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Habitat structure determining the spatial distribution of ichthyofauna in a Brazilian stream

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ABSTRACT. This work aimed to evaluate the relationship between parameters of fish communities and the habitat structure of a stream. Twenty three stretches six meters long were evaluated in the Samambaia stream located inside the Sumidouro Park, Rio das Velhas basin, state of Minas Gerais, Brazil. Fish samplings and habitat characterization were made for each stretch. Seven variables of habitat (vegetal cover, width, depth, substrate, flow, presence of aquatic plants and leaf litter) and two variables characterizing the longitudinal gradient (altitude and distance from the Sumidouro lagoon) were assessed. The fish community responded to habitat changes, presenting variation in richness and composition of species. Richness was positively influenced by the presence of leaf litter and aquatic plants. Furthermore, through similarity data (NMDS) and habitat structure (PCA), it was possible to observe the separation of the 23 stretches into two groups with a dissimilarity of approximately 90%. We concluded that the variation in richness and composition of species throughout the stream was strongly related to the variables of habitat structure. This variation is clearer when considering the longitudinal gradient which highlights a great difference between stretches nearer and farther from the mouth of Samambaia stream.

Keywords: freshwater fishes, longitudinal gradient, river continuum.

Estrutura do habitat determinando a distribuição espacial da ictiofauna de um córrego brasileiro

RESUMO. Este trabalho buscou avaliar as relações entre parâmetros da ictiofauna e aspectos da estrutura física de um riacho. Vinte e três trechos com seis metros de comprimento foram avaliados no Córrego Samambaia, localizado no Parque Estadual do Sumidouro, bacia do Rio das Velhas, estado de Minas Gerais, Brasil. Em cada trecho, foi feita a coleta de peixes e a caracterização do habitat, tendo sido avaliadas sete variáveis do habitat (cobertura vegetal, largura, profundidade, substrato, vazão, presença de plantas aquáticas e folhiço) e duas variáveis que caracterizam o gradiente longitudinal (altitude e distanciamento à montante da Lagoa do Sumidouro). A ictiofauna respondeu às mudanças de habitat, apresentando variação na riqueza e na composição. A riqueza foi influenciada positivamente pela presença de folhiço e plantas aquáticas. Além disso, por meio dos dados de similaridade e habitat físico, foi possível observar a separação dos 23 trechos em dois grupos com dissimilaridade de aproximadamente 90%. Concluímos que a variação na riqueza e na composição de espécies ao longo do córrego está fortemente relacionada às variáveis da estrutura do habitat. Essa variação fica clara quando se considera o gradiente longitudinal, a qual evidencia uma grande diferença entre os trechos mais próximos e mais distantes da foz do córrego Samambaia.

Palavras-chave: peixes de água doce, gradiente longitudinal, continuidade de rios.

Introduction

Changes in the structure of aquatic communities are determined mainly by the combined effect of environmental factors and biotic interactions. Environmental factors limit the amplitude of potential distribution of species, while biotic interactions may act determining the actual distribution (WELLBORN et al., 1996). Among the main environmental factors that may affect aquatic communities are the channel morphology (CAMARGO et al., 2012), water quality (VALLE JUNIOR et al., 2015) and the quality and quantity of physical habitat (GREGORY et al., 1991, PUSEY et al., 1993, GEHRKE; HARRIS, 2000).

Physical variables of the habitat (inside and surrounding a stream) are strongly related to the structure of riparian vegetation (GREGORY et al., 1991).The presence of vegetation in streams promotes not only the stability of margins but also controls microclimate, shading and transport of sediments, besides providing allochthonous resources and shelter for aquatic communities (NAIMAN; DÉCAMPS, 1997). However, the autochthonous production can be improved as the light incidence on the water body increase, which may occur with the suppression of riparian vegetation or the increase of channel width (VANNOTE et al., 1980). The substitution of allochthonous by autochthonous energy sources may alter the structure of communities with which some species are excluded and others are favored (FERREIRA; CASATTI, 2006). Therefore, physical conditions of the habitat may influence the biotic structure and organization within aquatic systems (MUGODO et al., 2006), what may reflect both on the community of benthic macroinvertebrates (CALLISTO et al., 2001; REZENDE et al., 2014) and fish assemblages (GORMAN; KARR, 1978; BÜHRNHEIM; COX FERNANDES, 2003; CASATTI et al., 2006).

Several studies have been assessing variations in the fish community and their relationship with the physical structure of the habitat (e.g. GRENOUILLET et al., 2004; SULLIVAN et al., 2004; MENDONÇA et al., 2005; DUBEY et al., 2012). Fishes became an important tool in such studies, since they present specific requirements of habitat and depend strongly on the dynamics and characteristics of the water. Most fish species present adaptations and morphological modifications that allow them to exploit specific characteristics of a given habitat (GATZ JÚNIOR, 1979; WILLIS et al., 2005; LEAL et al., 2011). Moreover, the choice of this group as a study tool presents several advantages to obtain environmental information, such as wide distribution, representativeness in different trophic levels, relatively easy identification and capacity to respond to degradation (KARR; DUDLEY, 1981).

Due to the great importance of freshwater fishes for the functioning of aquatic environment (LÉVÊQUE, 1995), it is necessary to define the factors that influence the presence and distribution of fish fauna. Therefore, the aim of this study was to observe the relationship between parameters of fish communities (richness, abundance and composition) and local physical aspects of a stream (vegetal cover, width, depth, substrate, flow, and presence of aquatic plants and leaf litter), also considering the influence of variables that characterize the latitudinal gradient (altitude and distance from the stretches) on these parameters. We hypothesized that besides the latitudinal gradient, fish communities are also structured by local instream physical habitat, and resources abundance related features would be more relevant than river morphology variables.

Material and methods

Study site

This study was developed in the Parque Estadual do Sumidouro (PESU) situated in the municipalities of Lagoa Santa and Pedro Leopoldo, state of Minas Gerais, Southeastern Brazil. PESU is a Protected Area that belongs to the category 'sustainable use of natural resources' – APA Carste Lagoa Santa (CASARIM et al., 2014), which contains two main watercourses – the Sumidouro lagoon and the Samambaia stream. The study area was the Samambaia stream located at 19°32′ S 43°56′ W, in the Rio das Velhas basin.

Samambaia stream, with 9.1 Km length, is the main water source of Sumidouro lagoon, flowing into sinkholes and then rising, flowing to the Rio das Velhas (IEF, 2010; PEREIRA; CALDEIRA, 2011; CASARIM et al., 2014). It is a dendritic stream and presents ramifications along its course. Furthermore, the flow changes in some stretches due to water diversion by farms in the region. The stream is located in a rural area, presenting good conditions of preservation, without deposition of sewage and effluents along its whole extension (IEF, 2010). However, it is possible to note the degradation of marginal vegetation in several stretches of the stream, especially near the lagoon, mainly due to the cattle-raising in the natural grass vegetation.

Sampling design

On October 2012, during dry season, 23 stretches six meters long were sampled throughout 2.5 Km of Samambaia stream inside PESU. The choice of the sampled sections aimed to cover the widest variety of physical characteristics of the stream, including stretches with variation in vegetation cover, presence and absence of litter, as well places with different substrates, widths, depths, flow rates and amount of aquatic plants. The choice of at least three stretches with very similar characteristics was standardized. After the selection each stretch was sampled only once (Figure 1).

Characterization of the physical habitat

In order to characterize the physical structure of the habitat we evaluated, in each stretch, the vegetal cover, mean width, mean depth, predominant substrate, flow, percentage of water surface covered by aquatic plants and presence of leaf litter. The vegetal cover was estimated through a densiometer, which consists of a convex spherical mirror (LEMMON, 1957).

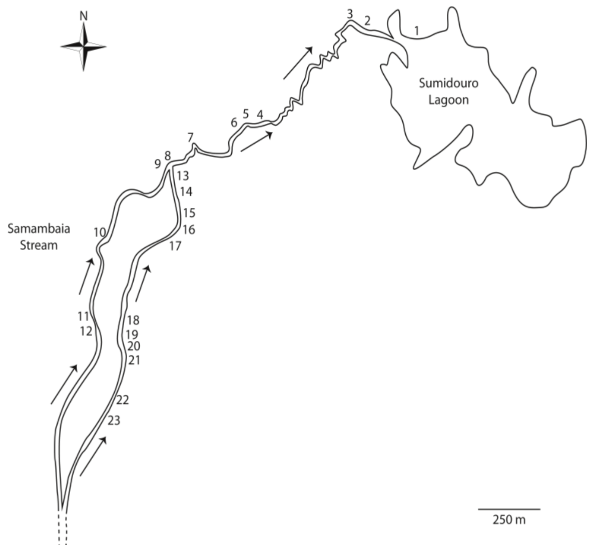

Figure 1. Illustration of the sampling points along the Samambaia stream (1-23), Parque Estadual do Sumidouro (PESU), Minas Gerais State, Brazil. The study area was the Samambaia stream located at 19°32′ S 43°56′ W, in the Rio das Velhas basin. Arrows indicate the flow direction (modified from CASARIM et al., 2014).

Six measurements were taken using the densiometer: four positioned in the center of the channel (upstream, downstream, right and left) and a measurement on each margin of the stream (right and left) (PECK et al., 2006). The density of vegetal cover was calculated through values obtained by the densiometer (KAUFMANN et al., 1999). The mean width of channel was obtained from three measurements throughout each sampled stretch. For mean depth, five measurements were made on the thalweg. The predominant type of substrate was visually categorized according to the granulometry (PECK et al., 2006) and the following categories were considered: 1) sediments larger than 16 mm of diameter (coarse gravel, pebbles and boulders); 2) sediments with diameter between 2 mm and 16 mm (fine gravel) and 3) sediments smaller than 2 mm (sand, silt, clay and mud). The flow was measured for each of the 23 stretches. The flow was calculated by multiplying the stretch area by the water speed. In order to calculate the area, three sections were marked within each stretch where five width and depth at equidistant points were measured. To calculate the water speed an object of neutral flotation was thrown into the water and the time spent to travel a given distance was recorded. This process was repeated three times throwing the object near the left and right margins and in the center of the stream. The percentage of aquatic plants (all types) was visually estimated observing how much of the water surface was covered by aquatic plants. For leaf litter, we only observed its presence or absence.

The altitude and distance of each stretch from the Sumidouro lagoon (where the stream discharges) were calculated by means of the geographical coordinates obtained through the Global Positioning System (GPS - Garmin Etrex Venture).

Fish collections

Fish collections were performed from downstream to upstream with sieves made from mosquito netting (80 cm in diameter, 1mm mesh size) and seine nets (3 m length, 5 mm mesh size) for a standardized time of 20 minutes per stretch. Each sampling transect was closed with block seine nets at both ends in order to collect the fish. All captured individuals were anesthetized with eugenol and subsequently fixed in formaldehyde 10%. In the laboratory, fishes were identified until the species level, with the aid of identification keys, and preserved in 70% ethanol. Specimens of each species were deposited in the Fish Collection of the Federal University of Lavras (CI-UFLA).

Data analysis

Data regarding physical habitat were standardized (values divided by the mean) because of their different units. Multiple regressions (standard method) were performed in order to evaluate possible relationships between the fishes and the variables of physical habitat. We considered as response variables the richness and total abundance of species, and variables of the physical structure of the habitat were considered explanatory. A Principal Component Analysis (PCA) was performed to obtain the distribution of each stretch according to the variables of physical structure of habitat. For these analyses, all the nine measured variables of habitat were considered (altitude, distance, depth, width, flow, substrate, presence of leaf litter, percentage of aquatic plant and vegetal cover).

Data regarding the composition of each stretch were ordered through the non-metric multidimensional scaling (NMDS) using the distance index of Bray-Curtis. The NMDS is a graphical representation of community relationships that preserves the rank order of among-samples dissimilarities (McCUNE; GRACE, 2002). Variables summarized by the first axis of the PCA were incorporated in the NMDS graph through a bubble type graph in which the size of the point corresponding to each sampled site is proportional to its value in the first axis of the PCA. This approach was applied to indicate how strong was the influence of environmental variables of the first axis of PCA on the composition of icthyofauna. Two groups were visually identified a posteriori on the NMDS graph (with incorporation of the first PCA axis) and in order to assess significant differences among the groups a similarity analysis (ANOSIM) was used. The contribution of each species for the separation of the groups ordered by NMDS was evaluated through the similarity percentage analysis (SIMPER). This analysis decomposes average records dissimilarities between all pair of samples, listing the species in decreasing order of such contributions (CLARKE; GORLEY, 2006).

Results

Overall, 3113 specimens belonging to nine families and 14 species of fishes were collected in the 23 sampled transects of the Samambaia stream. The Characiformes order was the most representative (98.9% of collected individuals), and the species *Hyphessobrycon santae* was the most abundant and frequent, being present in 18 of the 23 sampled stretches (Table 1). Among the species collected, at least two are classified as exotic to the Rio das Velhas basin: *Hoplosternum littorale* and *Tilapia rendalli* (CASARIM et al., 2014). The species richness was positively influenced by the presence of aquatic plant and leaf litter (Table 2). The abundance was not significantly influenced by any analyzed variable, however there were less individuals in the most distant stretches of the lagoon (Table 1 and 2).

The characterization of 23 stretches was obtained from the calculation of physical habitat metrics. From these data it was possible to observe the great variation in physical and biological characteristics between stretches, mainly when considering the longitudinal gradient (Table 3).

The first axis of PCA explained 43.21% of the ordination of stretches, and leaf litter, vegetal cover, width, distance and flow were the main explanatory variables (Table 4). A gradient related to structural characteristics of each sampled transect was observed when analyzing data of the first PCA axis incorporated to the NMDS ordination. There is a clear separation of two significantly different groups of sampled stretches (ANOSIM; $r = 0.582$, $p < 0.001$), in which the composition of group 1 was more influenced by the variables width and flow, and the composition of group 2 was more influenced by the presence of leaf litter, distance and vegetal cover (Figure 2). The dissimilarity between the two groups was approximately 90% (SIMPER, mean dissimilarity = 89.24), with the species *Hyphessobrycon sanctae, Hasemania nana, Characidium zebra* and *Astyanax taeniatus* being the most important ones regarding the differences between the two groups, contributing with 38.72, 27.84, 20.38 and 8.13%, respectively for the between-groups observed dissimilarity (Figure 2). These species were found in both groups, but were more abundant in the stretches included in the group 1.

Table 1. Fish species recorded in the Samambaia stream, located at the Parque Estadual do Sumidouro, Brazil. N = number of individuals collected in 23 transects of the stream. CI-UFLA = Number of UFLA Fish Collection. *Exotic species.

Taxon	Stretches																							N	CI-UFLA
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23		
CHARACIFORMES																									
Characidae																									
Astyanax lacustris (Lütken,1875)	-	6	1	-	-	6	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	14	CI-UFLA 0719
Astyanax rivularis (Lütken,1875)	-	8	-	-	-	-	-	-	-	-	-	7	-	-	-	42	-	-	4	-	9	2	-	72	CI-UFLA 0720
Astyanax taeniatus (Jenyns, 1842)	16	34	26	10	20	70	2	2	1	7	13	-	9	9	5	14	-	-	-	-	-	-	-	238	CI-UFLA 0718
Hasemania nana (Lütken,1875)	48	214	17	46	83	46	-	-	9	77	13	-	241	29	1	5	-	-	-	-	-	-	-	829	CI-UFLA 0717
Hyphessobrycon santae (Eigenmann, 1907)	119	662	118	42	82	101	18	4	11	23	2	-	142	43	6	12	21	2	-	-	-	-	4	1412	CI-UFLA 0716
Crenuchidae																									
Characidium zebra Eigenmann, 1909	1	8	-	-	43	5	106	-	194	19	10	6	28	18	22	9	23	-	1	3	5	2	-	503	CI-UFLA 0722
Erythrinidae																									
Hoplias malabaricus (Bloch, 1794)	-	-	-	2	3	-	-	-	2	1	1	-	-	-	-	1	2	-	-	-	-	-	-	12	CI-UFLA 0724
CYPRINODONTIFORMES																									
Poeciliidae																									
Poecilia reticulata Peters, 1859	-	-	-	2	-	-	-	-	-	-	3	1	-	-	-	-	-	-	-	-	-	-	-	6	CI-UFLA 0727
Gymnotidae																									
Gymnotus carapo Linnaeus, 1758	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	CI-UFLA 0725
PERCIFORMES																									
Cichlidae																									
*Tilapia rendalli** (Boulenger 1897)	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	CI-UFLA 0721
SILURIFORMES																									
Auchenipteridae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
*Trachelyopterus galeatus (*Linnaeus,1766)	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	CI-UFLA 0729
Callichthyidae																									
*Hoplosternum littorale** (Hancock, 1828)	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	CI-UFLA 0728
Heptapteridae																									
Pimelodella lateristriga (Lichtenstein, 1823)	-	-	-	-	-	-	2	2	-	-	-	1	-	-	-	-	-	-	-	1	2	4	4	16	CI-UFLA 0726
Rhamdia quelen (Quoy & Gaimard, 1824)	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	3	-	-	-	-	-	-	1	7	CI-UFLA 0723
TOTAL	184	933	162	102	232	229	128	9	218	129	42	16	420	99	34	86	46	2	5	4	16	8	9	3113	

Table 2. Influence of the studied variables over the richness and abundance of the ichthyofauna in the Samambaia stream, Parque Estadual do Sumidouro, Minas Gerais State. Set of analyzed variables: altitude, distance, depth, width, flow, substrate, presence of leaf litter, % of macrophyte cover and vegetal cover. b = correlation coefficient: indicates the relationship between the dependent and independent variables of the model; R^2 = determination coefficient: indicates how much the model can explain the observed values; AdjR^2 = alternative measurement of the determination coefficient that penalizes the inclusion of variables with low explanatory power, and p = significance level (< 0.05). P/A = presence and absence.

Analyzed variables	Multiple regression					
	Richness			Abundance		
	Explanatory variables	b	*P*	Explanatory variables	b	*p*
Altitude	Leaf litter	0.522	0.016	None		
Distance	Aquatic plants	0.891	0.008			
Depth						
Width						
Flow						
Substrate						
Leaf litter (P/A)						
Aquatic plants						
Vegetal cover						
Model	R^2= 0.768; F(9,13) = 4.764 p<0.005	Adj R^2 = 0.607		R^2=0.491; F(9,13) = 1.397 p<0.283	Adj R^2= 0.140	

Table 3. Characteristics and parameters of the fish community of the 23 stretches sampled throughout the Samambaia stream, Parque Estadual do Sumidouro, Brazil. P/A = presence and absence.

Stretch	Richness	Abundance	Characteristics of stretches								
			Altitude (m)	Distance from the lagoon (m)	Mean depth (cm)	Mean width (m)	Predominant substrate	Leaf litter (P/A)	Macrophytes cover (%)	Vegetal cover (%)	Flow (m^3/sec)
1	4	184	627	3	48.50	5.03	< 2 mm	Absent	0.00	0.00	0.38
2	7	933	643	218	37.00	3.80	< 2 mm	Absent	10.00	0.00	0.35
3	4	162	645	279	30.10	4.40	< 2 mm	Absent	0.00	0.00	0.32
4	5	102	649	898	47.00	2.50	2 – 16 mm	Absent	20.00	0.00	0.29
5	6	232	654	957	25.30	2.60	2 – 16 mm	Absent	20.00	0.00	0.27
6	6	229	638	1017	39.80	2.30	2 – 16 mm	Absent	40.00	0.00	0.33
7	4	128	645	1183	26.60	2.10	> 16 mm	Absent	5.00	0.00	0.34
8	4	9	646	1365	25.30	2.40	> 16 mm	Absent	30.00	0.00	0.30
9	6	218	647	1392	29.60	3.05	> 16 mm	Absent	40.00	0.00	0.36
10	7	129	665	1787	52.00	4.20	< 2 mm	Absent	50.00	7.00	0.43
11	6	42	647	2152	94.10	2.10	< 2 mm	Absent	100.00	4.00	0.25
12	5	16	682	2198	77.50	2.40	< 2 mm	Absent	100.00	0.00	0.34
13	4	420	607	1388	10.80	1.90	< 2 mm	Absent	10.00	25.00	0.05
14	4	99	634	1425	15.10	3.06	2 – 16 mm	Absent	10.00	5.00	0.15
15	4	34	653	1545	12.60	0.70	> 16 mm	Absent	0.00	25.00	0.05
16	7	86	659	1555	37.60	2.01	< 2 mm	Present	20.00	83.30	0.08
17	3	46	671	1585	30.80	1.40	< 2 mm	Absent	20.00	97.05	0.08
18	1	2	634	2113	40.50	1.09	2 – 16 mm	Absent	0.00	91.17	0.06
19	2	5	653	2141	38.50	1.25	2 – 16 mm	Absent	0.00	63.72	0.07
20	2	4	659	2188	52.10	0.96	2 – 16 mm	Absent	0.00	100.00	0.07
21	3	16	669	2231	56.60	0.80	< 2 mm	Present	0.00	100.00	0.06
22	3	8	670	2473	38.60	1.20	< 2 mm	Present	5.00	90.19	0.07
23	3	9	671	2488	40.50	1.40	< 2 mm	Present	0.00	95.09	0.09

Table 4. Main explanatory variables of the first and second axis of PCA. Variables that influenced the most (positively or negatively) are in bold.

Variables	Axis	
	PC1	PC2
Altitude	0.523	0.566
Distance	**0.812**	0.348
Depth	0.116	**0.890**
Substrate	-0.321	-0.162
Leaf litter	**0.702**	0.027
Aquatic plants	-0.246	**0.867**
Width	**-0.834**	0.101
Flow	**-0.857**	0.378
Vegetal cover	**0.926**	-0.140
Eigenvalue	3.889	2.185
% Explanation	43.207	24.281
Cumulative explanation	43.207	67.488

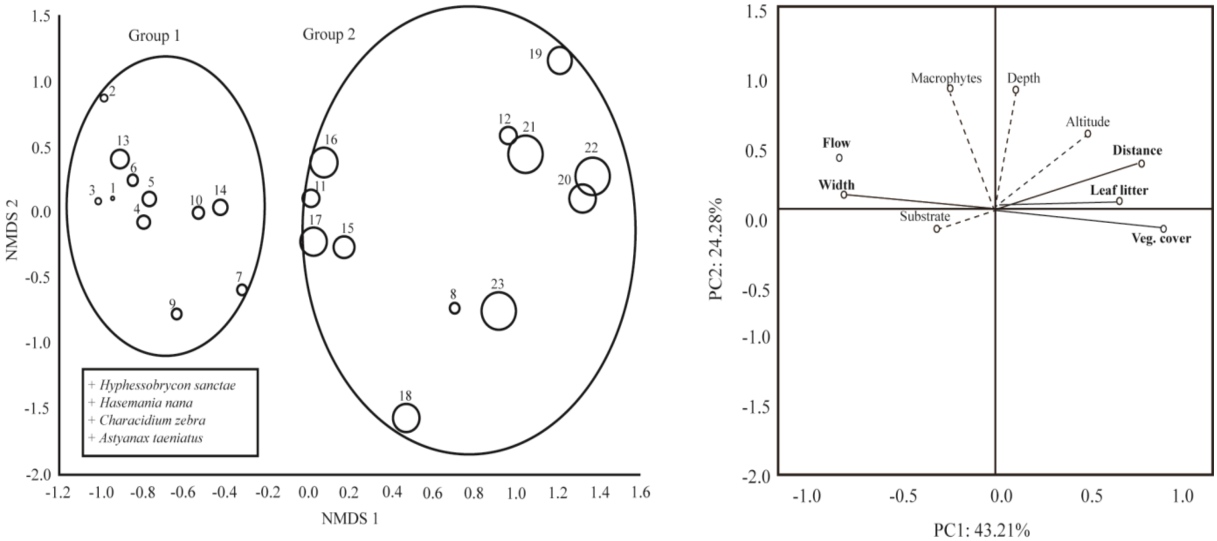

Figure 2. Two first axes of NDMS (stress = 0.11) plotted through the similarity index of Bray-Curtis using as bubble variable the first axis of the PCA. The most explanatory variables of axis 1: width and flow (negative values); vegetal cover, presence of leaf litter and distance from Sumidouro lagoon (positive values). *Hyphessobrycon sanctae, Hasemania nana, Characidium zebra* and *Astyanax taeniatus* were the species that most explained the dissimilarity between the two groups, being more abundant on group 1.

Discussion

In this study, it was possible to observe a mosaic of habitats and relate their physical variables to the structure of the ichthyofauna. Most of the studied variables altered the richness and composition of communities because they influenced the diversification of habitats and the supply of resources for aquatic communities. The richness was positively influenced by the presence of aquatic plant and leaf litter in the stretches. The presence of aquatic plant makes the environment more heterogeneous, since their presence is related to shelter availability (THOMAZ; BINI, 2003; THOMAZ; CUNHA, 2010) and food for aquatic organisms (CASATTI et al., 2003; PELICICE; AGOSTINHO, 2006). Therefore, species specialized in finding shelter in, or feeding on resources provided by aquatic macrophytes are favored in regions with the presence of such plants. However, not always the presence of macrophytes brings advantages to aquatic environments. Diverse human activities (e.g. input of residential and industrial sewage, agriculture, etc.) contribute to the eutrophication of water resources and one of the consequences is the high proliferation of aquatic macrophytes (THOMAZ; BINI, 2003). In such cases, the control or management is necessary.

The presence of leaf litter accumulated in the channel bed also contributes to diversification of habitats and the supply of resources. Its presence is strongly associated to the integrity of riparian vegetation, thus influencing the detritus chain and the community structure by providing shelter for fishes and invertebrates (GREGORY et al., 1991). This relationship was confirmed in the four stretches with the presence of leaf litter, where in all cases their presence was related to a higher percentage of vegetal cover (> 83%). Although the presence of leaf litter had influenced positively the richness, a decrease on fish abundance with the increase of distance of the lagoon was recorded, and consequently stretches with more vegetal cover, more leaf litter, lower width and smaller flow. This result can be explained by the lower productivity of the aquatic environment closer to the headwater due to the lower input of luminosity (CONNOR; MCCOY, 1979; VANNOTE et al., 1980, ANGERMEIER; SCHLOSSER, 1989). On streams in which riparian vegetation is abundant, great part of the energy came from allochtonous vegetal material and terrestrial insects of the riparian vegetation (GREGORY et al., 1991). Thus, one can hope that species specialized on exploiting such types of resources predominate in such environments.

Despite the short extension of the Samambaia stream, the physical pattern observed corresponds to those proposed by Vannote et al. (1980) in which zones next to the headwater present higher percentages of vegetal cover, narrower dimensions and greater input of allochtonous material (observed through the accumulation of leaf litter). Conversely, intermediate zones and those closer to the mouth (next to Sumidouro lagoon) presented no vegetal cover, greater width and aquatic macrophytes, what characterizes the autochthonous primary production. However it is important to note that this pattern may be influenced by the presence of natural grass vegetation in stretches near lagoon

These differences in the physical characteristics of each local can be one of the explanations for the visual separation of the 23 stretches into two groups with approximately 90% of dissimilarity between them. In the first group it was possible to observe stretches closer to the lagoon in which the channel width and the flow explained the ichthyofauna composition. The largest width (> 2m) and flow rates (> 0.2 m^3 $sec.^{-1}$) were observed on these stretches along the Samambaia stream. We highlight that part of stretches of group 1 is after the junction of bifurcation (stretches closest to the lagoon: 1-7), so this factor can explain the higher flow rates and widths observed in these group. Channel width is related to the size of the sampled area on each transect, this variable may have influenced the species richness according to the species-area relation, in which the richness increases progressively with the increase of the area (CONNOR; MCCOY, 1979; ANGERMEIER; SCHLOSSER, 1989). On the other hand, the flow promotes the diversification of habitats by controlling several important attributes in streams, such as speed, geomorphology of the channel and stability of the substrate (POFF; WARD, 1989). Together such attributes constitute the main factors that determine the distribution of fishes, because they are responsible for the formation of different habitat mosaics (GORMAN; KARR, 1978; ANGERMEIER; SCHLOSSER, 1989; BUNN; ARTHINGTON, 2002), for example, the differentiation between environments of fast flowing waters and pools (REZENDE et al., 2010).

In the second group the distance from lagoon had a great influence on the composition of fish fauna. Moreover, the fish fauna of this group was more related to the presence of a more consistent vegetal cover, as well as to the deposit of leaf litter in the bottom of the channel. According Pringle et al. (1988), riparian patch characteristics can affect the lotic food webs in terms of quantity and quality of leaf litter. Therefore, in addition to influences in species richness, the presence of leaf litter in the channel bed also exerts a great influence on the composition of the local fish fauna.

The morphology of fishes presents a strong relationship with the type and complexity of available habitats (WILLIS et al., 2005; LEAL et al., 2013; SOUZA et al., 2014). Thus, some species may present specific requirements of habitats and different adaptations to exploit each environment. Such preference toward specific habitats was observed for the four most abundant species (*Hyphessobrycon sanctae, Hasemania nana, Characidium zebra* and *Astyanax taeniatus*) in the group of stretches closer to the Sumidouro lagoon (group 1). These species, all of them Characiformes, represented 96% of the total of collected individuals. The order Characiformes is one of the largest groups of freshwater fishes, with species found both in lentic and lotic systems (BUCKUP et al., 2000; NELSON, 2006). The favorable conditions of the shallow lentic environment offer advantages to small-sized Characiformes, but disfavor the Siluriformes (FERREIRA et al., 2000), which were less abundant in points closer to the Sumidouro lagoon. From these four species abundant in group 1, *H. sanctae, H. nana* and *A. taeniatus* were recorded for the Sumidouro lagoon as well the two exotic species sampled in this study (CASARIM et al., 2014). Both of these two exotic species were captured in stretches near the lagoon (group 1), each with only one specimen collected. Thus, this result highlights the strong influence of the lagoon over the composition of species found in stretches closer to the stream mouth.

The fact that the fish community follows the modifications in habitat structure reaffirms the capacity that the ichthyofauna has to respond to alterations in the environment they inhabit, even on a small scale. However, it should be noted that a single sampling of fish fauna was done in each stretch, therefore new samples would be relevant to confirm the results obtained in this study. The variations in species richness and composition of the fish community throughout the stream were strongly related to variables of the physical structure of the habitat, which respond to variations in the longitudinal gradient. The characteristics of the stretches change as the distance from lagoon increases, presenting variations mainly in the channel morphology, productivity of the system, and habitat complexity. This variation can be explained by the dynamics of patches, where, in streams, patches may be determined by many interacting factors including substratum conditions, topography, current patterns, organisms, and disturbance (PRINGLE et al., 1988). However, it must be noted that possible human activities, such as cattle-raising, may occur inside PESU, even being a Conservation Unit. This kind of activities can mask the real conditions of the environment and greatly influence the stream characteristics. Even before the creation of PESU, the lake was indiscriminately used by predatory tourism and urbanization, what may have resulted in water contamination and colonization by exotic species, as observed in this present study.

Conclusion

The local fish community responded to habitat variations. Richness was related to resources abundance, and composition of species related to resources and stream morphology variables. There was also a separation of stretches into two groups with different physical characteristics and high dissimilarity regarding fishes. Probably the separation of these two groups occurred in response to the variables of habitat, which are highly related to the longitudinal gradient. Furthermore, some species showed more affinity to stretches with determined characteristics of the physical structure of the stream, thus suggesting that they may have specific habitat requirements.

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