euphonia violacea (Linnaeus, 1758)[lak] T	Violaceous Euphonia				1	SF
Passeridae						
Passer domesticus (Linnaeus, 1758)	House Sparrow				14	AF

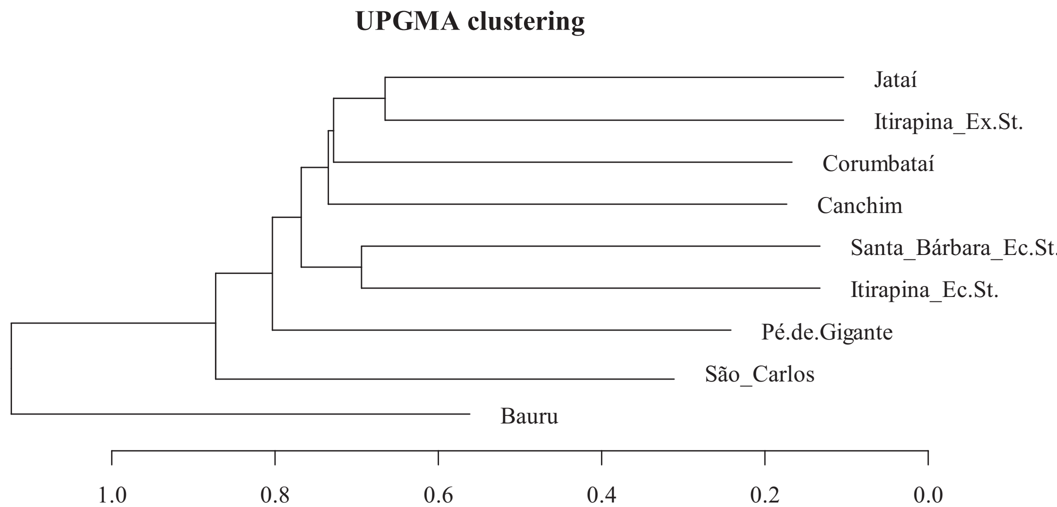

Figure 3. UPGMA clustering of Cerrado areas with bird assemblages sampled within São Paulo, with leaves hang according to the Euclidean distances from each other.

Table 2. Cerrado areas with exhaustive bird surveys within São Paulo state.

Area	Richness	Endemic species	Threatened species
Bauru Reserve	144	01	01
Canchim Farm	160	06	06
Corumbataí Reserve	180	02	02
Itirapina Ec. St.	231	11	32
Itirapina Ex. St.	210	05	06
Jataí Ec. St.	302	03	16
Cerrado Pé-de-Gigante	209	03	07
Santa Bárbara Ec. St.	**243**	**06**	**22**
UFSCar São Carlos	115	05	06

species, as well as in the number of endemic and threatened species (Table 1). Many other Cerrado bird assemblages in São Paulo are composed by forest species, and few are in conservation concern (Motta-Júnior 1990, Develey et al. 2005, Telles & Dias 2010, Cavarzere et al. 2011). In the Cerrado, forest habitats such as *cerradão* woodlands attract more forest avian species (Silva 1995b, Silva & Santos 2005), which could explain parts of the differences between studies.

On the other hand, Santa Bárbara and Itirapina Ecological Stations were more similar regarding the different types of avifauna, differing from geographically closer areas (Figure 3). It has been suggested that closer specific composition in both areas is due to similarities in the mosaic of grassland and savanna physiognomies and their surroundings (Willis 2004, Motta-Júnior et al. 2008). Differences in species composition between them probably reflect the proportions of occupation by physiognomies on each. Santa Bárbara has a greater extension of arboreal formations, which takes nearly 20% of its surface while in Itirapina, grasslands cover 40% of the area (São Paulo 2006, 2011). Apart from that some absences in the Santa Bárbara assemblage are due to the distribution of certain species in the state, for instance, *Clibanornis rectirostris* (Wied, 1831) and *Myiothlypis leucophrys* (Pelzeln, 1868) from Itirapina riparian vegetation, which are lacking on the left bank of Tietê river (Willis & Oniki 2003).

Grassland avifaunas in both Santa Bárbara and Itirapina are highlighted for the number of threatened species (Motta-Júnior et al. 2008). Within these reserves, grasslands have lost their areas due to colonization by pine *Pinus elliottii* Engelm as well as by vegetation densification, with more intensity at Santa Bárbara where previously it was practiced extensive livestock. To make cattle farming possible, people used to set fire in the local vegetation, favoring the grasslands and preventing an increasing in tree density. With the suppression of these activities, open-habitats tend to be restricted to areas where the soil suffers water saturation, at least seasonally (São Paulo 2011). Moreover, avoiding fire, which leads vegetation densification, may eliminate bird habitats in the medium and long terms, since several species are adapted to the fire dynamic in the Cerrado (Parker III & Willis 1997). In turn, the loss of grassland birds will have an impact on local ecological processes in both reserves, since this assemblage is functionally complementary to the forest and savanna environments (Batalha et al. 2010).

Scientific evidence about management implications on fauna, such as avoiding fires aiming to improve the effectiveness of protected areas, is still limited (Geldmann et al. 2013). The Santa Bárbara Ecological Station Management Plan was recently completed (São Paulo 2011). Its main goal is to recover local physiognomies to the proportions observed in 2011. To reach this goal, some priority researches were listed, such as the role of controlled fires and herbivory in order to maintain the mosaic of vegetation, and the controlling and eradication of invasive exotic plant species (São Paulo 2011). These researches must evaluate the natural occurrence of fire, its frequency, and which areas need to be managed annually to maintain the percentage representation of physiognomies. Results obtained in other Cerrado regions may not necessarily be generalized, with case studies and gathering of researchers from different knowledge areas important to carry out a comprehensive evaluation (França et al. 2007).

Thus, avifauna monitoring may contribute to evaluate the effectiveness of management actions at Santa Bárbara Ecological Station, especially when regarding noteworthy records.

1. Noteworthy records

Greater Rhea *Rhea americana* (critically endangered, SP). Species globally nearly threatened and heavily hunted in the region in recent decades, as well as suffering from poisoning by use of herbicides and frequent burning of vegetation. In São Paulo, the species has been seen only on the border with Mato Grosso do Sul state, and at Itirapina Ecological Station (Motta-Júnior et al. 2008). At Jataí Ecological Station, it was already common in the 1960s, but it is now disappeared (Dias 2000). In our study, we recorded Greater Rhea solely by tracks in October 21, 2009 (22°49'30"S, 49°14'51"W) and a photograph taken by camera trap, installed by mastozoologists on 09/01/2008. Nowadays, the local species occurrence has been reported only to a disturbed Cerrado area at Thermas de Santa Bárbara, a settlement surrounding the reserve, what warrant additional surveys covering both their inner and outer areas.

Rufous-faced Crake *Laterallus xenopterus* (critically endangered, SP; vulnerable, Red list). Some duets of this secretive crake were heard in contact areas between wet grasslands and riparian vegetation. A recording was obtained on October 23, 2009 at coordinates 22°48'54"S and 49°10'41"W. This is a poorly known species deemed to be threatened both in the state and in international lists. Its occurrence in São Paulo until then was based on a single specimen, found dead on a railway line in the town of Itirapina (Willis 2004, Vasconcelos et al. 2006). Despite lacking records, it can be more widespread than we think. Its trilling call's similarity with congeners and sympatric (*e.g.* Rufous-sided Crake *L. melanophaius*) along with limited access to their occurrence areas by researchers possibly make it difficult to detect. The species is considered threatened mainly due to habitat destruction, addressed by drainage of wetlands and adjacent afforestation with *Eucaliptus* and *Pinus* plantations (del Hoyo et al. 1996).

Ocellated Crake *Micropygia schomburgkii* (critically endangered, SP). Heard in patches of *campo cerrado*, sometimes over wet grasslands. This rail responds well to playback techniques, even at a distance. We noticed that this species approaches when closer to the sound source, walking carefully and silently. Nonetheless, this behavior probably does not prevent its detection, as the species has been recorded increasingly in other parts of Brazil by ornithologists who have knowledge of its vocalization (Vasconcelos et al. 2006, Lopes et al. 2009). In São Paulo, the species is threatened by conversion of grasslands to monoculture plantations, being detected only once in a narrow range of Cerrado at Lençóis Paulista (Marcondes & del Rio 2012).

Short-eared Owl *Asio flammeus* (endangered, SP). Species detected only once on March 27, 2012 perched in a pine tree inside a patch of wet grassland (22°48'42"S, 49°10'60"W), and singing series of 13-16 notes. This species inhabits marsh-like vegetation on the riverbanks and in flooded areas, and is adversely threatened by human presence (Silveira et al. 2009).

Collared Crescentchest *Melanopareia torquata* (endangered, SP). The only species of this genus in Brazil, occurring in *campos cerrados* and cerrado *sensu stricto* at altitudes up to 1000m. At Santa Bárbara Ecological Station, the species is observed foraging for insects on the ground by gleaning techniques. Originally classified as part of the family Furnariidae, *M. torquata* has been included among Formicariidae, and after among Rhinocryptidae, due to its morphological similarity with tapaculos. Only after recent molecular studies a new family was created for *Melanopareia*, known as Melanopareiidae, within which exclusively groups species of the genus (Ericson et al. 2010). In addition to its typical, monotonous call, the species is notable for a warming call similar to the vocalization of *M. schomburgkii*. In São Paulo, this species was once abundant in the 90s (Motta-Júnior 1990), and today it has declined due to loss of natural open savannas and widespread invasive grasses. In this context, it is imperative to understand the role of *Urochloa* spp. on Collared Crescentchest ecology. Although it has been implied that the species does not tolerate habitat changes promoted by exotic plants (Kanegae et al. 2012b), we have observed it foraging in grounds intensely invaded by this African grass.

Sharp-tailed Tyrant *Culicivora caudacuta* (critically endangered, SP; vulnerable, BR, Red list). Species present in the few dry natural grasslands and more open moist fields with tall grasses that remain in the ecological station. Known for nesting in bushes of ironweed *Vernonia* (Asteraceae; del Hoyo et al. 2004), *C. caudacuta* can rely on seven herbaceous species of this genus in *campos cerrados* of Santa Bárbara (São Paulo 2011). Due to current loss of habitat outside nature reserves in southeastern Brazil, it has a strong tendency to remain confined in the few protected dry grasslands such as Santa Bárbara Ec. St., free of charge by agricultural conversion.

Cock-tailed Tyrant *Alectrurus tricolor* (critically endangered, SP; vulnerable, BR, Red list). This species currently shows irregular distribution, largely due to the rarity of undisturbed open-habitats, especially tall grasses. In the Cerrado, these environments have been quickly converted in agricultural areas. In São Paulo, this species has not been detected in other places, except at Itirapina Ecological Station (Motta-Júnior et al. 2008). When breeding, males display nuptial conspicuous behaviors such as flights up to 4 m in height followed by freefalls to the ground, and vertical movements of the long tail. This behavior was observed near to a female on October 21, 2008 (22°47'08"S, 49° 14'24"W) at a site recovering from burning.

Sedge Wren *Cistothorus platensis* (critically endangered, SP). Open-habitat species with a large vocal repertoire, usually forages low down in vegetation looking for insects. Inhabitant of *campo*s, seasonally wet grasslands and freshwater marshes, it has declined due to habitat loss from changes in land use, and converting natural grasslands to forestry and pastures. In Santa Bárbara, this bird was once relative abundant in the 70s and 80s with a record of 27 individuals in 17 transect hours (Willis & Oniki 1981). It has not been recorded there recently and even using sound emissions by playback techniques, intensive searches in habitats with potential occurrences were not successful in finding the species, suggesting a possible local extinction (A.S. Lucindo & M.M. Dias, unpublished data). It is necessary a detailed search for isolated population of the species at surroundings, in order to develop management actions.

Ochre-breasted Pipit *Anthus nattereri* (critically endangered, SP; vulnerable, BR, Red list). Grassland species are known for preferring burnt areas (not over-frequent burnings) and lightly grazed grasslands (Parker III & Willis 1997). Although recorded in Itirapina in the past, the species has not been sighted since 2000, even during breeding season (Willis 2004, Motta-Júnior et al. 2008), suggesting a possible local extinction. In Santa Bárbara, the species has not been found since Willis & Oniki's studies, even using playback sounds from elsewhere (A.S. Lucindo & M.M. Dias, unpublished data). It makes even more serious the situation of the species on site. As it is a restricted species regarding the environment occupied, it may have disappeared due to conversion of grasslands into *Pinus* plantations and vegetation densification (Silveira et al. 2009). Further studies are needed to clarify its actual condition locally.

White-rumped Tanager *Cypsnagra hirundinacea* (endangered, SP). Although considered rare in São Paulo, the species is frequently observed in *campos cerrados* in the ecological station, forming monospecific flocks from two to three individuals. It is commonly seen foraging for insects in the tree and bush stratum above 1.5m. It is highly territorial, since actively responds to audio playback, vocalizing and flying over the sound source in searching for the supposed intruder. In São Paulo, it is threatened due to disturbance and destruction of their habitats (Silveira et al. 2009).

White-banded Tanager *Neothraupis fasciata* (endangered, SP). Species usually observed in groups of two or more individuals in the *campo cerrado* and cerrado *sensu stricto*, sometimes feeding on the ground. We found this species joining mixed flocks with *S. atricollis*. Their diet includes insects, seeds and fruits. In the ecological station, the bird actively feeds on *Aegiphila lhotskiana* (Lamiaceae) when bearing fruiting. The main threat to its existence is the conversion of natural areas into pasture and farmland (Silveira et al. 2009).

Plumbeous Seedeater *Sporophila plumbea* (endangered, SP). Coveted for cagebird trade, this short-distance migrant species also suffers from habitat loss, which must be addressed through the conservation of natural grasslands. In Jataí, it was frequently seen in the 60s, but has not been observed recently (Dias 2000). In Cerrado Pé-de-Gigante, it was usually observed in the 90s (Develey et al. 2005). For now, Santa Bárbara along with Itirapina emerge as priority conservation areas for *Sporophila* seedeaters in general, since they still rely on Cerrado formations and specific grassland environments. However, both invasive grasses and vegetation densification due to fire protection have leaded to a gradual modification of its preferential habitat.

Pearly-bellied Seedeater *Sporophila pileata* (vulnerable, SP). Originally considered as a subspecies of *S. bouvreuil* (Copper Seedeater), this taxon was recently recognized as a full species (Machado & Silveira 2010). Some couples have been spotted in *campo cerrado* when foranging in mixed flocks with *S. plumbea*, which can indicate the use of the region as a stopover on their migratory routes.

Black-masked Finch *Coryphaspiza melanotis* (critically endangered, SP; vulnerable, BR, Red list). Restricted bird to grassland environments, it usually lives on the ground, rising in grasses with emerging stalk during its breeding season. The Black-masked Finch has high research and conservation priority, because it is a rare and declining species (Stotz et al. 1996, Silveira & Straube 2008). Recently, some efforts to find it using playbacks were not successful at Santa Bárbara grasslands, suggesting a possible local extinction (A.S. Lucindo & M.M. Dias, unpublished data). However, it is worth considering that the species was detected by Motta-Júnior et al. (2008), and a few years thereafter it was thought to be extinct in Itirapina (Willis 2004). Therefore, new searches covering the surroundings are needed to find some isolated population, and develop management actions.

2. Concluding remarks

To recognize the species at Santa Bárbara Ecological Station is the first step towards preparing an effective strategy to conserve the local avifauna. Key approaches to improve knowledge of this bird assemblage include analyses of habitat use via BARCI designs (Before-After Reference Control-Impact), and population size estimates for species of conservation concern (e.g. Kanegae 2011, Kanegae et al. 2012a, 2012b). Conservation of the grassland and savanna biota at Santa Bárbara Ecological Station in the medium and long terms is a challenge that must be faced with management grounded on scientific research. Knowledge of birds at this reserve will allow us to use local avifauna as an indicator of the effectiveness of actions deployed.

Acknowledgments

The authors thank the Instituto Florestal do Estado de São Paulo and its staff for fieldwork support at Santa Bárbara Ecological Station; Marcio Port Carvalho, for kindly providing the photograph of the Greater Rhea; and the anonymous reviewers, for criticism and suggestions. A.S. Lucindo is a PhD candidate, and receives a doctoral scholarship from CAPES.

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Received 16/10/2014
Revised 16/04/2015
Accepted 15/05/2015

Biota Neotropica 15(4): e0052, 2015
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)

short communication

First record of the endemic phytophilous cladoceran *Celsinotum candango* Sinev & Elmoor-Loureiro, 2010, in Minas Gerais state, in a threatened shallow lake at Serra do Gandarela

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MOREIRA, F.W., DIAS, E.S., SANT'ANNA, W.M.E. **First record of the endemic phytophilous cladoceran *Celsinotum candango* Sinev & Elmoor-Loureiro, 2010, in Minas Gerais state, in a threatened shallow lake at Serra do Gandarela.** Biota Neotropica. 15(4): e0052. http://dx.doi.org/10.1590/1676-0611-BN-2015-0052

Abstract: This study describes the occurrence of the phytophilous cladoceran *Celsinotum candango*, which has been considered, up to now, an endemic species of the Brazilian Cerrado, with only two previous records in the wetlands of Brasilia, Federal District. The cladoceran has now been registered at Coutos Lake ("Lagoa dos Coutos"), an altitudinal, temporary shallow lake, located in ironstone outcrops at Serra do Gandarela, Minas Gerais state. This mountain ridge was recently turned into an integral protection conservation unit, the Gandarela National Park. However, many shallow lakes, including this one, were excluded from the delimited area of the park, and are now at risk of disappearing due to expansion of mining activities. The information provided here reveals the importance of these shallow lakes to aquatic biodiversity, and reinforces the need for the inclusion of these rare aquatic ecosystems into the recently created Gandarela National Park.
Keywords: *Cladoceran, Celsinotum, occurrence, shallow lake, Serra do Gandarela, Minas Gerais.*

MOREIRA, F.W., DIAS, E.S., SANT'ANNA, W.M.E. **Primeiro registro do cladócero fitófilo endêmico Celsinotum candango Sinev & Elmoor-Loureiro, 2010, no estado de Minas Gerais, em uma lagoa ameaçada da Serra do Gandarela.** Biota Neotropica. 15(4): e0052. http://dx.doi.org/10.1590/1676-0611-BN-2015-0052

Resumo: O objetivo deste estudo foi descrever a ocorrência do cladócero fitófilo *Celsinotum candango*, uma espécie considerada, até o momento, endêmica do cerrado brasileiro, com registros anteriores em apenas duas áreas úmidas de Brasília (Distrito Federal). O cladócero foi agora encontrado na Lagoa dos Coutos, uma lagoa temporária de altitude, localizada em área de afloramento ferruginoso da Serra da Gadarela, no estado de Minas Gerais. A Serra foi recentemente transformada em uma unidade de conservação (Parque Nacional do Gandarela). Entretanto, esta lagoa, além de outras, foi excluída da área delimitada para o Parque, e está agora sob risco de desaparecer, em função da expansão da atividade de mineração. As informações fornecidas no presente estudo revelam a importância dessas lagoas para a biodiversidade aquática, e reforçam a necessidade de inclusão desses raros ecossistemas aquáticos na recém-criada unidade de conservação do Parque Nacional do Gandarela.
Palavras-chave: *Cladócero, Celsinotum, lagoa, Serra do Gandarela, Minas Gerais.*

Introduction

Small lakes are vital inland bodies of freshwater, representing around 30 percent of the global surface area of standing water (Downing et al. 2006; Ewald et al. 2012). These wetlands are recognized as ecosystems of extreme ecological importance, but are nevertheless still neglected in terms of conservation (Maltby 1991; Downing 2010). Altitudinal shallow lakes have also been considered crucial, not only because of the exclusive species they can support, but also due to the suitable environment they provide for the interaction amongst distinct animal groups such as insects, amphibians, birds, mammals, and several others, hence contributing to the maintenance of local and regional diversity (Wiggins et al. 1980; Williams 2006). These shallow environments are usually colonized by aquatic macrophytes, which contribute to their high environmental heterogeneity by diversifying habitats and ecological niches (Drew et al. 2005, Van Der Valk 2012, Lukacs & Finlayson 2010).

When compared to the organisms associated to the macrophytes in these humid areas, the phytophilous cladoceran can be considered a group of exceptional diversity. Although they harbor up to 70% of the known cladoceran species (Elmor-Loureiro 2000, Forró et al. 2008), it was only recently that wetlands of the Brazilian Cerrado were added to research aimed at taxonomic knowledge for these organisms. As a result, new species were described and new geographic patterns were established for the phytophilous cladoceran (Sinev & Hollwedel 2002, Serafim-Junior et al. 2003, Elmoor-Loureiro 2007, Elmoor-Loureiro et al. 2009, Sousa et al. 2014 and others).

The freshwater cladoceran *Celsinotum candango* was described very recently (Sinev & Elmoor-Loureiro 2010), having its first occurrence in Brazil attributed to a phytophilous community in a shallow pond in Brasília, Federal District. So far, there is only one more record of the species, also in a shallow pond from the Cerrado wetlands (Sousa et al. 2013). In our study, we describe the presence of this species in a temporary shallow lake, "Lagoa dos Coutos" (Lake Coutos), located in ironstone outcrops at Serra do Gandarela (southern portion of the Espinhaço mountain range). This is the third record in Brazil and first in Minas Gerais of the cladoceran *Celsinotum candango.*

Serra do Gandarela is one of the most important synclines of the Minas Gerais central region and it houses several springs that supply water to the Belo Horizonte metropolitan region, including streams and creeks of special class water (ICMBio 2010). Serra do Gandarela is also an important ecological corridor, joining the Caraça region to two important basins: Rio Doce/Piracicaba and São Francisco/Rio das Velhas. According to Jacobi and Carmo (2008a), there is a very high level of plant diversity at Serra do Gandarela. This is a result of mineral and topographical heterogeneity of the outcrops, which creates distinct microhabitats, resulting in a unique association of extremely adapted plants. These adaptations can include metallophytes or, at least, metal-tolerant plant species (Jacobi et al. 2007).

Due to the occurrence of these unique environments, high biodiversity and endemic levels, and imminence of impact associated with mining activity, in addition to other anthropic activities, the creation of the National Park of the Serra do Gandarela was proposed and then promulgated on October 13th, 2014 through a Decree-Law. However, only 31.4 out of the 38 hectares initially proposed by the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) were considered, excluding rare shallow lakes from complete protection, among them, the Coutos Lake. Mining activity has expansion projects in these unprotected areas, which will inevitably result in the extinction of these aquatic ecosystems. We hope that the information of our study will contribute to reinforce the need to prioritize the preservation of such unique aquatic ecosystems that are still not very well known, but potentially relevant to aquatic biodiversity.

Material and Methods

The Coutos Lake (19°59'6.54" S; 43°33'4.75" W), is a temporary shallow lake (as described by Williams 2006), located in an ironstone outcrops area, in the municipality of Barão dos Cocais, at about 100km from the state capital, Belo Horizonte. This lake is located in the Rio Doce basin, at 1072m above sea level, under highland subtropical climate with dry winters and rainy summers. It is a shallow pond with 0.65 cm depth average, reaching 1.5 m during the rainy period, until complete dryness in August. Figure 1. During our study (from January to June/2013), water temperature ranged from 29 to 18 °C, presenting higher variation during the summer (25.6 ± 1.4). The Coutos Lake can be considered oligotrophic (chlorophyll *a* averaging < 5 g.µL^{-1}), with neutral to acid waters (pH ranging from 7.46 to 4.77), and low conductivity (from 70 to 120 µS.cm^{-1}) (Dias, 2014). Since it is a shallow lake, it presents dense macrophyte banks throughout its whole extension, with patches dominated by *Eleocharis minima*. Several other species of macrophytes have also been found in Coutos Lake, such as *Nymphoides indica*, *Polygonum mesneirianum*, *Helanthium tenellum*, *Utricularia* sp., and *Egeria najas* (Dias 2014).

Specimens of the cladoceran *Celsinotum candango* were found among samples of macrophytes collected in January 15th, February 15th and June 19th 2013, during a decomposition experiment. The macrophytes samples were collected through the use of "litter bags", with dimensions of 10x20 cm (Petersen & Cummins 1974). The specimens were extracted from the samples under a stereomicroscope, preserved in 70% alcohol, and identified according to description given by Sinev & Elmoor-Loureiro (2010). All specimens were measured using an eyepiece-micrometer and deposited in the aquatic invertebrate collection of Aquatic Ecology, Evolution and Conservation Laboratory at the Federal University of Ouro Preto. Water temperature (°C), conductivity (µS.cm^{-1}) and pH were obtained with a Horiba (model U-50) analyzer.

Results and Discussion

The genus *Celsinotum* was initially considered endemic to Australia (Frey, 1991); however, it has been registered in other places lately, amplifying its distribution. In Brazil, *C. laticaudatum* had only been found in the Northern part of the Brazilian Amazon (Smirnov & Santos-Silva 1995), while *C. candango* had only been found in the Brazilian Cerrado (Sinev & Elmoor-Loureiro 2010, Sousa 2013). This paper now presents the first record of *C. candango* in the state of Minas Gerais and, furthermore, its first record in an altitudinal temporary lake on ironstone outcrops.

Family Chydoridae Stebbing, 1902

Celsinotum candango Sinev and Elmoor-Loureiro 2010 (Figure 2A-D).

Family Chydoridae Stebbing, 1902

Celsinotum candango Sinev & Elmoor-Loureiro 2010 (Figure 2A-D).

According to the description of Sinev and Elmoor-Loureiro (2010), *Celsinotum candango* clearly differs from all other species of the genus in proportions of the postabdomen, as the postanal portion is only 1.2–1.3 times longer than anal one in all other species. *C. candango* also differs from the other Brazilian species *C. laticaudatum* Smirnov and Santos-Silva 1995 in longer spine on basal segment of antenna exopodite (about 2/3 length of middle segment of antenna), in the shape of the postabdomen (it is only weakly narrowing distally, distal part of postanal portion is almost rectangular) and in the postabdominal denticles, in this species distalmost denticles are long and single (Sinev & Elmoor-Loureiro 2010).

The four *C. candango* individuals found in Coutos Lake (adult parthenogenetic females) were small, with a maximum length of 0.65 mm. The individuals were found in water temperature ranging from 24.7 to 18°C, conductivity from

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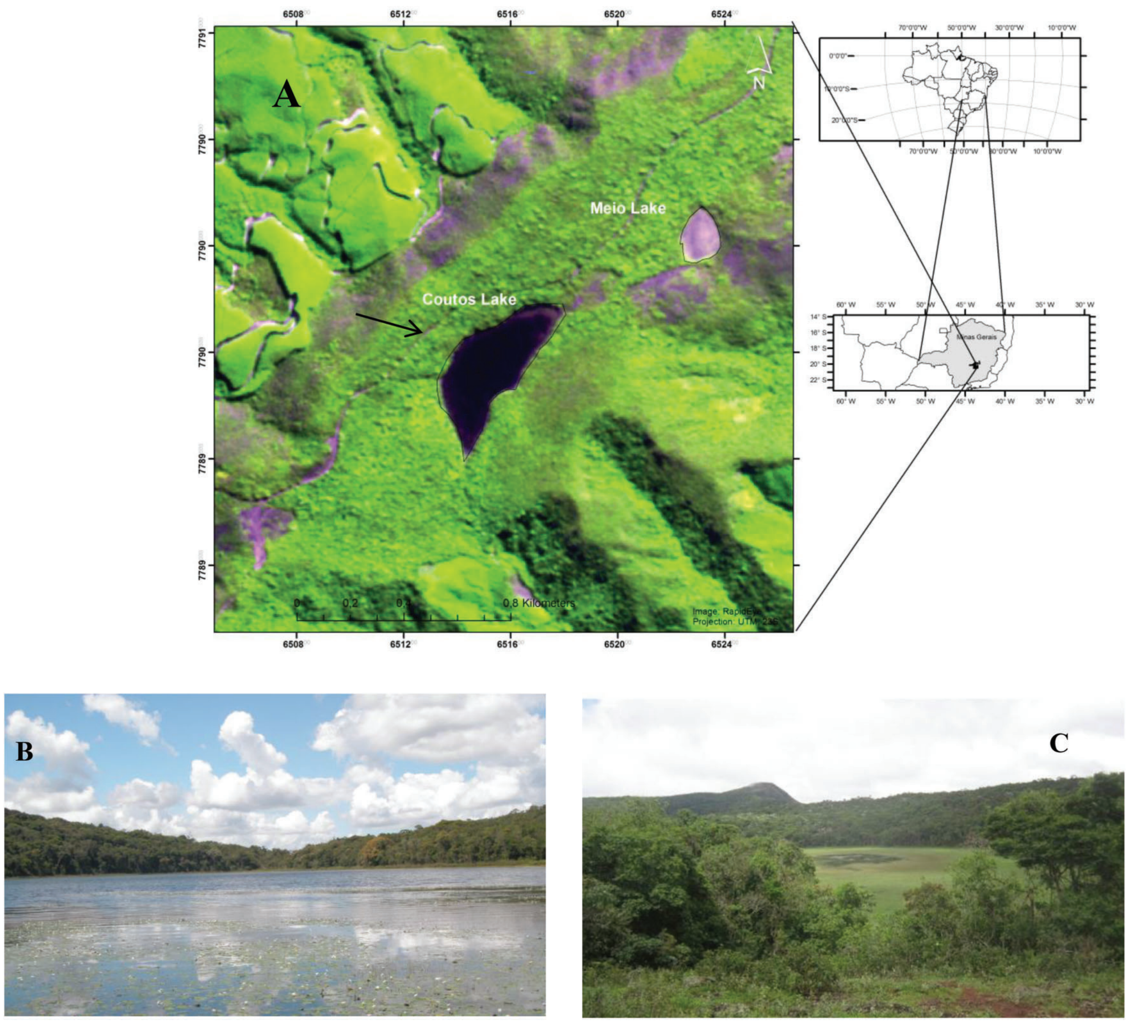

Figure 1. Map of Gandarela Ridge location and Lagoa dos Coutos. Gandarela Ridge location (A). Coutos Lake panoramic view during rainy period (January/2012) (B). Coutos Lake during dry period (August/2013) (C).

109 to 91 μS.cm^{-1} and lake water with acid feature (pH from 6.4 to 5.3) Table 1. The specimens presented the characteristic postabdomen, with postabdominal claw from 65-70 μm in length and postanal margin with clusters of small distalmost denticles in each, besides the spine on basal segment of exopodite of antenna as shown in Figure 2. We did not find ephippial forms from *C. candango*, in spite of the occurrence of other cladocerans resting eggs, and the temporary characteristic of Coutos Lake. The species is considered endemic to the Brazilian Cerrado wetlands (Sousa et al. 2014), and presents restricted geographic distribution with ecological preference for shallow environments, dominated by macrophytes.

Traditionally, most studies in aquatic ecology have been directed to 'permanent' (i.e., hydroperiod > 1 year) lentic and

Table 1. Limnological variables at Coutos Lake during the sampling of *Celsinotum candango* specimens, in 2003.

	Conductivity (μS.cm^{-1})	pH	Temperature (^{o}C)
January	109	5.7	24.9
February	100	6.4	24.7
June	91	5.3	18.0

lotic systems. As a result, we know more about communities in permanent waters than we do about those in temporary ones and have less evidence to protect these unique, endangered habitats than for other systems (Schwartz & Jenkins 2000). The results of our study reinforce the importance of small ponds to aquatic biodiversity, by congregating plants diversity, environmental heterogeneity, and invertebrate assemblages with specific habitat requirements, such as phytophilous cladocerans. All these features can enhance the occurrence of exclusive species in these temporary aquatic ecosystems.

Coutos Lake can nowadays be considered a threatened aquatic ecosystem in the Gandarela ridge. The intense expansion of mining activity in the region is considered one of the greatest threats to the integrity of Serra do Gandarela ecosystems (Jacobi & Carmo 2008b, Carmo et al. 2012). The creation of the Gandarela National Park did not reach these areas of extreme relevance to the preservation of species and ecosystems in ironstone outcrops of the Serra, not even shallow lakes that still deserve further research in order to describe their biodiversity. The record of this recently discovered cladoceran species reveals that there probably is still much more to find in these unique ecosystems that are now critically threatened of disappearing.

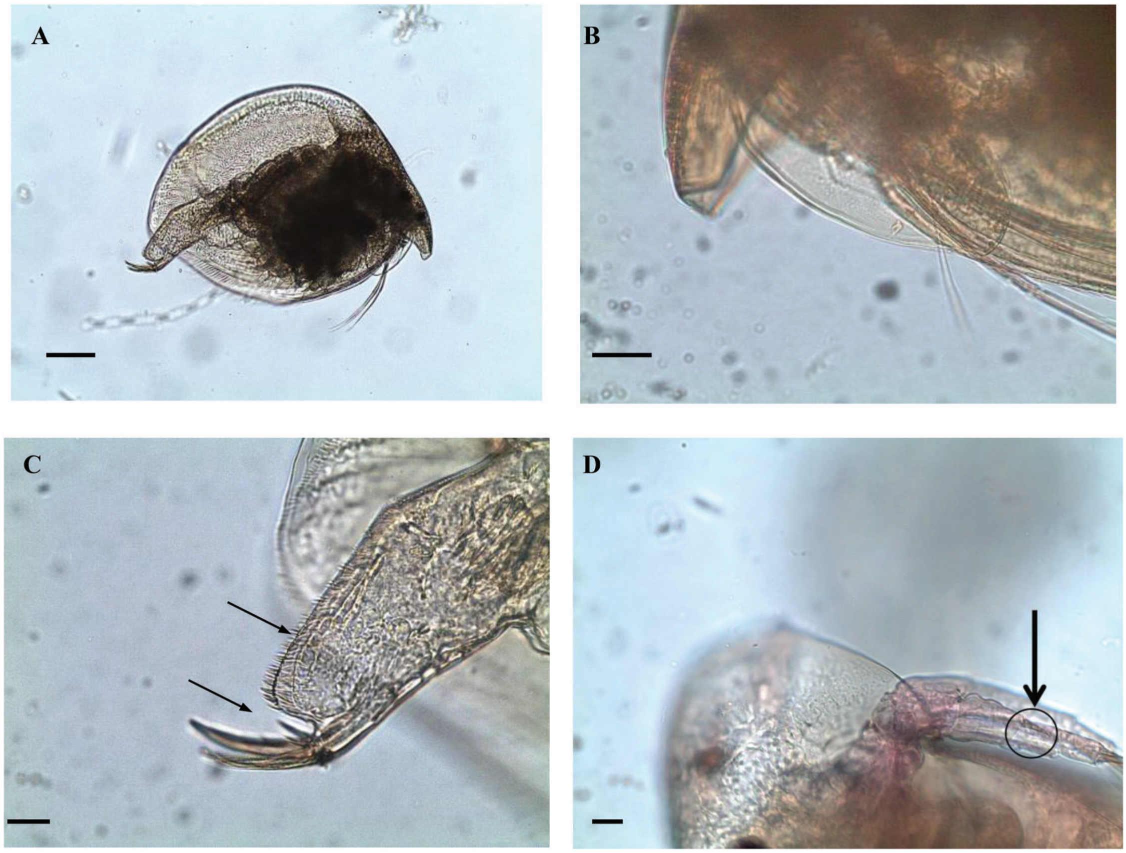

Figure 2. Aspects of *Celsinotum candango* registered in Coutos Lake, Serra da Gandarela, MG. (A) General aspect of the individual. (B) Detail of rostrum and labrum . (C) Postabdomen. Detail of postanal margin of postabdomen, lateral setules and terminal claw; (D). Detail of antenna and spine on basal segmento of exopodite. Scale bars 0.1 mm for A- B, 0.01mm to C and D.

Acknowledgments

We are very grateful to Gleicidele Tamires Tenório Pedrosa for macrophytes identification. The authors thank CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) for a fellowship grant to Emerson Dias. Sincere thanks to Transport Sector of the Federal University of Ouro Preto, for extensive assistance during field collections. For specimen confirmation we would like to thank Dr. Lourdes M.A. Elmoor-Loureiro. Funding to this project was provided by FAPEMIG (CRA - APQ-01767-11). EMES is a researcher of the Brazilian National Council for Scientific and Technological Development (CNPq). We thank the reviewers for constructive comments to the manuscript.

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Received 1/05/2015
Revised 7/08/2015
Accepted 1/10/2015

Biota Neotropica 15(4): e0006, 2015
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)

inventory

Ichthyofauna of the hydrographic basin of the Chasqueiro Stream (Mirim Lagoon system, southern Brazil): generating subsidies for conservation and management

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CORRÊA. F., OLIVEIRA, E.F., TUCHTENHAGEN, T., POUEY, J., PIEDRAS, S. **Ichthyofauna of the hydrographic basin of the Chasqueiro Stream (Mirim Lagoon system, southern Brazil): generating subsidies for conservation and management.** Biota Neotropica. 15(4): e0006. http://dx.doi.org/10.1590/1676-0611-BN-2015-0006

Abstract: Studies that organize lists of species are essential and act as the starting point for future discussions on the ecology of fish in environments that are poorly studied. The present paper describes the fish assemblage of the hydrographic basin of Chasqueiro Stream, an important component of the Mirim Lagoon system. Fish were collected during one year period between August/2012 and July/2013 in six sites, comprising three biotopes: upstream, reservoir and downstream. A total of 22,853 specimens were collected, and were distributed into 83 species, 20 families, and eight orders. The two species with the largest number of individuals captured were *Bryconamericus iheringii* with 2,904 (12.71%) and *Cheirodon ibicuiensis* with 2,868 (12.55%). Characiformes and Siluriformes were the most representative orders in terms of richness and abundance. *Bryconamericus iheringi* and *Cyanocharax alburnus* were the species with the highest abundance upstream, while *Hyphessobrycon luetkenii* and *Corydoras paleatus* contributed more to the abundance downstream. *Cheirodon ibicuhiensis* and *Heterocheirodon jacuhiensis* were the most representative species in the reservoir. This study revealed a rich fauna of fish, which should be preserved for future generations and for the maintenance of local and regional biodiversity.
Keywords: *Neotropical region, costal plain, Patos-Mirim Lagoon system.*

CORRÊA. F., OLIVEIRA, E.F., TUCHTENHAGEN, T., POUEY, J., PIEDRAS, S. **Ictiofauna da bacia hidrográfica do arroio Chasqueiro (sistema da Lagoa Mirim, sul do Brasil): gerando subsídios para plano de conservação e gestão.** Biota Neotropica. 15(4): e0006. http://dx.doi.org/10.1590/1676-0611-BN-2015-0006

Resumo: Estudos que organizam listas de espécies são essenciais como ponto de partida para futuros debates sobre a ecologia de peixes em ambientes que são pouco estudados. O presente artigo descreve a fauna de bacia hidrográfica do arroio Chasqueiro, componente importante do sistema da Lagoa Mirim. Os peixes foram coletados no período de um ano, entre os meses de agosto de 2012 e julho de 2013, em seis locais amostrais, que compreendem três biótopos, montante, reservatório e jusante. Um total de 22.853 indivíduos foi coletado, distribuídos em 83 espécies, 20 famílias e oito ordens. As duas espécies com maior abundância foram *Bryconamericus iheringii* com 2.904 (12,71%) e *Cheirodon ibicuiensis* com 2.868 (12,55%). Characiformes e Siluriformes foram as ordens mais representativas em termos de riqueza e abundância. *Bryconamericus iheringii* e *Cyanocharax alburnus* foram as que apresentaram as maiores abundâncias a montante, *Hyphessobrycon luetkenii* e *Corydoras paleatus* contribuíram mais na abundância a jusante, enquanto no reservatório as mais abundantes foram *Cheirodon ibicuhiensis* e *Heterocheirodon jacuhiensis*. Este estudo revelou uma rica ictiofauna na bacia hidrográfica do arroio Chasqueiro, a qual deveria ser preservada para as gerações futuras e para a manutenção da biodiversidade local e regional.
Palavras-chave: *Região neotropical, planície costeira, Arroio Chasqueiro, sistema lagunar Patos-Mirim.*

Introduction

Having knowledge of the fish species that colonize a hydrographic basin is the first step in producing information about the structure of the local assemblage, as well as the trophic and reproductive dynamics. The Neotropical region has the highest diversity of freshwater fish species in the world, with estimates of up to approximately 8,000 species (Schaefer 1998, Lévêque et al. 2008, Albert & Reis 2011). López-Fernández et al. (2012) emphasize that knowledge of the fish fauna is of utmost importance, because it can reveal the relative role of adaptive processes, structural complexity, evolutionary history, and morphological and functional diversification. Indeed, studies that organize lists of species are essential and act as the starting point for future discussions on the ecology of fish in environments that are still poorly studied (Schifino et al. 2004, Vaske et al. 2005). Agostinho et al. (2008) stress that the diversity of fish in the continental ecosystems of Brazil is poorly known, and is greatly associated with the absence of an inventory in these environments. Carrying out studies that include lists of fish species in hydrographic basins is the initial and a fundamental step to the proper management and preservation of fish fauna (Raghavan et al. 2008, Santos et al. 2015). Information about species composition is the basis for recognizing the structure of the assemblage, as well as understanding its dynamics. The detection of these patterns allows the possibility of a more precise conservation plan for the area, defining the priorities in detail.

The fish fauna of freshwater ecosystems have suffered directly from the impacts associated with urban population growth (Pendleton et al. 2014). Other factors such as the introduction of exotic species (Vitule 2012), pollution and deforestation (Carvalho et al. 2012), busbaraquatic ecosystems (Burns et al. 2006, Barletta et al. 2010), and predatory fishing have contributed significantly to the decline in species richness. It is worth mentioning that the changes and loss of natural habitats have been directly influenced by human activities, which have led to loss of biodiversity (Teixeira et al. 2005, Schindler 2007, Barros et al. 2012). For example, Daga et al. (2012), studying the influence of human activity on the fish assemblage in a sub-basin of the San Francisco River, showed that along a longitudinal gradient there is a significant urbanization effect on the fish assemblage, primarily caused by urban organic effluents and urban activity runoff. An aspect that hinders understanding of the impacts of human activities on the fish community in a hydrographic basin is the lack of studies about local or regional species composition.

Among the countries that form the Neotropical region, Brazil has around 2,500 freshwater fish species in its hydrological systems (Reis et al. 2003, Buckup et al. 2007), which is related to the large diversity of aquatic systems present in its different biomes. In southern Brazil, transgression and regression events created the largest lagoon complex in South

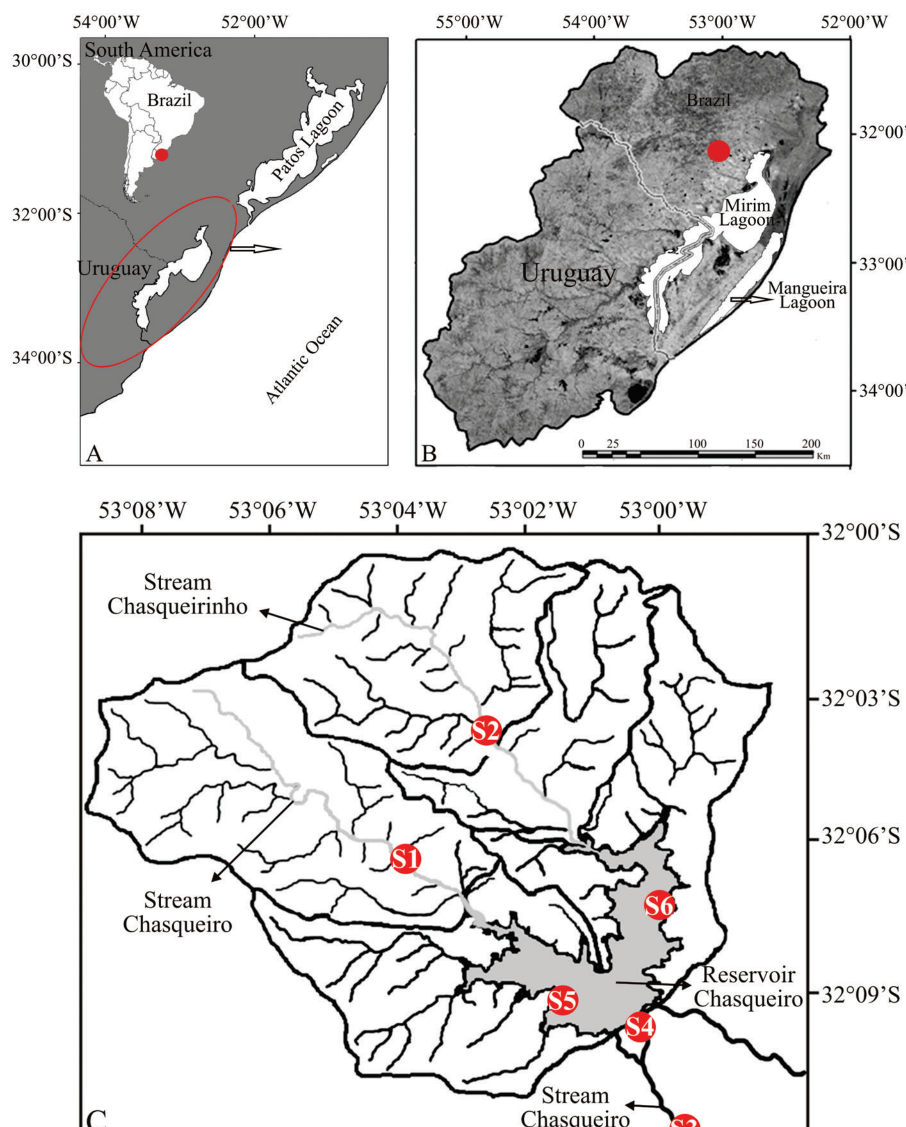

Figure 1. Study area, showing south America with the countries Brazil and Uruguay, delimitation of Mirim Lagoon system (circle red) (A), localization of hydrographic basin Chasqueiro Stream (dot red) (B) and samples sites, 1 and 2 (upstream), 3 and 4 (downstream), 5 and 6 (reservoir) (C).

 http://dx.doi.org/10.1590/1676-0611-BN-2015-0006

America, formed by the Patos and Mirim lagoons, which together comprise an area of about 14,000 km^2 (Villwock 1987, Kotzian & Marques 2004). It is worth mentioning that the communication between the Patos and Mirim lagoon systems occurs through a natural channel called São Gonçalo. In 1977, a dam was constructed to prevent the entry of salt water into the region of Mirim Lagoon, the main water source used for agriculture, particularly for rice cultivation (Burns et al. 2006, Corrêa et al. 2015). The hydrographic system of Mirim Lagoon is formed by a complex composed of 22 basins, distributed between Brazil and Uruguay (Kotzian & Marques 2004). However, there is still an absence of studies and knowledge of the fish fauna occurring in the sub-basins located in southern Brazil (Buckup & Reis 1997, Garcia et al. 2006, Ceni & Vieira 2013). In this context, the present study describes the fish assemblage of the hydrographic basin of Chasqueiro Stream, an integral part of the Mirim Lagoon system, with the goal of contributing to the advancement of knowledge on the composition of its ichthyofauna, as well as the production of information that can be used in action protocols aiming the system conservation.

Material and methods

The hydrographic basin of Chasqueiro Stream (BHAC) is located in the western region of the hydrographic system of Mirim Lagoon, municipality of Arroio Grande, southern Brazil (31°6'51"S/50°5'17"W) (Figure 1). The region has a subtropical climate (according to Köppen), with an average annual rainfall ranging from 1,200 to 1,450 mm, with monthly average temperatures of 25°C in the hottest months and 11°C during the coldest. The BHAC is formed by two principal streams (Chasqueiro and Chasqueirinho) and a reservoir. The area upstream from the reservoir is 248.42 km^2, and is formed by the Chasqueiro Stream (114.84 km^2) and the Chasqueirinho Stream (133.58 km^2) basins. Chasqueiro Reservoir has an area of 1,800 ha, and is used primarily for rice monoculture (Sondotécnica 1986). Six sampling points were established along the BHAC: upstream – sites 1 (Chasqueiro Stream) and 2 (Chasqueirinho Stream); downstream – sites 3 and 4 (Chasqueiro Stream); Chasqueiro Reservoir – sites 5 and 6 (Figure 1; Figure 2) and a description of the sampling sites is shown in Table 1. Fish were collected monthly for one year between August/2012 and July/2013 (SISBIO #n.34389-1), totaling 72 samples. Because of the diversity of habitats that were investigated, it was not possible to maintain a standardized effort for all points and became necessary to employ different collection apparatuses, assuming that the use of the set of fishing gear increased the sampling efficiency. The following apparatuses were used: a) gill net: 75 m long with 10 meshes; 20, 30, 40 and 50 mm (knot to knot) submerged for a period of 24h (checked after 12h); used in reservoir depths between 1.0 and 2.5 m in order to capture larger individuals (> 200 mm); b) beam trawl: 5 m long, 2.25 high, with 5 mm mesh (knot to knot) employed in the coastal zones of the reservoir and downstream, with five trawls at each site per collection; c) two dip nets: 5 mm mesh opening, 35 cm wide and 50 cm long, used upstream and downstream in areas with and without vegetation, and used for 30 minutes at sites with depths

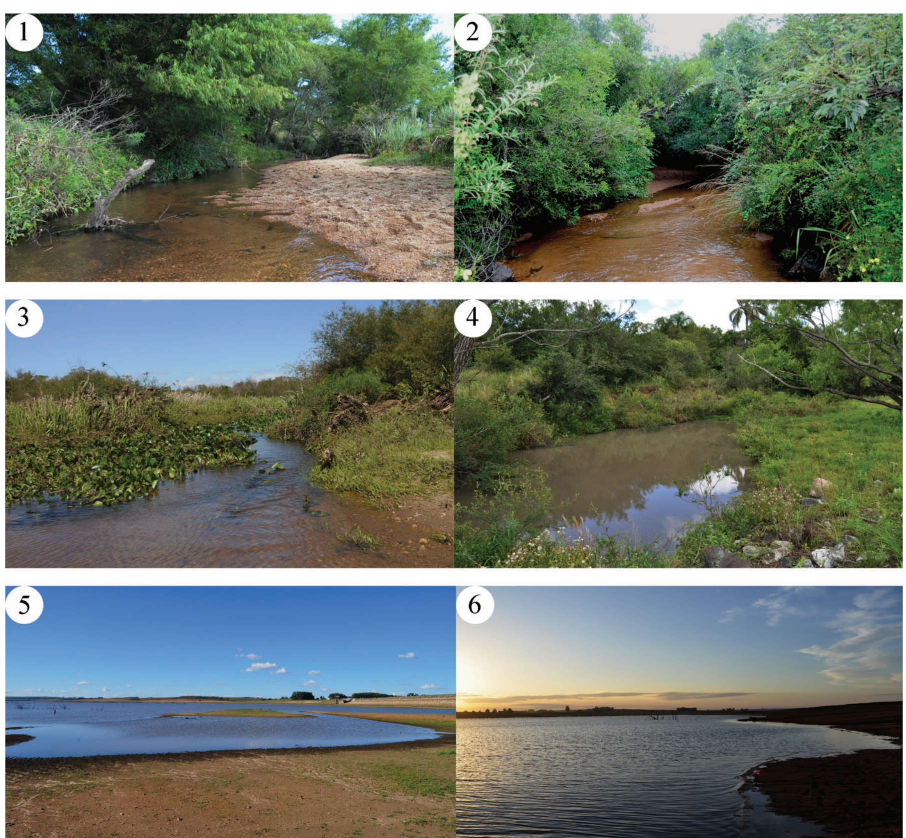

Figure 2. Photograph of the sampling sites 1 and 2 (upstream), 3 and 4 (downstream), 5 and 6 (reservoir) (C), hydrographic basin Chasqueiro Stream, Mirim Lagoon system, southern Brazil.

Table 1. Characterization of sampling sites, upstream, downstream and reservoir, presenting the biotopes, general characteristics, substrate and geographic coordinates, the sites located in the hydrographic basin of Chasqueiro Stream, Mirim Lagoon system, southern Brazil.

Sample sites	Biotopes	General characteristics	Substrate	Geographic coordinates
S1	Upstream	Margins formed by pastures. In some stretches, herbaceous individuals, shrub, and tree species are found; for example, *Eryngium* spp., *Baccharis* spp., and *Salixum boldtiana*, respectively. It features an average width of 7.9 m and an average depth of 29.1 cm. Features locations with little riffle and pool.	The substrate consists of 97.9% sand, 1.6% clay, and 12.5% silt. Presence of boulders derived from anthropogenic activities.	32° 07' 43.97"S 53° 03' 8.03"W
S2		Both margins contain arboreal vegetation. Presence of groups of rooted herbaceous species in stream bed. Shading occurs around 80% of the water. Left margin with siltation in the bed of course. Has an average width of 7.6 m and average depth of 43.8 cm. Present locations with little riffle and pool.	The substrate consists of 99.4% sand, 0.4% clay, and 0.2% silt. Occurrence of boulders derived from anthropogenic activities.	32° 06' 05.89"S 53° 03' 0.94"W
S3	Downstream	Presence of free and floating aquatic macrophytes such as *Eichhornia crassipes* and rooted *Polygonum punctatum*. Groups of shrubs and tree species on both sides of individuals such as *Calliandra brevipes*. Average width of 6.2 m and average depth of 31.9 cm. Presents with a flow site and with a predominance of local shallows.	Substrate consisting of 90.67% sand, 10.08% clay, and 23.1% silt.	32° 12' 11.08"S 52° 58' 9.70"W
S4		On both sides graminóide is the predominant vegetation. Posterior part of the left bank reveals an arboreal stratum. Presence of floating aquatic macrophytes. It features shadowing of the water depth around 50%. Has an average width of 5.0 m and average depth of 66.7 cm. Environment essentially shallows.	Predominantly sand with 90.5%, followed by silt and clay with 5.5% and 3.9%.	32° 09' 55.73"S 53° 00' 9.46"W
S5	Reservoir	Margins are predominantly anthropogenic fields of grasses used for grazing.	The site has a substrate with a predominance of 73.60% sand, followed by clay and silt with 14.0% and 12.4%. Local occurrence of boulders.	32° 10' 05.09"S 53° 01' 6.53"W
S6		It features anthropogenic fields consisting of grasses used for grazing on the shores.	A predominance of sand substrate with 73.5%, followed by clay and silt with 14.0% and 12.2%. Locations with muddy bottoms are present.	32° 08' 59.69"S 53° 00' 1.16"W

of 10 cm to one meter and d) one sieve with 5 mm mesh, 80 cm wide and 160 cm long, employed upstream and downstream, and used for 15 minutes per month at each site.

The collected fish were stored in plastic bags, labeled, and fixed in 10% formalin, and were then taken to the laboratory where they were transferred to 70% alcohol. Specimens were identified with the help of specialized literature (Reis & Malabarba 1988, Buckup & Reis 1997, Rodriguez & Reis 2008, Caravalho & Reis 2009, Bertaco & Lucena 2010, Carvalho et al. 2012, Lucena et al. 2013, Malabarba et al. 2013), and specialists were consulted when needed for species confirmation. The list of species was formulated according to Wiley & Johnson (2010) and Malabarba et al. (2013). The specimen testimonies were deposited in the ichthyological collection of the Federal University of Rio Grande (FURG). The number of species was estimated for each sampling site, and the Shannon-Wiener diversity index (H') and Pielou's evenness index were also used for calculations with PAST 3.0 statistical software (*PAlaeontological STatistics*, Hammer et al. 2014).

Results and Discussion

A total of 22,853 individuals were collected. They were represented by 83 species, 20 families, and eight orders (Table 2). The two species with the greatest number of individuals captured were *Bryconamericus iheringii* (2,904; 12.71%) and *Cheirodon ibicuiensis* (2,868; 12.55%). When the data of the orders were compared among different biotopes (upstream, downstream, and

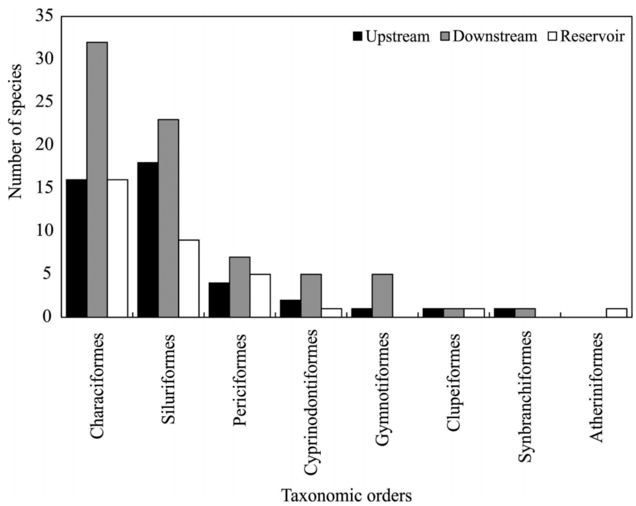

Figure 3. Number of fish species by taxonomic order, for the three biotopes (upstream, downstream and reservoir) of hydrographic basin Chasqueiro Stream, Mirim Lagoon system, southern Brazil.

reservoir), Characiformes and Siluriformes were the most representative in terms of abundance and richness (Table 2; Figure 3). Artioli et al. (2009), studying dominance patterns of an aquatic ecosystem in southern Brazil, also recorded high abundance of Characiformes species (e.g. *Bryconamericus iheringii*). Similarly, Becker et al. (2013) studied the fishes of the Taquari-Antas River basin and Garcia et al. (2006) compared the dominance patterns of the fish fauna of Taim wetlands. The predominance of species belonging to Characiformes and Siluriformes corroborates studies conducted in Neotropical aquatic ecosystems (Lowe-McConnell 1999, Becker et al. 2013, Viana et al. 2013). The high diversity, as well as the abundance of Characiformes and Siluriformes in the Neotropical region, is related to several factors, e.g. the ecological and behavioral patterns of the species (Carvalho et al. 2012), diversity of ecosystems (Oliveira et al. 2012), as well as evolutionary and geological processes (Lévêque et al. 2008). Teixeira et al. (2005) emphasize that the differences in physiography over a longitudinal gradient corresponded to the changes in the diversity and abundance of the fish assemblage, where species of Characiformes and Siluriformes have wide spatial distribution.

The rarest species in the system were *Trachelyopterus lucenai* and *Gymnotus pantherinus* (0.004%), which corroborate data reported by Artioli et al. (2009) in Mangueira Lagoon, Rio Grande do Sul state. *Trachelyopterus lucenai* is not considered a native species of the region, and might have come to the hydrographic basin through irrigation channels (rice fields) (Bertoletti et al. 1992, Becker et al. 2013).

Eleven species common to every collection site were identified among the upstream, downstream, and reservoir biotopes: six species of Characiformes (*Astyanax eigenmanniorum*, *Bryconamericus iheringii*, *Cheirodon ibicuhiensis*, *Cheirodon interruptus*, *Cyanocharax alburnus* and *Hyphessobrycon luetkenii*), three of Siluriformes (*Corydoras paleatus*, *Pimellodela australis* and *Homodiaetus anisitsi*), and two of Perciformes (*Gymnogeophagus gymnogenys* and *Crenicichla lepidota*). These species are illustrated in Figure 4.

The number of species collected represents a total of 51.87% of the 160 total species recorded for the Patos-Mirim Lagoon system (Becker et al. 2013). Studies to expand lists of fish species in the Mirim Lagoon system were conducted in the Taim Ecological Reserve (Buckup & Malabarba 1983, Grosser et al. 1994, Garcia et al. 2006), where 51 to 62 fish species were recorded. Based on analysis of the different sampling sites, the stretch that showed a larger number of individuals consisted of sites 3 (downstream) (5,665; 24.79%) and 5 (reservoir) (5,600; 25.5%). Note that downstream site 3 presents a large predominance of aquatic macrophytes that provide refuge from predators, which are important for feeding and reproduction (Lowe-McConnell 1999). However, at site 5, the high abundance may be associated with the high reproduction rate of the forage species (e.g. *Cheirodon ibicuiensis* and *Astyanax* aff. *fasciatus*). Agostinho et al. (1999) describe how the high abundance of forage species is associated with a high reproduction rate, as well as how feeding flexibility favors the colonization of these reservoir species.

The dominant species at site 3 was *Hyphessobrycon luetkenii* (1,454; 25.66%), while at site 5, *Cheirodon ibicuiensis* was the most representative species (1,414; 25.25%). In terms of number of species, sites 3 and 4 (downstream) showed higher values of species richness (67; 80.72%) and (53; 63.85%), respectively. However, site 6 was less diverse (28; 33.73%) (Table 2). *Bryconamericus iheringii* and *Cyanocharax alburnus* were the species with the highest abundance upstream. *Hyphessobrycon luetkenii* and *Corydoras paleatus* contributed more to the abundance downstream. The most representative species in the reservoir were *Cheirodon ibicuhiensis* and *Heterocheirodon jacuhiensis*.

Regarding ecological indices, the upstream Shannon diversity index values were 2.57 and 2.22 at sites 1 and 2, respectively. However, the downstream Shannon diversity index values at sites 3 and 4 were greater (3.00 and 2.83, respectively), while the reservoir was the least diverse biotope (2.04 and 2.09) (Table 2). The same pattern can be observed in relation to the evenness index of Pielou, as the downstream sites demonstrated the highest values (0.75 and 0.72), while the reservoir presented the lowest equitability values (0.30 to 0.63) (Table 2). At the six BHAC sampling sites, two species expanded their spatial distribution: *Acestrorhynchus pantaneiro*, an invasive species in the Patos-Mirim Lagoon system (Einhardt et al. 2014) and *Cyphocharax spilotus*, which was recorded in the northern part of this system and in the BHAC (Corrêa et al. 2014). The richness found in the BHAC may be associated with broad environmental heterogeneity, since the basin is formed by a large variety of ecosystems (rivers, streams, wetlands and reservoir). Landscapes with different lotic, lentic and semilentic aquatic systems tend to present larger functional habitats and greater microhabitat diversity for fishes, increasing the availability of feeding resources, breeding sites and refuges against predation (Matthews 1998). BHAC also showed high species diversity compared to similar studies in aquatic systems. For example, in the coastal streams of austral Brazil, Bastos et al. (2013) recorded a total of 41 species, while Artioli et al. (2009) documented the occurrence of 52 species in Mangueira Lagoon, located in the same coastal plain, with the largest values comparable to those found in other aquatic environments in southern Brazil (Lucena et al. 1994, Tagliani 1994, Malabarba et al. 2009, Carvalho et al. 2012). Lower numbers of species in the studies described above can be associated with the type of sampler, as well as lower environmental heterogeneity; however, the outstanding abundance of Characiformes and Siluriformes are documented for every location (Artioli et al. 2009, Carvalho et al. 2012, Bastos et al. 2013, Silva et al. 2014).

Table 2. Taxonomic list of the 83 species de fishes, collected during August/2012 and July/2013, in six sites in the hydrographic basin of Chasqueiro stream, Mirim Lagoon system, southern Brazil. With respective order, family, species and voucher number. The number is the identification of each picture of figure 3.

		Upstream		Downstream		Reservoir		
Orden/Family/Species	**Number**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**Voucher number**
Clupeiformes								
Clupeidae								
Platanichthys platana (Regan, 1917)	1	X			X	X	X	0043
Characiformes								
Acestrorhynchidae								
Acestrorhynchus pantaneiro Menezes, 1992	2				X			0061
Characidae								
Astyanax dissensus (Lucena et al. 2013)	3			X				0063
Astyanax laticeps (Cope, 1894)	4	X	X		X			0064
Astyanax eigenmanniorum (Cope, 1894)	5	X	X	X	X	X	X	0003
Astyanax aff. *fasciatus* (Cuvier,1819)	6			X	X	X	X	0008
Astyanax henseli Melo & Buckup, 2006	7			X	X	X		0005
Astyanax jacuhiensis (Cope, 1894)	8			X	X		X	0018
Astyanax spp.	9			X				0062
Bryconamericus iheringii (Boulenger, 1887)	10	X	X	X	X	X	X	0034
Charax stenopterus (Cope, 1894)	11			X	X	X	X	0009
Cheirodon ibicuhiensis Eigenmann, 1915	12	X	X	X	X	X	X	0054
Cheirodon interruptus (Jenyns, 1842)	13	X	X	X	X	X	X	0024
Cyanocharax alburnus (Hensel, 1870)	14	X	X	X	X	X	X	0015
Diapoma speculiferum Cope, 1894	15				X			0074
Heterocheirodon jacuiensis Malabarba & Bertaco, 1999	16	X		X	X	X	X	0049
Hyphessobrycon boulengeri (Eigenmann, 1907)	17	X		X	X			0052
Hyphessobrycon igneus Miquelarena, Menni, López & Casciotta, 1980	18			X	X			0081
Hyphessobrycon luetkenii (Boulenger, 1887)	19	X	X	X	X	X	X	0007
Hyphessobrycon meridionalis Ringuelet, Miquelarena & Menni, 1978	20			X	X			0019
Macropsobrycon uruguayanae Eigenmann,1915	21			X				0050
Mimagoniates inequalis Eigenmann, 1911	22	X	X					0047
Oligosarcus jenynsii (Günther, 1864)	23			X	X	X	X	0059
Oligosarcus robustus Menezes, 1969	24			X	X	X	X	0028
Pseudocorynopoma doriae Perugia, 1891	25	X	X	X	X	X		0011
Crenuchidae								
Characidium orientale Buckup & Reis, 1997	26	X	X	X	X			0033
Characidium pterostictum Gomes, 1947	27	X	X					0037
Characidium rachovii Regan, 1913	28			X	X			0016
Characidium tenue (Cope, 1894)	29	X		X	X			0022
Curimatidae								
Cyphocharax saladensis (Meinken, 1933)	30			X	X			0077
Cyphocharax spilotus (Vari, 1987)	31			X	X			0044

Continued on next page

Table 2. Continued.

Orden/Family/Species	Number	Upstream		Downstream		Reservoir		Voucher number
		S1	S2	S3	S4	S5	S6	
Cyphocharax voga (Hensel, 1864)	32	X		X	X	X	X	0001
Steindachnerina biornata (Braga & Azpelicueta, 1987)	33			X	X			0083
Erythrinidae								
Hoplias aff. *malabaricus* (Bloch, 1794)	34			X	X	X	X	0029
Siluriformes								
Auchenipteridae								
Trachelyopterus lucenai Bertoletti, Pezzi da Silva & Pereira, 1995	35			X	X			0041
Callichthyidae								
Corydoras paleatus (Jenyns, 1842)	36	X	X	X	X	X	X	0030
Callichthys callichthys (Linnaeus, 1758)	37			X				0026
Heptapteridae								
Heptapterus mustelinus (Valenciennes in d'Orbigny, 1835)	38	X	X	X				0035
Pimellodela australis Eigenmann, 1917	39	X	X	X	X	X	X	0012
Rhamdia quelen (Quoy & Gaimard, 1824)	40			X	X	X	X	0084
Loricariidae								
Ancistrus brevipinnis (Regan, 1904)	41		X			X	X	0067
Hisonotus armatus (Carvalho et al. 2008)	42			X	X			0040
Hisonotus spp.	43			X				0068
Hisonotus taimensis (Buckup, 1981)	44			X				0069
Hisonotus cf. *notopagos* Carvalho & Reis, 2011	45			X	X			0065
Hisonotus laevior Cope, 1894	46	X	X	X	X			0039
Hisonotus nigricauda (Boulenger, 1891)	47	X	X	X	X	X		0076
Hypostomus commersoni Valenciennes, 1836	48	X	X			X	X	0014
Loricariichthys anus (Valenciennes, 1836)	49	X				X	X	0045
Otothyris rostrata Garavello, Britski & Schaefer, 1998	50			X				0066
Otocinclus flexilis Cope, 1894	51	X		X				0010
Rineloricaria baliola Rodriguez & Reis, 2008	52	X	X	X	X			0056
Rineloricaria cadeae (Hensel, 1868)	53	X	X	X	X			0021
Rineloricaria longicauda Reis, 1983	54	X	X	X	X			0057
Rineloricaria microlepidogaster (Regan, 1904)	55	X	X	X	X			0006
Rineloricaria strigilata (Hensel, 1868)	56	X	X					0070
Pseudopimelodidae								
Microglanis cottoides (Boulenger, 1891)	57	X	X	X	X			0023
Trichomycteridae								
Homodiaetus anisitsi Eigenmann & Ward, 1907	58	X	X	X	X	X	X	0048
Scleronema cf. *angustirostri* (Davincenzi, 1942)	59	X	X	X				0032
Aspredinidae								

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Table 2. Continued.

Orden/Family/Species	Number	Upstream		Downstream		Reservoir		Voucher number
		S1	S2	S3	S4	S5	S6	
Pseudobunocephalus iheringii (Boulenger 1891)	60	X	X	X	X			0038
Pimelodidae								
Parapimelodus nigribarbis (Boulenger, 1889)	61					X	X	0025
Pimelodus pintado Azpelicueta, Lundberg & Loureiro, 2008	62			X				0058
Gymnotiformes								
Gymnotidae								
Gymnotus pantherinus (Steindachner, 1908)	63		X					0072
Gymnotus aff. carapo Linnaeus, 1758	64			X				0027
Hypopomidae								
Brachyhypopomus bombilla (Loureiro & Silva, 2006)	65			X				0042
Brachyhypopomus draco Giora, Malabarba & Crampton, 2008	66			X				0082
Brachyhypopomus gauderio Giora & Malabarba, 2009	67			X	X			0075
Sternopygidae								
Eigenmannia trilineata López & Castello, 1966	68				X			0060
Cyprinodontiformes								
Anablepidae								
Jenynsia multidentata (Jenyns, 1842)	69	X	X	X		X	X	0013
Jenynsia onca (Lucinda, Reis & Quevedo, 2002)	70	X						0080
Poeciliidae								
Cnesterodon decemmaculatus (Jenyns, 1842)	71			X	X			0053
Phalloceros caudimaculatus (Hensel, 1868)	72	X	X	X	X			0017
Phalloceros aff. *caudimaculatus* (Hensel, 1868).	73			X				0071
Phalloptychus cf. *iheringii* (Boulenger, 1889)	74			X				0073
Atheriniformes								
Atherinopsidae								
Odontesthes spp.	75					X	X	0046
Perciformes								
Cichlidae								
Australoheros acaroides (Hensel, 1870)	76			X	X			0036
Cichlasoma portalegrense (Hensel, 1870)	77			X				0055
Geophagus brasiliensis (Quoy & Gaimard, 1824)	78	X		X	X	X	X	0004
Gymnogeophagus gymnogenys Hensel, 1870	79	X	X	X	X	X	X	0020
Gymnogeophagus rhabdotus Hensel, 1870	80	X		X	X	X		0002
Crenicichla lepidota Heckel, 1840	81	X	X	X	X	X	X	0078
Crenicichla punctata Hensel, 1870	82				X	X	X	0079
Synbranchiformes								
Synbranchidae								
Synbranchus marmoratus Bloch, 1785	83	X	X	X				0031
Taxa		**47**	**33**	**67**	**53**	**31**	**28**	
Shannon_H		**2.57**	**2.22**	**3.00**	**2.83**	**2.04**	**2.09**	
Equitability_J		**0.71**	**0.64**	**0.75**	**0.72**	**0.60**	**0.63**	

Figure 4. Picture of the 83 species of fishes collected in the hydrographic basin Chasqueiro Stream, Mirim Lagoon system, southern Brazil.

The downstream biotope presented the greatest richness, which may be related to increased diversity of habitats and micro habitats observed in this biotope, which corroborates the river continuum theory (Vannote et al. 1980), where changes along the longitudinal gradient (upstream to downstream) tend to increase the biological diversity. This is related to higher solar incidence and temperature variations, which increase structural complexity, e.g. the presence of macrophytes with this higher primary productivity. Another aspect that may influence the increase in fish diversity in a hydrographic basin is the presence of environmental barriers. Winemiller et al. (2008) explain that environmental barriers limit dispersion, which tends to influence diversity along a longitudinal gradient. Therefore, this study provides important data about ecosystems that compose the hydrographic basin of Chasqueiro Stream. Indeed, the richer biotopes were upstream and downstream, where there was better ecological and functional structure. Furthermore, there was a strong predominance of Characiformes and Siluriformes, reflecting the environmental heterogeneity of these environments. Downstream environments were

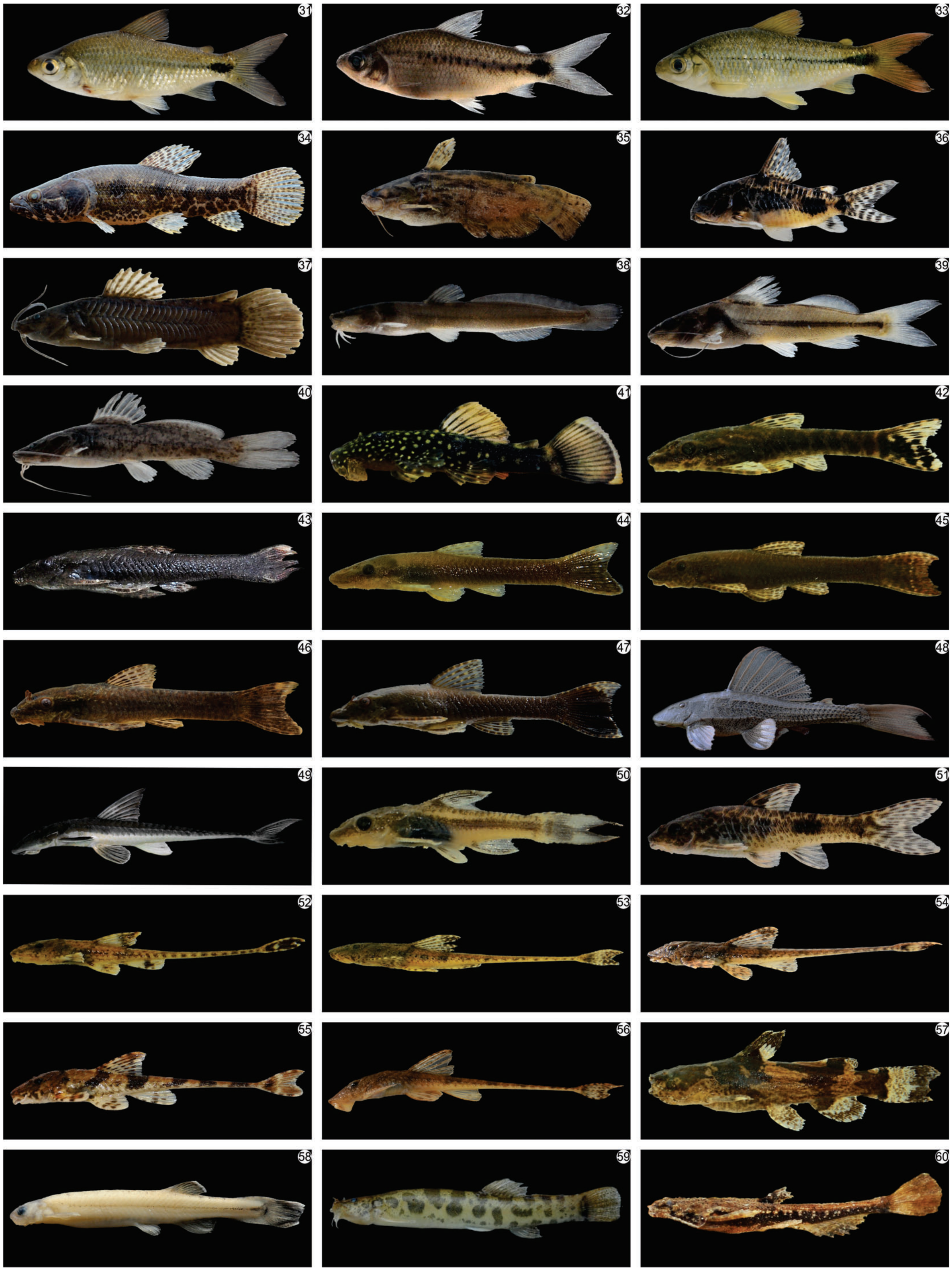

Figure 4. Continued.

more susceptible to environmental degradation caused mainly by rice cultivation.

However, the reservoir has the lowest diversity, reflecting a more homogeneous environment and the presence of invasive species (e.g. *Odonthestes* spp.) (Figure 4). The information mentioned above can be used for management plans and regional conservation, adopting mitigation measures for the preservation of this important ecosystem in southern Brazil. Further studies about the spatial and temporal distribution of species can help answer important questions about the dynamics of the assemblage organization, as well as provide additional assistance for formulating conservation programs for the ichthyofauna basin and greater control over environmental impacts, such as those resulting from irrigation and rice cultivation.

Acknowledgments

To Anna Carolina, Aline Luçardo, Cristiano Costenaro, Marcos Einhardt, Mariana Xavier and Roger Aguilar by assistance

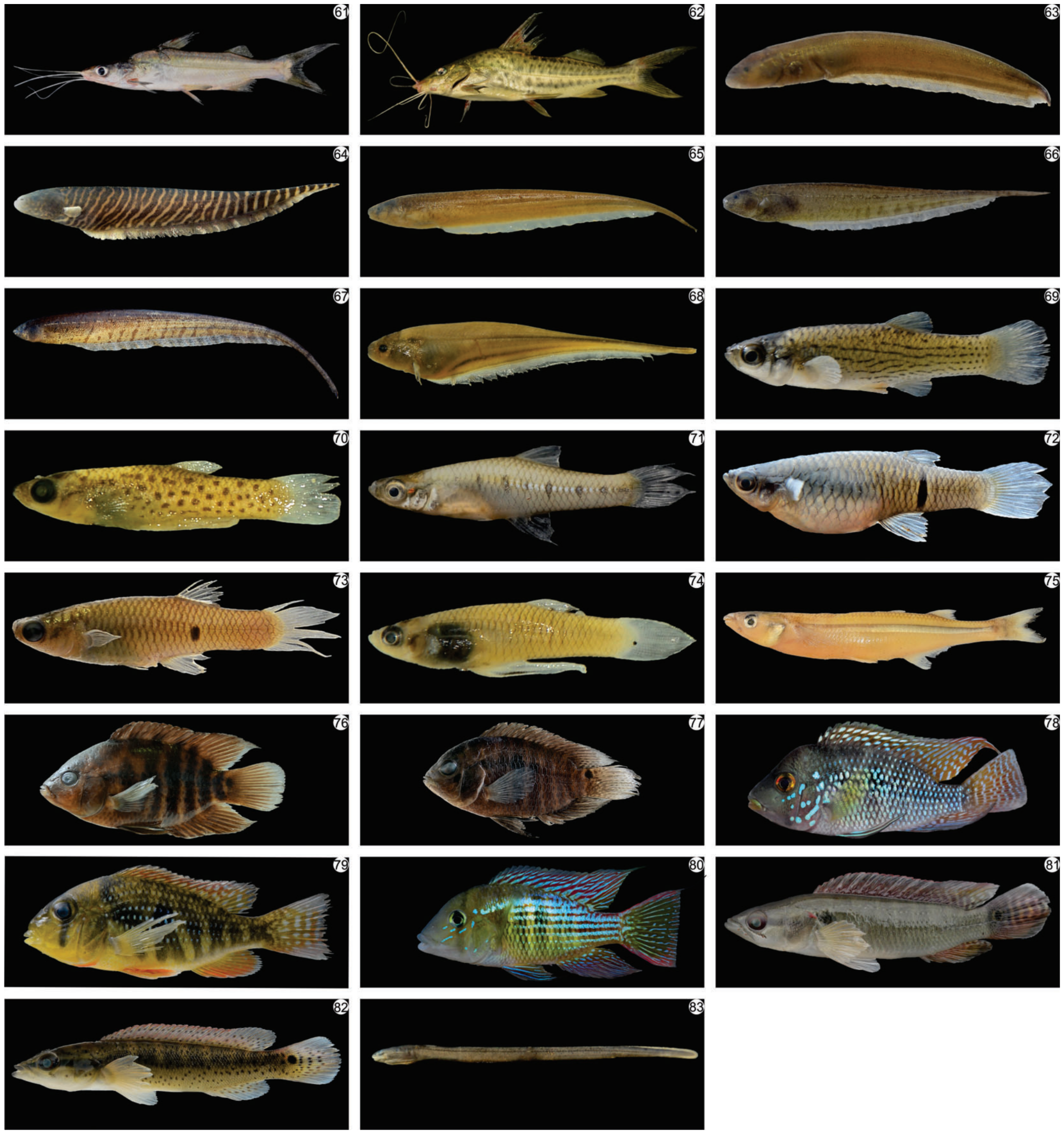

Figure 4. Continued.

in the fieldwork and laboratory, and two anonymous referees by their valuable suggestions. We are grateful to SISBIO license for the field collection, Mirim Lagoon Agency (ALG) and Coordenacão de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) in terms of field study and financial support.

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Received 16/01/2015
Revised 12/08/2015
Accepted 28/09/2015

Biota Neotropica 15(4): e201503, 2015
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)

erratum

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ISSN 1676-0611 (online edition)

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Biota Neotropica 15(4): e0001, 2015
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
article

Intra- and inter-annual changes in the condition factors of three Curimatidae detritivores from Amazonian floodplain lakes

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CORREIA, G.B., SIQUEIRA-SOUZA, F.K., FREITAS, C.E.C. **Intra- and inter-annual changes in the condition factors of three Curimatidae detritivores from Amazonian floodplain lakes.** Biota Neotropica. 15(4): e0001. http://dx.doi.org/10.1590/1676-0611-BN-2014-0001

Abstract: The flood pulse is a key factor that drives the biota of large rivers with adjacent floodplains, but the direction and intensity of its effects are not uniform for all trophic guilds of fish. In this study, we tested the existence of intra- and inter-annual changes in the relative condition factors (kn) of three Curimatidae: *Potamorhina altamazonica, Potamorhina latior*, and *Psectrogaster rutiloides*. We used weight and length data from fish that were caught in eight floodplain lakes of the Rio Solimões. These data were from experimental fisheries during each season of the hydrological cycle: flooding, flood, drying, and dry from 2004, 2005, and 2006. In general, there are similar patterns of intra-annual changes for these three species, with the highest estimates of kn during high water conditions. The lowest values were observed during the drying and dry seasons of 2005, when an extreme drought occurred in the Amazon basin. Higher values were observed during the same seasons in the year post-drought. We hypothesized that these patterns would be explained by the biological characteristics of these species and the effects of intra-annual hydrological changes, mainly the flood pulse effect, and by inter-annual climatic events, which are determined by global climate phenomena.
Keywords: *Weight-length relationship, Curimatidae, environmental effects, relative condition factor, floodplain lakes.*

CORREIA, G.B., SIQUEIRA-SOUZA, F.K., FREITAS, C.E.C. **Variação intra e interanual do fator de condição de três espécies detritívoras de Curimatidae em lagos de várzea da Amazônia.** Biota Neotropica.15(4): e0001. http://dx.doi.org/10.1590/1676-0611-BN-2014-0001

Resumo: O pulso de inundação é considerado um fator chave no direcionamento da biota de grandes rios associados a área de várzea, mas a direção e intensidade dos efeitos do pulso de inundação não são uniformes para todas as guildas tróficas dos peixes. Neste estudo, nós testamos a existência de mudanças intra e inter-anuais no fator de condição (Kn) de três curimatideos: *Potamorhina altamazonica, Potamorhina latior e Psectrogaster rutiloides*. Foram usados dados de peso e comprimento de peixes capturados em oito lagos, localizados na planície aluvial do rio Solimões. Estes dados foram obtidos em pescarias experimentais realizadas em quatro fases do ciclo hidrológico: enchente, cheia, vazante e seca nos anos de 2004, 2005 e 2006. Observamos um padrão similar de variação intra-anual para as três espécies, com maiores valores de Kn durante o período de águas altas. O valor mais baixo foi observado no período de vazante e seca em 2005 quando ocorreu um evento de seca extrema na bacia. Valores altos foram observados, durante o mesmo período, no ano posterior a seca. Consideramos que estes padrões são explicados pelas características biológicas das espécies e pelo efeito das mudanças ambientais determinadas pelo efeito do pulso de inundação, além da contribuição de eventos climáticos em escala global.
Palavras-chave: *Relação peso-comprimento, Curimatidae, efeitos ambientais, fator de condição relativo, lagos de várzea.*

Introduction

The flood pulse is the environmental phenomenon that drives the biological process in large rivers with adjacent floodplains (Junk et al. 1989), such as rivers in the Amazon Basin. This phenomenon is predictable, and aquatic Amazonian organisms have developed several types of adaptations to survive in this dynamic system, with markedly alternating aquatic-terrestrial phases. In this basin, there is sufficient information to corroborate the statement that ecological and physiological processes, which happen to fish, are determined by changes in the aquatic environment that are regulated by the flood pulse (Junk et al. 1997) from the level of organisms (Val & Almeida-Val 1995; Soares et al. 2006) to populations (Fernandes 1997) to communities (Tejerina-Garro et al. 1998; Granado-Lorencio et al. 2005; Garcez & Freitas 2008). These effects should be different for species from different trophic or reproductive guilds.

However, other climatic phenomena could happen in different temporal scales and intra- and inter-annual changes in environmental conditions should cause detectable effects at the organism level. Below a specific level of intensity, these changes should be buffered by the physiological plasticity inherent to each species. Above this level, these environmental changes could result in detectable changes at the organism level. It is possible that high-magnitude climatic events could also be evident at the population level (Ficke et al. 2007; Freitas et al. 2012).

The parameter *a* of the weight-length relationship is termed the condition factor (Le Cren 1951) because of its ability to represent fish well-being. There is a consensus that the condition factor is influenced by environmental conditions or physiological or behavioral processes (Froese 2006). For example, food availability or reproductive stages could determine the variability observed in the condition factor.

Curimatidae is a family of toothless freshwater fish with a large geographic distribution in the Neotropics (Vari 1984; 1992; Reis et al. 2003). In the Amazon basin, they are observed mainly in the Central Amazon and in the headwaters of nutrient-rich rivers (Araújo-Lima & Ruffino 2003). This group is composed almost exclusively of relatively small (<25 cm) benthopelagic species with diurnal behavior that live in lakes and rivers of white and black waters (Saint-Paul et al. 2000; Siqueira-Souza & Freitas 2004). *Potamorhina altamazonica* (Cope 1878), *Potamorhina latior* (Spix and Aagassiz 1829) and *Psectrogaster rutiloides* (Kner 1858) are three Curimatidae species, termed "branquinhas," in the Amazon basin. They are short-distance migratory species (Araújo-Lima & Ruffino 2003), which have annual migration patterns to breed upriver (Lima & Araújo-Lima 2004; Granado-Lorencio et al. 2005), and their larvae drift in the main stem of the Amazonas River (Araújo-Lima 1991). They are detritivores, mainly eating organic material, algae and microorganisms (Mérona & Rankin-de-Mérona 2004; Pouilly et al. 2004), and could be favored by seasons with high availability of these items in the environment. In an opposite way, seasons with low availability of detritus could be severely adverse to this species group.

In the present study, we analyzed modifications in the condition factor of the species *Potamorhina altamazonica*, *Potamorhina latior* and *Psectrogaster rutiloides* with the aim of identifying the seasons that result in advantageous and disadvantageous environmental conditions for these species, which have the same feeding behavior. These environmental conditions were associated with two temporal scales: intra- and inter-annual effects. Our data include the severe drought of 2005 (Marengo et al. 2008), and we believe that the results of the present study constitute a preliminary insight into the effects of extreme climatic events on Amazonian fish species at the population level.

Material and Methods

Study Area

The fish were collected in eight floodplain lakes from 2004 to 2006. These lakes are placed at the banks of a stretch of 400 kilometers of the Rio Solimões, nominally: Baixio (03° 18' 01"; 60° 05' 30"), Preto (03° 20' 39"; 60° 35' 22"), Iauara (03° 36' 20"; 61° 18' 16"), Ananá (03° 54' 23"; 61° 40' 33"), Maracá (03° 50' 00"; 62° 34' 00"), Araçá (03° 46' 14"; 62° 22' 01"), Poraquê (03° 57' 46.7"; 63° 09' 41.2") and Aruã (04° 06' 29"; 63° 32' 10") (Figure 1). All of these lakes are typical perennial floodplain lakes that remained connected to the main river for most of the year.

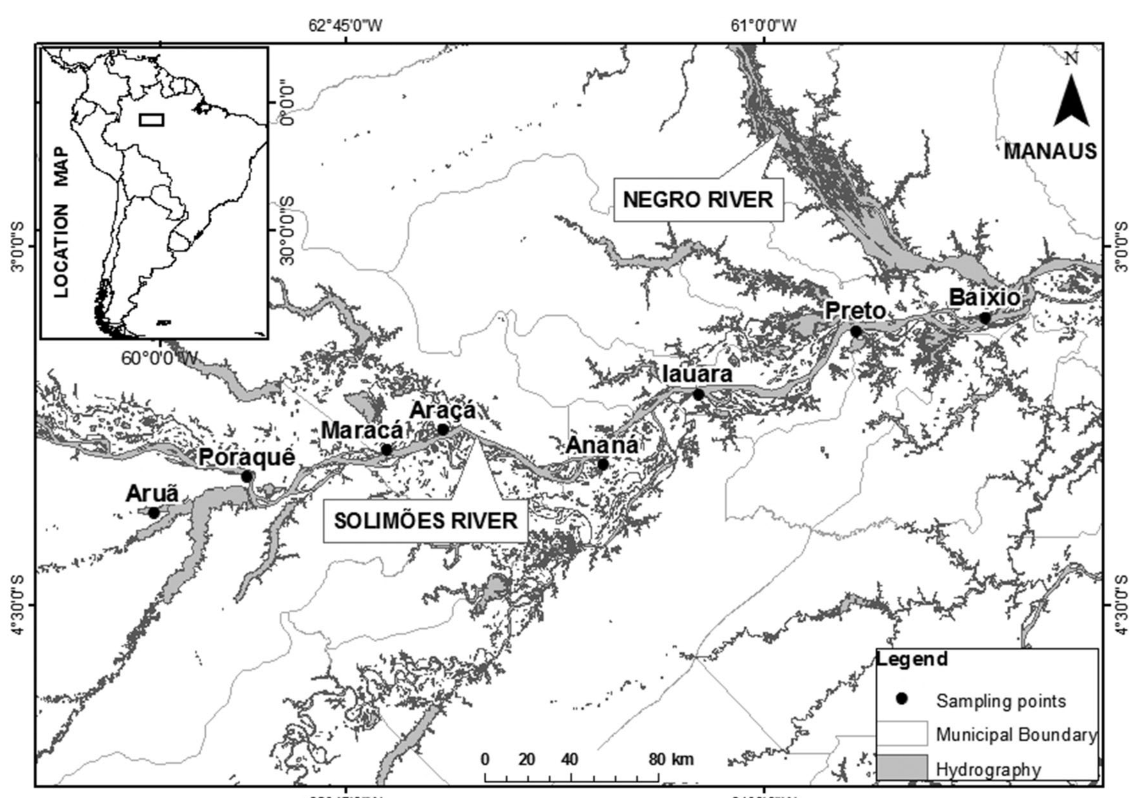

Figure 1. Study area showing the sampled lakes and the stretch of the Rio Solimões.

Data Sampling and Analysis

Samples were taken once during each of the four stages of the hydrologic cycle, performed in experimental fisheries with gillnets of standard dimensions (20 meters in length by 2 meters height) and different mesh sizes (30, 40, 50, 60, 70, 80, 90, and 100 mm between opposite knots). To encompass the maximum fish activity periods, the nets were set between 05:00 and 06:00 h (pre-dawn) and brought in with the catch 12 h later (just after dusk). The sampling efforts were held constant for each lake and sample date. Fish were identified, measured by standard length (centimeters) and total weight (grams), and preserved in formalin 10% for permanent storage in the Laboratory of Fishery Ecology of the Federal University of Amazonas in Manaus, Brazil.

The parameters *a* and *b* from the weight-length relationship were estimated by non-linear estimation using the algorithm of Levenberg-Marquardt (Myers 1990). The relative condition factor (kn) was calculated by the equation $kn = W/We$, proposed by Le Cren (1951), where W is the total weight of an individual and We is the mean weight estimated for each length by the equation $We = a.\ L^b$, where *a* and *b* are the parameters from the weight-length relationship. The index kn represents the variability of the condition factor around the mean estimated value. It is independent of fish size and is useful for comparisons between fish of different sizes.

Following Bittencourt & Amadio (2007), to define the seasons of the hydrological cycle, we clustered the estimated values of kn into years and seasons of the hydrological cycle to test the hypothesis that inter- and intra-annuals means are similar. Prior to the data analysis, we tested the hypothesis of variance homogeneity. Because this hypothesis was rejected, all data were log-transformed prior the use of a two-way Anova using the year and the hydrologic season as factors. We employed a Tukey's test when the null hypothesis was rejected. All statistical analyses were performed in the R statistical software package version 2.15.3 (R Core Team 2013).

Results

We measured 1058 individuals of *Potamorhina altamazonica*, 635 of *Potamorhina latior* and 873 of *Psectrogaster rutiloides*. The mean standard length of *P. altamazonica* was 16.12 ± 3.21 cm, and the mean weight was 111.32 ± 64.67 g. *Potamorhina latior* was slightly smaller, with a mean standard length of 14.80 ± 2.87 cm and a mean weight of 68.98 ± 42.86 g. *Psectrogaster rutiloides* had the smallest average size, with a mean standard length of 12.88 ± 2.03 cm and a mean weight of 64.44 ± 31.26 g. The relative condition factor ranged from 0.8256 to 1.1552 for *P. altamazonica*, from 0.8637 to 1.3149 for *P. latior*, and from 0.8558 to 1.3830 for *P. rutiloides* (Table 1).

The weight-length relationships were as follows: $W = 0.0357.L^{2.859}$ with r = 0.96 for *P. altamazonica*; $W = 0.0100.L^{3.23}$ with r = 0.94 for *P. latior*; and $W = 0.0600.L^{2.71}$ with r = 0.89 for *P. rutiloides* (Figure 2).

There were intra- and inter-annual differences in the relative condition factors of *Potamorhina altamazonica*, *Potamorhina latior* and *Psectrogaster rutiloides*, besides noticeable interactions effects between year and season of the hydrological cycle (Table 2). For *P. altamazonica*, the intra-annual estimates of kn were consistently constant for 2004 and 2006, but there were clear decreases between the seasons of flooding-flood for drying-dry in 2005 (Table 3, Figure 3A). The pattern for *P. latior* is somewhat similar to that of *P. altamazonica*; one marked difference was that the highest values occurred during the flood season, followed by a decrease in the drying and dry seasons; the differences were mainly evident for 2004 and 2005. Nevertheless, there was a marked decline in kn in the drying-dry seasons of 2005, similar to the decrease observed for *P. altamazonica* (Table 3, Figure 3B). In addition to the differences in the intra-annual patterns, it is evident that for both *Potamorhina* species, increases in the relative condition factors occurred during the drying and dry seasons in 2006 (Figures 3A and 3B). *Psectrogaster rutiloides* showed a slightly different intra-annual pattern from those of the *Potamorhina* species, mainly because of the estimates for 2006, when there were higher values during the drying-dry seasons than during the flooding-flood seasons (Table 3, Figure 3C). These three species showed a similar inter-annual pattern of lowest kn values during the drying and dry seasons of 2005. *Potamorhina altamazonica* and *Psectrogaster rutiloides* also exhibited an increase in kn for these same periods of the following year (Figures 3A and 3C).

Discussion

The hydrological cycle of large rivers in the Amazon basin is monomodal and predictable, with a flood season between June and July and a dry season near the end of the year (Figure 4).

Table 1. Estimates of relative condition factor for the three Curimatidae species, collected at the Rio Solimões, by year and season of the hydrological cycle.

Year	Season	*P. altamazonica*	*P. latior*	*P. rutiloides*
2004	Flooding	1.1091 ± 0.1805	1.1395 ± 0.1468	1.2351 ± 0.2193
	Flood	0.9702 ± 0.1354	1.2848 ± 0.3932	1.3830 ± 0.2748
	Drying	1.1482 ± 0.0807	1.1852 ± 0.1943	1.1582 ± 0.1032
	Dry	0.9640 ± 0.2507	0.9579 ± 0.1733	1.0680 ± 0.2058
2005	Flooding	1.0319 ± 0.1499	1.0963 ± 0.1524	0.9279 ± 0.0965
	Flood	1.1180 ± 0.2050	1.3149 ± 0.2286	1.1379 ± 0.0882
	Drying	0.8256 ± 0.0937	0.9408 ± 0.0862	0.8558 ± 0.0816
	Dry	0.8539 ± 0.0952	0.8637 ± 0.1394	0.8679 ± 0.1362
2006	Flooding	0.9697 ± 0.0977	0.9974 ± 0.1273	0.9426 ± 0.0844
	Flood	1.0282 ± 0.0937	1.1356 ± 0.1899	1.0218 ± 0.1562
	Drying	1.0505 ± 0.0854	1.2145 ± 0.1559	1.1706 ± 0.1392
	Dry	1.1552 ± 0.2240	1.1588 ± 0.1555	1.2010 ± 0.1403

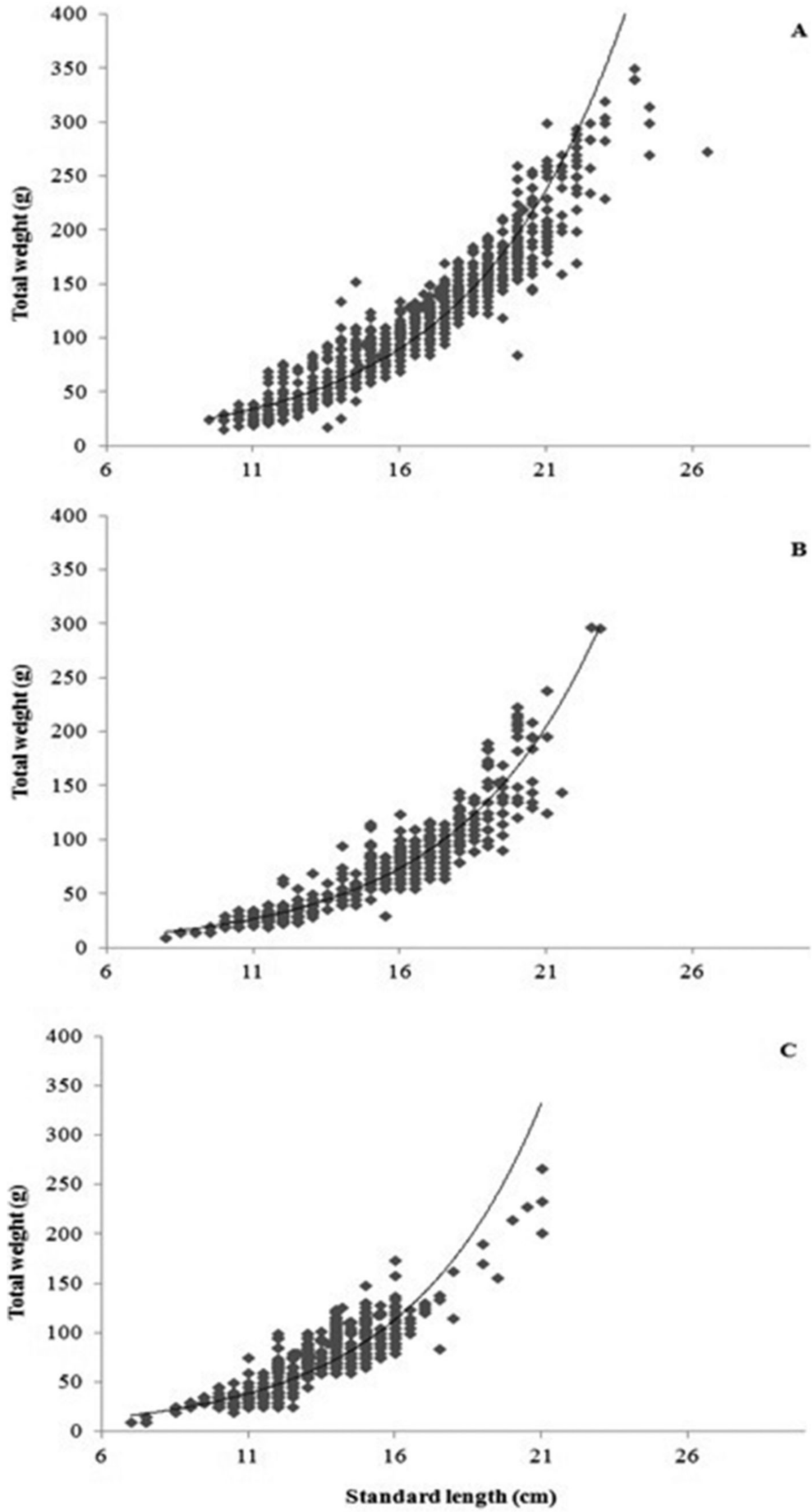

Figure 2. Weight-length relationships estimated for (A) *Potamorhina altamazonica*, (B) *Potamorhina latior* and (C) *Psectrogaster rutiloides* amostrados no rio Solimões.

Table 2. Summary of intra- and inter-annual two-way Anova applied to data of relative condition factor of *Potamorhina altamazonica*, *Potamorhina latior* and *Psectrogaster rutiloides*.

Source of Variation	*P. altamazonica*			*P. latior*			*P. rutiloides*		
	F	df	p	F	df	p	F	df	p
Season	12.26	3	< 0.01	22.07	3	< 0.01	8.32	3	< 0.01
Year	27.23	2	< 0.01	17.96	2	< 0.01	69.78	2	< 0.01
Season*Year	41.11	6	< 0.01	33.05	6	< 0.01	31.99	6	< 0.01
Error		1046			623			861	

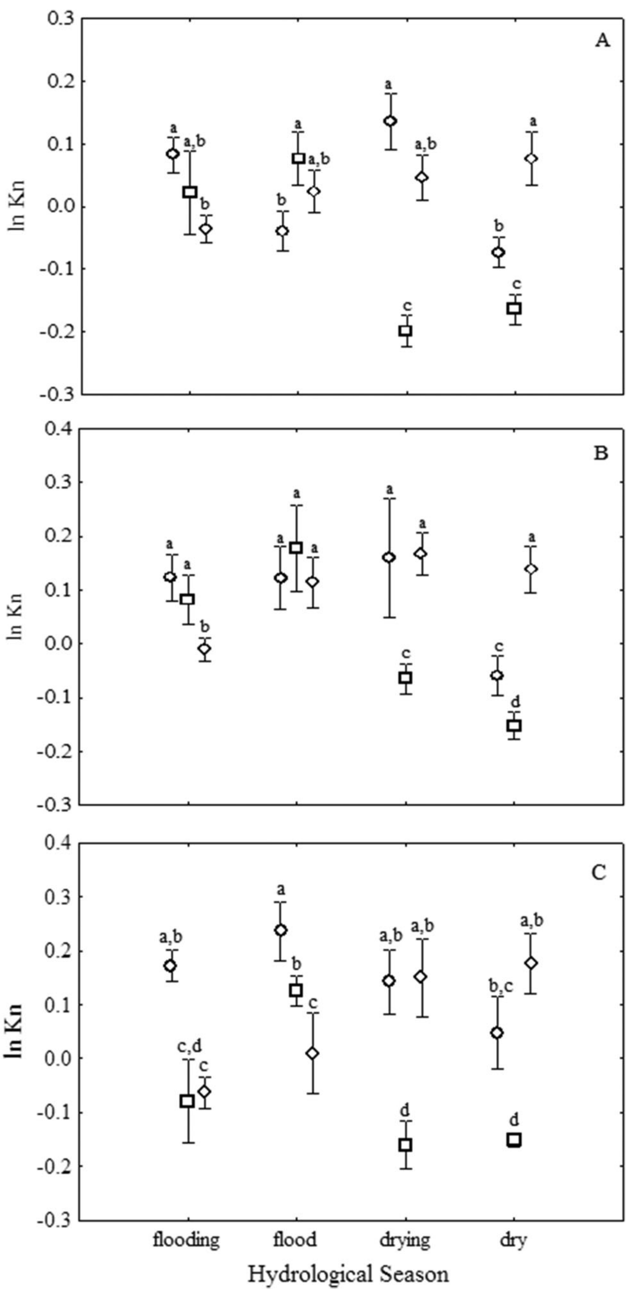

Figure 3. The dynamics of the condition factor during the seasons of the hydrological cycles of 2004 (circle), 2005 (square), and 2006 (triangle) for (A) *Potamorhina altamazonica*, (B), *Potamorhina latior* and (C) *Psectrogaster rutiloides.* Vertical bars denote 0.95 confidence intervals around the mean.

These shifts between high and low water periods represent deep changes in the aquatic environment (Junk et al. 1989), and the resident biota had developed several strategies to survive in this dynamic system. Nevertheless, a low water season is typically an unfavorable period for fishes, mainly for those species that explore flooded forest and other habitats that are specific to the flood seasons.

We hypothesize that the intra-annual differences, observed within each year, in the condition factor are most likely related to food availability. The feeding behaviors of *Potamorhina altamazonica*, *Potamorhina latior*, and *Psectrogaster rutiloides* are characterized by a strong dependence on items, such as detritus, algae, and plankton (Mérona & Rank de Mérona 2004), which are more abundant during the flooding and flood seasons. Detritus represents an important food source for Amazonian fish and is composed of organic and inorganic material that originates from plants and litter (Fernandes 1997). In addition to habitats that are available during high water periods, such as those containing macrophytes, debris and trees of flooded forest areas can serve as substrates for algae and periphyton (Piedade et al. 2010).

These Curimatidae species undergo lateral migrations during the receding water season, leaving the floodplain lakes toward the river channel during August and September (Fernandes 1997). The stimulus for this migration is not reproductive, unlike the migration that occurs at the beginning of the flooding season, when these species migrate out from the floodplain to breed upriver. The August-September migration is a strategy to avoid the disadvantageous condition of the dry season, although some

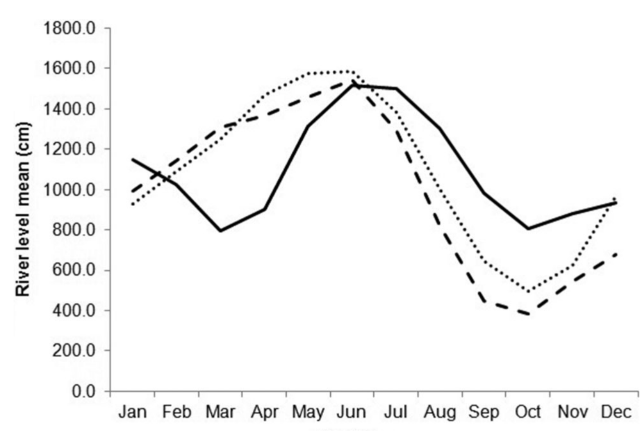

Figure 4. River level (cm) at Coari Station for (——) 2004, (- - - -) 2005, and (·······) 2006 (Source: Agência Nacional de Águas – ANA, Coari Station, Code: 13150003).

same species have developed a physiological resistance to hypoxia (Soares & Junk 2000; Anjos et al. 2008). The gradual drying of the floodplains increases fish densities and intensifies biotic interactions, mainly predation and competition, because habitat and food resources are declining. The fish that remain in the floodplain lakes during the dry seasons become stranded in isolated pools, where they compete for limited resources and are at risk of being preyed upon by predators, such as piscivorous fish, birds and other vertebrates (Winemiller & Jepsen 1998).

By contrast, our hypothesis to explain the interaction effects could be associated with climatic events. The main driver of the inter-annual variability of the river level at the Amazon basin is the El Niño–Southern Oscillation (ENSO). Historically, the term "El Niño" has been used to describe the coastal warming of the near-equatorial Pacific Ocean off the coast of Peru (Lehodey et al. 2006). However, the extreme drought that occurred in 2005 (Figure 4) was a result of the summed effects of the ENSO and the warming of the Southeast Atlantic Ocean. This extreme climatic event caused drastic effects on the Amazonian environment (Marengo et al. 2008) and was responsible for the lowest kn values for the second half of 2005.

The rapid recovery of these species in the year post-drought, with high kn estimates mainly for the second half of the year during the low water seasons could be associated with three non-exclusive phenomena: (i) these species could be identified as r-strategists along the r-K continuum for fishes (Jones 1976) or periodic strategists (Winemiller 1992) thus they are able to colonize the newly flooded floodplains immediately after the drought because the river channel can be assumed as source grounds; (ii) the predation rate could be decreased after the drought because potential predators are K-strategists within the same r-K continuum (Jones 1976) or equilibrium strategists in the sense of Winemiller (1992), and their ability to colonize should be decreased compared to Curimatidae species; and (iii) the availability of detritus is increased after the drought because the floodplain environment was enriched/fertilized after this extreme drought.

Freitas et al. (2013) studied the floodplains assemblages during the same time period of the present study and observed a disproportionate post-drought increase in abundance among fish species that develop annual migrations as part of their life cycles. These species are more resistant to extreme drought because they can explore other perennial environments. Another possible explanation is what is termed the fertilizer hypothesis. We are in agreement with Freitas et al. (2013), that the increased levels of algivore and detritivore species might be an indication that the abundance of fish carcasses and growth of terrestrial plants on exposed soil during extended low water periods provide elevated nutrient levels in returning flood waters, which benefit fish that feed on algae or decomposing vegetation. This type of nutrient enrichment should affect other biotic interactions, including changes in the normal intensity of predator–prey relationships (Davis et al. 2010).

Acknowledgments

We thank I. Santos, W. Dias, and J. Pena for help in field work. The research was supported by grants 0.1.04.0567.00 and 0.1.06.1223.00 from PIATAM Project, funded by FINEP, and by grants 023/2009 – PRONEX/FAPEAM-CNPq and 563073/2010-1 – CNPq.

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Received 27/01/2014
Revised 30/06/2015
Accepted 14/10/2015

Biota Neotropica 15(4): e0091, 2015
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)

short communication

The response of bats (Mammalia: Chiroptera) to an incidental fire on a gallery forest at a Neotropical savanna

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OLIVEIRA, H. F. M., AGUIAR, L.M.S. **The response of bats (Mammalia: Chiroptera) to an incidental fire on a gallery forest at a Neotropical savanna.** Biota Neotropica. 15(4): e0091. http://dx.doi.org/10.1590/1676-0611-BN-2015-0091

Abstract: Fire is a common and natural event in Cerrado that can influence the composition of trees and mammals and change the entire conditions of the environment. This study was developed in a gallery forest of Distrito Federal - Brazil. Bat samplings were conducted for a total of six nights after a fire that happened on the gallery forest. Three samplings were conducted: one day, three months and seven months after fire. A total of nine mist nets (12 m x 3 m) were opened from 7pm to 1am. Captured bats were measured and identified to species. Shannon index measured the species diversity of bats in the gallery forest over time. A rarefaction curve was made to assess the estimated bat richness in each of the samplings and a chi-square test was used to check whether there have been changes on bat abundances over time. A total of 46 bats from 8 different species and one family were captured. The most abundant species was *Sturnira lilium.* Species diversity and abundance increased over time and there was a gradual accumulation of species and specimens indicating that the succession and recovery of the forest occurs due to a temporal addition of specimens and species in the assemblage and not as punctual occurrences. Probably, this recovery pattern reflects a gradual increase in the availability of resources and recovery of the forest canopy, progressively offering more shelter and food for the bat assemblage.
Keywords: *Chiroptera, Cerrado, fire, impact, recovery.*

OLIVEIRA, H. F. M., AGUIAR, L.M.S. **Resposta dos morcegos (Mammalia: Chiroptera) a queimada acidental em mata de galeria de uma savana Neotropical.** Biota Neotropica. 15(4): e0091. http://dx.doi.org/10.1590/1676-0611-BN-2015-0091

Resumo: O fogo é um evento comum e natural no Cerrado que pode influenciar a composição de árvores e mamíferos e mudar totalmente as condições do ambiente. Esse estudo foi desenvolvido na mata de galeria do Distrito Federal – Brazil. As amostragens dos morcegos foram conduzidas por um total de seis noites depois da ocorrência do fogo na mata de galeria. Três amostragens foram conduzidas: um dia, três meses e sete meses depois que o fogo ocorreu. Um total de nove redes de neblina (12 m x 3 m) foram abertas das 7pm a 1am. Os morcegos capturados foram medidos e identificados ao nível de espécie. O índice de Shannon mediu a diversidade de espécies de morcegos na mata de galeria ao longo do tempo. Uma curva de rarefação foi feita para acessar a riqueza estimada de morcegos em cada amostragem e um teste qui-quadrado foi usado para verificar se houve mudanças na abundância de morcegos ao longo do tempo. Um total de 46 morcegos de 8 espécies diferentes e uma família foram capturados. A espécie mais abundante foi *Sturnira lilium*. A diversidade de espécies e abundância aumentaram com o tempo e houve um acúmulo gradual de espécies e espécimes indicando que a sucessão e recuperação da mata ocorreu com uma adição temporal de espécimes e espécies na assembleia e não de forma pontual. Provavelmente, o padrão de recuperação reflete o aumento gradual na disponibilidade de recursos alimentares e recuperação do dossel da mata, que progressivamente passaram a ofertar mais abrigo e alimento para a assembleia de morcegos.
Palavras-chave: *Chiroptera, Cerrado, fogo, impacto e recuperação.*

Introduction

Bats are the only mammals capable of true flight. This ability enabled them to explore an enormous variety of niches that had never been used by any other mammal species (Norberg 1994). In the Neotropical region, frugivory is a common characteristic of bat species from the Phyllostomidae family (Altringham 1997). There are different explanations concerning the occurrence of frugivorous bats in the Neotropics. In most cases, bat occurrence is associated with food distribution and availability (Morrison 1978; Heithaus & Fleming 1978; Fleming 1988; Lima & Reis 2004). In total, the neotropical savannah of Cerrado comprises about 106 bat species (Aguiar & Machado 2010) making it the richest group of mammals in this domain (Marinho-Filho & Guimarães 2001). Although gallery forests comprise only 5% of the total area of Cerrado, this formation hosts more than 80% of its mammal species and most of them are bats (Marinho-filho & Gastal 2000).

Fire is a common and natural event in Cerrado regions (Miranda, Bustamente & Miranda 2002) and form an important structuring factor of their vegetal communities and phytophysiognomies (Hoffman & Moreira 2000). Fires can cause high mortality rates of wooded plants and mammals, influencing the composition of tree species and the mammalian fauna (Hoffman & Moreira 2000; Henriques et al. 2000; Briani et al. 2004) as they tend to favor the establishment of gramineae and pioneer species (Hoffman & Moreira 2000). Although gallery forests are more difficult to burn due to their low amount of gramineae and high humidity (Hoffman et al. 2003), fires are an important component of their dynamics, especially in their borders (Hoffman 1999). Fires can induce changes in forest structure, composition and promote the development of plant species that are more light tolerant (Miguel et al. 2011) and shifts in the composition of trees (Santiago et al. 2005), but borders are usually less affected as they have plants that are more adapted and resistant to it (Meave et al. 1991).

The few studies reporting the effects of fire on the mammal fauna are for small non-flying mammals (Viera & Marinho-Filho 1998; Vieira 1999; Henriques et al. 2000; Briani et al. 2004). Most studies reporting the effects of fire on bats have been carried out on North American forests with special attention to insectivorous species (Boyles & Aubrey 2006; Dickinson et al. 2008; Loeb & Waldrop 2008; Lacki et al. 2009; Layne 2009; Fisher & Wilkinson 2005; Johnson et al. 2010; Dickinson et al. 2010; Perry 2011; Silvis 2011; Armitage & Ober 2012). According to Fisher & Wilkinson (2005), bat activity after fire may vary according to the density of the remaining trees. In some cases, insectivorous bats may be unresponsive to fire (Loeb & Waldrop 2008), fire may increase shelter availability in dead trees (Boyles & Aubrey 2006) or decrease bat activity (Silvis 2011). However, there is no study on the effect of fire in frugivorous and nectarivorous bats or the response of the chiropterofauna to fire in Cerrado.

The objective of this study is to report the response of frugivorous and nectarivorous bat species to a fire that burned a gallery forest in the Neotropical savanna of Cerrado.

Methods

This study was developed in a gallery forest of a small farm (Chácara Solar da Águia – 15°55.640’ S; 47°49.890’ W) located in the Distrito Federal - Brazil. The forest was characterized by its reduced width (100 meters in the portion sampled), presence of clearings and exotic plants, like bamboos, and pastures in its surrounding area. The fire burned the whole forest, from small shrubs to tall trees, along its whole width and at least 4 km of its extension. Fire promoted an increase in the number and size of gaps, a reduction of its width and the establishment of pioneer plants inside it. Bat sampling was conducted for two consecutive nights each time in a total of six nights. The first sampling started one day after the fire (19th and 20th of September of 2007), the second after three months and the last sampling after seven months. A total of nine mist nets (eight 2m x 12m and one 2m x 6m) were opened from 7pm to 1am on each night. Captured bats were tagged with plastic rings, had their forearm lengths measured with a caliper and were identified to species level (Vizotto & Taddei 1973).

Shannon index was used to measure the diversity of species in each sampling with Biodiversity Pro software (McAleece 1997). A rarefaction curve was made to assess the estimated bat richness in each samplings and the chi-square test was used to check whether there have been changes in the abundance of bats over time. Both calculations were made with the software R (Ihaka & Gentleman 1996).

Results and discussion

A total of 46 bats from 8 species and one family were captured (Table 1). The highest richness of species, abundance and diversity were registered in the last sampling. The most

Table 1. Bat assemblages captured after one day, three and seven months of a fire that happened in a forest gallery of Distrito Federal - Brazil.

	Abundance			
Guild/Species	**After 1 day**	**After 3 months**	**After 7 months**	**Total**
Frugivorous				
Sturnira lilium	04	04	08	16
Carollia perspicillata	00	04	04*	07
Artibeus cinereus	00	01	10	11
Artibeus fimbriatus (Gray, 1838)	00	00	03	03
Artibeus planirostris (Spix, 1823)	00	00	01	01
Artibeus lituratus (Olfers, 1818)	00	00	05	05
Platyrrhinus lineatus (E. Geoffroyi, 1810)	00	00	01	01
Nectarivorous				
Glossophaga soricina (Pallas, 1766)	00	01	02	03
Total	04	10	33	46
Richness	01	04	08	08
Diversity (Shannon)	0,00	1,19	1,82	1,83
Equitability	1,00	0,82	0,84	0,78

*Recaptured specimen

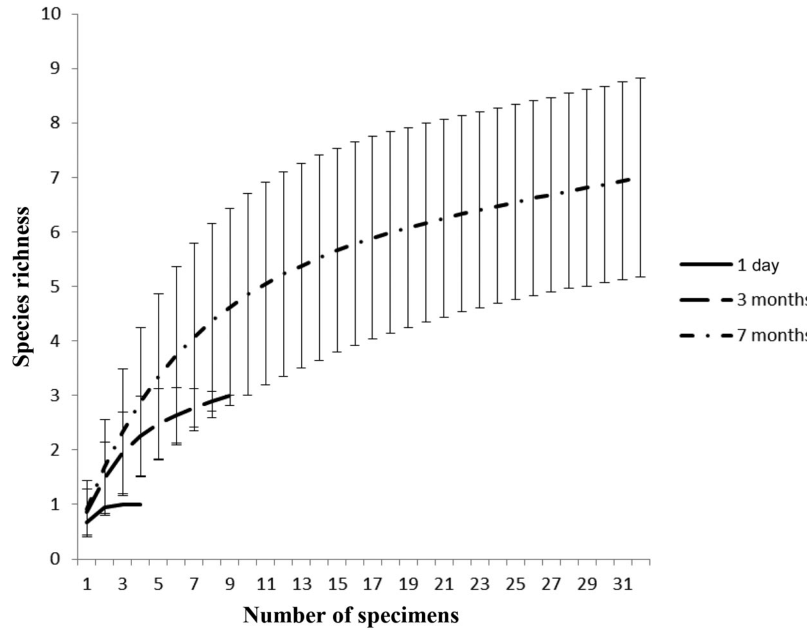

Figure 1. Rarefaction curve of bat species captured after one day, three months and seven months of a fire that happened in a forest gallery of Distrito Federal - Brazil.

abundant species was *Sturnira lilium* with 16 captured specimens, representing 43.5% of the total catches. One *Carollia perspicillata* was recaptured in the seventh month, suggesting that after three months, some specimens were already using the area more continuously after the fire. The diversity of species increased over time, as can be seen by the increasing values of H', indicating recovery of the area. The χ^2 test showed a significant difference ($\chi^2 =$ 29,92 DF = 2, 9 $<$ 0,001) in the total of bats captured in each period, indicating an increase in the abundance of bats over time. Rarefaction curves (Figure 1) didn't evidence differences in species richness between areas, but a gradual accumulation of species and specimens was observed and all of the species captured in the first or second month of sampling were also captured on a later moment and always with a higher abundance than was previously recorded.

These results indicate that the succession of the gallery forest for bats is given by the temporal addition of specimens and species in the assemblage and not by their punctual occurrences. Although it's difficult to estimate the recovery of the forest itself after a fire as the conditions probably don't return to the initial phase as there is a change in the composition of tree species (Santiago et al. 2005), the present recovery pattern for bats seems to be more related to a gradual increase in the availability of food resources and shelter in the area.

In contrast to the fauna of small non-flying mammals, which normally reach their abundance peak shortly after fire due to an increase in the gramineae of the area (Yarnell et al., 2007), the low abundance and richness of bats during the first sampling may have been influenced by the high mortality of wooded plants that can happen after a fire (Santiago et al. 2005), which resulted on an initial decrease of food supply and shelter deficit under foliage.

The gradual increase in richness and abundance over the following months may also have occurred as a result of the establishment of pioneer plants such as some Solanaceae that were found in the area and the recovery of the foliage in the canopy. Boyles & Audrey (2006) reported a rise in light penetration and a reduction of tree density together with an increased availability of shelters for bats in a semi deciduous forest in United States of America after fire. Nardoto (2000) observed that at heights above 160 cm, foliage may be exposed to hot air flows with possible and intense fall of leaves only a few days after fire. This effect could have reduced the availability of shelter for species that roost under leaves, like species of the genus *Artibeus*, justifying its record only later in the assemblage. The late record of *Artibeus* species was not expected as they are common species in gallery forests and could easily cross substantially modified areas as they are highly vagile (Bernard & Fenton 2003; Costa et al. 2006; Jr et al. 2008). This fact helps to reinforce the big impact of the fire on the bat assemblage.

Although natural regenerating gallery forests are stable regarding their vegetation composition and structure (Oliveira & Felfili 2005) and to keep their diversity of plant species (Felfili 1997), fire can cause intense death of trees in gallery forests and change their floristic composition (Santiago et al. 2005), promote secondary succession and formations of clearings that play similar roles as the gaps of continuous forests (Kellman and Meave 2007). There is usually an increase in the abundance of some species of bats in open and degraded environments, like *S. lilium* and other frugivore species (Castro-Luna et al. 2007; Willig et al. 2007). The colonization of forest clearings by pioneer plants in this study, especially from the family Solanaceae, may have occurred together with the recording of the first bat species after fire and the initial recovery of the forest. Silva *et al.* (2005) observed the formation of clearings and the presence of a great number of species of the genus *Cecropia*, *Piper* and *Solanum* in a semideciduous broadleaved forest after the fire. These plant genera constitute some of the main plant items in the diet of species such as: *C. perspicillata*, *Sturnira lilium* and *Artibeus* spp. (Bizerril & Raw 1998; Garcia et al. 2000; Aguiar & Marinho-Filho 2007; Mikich 2002). These bat species are also, in many cases, dispersers of pioneer plants (Bizerril & Raw 1998; Garcia et al. 2000; Aguiar & Marinho-Filho 2007; Mikich 2002), indicating that they could also be helping in the regeneration process of the forest.

Although fire may have momentarily diminished the supply of food and shelter for bats, as time went by, conditions have changed and there was an increase of food supply, especially those that are more adapted to relatively altered environments and forest gaps. Therefore, it is possible that bat assemblages in gallery forests may have a considerable capacity for recovery when affected by fires and succession in these areas may occur on basis of temporal sum of specimens and species and not by eventual colonization as frugivorous species are most likely attracted by the reestablishment of original features of the forest and colonization by pioneer plants used in their diets.

Acknowlegdments

We would like to acknowledge the owner of the farm Solar da Águia by the permission to work on his property, to Ibama for the permission to capture the bats and to the University of Brasília, CAPES and FAP-DF for the funding and support to develop this research.

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Received 20/07/2015
Accepted 18/11/2015