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Influence of local and landscape characteristics on the distribution and diversity of fish assemblages of streams in the Ivinhema River basin, Upper Paraná River

Influência de características locais e da paisagem sobre a distribuição e diversidade das assembleias de peixes de riachos na bacia do Rio Ivinhema, Alto Rio Paraná

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Abstract: Objectives: Among the most relevant issues in community ecology is the influence of different ways of addressing the pattern of diversity and distribution of species, and based on this, the present study sought to evaluate the influence of landscape and local characteristics on the richness and composition of fish assemblages in the Ivinhema River basin. **Method:** In the present study, we used data of distribution of fish species in 25 stretches of streams of the Ivinhema River basin, Upper Paraná River, aiming to know the role of local characteristics and land use on fish assemblages. **Results:** We identified 113 fish species, and those sampled in a greater number of sites were: *Astyanax altiparanae* and *Serrapinnus notomelas*. The richness varied between 4 and 65 species. The regression tree allowed explaining 89.3% of richness variation, and permitted to identify that altitude is the main predictor of richness. According to the canonical correspondence analysis, variables that most influenced the species distribution were: altitude, depth, width, velocity, conductivity and percentage of built-up areas. **Conclusions:** Our results suggested that factors that most influenced fish assemblages in the Ivinhema River basin were physiographic and limnological characteristics, followed by land use.

Keywords: species distribution, species richness, fish assemblages, landscape ecology.

Resumo: Objetivos: Entre as questões mais importantes em ecologia de comunidades está a influência das diferentes formas de abordagem sobre o padrão de diversidade e distribuição das espécies, com base nisso o presente trabalho buscou avaliar a influência das características locais e de paisagem sobre a riqueza e composição das assembleias de peixes na bacia do rio Ivinhema. **Método:** no presente trabalho utilizamos dados da distribuição das espécies de peixes em vinte e cinco trechos de riachos da bacia do rio Ivinhema, Alto Rio Paraná, visando compreender o papel de características locais e de uso do solo sobre as assembleias de peixes; **Resultados:** Identificamos 113 espécies de peixes, sendo que as amostradas em maior número de pontos foram *Astyanax altiparanae* e *Serrapinnus notomelas*. A riqueza variou entre 4 e 65 espécies. O resultado da árvore de regressão permitiu explicar 89.3% da variação da riqueza e permitiu identificar que a altitude é o principal preditor da riqueza. Conforme a análise de correspondência canônica, as variáveis que mais influenciaram a distribuição das espécies foram: altitude, profundidade, largura, velocidade,condutividade e áreas edificadas. Conclusões: Nossos resultados sugerem que os fatores que mais influenciam as assembleias de peixes na bacia do rio Ivinhema são as características fisiográficas e limnológicas, seguidas pelo uso do solo.

Palavras-chave: distribuição de espécies, riqueza de espécies, assembleias de peixes, ecologia da paisagem.

1. Introduction

There are around 28.900 fish species in the world, 11.000 are exclusive to freshwater(Lévêque et al., 2008).About 4,500 freshwater species were described only in the Neotropics, a number that has increased every year(Nelson, 2006).

Fish communities are influenced by different factors such as limnological variables (Tundisi and Tundisi, 2008; Melo et al., 2009), biotic variables (Winemiller et al., 2008; Araujo and Tejerina-Garro, 2009), hydrological factors (Poff, 1997), with the relative importance of each one of these sources changing according to the environment and scale analyzed.

It can be highlighted the studies of Feyrer and Healey (2003), which determined the importance of environmental variables on the fish fauna of the South Delta in California, and of Hanchet (2012) who examined the effect of four different land uses on the distribution of native fish in the Waikato River, New Zealand. Although Ward and Stanford (1989), Fitzgerald et al. (1998), Lammert and Allan (1999) have already sought to relate land use to the fish fauna in micro basins, studies on this subject in neotropical regions are scarce.

In the Neotropics, studies relating the influence of different forms of land use on fish are scarce, however there are studies presenting the influence from urbanization (Paul and Meyer, 2001; Araujo and Tejerina-Garro, 2009; Furlan et al., 2012),agriculture and livestock farming (Casatti et al., 2006; Ferreira and Casatti, 2006) and benefits of riparian areas (Cetra and Petrere Junior, 2006; Teresa and Casatti, 2010) on the fish community. Gerhard (2005) in the Corumbataí River basin examined the relationship between land use: native forest, pasture, canebrake, and the diversity of fish species.

The Paraná River basin is the second largest basin in South America and the fourth largest in the world, and is an example of highly impacted river, with great changes in its bed and in fish fauna. The Upper Paraná River system includes all the catchment of the Paraná River upstream of the Sete Quedas Waterfalls, currently dammed for the construction of the Itaipu hydroelectric power plant (Agostinho and Júlio Junior, 1999; Langeani et al., 2007).

The fish community of the Upper Paraná River has received increased attention in recent years, with studies reporting the species composition (Castro et al., 2003; 2004; 2005; Langeani et al., 2007), and the influence of the longitudinal variation (Pavanelli and Caramaschi, 2003). The influence of physiographic characteristics of the watershed was commented by Súarez et al. (2007) and Súarez and Lima Junior (2009), the influence of the riparian vegetation is mentioned by Cetra and Petrere Junior (2006), the effects from urbanization on the diversity and distribution of species was detected by Felipe and Súarez (2010) in streams of the Ivinhema River basin.

Aquatic ecosystems are the most affected by human interferences(Tejerina-Garro et al., 2005). The overexploitation of the soil, pollution, changes in the flow, destruction of natural habitats are the main threats to biodiversity(Dudgeon et al., 2006). Ward and Stanford (1989) affirm that stream ecosystems should be studied and analyzed in four dimensions: longitudinal, lateral, vertical and temporal, and laterally emphasizing mainly the land use. Thus, the present study aimed to evaluate the influence of landscape and local characteristics on the composition of fish community on the Ivinhema River basin, by responding the following questions: 1) How do landscape and local characteristics interfere with species richness in the sampled streams? 2) Which buffer range: 1, 5 or 10km best explain the distribution of fish species in the Ivinhema River basin? 3) What variables best explain the distribution of fish species in the sampled streams in the Ivinhema River basin?

2. Material and Methods

2.1. Study area

The Ivinhema River basin is located in the south-central portion of the Mato Grosso do Sul State, in the Paraná River basin, between latitudes 21° and 23° S and longitudes 53° 30' and 56° W (Mato Grosso do Sul, 1990). It has an area of 45.000 km² and is formed by the rivers Dourados, Brilhante, Vacaria and Santa Maria. Its headwaters are located approximately 700 meters above sea level and its mouth is on the Paraná River, around 218 meters altitude.

2.2. Sampling

Twenty five sampling sites were established across the Ivinhema River basin, including headwaters, middle course and mouth of the basin, as well as the major forms of land use (Figure 1).

In this study, we used a data base of fish species occurrence between 2001 and 2013 throughout the Ivinhema River basin. At least six sampling were taken along the year in all sampling sites, in

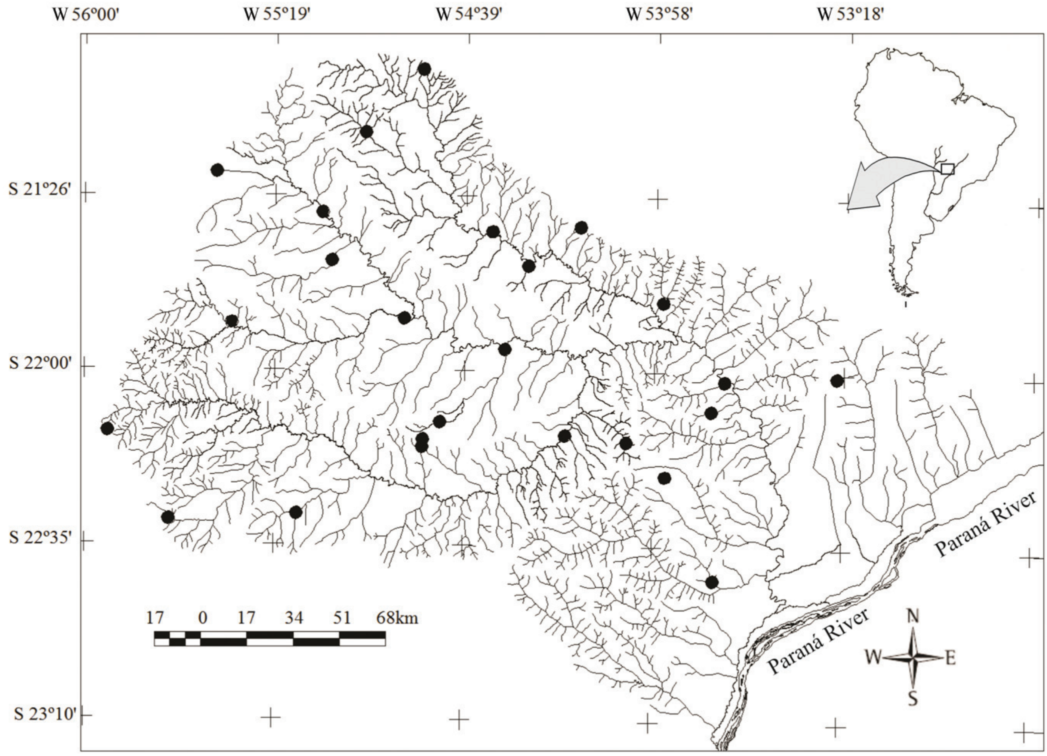

Figure 1. Sampling sites in the Ivinhema River basin, Upper Paraná River from 2001 to 2013.

order to include the influence of seasonal variation on the composition of fish species. For samplings, it was used rectangular sieves (1.2 × 0.8m) with 2mm mesh size, electrofishing, seining nets with different mesh sizes, and gill nets that were installed in the afternoon of one day and withdrawn at noon of the next day. At each location, samplings were performed in stretches of approximately 100m length.

Collected fish were fixed in 10% formaldehyde and after 72 hours they were transferred to 70% alcohol. The identification was based on Graça and Pavanelli (2007) and consultations to experts whenever necessary.

At each location the following environmental variables were measured: electrical conductivity ($\mu S/cm^{-1}$), using a conductivimeter (Delta OHM Conductivity Meter HD 8706-R2), depth (m) and width (m) were obtained at five points in each stretch sampled (100m), using a graduated wooden rod and water velocity (m/s^{-1}) was taken by a digital flow meter (Global Water FP101). At least five estimates were taken at approximately equidistant locations, which were later used to describe the average of the site.

For the analysis of land use we used LANDSAT 5 imagery, from 2010; data were processed through the Georeferenced Information Processing System (SPRING) (INPE, 2010) developed by the National Institute for Space Research (INPE). It was created buffers with 1, 5 and 10 km radius within which it was quantified the main forms of land use in the basin: agriculture and livestock farming, built-up area, forest fragments and wetlands.

A supervised classification of land use was done through the Bhattacharya algorithm (Moreira, 2005), for developing the methodology are selected areas with known types of land use and then the algorithm recognizes similar areas based on spectral properties of the image.

2.3. Data analysis

A possible spatial pattern in richness and composition of fish assemblages was analyzed by the Moran's I test for species richness, and for species occurrence we used a Mantel correlogram (Legendre and Fortin, 1989; Legendre, 1993). The Moran's I autocorrelation index and its significance was calculated in the software SAM (Spatial Analysis in Macroecology) developed by Rangel et al. (2010), whereas the Mantel correlogram for species composition was obtained by using the function mgram in the software ecodist using the platform R (R Development Core Team, 2011).

Two partitions of variance were performed; the first to check which buffer range (1 km, 5 km or 10 km) most influenced the variation of the data, the second to check which data set 1) limnological parameters and physiographic characteristics of the basin, 2) land use, or 3) the position of the sampling site in the watershed – that best explain the variation of species occurrence (Borcard et al., 1992).

In order to analyze the influence of environmental variables on the diversity, represented in this study by richness, a regression tree was carried out, using richness in response to environmental variables and classes of land use as explanatory variables. According to De'ath and Fabricius (2000), the regression tree is a variance partitioning method, in which observations are sequentially divided into more and more homogeneous groups according to the explanatory variables provided.

To verify the individual influence of environmental variables on species occurring in more than 10% samples (at least three sites) a Canonical Correspondence Analysis (CCA) was applied. The individual importance of environmental descriptors was quantified through an envfit routine, which uses a randomization process (999 permutations) to define the significance of environmental variables and landscape metrics for obtaining the value of r^2. All statistical analyses were run by means of the package vegan in the platform R (R Development Core Team, 2011).

3. Results

In total, 113 species were sampled along the stretches sampled in the Ivinhema River basin. Species registered in a greater number of stretches were *Astyanax altiparanae* (84% of sampled stretches) and *Serrapinnus notomelas* (80% of sampled stretches). Twelve species occurred in more than 50% stretches of streams sampled, while 24 species occurred in only one stretch. In this way, most species occurred at low frequency in the studied stretches (Figure 2).

The species richness in the stream stretches varied from 4 to 65 species (mean=22.8; sd=16.09). Sites with higher richness (65 and 54 species) are located in the lower portion of the basin. The site with the lowest richness (four species) is located in the upper portion of the basin, near the headwaters.

The electrical conductivity ranged from 12.3 to 401.6μS/cm^{-1}, the width of streams varied from 0.4 to 52 m, the depth from 0.3 to 3,5 m, the water velocity between 0.16 and 1.38m/s^{-1} and the altitude between 244 and 680 m.

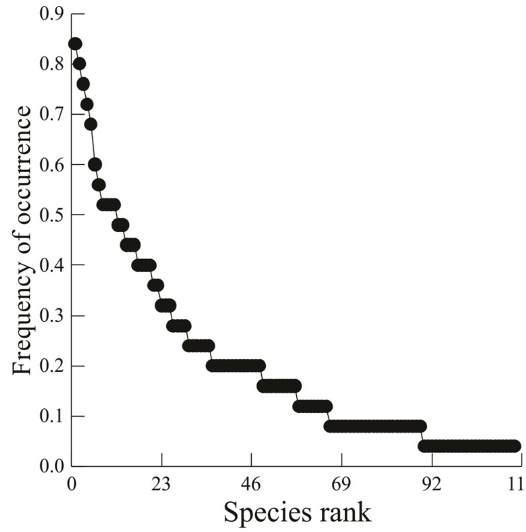

Figure 2. Frequency of occurrence of fish species sampled in streams of the Ivinhema River basin, Upper Paraná River, from 2001 to 2013.

The Mantel correlogram and Moran's I spatial autocorrelation evidenced no significant spatial autocorrelation for species richness and for species composition only final distance classes have spatial autocorrelation statistically different from zero (Figure 3).

The first partition of variance pointed that the buffer with 1km radius is the most indicated to quantify the importance of the landscape on the fish distribution. The 1km radius explained 21.84% variance of data obtained, while radii of 5 and 10 km explained 19.26% and 15.42%, respectively (Figure 4a). Considering all buffers in the range of 10km, the main land use was agriculture and livestock with 75.6% total area of buffers, followed by forest remnants (17.81%), wetlands (3.57%) and built-up area (2.92%).

Based on the second partition of variance, data of fish species distribution were primarily influenced by limnological and physiographic variables (r^2= 29.69%), followed by land use (r^2= 21.87%) and location of the sampling site in the basin (r^2= 15.83%) (Figure 4b).

The regression tree identified the altitude as the main predictor of species richness, followed by the forest fragments, agriculture and livestock farming, and depth of the sampled stretches. The results also showed that 89.3% of variation of species richness was explained by the selected variables. In this way, stretches with altitude higher than 338 m and area of agriculture and livestock farming had lower species richness (mean= 14.7). While places with altitudes below 338 m present mean richness 33.9 species.

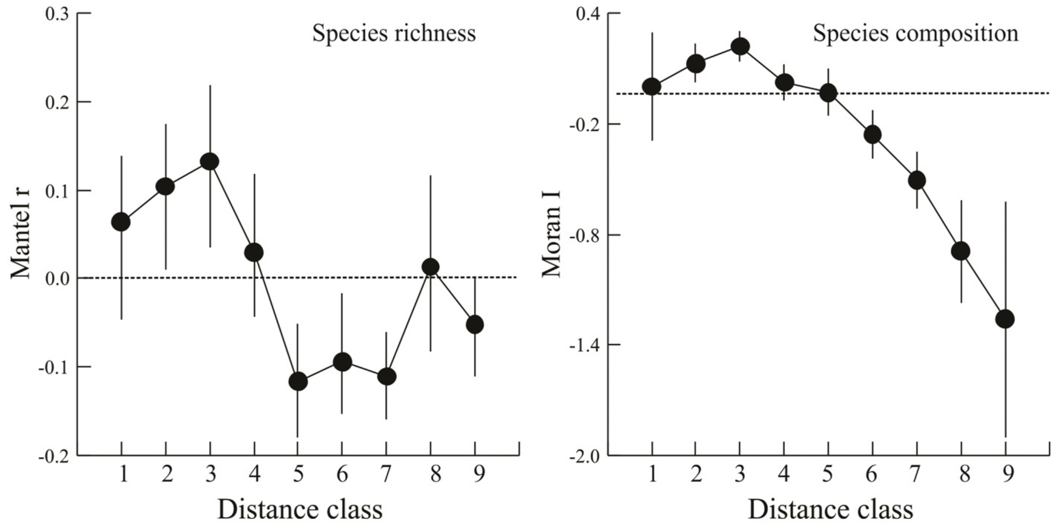

Figure 3. Spatial autocorrelation for species richness (Mantel correlogram) and composition (Moran's I) in the Ivinhema River basin, Upper Paraná River, from 2001 to 2013.

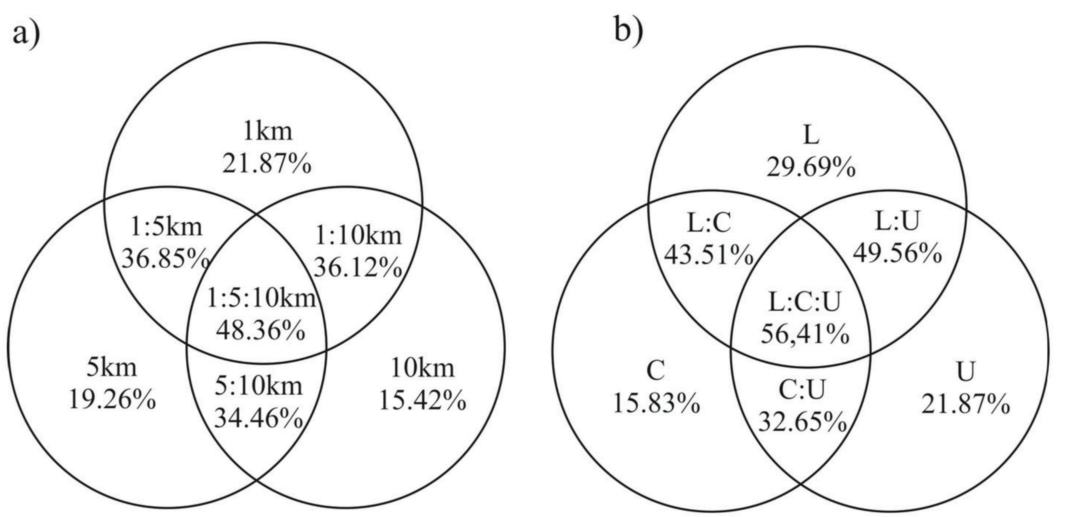

Figure 4. A) Venn diagram with the variation percentage explaining the different buffer radii (1, 5 and 10 km) in the partition of variance.B) Venn diagram with the variation percentage explaining the composition of the fish community based on the partition of variance based on: limnological and physiographic variables (L), geographical position (C), land use (U), fraction explained by environmental and land use characteristics (L:U), fraction explained by environmental variables and location of the site (L:C), fraction explained by land use metrics and geographical position (U:C), fraction explained by environmental factors, land use, and geographical position (L:U:C).

Places with forest fragmentation highest 9% of the buffer area present a mean richness of 25.5 species (Figure 5).

The canonical correspondence analysis suggested that 41.88% of data variation was explained by the first two CCA axes, the first axis explained 26.46%, and the second15.42%. The most important environmental descriptors to determine the species occurrence in the Ivinhema River basin were: altitude, depth and width, followed by conductivity and % of built-up areas (Table 1 and Figure 6).

The results of CCA also suggested that the group made up of *Parodon nasus*, *Hypostomus strigaticeps*, *Astyanax fasciatus* mainly occurs in locations with higher altitude, degree of urbanization and electrical conductivity, complementarily *P. reticulata* occur isolated of others species. Inversely *S. marginatus* and *L. lacustris* occur mainly in lower altitude sites and with small values of conductivity and urbanization rate. On the other hand, a set of species including *Roeboides paranensis*, *Pselogrammus kennedyi*, *Salminus brasiliensis, Prochilodus lineatus*,

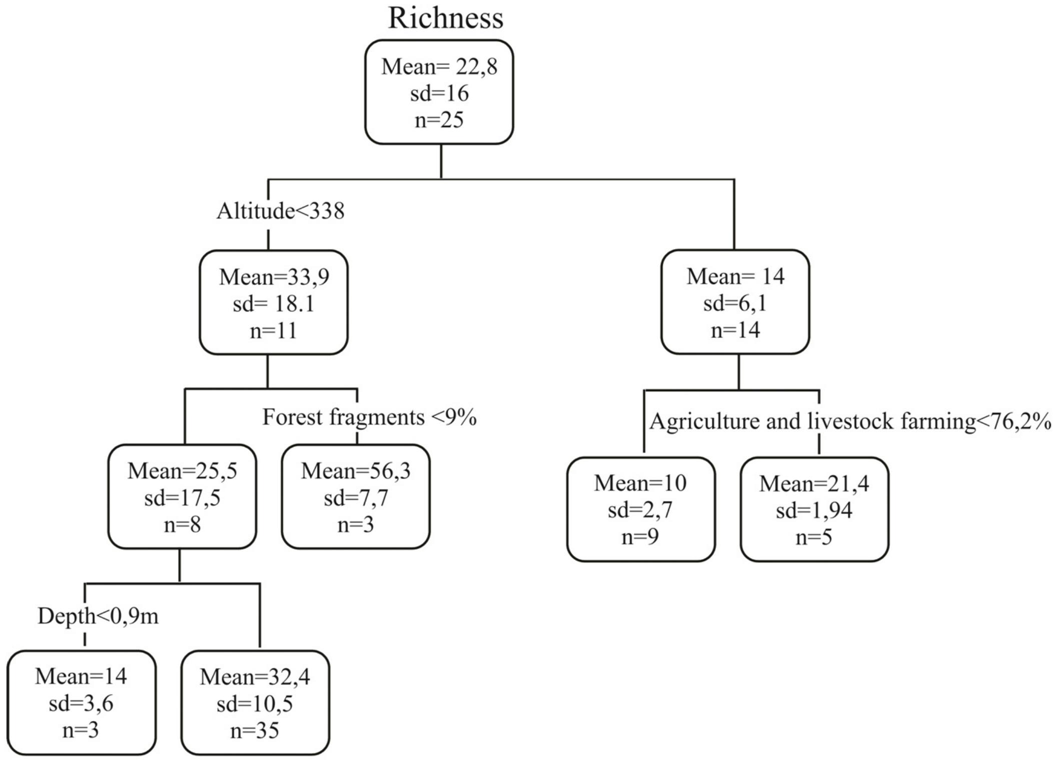

Figure 5. Regression tree of fish species richness in streams of the Ivinhema River basin, Upper Paraná River, from 2001 to 2013.

Table 1. Results of the Canonical Correspondence Analysis (CCA) for fish communities of the Ivinhema River, Upper Paraná River. *= Significant at α = 0.05; ***=Significant atα= 0.001.

Environmental Characteristics	Axis1	Axis2	r^2
Agriculture and livestock farming (%)	–0.10	–0.99	0.10
Forest Fragments (%)	0.34	0.94	0.05
Wetlands (%)	0.99	0.13	0.01
Built-up areas (%)	–0.81	0.57	0.20
Stream average width	0.91	0.40	0.73***
Stream average depth	0.95	0.30	0.66***
Average water velocity	0.74	0.66	0.16
Altitude	–0.68	0.72	0.50***
Electrical Conductivity	–0.22	0.97	0.41***
Summary statistics of axes 1 and 2			
Explanation Percentage (%)	*26.46%*	*15.42%*	

Serrasalmus maculatus among others, occurs in deeper and wider sites.

4. Discussion

Brazil is home to about 43% of the known freshwater fish fauna (Buckup et al., 2007), but the knowledge on the composition of fish assemblages in different Brazilian river basins is still very weak and irregular(Silva Filho et al., 2011).

The most complete survey of the fish fauna of the Upper Paraná River basin listed 310 fish species (Langeani et al., 2007), in addition to other 50 species under description totaling 360 species, in this way, the present study found 28.9% of the species richness of the Upper Paraná River.

The richness registered in the present study was higher than that recorded by Súarez et al. (2011), who recorded 111 species along 200 sampling stretches in the Ivinhema River basin. The streams

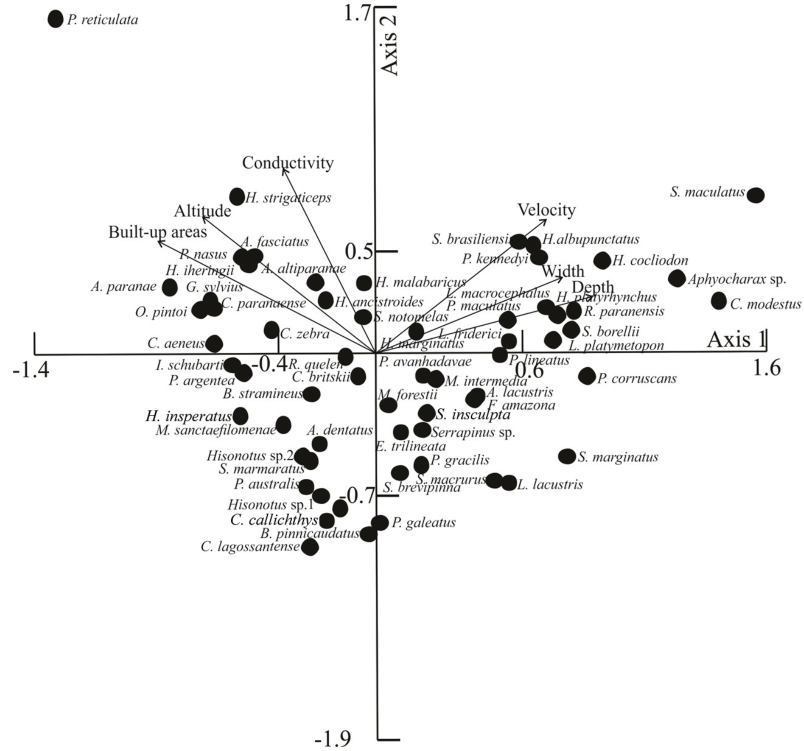

Figure 6. Scatter plot of distribution of fish species in the Ivinhema River basin, Upper Paraná River, from 2001 to 2013.

sampled in this study are mostly the same sampled in the study of Súarez et al. (2011), with only six exceptions, besides the inclusion of the most current data, which allowed complementing the species list through the record of large sized species, typical of rivers with larger volumes (eg. *Auchenipterus ucayalensis*, *Clarias gariepinnus*, *Hemiodus orthonops* and *Sorubim lima*).

The predominance of *A. altiparanae* and *S. notomelas* is consistent with previous studies conducted in the Ivinhema River basin (Pavanelli and Caramaschi, 2003, Costa-Pereira et al., 2012) and is the result of the great dispersal ability and generalist habit of these species (Orsi et al., 2004; Gomiero and Braga, 2008) which have a wide distribution in the Upper Paraná River basin. On the other hand, the low number of species with widespread occurrence in the basin, with 10.1% of species occurring in more than 50% of the sampled sites suggests that few species have ecological characteristics that allow an extensive occupation of the Ivinhema River basin.

According to the neutral theory of biodiversity (Hubbell, 2001) the species composition at regional level significantly influences local communities, since species with wider distribution should be those with higher dispersal ability. In this sense, as the most common species for the Ivinhema River basin are also registered as common in other sub-basins of the Upper Paraná River basin, we believe that the widespread distribution of these species is a result of their dispersal ability. Cottenie (2005) analyzed the relative influence of environmental characteristics vs. spatial processes and observed that neutral processes were considered the only responsible for structuring only 8% of the natural communities analyzed, but by disregarding the dispersal process according to the neutral theory, 37% of communities would not have an important pattern of organization. Thereby, probably the great dispersal ability of fish species, associated with other ecological characteristics of them and/or of environments can interact and define the structure of local communities.

Despite the low number of sampling sites when compared to Súarez et al., (2011) also in Ivinhema River Basin, we observed the variation of the longitudinal gradient in the species richness. Nevertheless, these results were partially masked by other environmental variables. Wiens (1984) argues that communities are influenced by a spatial gradient, among few studies on large scale of fish distributions Bistoni and Hued (2002) was detected altitudinal variation richness on the gradient in rivers of Argentina.

The relationship of richness with volume of streams was expected, drawing an analogy with the island biogeography theory, once the volume of streams is a measure equivalent to the area of islands (MacArthur and Wilson, 1967; Gorman and Karr, 1978) and has been detected in other studies on stream fish. Súarez et al. (2007) detected that habitat characteristics along with the separation of microbasins and the colonization dynamics are involved in the determination of fish assemblages. Couto and Aquino (2011) characterized the spatial and seasonal distribution of streams inside a conservation unit in the Federal District, Brazil, and concluded that the fish assemblage was strongly affected by the habitat complexity. In this context, habitats in the lower portion of the basin, with higher volume, present a higher complexity of habitats than those located in the headwaters, where the high velocity and low volume simplify the habitats.

In a complementary way, the river continuum concept (Vannote et al., 1980) suggests that characteristics as diversity and productivity changes along the water course, causing the distribution of organisms to be determined according to physical characteristics of the stream, which is expected according to its position in the drainage network. Sites close to the headwaters are shallow and have a higher amount of riparian vegetation, favoring thus the presence of individuals whose existence requires allochthonous foods. As the volume of the water body increases, also increases the incidence of solar radiation favoring the primary production, increasing the diversity of foods, and thus a higher diversity of fish.

Values found for the spatial autocorrelation indicate no spatial autocorrelation for species richness and significant autocorrelation for species composition only in final distance gradient, which was also observed by Cunico et al. (2012) who studied the effects of local and regional environmental factors on the structure of fish assemblage in the Pirapó River basin, Brazil, and found no correlation between the matrix of distance of sampled sites and collection periods, but, this conclusion was influenced by the smaller spatial and temporal scale analyzed by these authors.

Although the concept of the local composition of species considers it as the result of factors at the local, regional and biogeographically scales (Gotelli and Graves, 1996), few studies have examined the importance of different spatial scales on the organization of fish communities. Although our study did not present a distribution of sampling sites that allow a biogeographical approach, the observation that local characteristics are more important than landscape characteristics and the mere geographic location allows directing future studies on fish communities in neotropical streams. On the other hand, the inclusion of the altitude as a local characteristic interfere with our conclusions, since it is known that the longitudinal variation is extremely important for fish distribution in the watershed scale (Vannote et al., 1980).

In the Ivinhema River basin are present totally or partially 25 municipalities and about 26% of the state population, in this way the basin is under anthropogenic pressures that cause changes in water quality, which in turn impact fish assemblages in the water body. Casatti et al., (2010) studied changes in fish communities along an integrity gradient in streams of the Serra da Bodoquena, and observed differences between fish communities in urban areas, and verified that species such as *Poecilia reticulata* and *Corydoras aeneus*, in this studied area, can be considered indicators of urban areas.

In a study developed in urban streams of the city of Dourados, Ivinhema River basin, Felipe and Súarez (2010) observed that sites with higher level of urbanization presented predominance of *Astyanax altiparanae*, *Poecilia reticulata* and *Corydoras aeneus*, species with higher tolerance to environmental degradation, but the scale considered in this study was smaller and totally inside the urban area, where local characteristics (eg. sewage disposal) still have a great importance. Another research performed by Cunico et al. (2012) examined fish communities under different levels of human influence in the city of Maringá (Paraná State) and concluded that the urbanization had interfered with species richness and composition, with dominance of *Poecilia reticulata* in the streams.

One of the main problems of the growing urbanization surrounding rivers is the increased discharge of effluents into rivers, leading to an increase in the electrical conductivity of water(Metcalf and Eddy, 1991). Studies undertaken in streams of the Ivinhema River basin under low human influence have shown that the electrical conductivity varies between 4 and 50 $\mu S.cm^{-1}$ in headwaters stretches and up to 100 $\mu S.cm^{-1}$ in lower stretches of the basin (Valério et al., 2007; Súarez and Lima Junior, 2009), considering relatively intact streams, however streams situated in urban areas present conductivity of approximately 700 μS.cm^{-1}and lower values of species richness, as well as the predominance of *C. aeneus* and *P. reticulata*, confirming previous studies.

With the increase in urban areas there is an increase in the runoff due to the increase in impervious surfaces (Tucci, 2003). Given the need for large areas for agriculture and livestock farming, the deforestation of areas with native vegetation becomes indispensable. In this way, Roth et al. (1996) detected that streams with little agriculture and greater amount of wetlands in their vicinity, also present a higher diversity of habitats. Likewise, Wang et al. (2001) states that the urbanization has a negative effect on the fish fauna due to soil sealing.

The altitude can be determinant by summarizing some limnological characteristics such as: water temperature, flow and reproductive rate (Tondato and Súarez, 2010). Many species have limitation as for high altitudes (Matthews, 1998),or by finding factors limiting its dispersal to higher sites (Valério et al., 2007).

5. Conclusions

Then, our conclusions are that the buffer with 1km radius is the most indicated to quantify the importance of the landscape on the stream fish distribution. The fish species diversity are mainly explained by a combination of limnological/ physiographic and landscape characteristics (altitude, % by the forest fragments, % agriculture and livestock farming, and stream depth). And finally, the most important environmental descriptors to determine the species occurrence in the Ivinhema River basin were: altitude, depth and width, followed by conductivity and % of built-up areas.

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