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Aplicação de espécies de peixes como bioindicadores de mesohabitats de riachos inseridos no Sistema do alto rio Paraná, Brasil

Thiago Rodrigues Barbosa*, Dyego Leonardo Ferraz Caetano[1], Luana Gabriela Marques da Silva[2]

TRB - 0000-0003-0967-5 DLFC - 0000-0002-2409-0 LGMS - 0000-0002-8890-4009

1- Universidade Estadual do Norte do Paraná - UENP

2- Universidade Federal de Santa Catarina

* thiago.wover@gmail.com

ABSTRACT

The objective of this study was to explore the presence of fish species as potential environmental quality indicators in tributaries belonging to the Paranapanema River basin, Upper Parana River System. We also sought to verify the possible occurrence of species associated with mesohabitats that indicate good or poor environmental quality, using the Indicator Value (IndVal) method for such verification. The sample units were distributed in 28 stretches of streams, and 3,103 individuals were collected, distributed in five orders and 33 species, so that *Astyanax bockmanni* was the most abundant species. Regarding the potential bioindicator, only a total of 13 species showed that they are possible indicators of at least one environmental variable (significance of $p < 0.05$), so that *Phalloceros harpagos* and *Geophagus brasiliensis* were associated with high values of Salinity and Total Solids Dissolved, allowing us to observe, in a cautious way, that these species may be associated to environments with high amount of organic and inorganic particles suspended in water, indicating poor environmental quality.

Keywords: Fishes; IndVal; Stream ecology.

RESUMO

O objetivo do presente trabalho foi investigar a ocorrência de espécies de peixes com potencial indicador de qualidade ambiental em riachos localizados na bacia do Rio Paranapanema, no sul do Brasil. As amostragens dos parâmetros ambientais e dos peixes ocorreram em 28 trechos de riachos localizados na bacia do rio Paranapanema, sistema do alto rio Paraná. Para verificar o potencial indicador das espécies para cada categoria de qualidade ambiental (má, regular e boa) relacionada às características ambientais mensuradas foi utilizado o método IndVal (Indicator Value). Foram capturados 3.103 indivíduos, distribuídos em cinco ordens e 33 espécies, de modo que *Astyanax bockmanni* foi a mais abundante. Apenas 13 espécies demostraram serem possíveis indicadoras de pelo menos uma variável ambiental (significância de $p < 0,05$). *Phalloceros harpagos* e *Geophagus brasiliensis* associaram-se a altos valores de Salinidade e Sólidos Totais Dissolvidos, possibilitando- nos constatar, de forma cautelosa, que essas espécies podem estar associadas aos ambientes com alta quantidade de partículas orgânicas e inorgânicas em suspensão na água, indicando má qualidade ambiental.

Palavras-chave: Peixes; IndVal; Ecologia de Riachos.

INTRODUCTION

The impacts of anthropic activities have resulted in severe damage to neotropical aquatic ecosystems, highly affecting hydrology, and local biological diversity (LOBO et al., 2015; BORGES et al., 2020; MILLER et al., 2021). In this context, damage like the degradation of riparian vegetation implies directly on the fish communities in streams.

According to Lobón-Cerviá et al. (2016) and Manoel, Uieda (2018), when intact, riparian forests promote the supply of allochthonous materials (i.e. fruits, trunks, and leaves) used as resources, reproductive sites, and refuge for many species of fish. The plating of the main canal and homogenization of the riverbed are the main consequences resulted from the degradation of riparian vegetation (CASATTI, 2010; COLLIER et al., 2019; TURUNEN et al., 2019).

In addition to providing physical and food resources for the local ichthyofauna, riparian vegetation also plays an important role in maintaining the physical and chemical parameters of water (DAGA et al., 2012; MANOEL, UEIDA, 2018; COLLIER et al., 2019). Since when absent or reduced there is a large entrance of sunlight and sediments, raising the temperature and level of total solids dissolved in the water, affecting the stream ichthyofauna (CASATTI, 2010; LARENTIS et al., 2022). The increase in water temperature in association with a high concentration of nutrients allochthonous can trigger a process of eutrophication (BARBOSA et al., 2020; MILLER et al., 2021; LARENTIS et al., 2022). This event is even more intense in urban watersheds, which recurrently receive a large load of organic matter from the release of untreated domestic and industrial effluents (WINEMILLER et al., 2008; DAGA et al., 2012).

According to Albert (2005) and Daga et al. (2012), the input of nutrients through leaching and release of sewage in stream promote alterations in concentration of the total phosphorus, nitrogen, as variations in pH and reduction in oxygen levels, modifying the composition and structure of the ichthyofauna. This is reflected in a high occurrence of tolerant and non-native species to the detriment of native species with specialist habits (DAGA et al., 2012; CAETANO et al., 2016; CAETANO et al., 2021; PAREDES DEL PUERTO et al., 2021).

Thus, many recent studies have intensified the correlation between fish communities and biotic integrity indexes, and the decrease in species richness to loss of habitat complexity (DAGA et al., 2012; COLLIER et al., 2019; BARBOSA et al., 2020; GARCIA et al., 2021; MILLER et al., 2021). Despite being very promising, these studies are underexplored, not following the speed of environmental impacts from anthropic activity (GALVEZ et al., 2007; CRUZ et al., 2013).

There is a great effort to analyze only the physical and chemical parameters of the rivers, streams, and lakes, such as temperature, dissolved oxygen, pH, turbidity, among others (AAZAMI et al., 2015). However, when analyzed individually, without considering their importance in maintaining local biological communities, these parameters establish values that demonstrate only the potability indexes of water, but do not infer any information regarding the maintenance of the biotic characteristics of the environment, providing a temporal and spatial discontinuity of the samplings, masking the real situation of the environment (GOULART, CALLISTO, 2003; MORAIS, AZEVEDO, 2017).

The use of biological indicators (bioindicators) makes it possible to portray environmental conditions and how organisms respond to variations resulting from human activity (DANZE, VERCELLINO, 2018). Bioindicators are diverse organisms, animal or plant, species, or even biological communities, whose presence provides information on the environmental conditions of where they are inserted, being widely used in the evaluation of the biotic integrity of a specific environment and environmental monitoring programs (MACHADO et al., 2008; CETESB, 2012).

Fish are known as being great biological indicators, since they have ample mobility and position near the top of the food chain, besides belonging to various trophic levels, presenting high sensitivity to environmental changes, and being identified with relative ease (ARAÚJO, 1998; FREITAS, SOUZA, 2009; AAZAMI et al., 2015; SOUZA, VIANNA, 2019). However, the use of ichthyofauna in the quantification of anthropic impacts in aquatic environments is less common when it comes to streams, with many of these studies directed to large rivers (ROSA et al., 2016).

OBJETIVES

Thus, the present work aims to verify the occurrence of species potentially indicators of environmental parameters and environments related to bad and superior quality, in different mesohabitats of streams in the Paranapanema basin, a system of the upper Paraná River.

MATERIAL AND METHODS

Study area

The Paranapanema river basin has as its main tributaries the rivers Pardo, Itararé, Tibagi and Pirapó (ZIESLER, ARDIZZONE, 1979; JARDULI et al., 2020). It comprises an area of approximately 109,600 km\² (SAMPAIO, 1944), widely impacted by a succession of hydroelectric power plants along its way (CTG/BR, 2018; VOTORANTIM ENERGIA, 2020; JARDULI et al., 2020). Land use in this basin is basically concentrated in agricultural activities (i.e., livestock, crops, silviculture, and pasture) and some stretches of reforestation (SEMA/PR, 2010; SEMA/PR, 2015).

The sub-basins of the Paranapanema and Cinzas rivers belong to the system of the Paraná River. The hydrographic basin of the Cinzas River has an area of approximately 9,612.8 km² (SEMA/PR, 2010), being the most important in the Pioneer North of the state of Paraná. Its extension is 240 km, and the most important tributaries are the Grande River, Jaboticabal River, the Vermelho River, and the Laranjinha River. The use of soil in this basin consists of industries in the agribusiness sector, with emphasis on alcohol distilleries, sugar mills, slaughterhouses, dairy products, and agricultural sector based on grain farming, as well as areas of artificial pasture, natural fields and reforestation areas (SEMA/PR, 2010).

The samples of environmental parameters and fish specimens were made between July and August 2016, in 28 sections (P1 to P28), with 50m each, of streams of the basin of the Paranapanema river located in the municipalities of Jacarezinho, Ribeirão Claro and Santo Antônio da Platina, Paraná, Brazil (figure 1). All excerpts were chosen based on the presence of two types of mesohabitats (riffle and pool) (table 1). The riffles, streams parts known by the lower depth and higher speed flow of water, and the pools are more profound, in addition to having lower water speed (CASTRO, 1999). Among the 28 sections, 14 have margins with riparian vegetation with shrubs and/or trees, 10 with the predominance of pasture and four are sowing, without any vegetation on its margins.

Collect of environmental data

The physical and chemical variables measured on the water were: Dissolved Oxygen (in mg; Hanna® HI-9146), Total Solids (TDS), Temperature, pH and Salinity (Hanna® HI-991300), and Conductivity (Instructherm® CD-860), measured on the margins and center of four random transverse transects, two of which are located in pool and two in riffles.

Table 1: Information on sampled sites in 28 streams belonging to basins of Paranapanema River and Cinzas River, upper Paraná River system, State of Paraná, Brazil.

Tabela 1: Informações sobre os pontos de coleta em 28 riachos pertencentes às bacias do Rio Paranapanema e Rio Cinzas, sistema do alto Rio Paraná, Estado do Paraná, Brasil.

Identification	Occupancy of margins	Basin	Coordinates
P1 - Ribeirão Ouro Grande	Pasture / grass	Paranapanema river	23°10'12.30"S, 49°53'51.83"W
P2 - Ribeirão Ouro Grande	Pasture / grass	Paranapanema river	23° 9'49.93"S, 49°54'0.20"W
P3 - unknown name 1	Pasture / grass	Paranapanema river	23°14'29.25"S, 49°51'31.62"W
P4 - unknown name 2	Pasture / grass	Paranapanema river	23°10'7.80"S, 49°53'20.21"W
P5 - Ribeirão Anhumas	Pasture / grass	Paranapanema river	23°10'35.50"S, 49°49'31.50"W
P6 - unknown name 3	Pasture / grass	Paranapanema river	23°11'51.51"S, 49°47'27.30"W
P7 - Ribeirão Claro	Pasture / grass	Paranapanema river	23° 9'1.30"S, 49°46'0.60"W
P8 - Ribeirão da Cruz	Pasture / grass	Paranapanema river	23°17'50.07"S, 49°46'26.00"W
P9 - Ribeirão dos Abreu	Pasture / grass	Paranapanema river	23°19'38.59"S, 49°48'14.05"W
P10 - Ribeirão Cachoeira	Pasture / grass	Paranapanema river	23°15'54.86"S, 49°42'44.29"W
P11 - Ribeirão Cachoeira	Pasture / grass	Paranapanema river	23°15'14.76"S, 49°42'14.19"W
P12 - Ribeirão Água dos Anjos	Pasture / grass	Cinzas river	23°13'24.88"S, 49°57'26.13"W
P13 - Ribeirão Monjolinho	Pasture / grass	Cinzas river	23°15'58.67"S, 49°55'7.69"W
P14 - Ribeirão Ubá	Pasture / grass	Cinzas river	23°13'43.83"S, 50° 2'15.30"W
P15 - Riacho da Platina	Pasture / grass	Cinzas river	23°18'19.25"S, 50° 2'3.46"W
P16 - unknown name 4	Preserved riparian vegetation	Paranapanema river	23°10'37.00"S, 49°55'11.90"W
P17 - unknown name 5	Preserved riparian vegetation	Paranapanema river	23°12'6.70"S, 49°53'37.98"W
P18 - unknown name 6	Preserved riparian vegetation	Paranapanema river	23°14'31.05"S, 49°51'34.82"W
P19 - Ribeirão Claro	Preserved riparian vegetation	Paranapanema river	23° 8'9.40"S, 49°45'33.30"W
P20 - Ribeirão da Cruz	Preserved riparian vegetation	Paranapanema river	23°17'26.46"S, 49°46'38.42"W
P21 - Ribeirão Taquaruçú	Preserved riparian vegetation	Paranapanema river	23°18'28.20"S, 49°47'51.34"W
P22 - Ribeirão Taquaruçu II	Preserved riparian vegetation	Paranapanema river	23°19'29.21"S, 49°48'16.71"W
P23 - Ribeirão dos Abreu	Preserved riparian vegetation	Paranapanema river	23°19'40.43"S, 49°48'40.21"W
P24 - Ribeirão Água dos Anjos	Preserved riparian vegetation	Cinzas river	23°13'15.72"S, 49°57'13.54"W
P25 - Ribeirão Monjolinho	Preserved riparian vegetation	Cinzas river	23°16'28.58"S, 49°55'47.32"W
P26 - Ribeirão Ubá	Preserved riparian vegetation	Cinzas river	23°14'15.29"S, 50° 2'12.60"W
P27 - Ribeirão Bonito	Preserved riparian vegetation	Cinzas river	23°22'14.58"S, 50° 3'53.11"W
P28 - Ribeirão Lajeadinho	Preserved riparian vegetation	Cinzas river	23°18'0.24"S, 49°58'12.15"W

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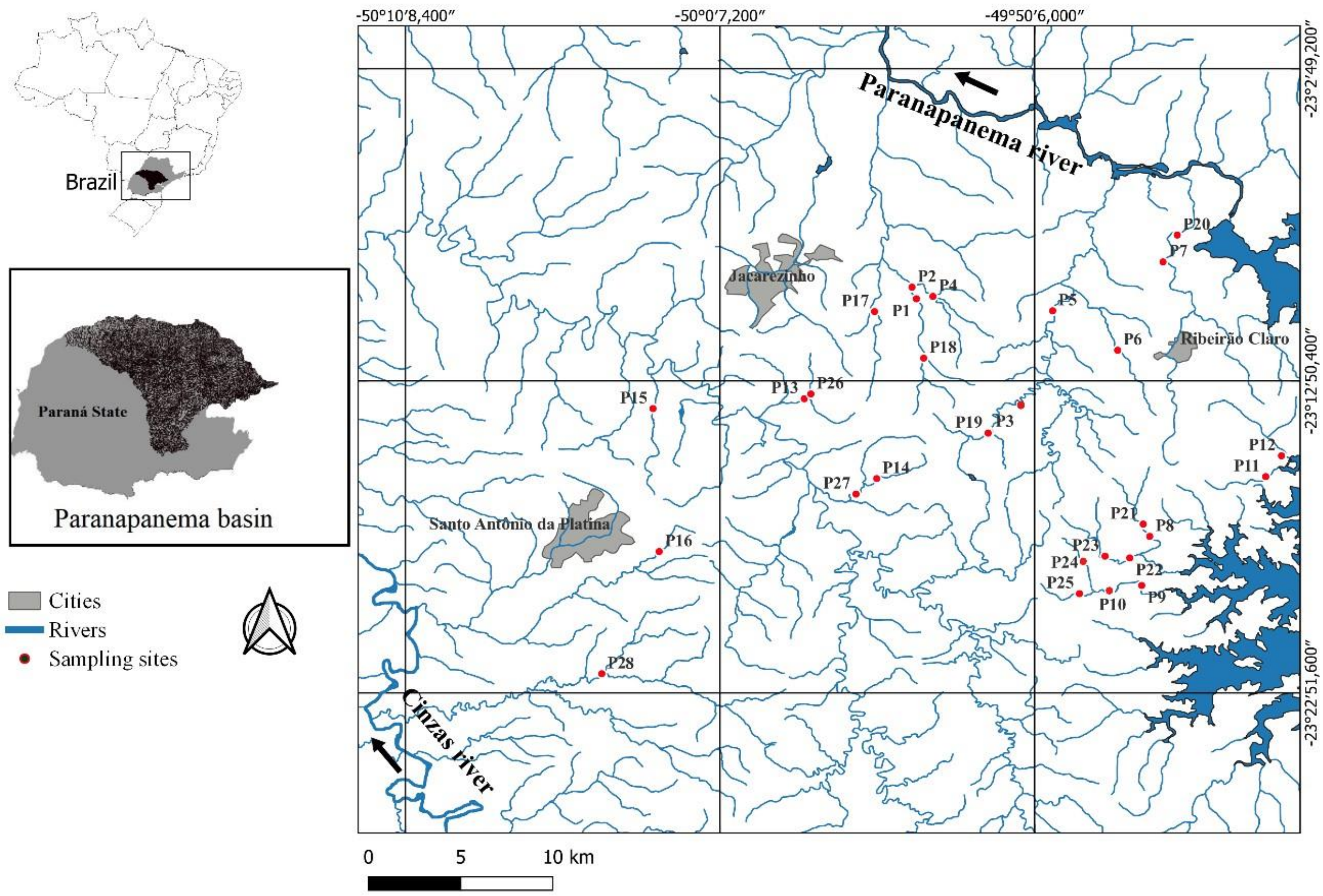
Figure 1: Sampling sites located in streams of the upper Paraná River system represented by the red dots.

Figura 1: Unidades amostrais localizadas em riachos do sistema do alto Rio Paraná representadas por pontos em vermelho.



The following structural and hydrological parameters were measured, according to Mendonça et al. (2005): mean channel width (m), using four equidistant measurements along the stretch, two in riffles and two in pools; average and maximum depths (m), calculated from nine equidistant surveys in the section of the four transverse transects; composition of the substrate in each stretch by sampling the nine equidistant points in each of the four transverse transects, characterizing the diversity of substrates (Shannon) in the sample units and the frequency of occurrence of each type of substrate, which were classified in: sand, clay, gravel, concrete, leaf, grass, boulder, rock and trunk.

Fish collection

The fish were caught using alternating current electric fishing equipment of 127 v. The standardized time was 50 minutes of capture in each stretch, always in the daytime, in the downstream upstream direction.

The individuals captured were anesthetized in benzocaine, immersed in formalin 10% and subsequently preserved in 70% alcohol. The identification of the species was performed according to Oyakawa et al. (2006) and Ota et al. (2018). A batch of each species was deposited in the fish collection of the Museu de Ictiologia do Núcleo de Pesquisas em Limnologia Ictiologia e Aquicultura, da Universidade Estadual de Maringá (Nupélia/UEM). The fieldwork is under license (ICMBio/IBAMA-number: 30357-3; authentication code: 76974589).

Data analysis

For each point, the specific and relative richness and abundance of the species was quantified. In addition, the following diversity indexes were applied: Shannon diversity index (H'), calculated using the formula: H' = - Σ pi. ln pi, where pi= relative frequency of each species in the community; Pielou's equitability index, determined with formula J= H'/H'max, so that H' is the Shannon and H'max diversity index (maximum diversity) is the logarithm of species richness; and Simpson's Dominance index, calculated using D= $(pi)^2$, where pi= proportion of species in the community (MAGURRAN, 2004).

To verify the presence of potential environmental quality indicators, the Indicator Value Method (IndVal) was used; (DUFRENE, LEGENDRE, 1997), which correlated ichthyofauna (abundance and relative frequency of species) with the environment variables of the stretches where they were captured. IndVal employs Monte Carlo, a test with more than 5,000 permutations and significant values of p = < 0.05 to define indicator species of specific physical and chemical characteristics. IndVal was calculated using pc-ORD v.5.0 software (MCCUNE, MEFFORD, 2006).

The physical and chemical variables were classified into three categories, and the mesohabitats were classified into two according to Caetano et al., (2016) (table 2). The values of the categories were defined by dividing the interval between the lowest and highest values of each abiotic variable overall. Independently of the abiotic variables, the category 1 was attributed to mesohabitats of riffle and physical and chemical variables of lower values; category 2 was attributed to the mesohabitats of pool and physical and chemical variables of median values; finally, category 3 was attributed to the physical and chemical variables of higher values. It is important to note that Riffle and Pool do not indicate the quality of the environment, but only the type of mesohabitat to which the species is related.

RESULTS

A total of 3,103 individuals were captured, distributed in 36 species, 11 families and five orders (table 3).

Table 2: Categories of physical and chemical variables used in IndVal analyses, modified of Caetano et al. (2016).

Tabela 2: Categorias das variáveis físicas e químicas usadas na análise de IndVal, modificado de Caetano et al. (2016).

Variable	Category 1	Category 2	Category 3
Mesohabitat	Riffle	Pool	-
Oxygen [mg.L]	< 9	9 – 10	> 10
Salinity [US/cm]	< 251.89	251.89-252	> 252
Temperature [°C]	< 17.62	17.62-18	> 18
Total Dissolved Solids [mg]	< 125.83	125.83-126	> 126

Category 1: Low values; Category 2: Average values; Category 3: High values, except for the variable mesohabitat.

Categoria 1: Valores baixos; Categoria 2: Valores médios; Categoria 3: Valores altos, exceto para a variável mesohabitat.

Regarding ecological parameters, the highest equitability was verified in P14, and the lowest in P4. For the diversity of Shannon (H'), the highest value was verified in P22, and the lowest in P4. Finally, the highest dominance was observed in P4, and the lowest in P16 (table 5). It was also observed that *P. harpagus*, *B. iheringii* and *A. bockmanni* presented greater abundance in P24, point with high dominance, low equitability, and diversity. Whereas *T. diabolus* and *B. iheringii* were more abundant in points P19 and P20, two points which presented good values in the parameters of diversity, such as low dominance and high diversity and equitability (table 4).

Regarding the chemical and physical characteristics of the water, P4, P15, P16 and P26 showed the highest values in salinity and TDS. In contrast, P9, P12, P21 and P22 exhibited the lowest salinity and TDS values (table 6).

Regarding the water temperature, P4, P21, P23, P25, P26 and P27 showed the highest values, while P6, P16, P17 and P19 showed the lowest temperatures among the sample units studied. Finally, the lowest concentrations of dissolved oxygen were recorded in P1, P2, P4 and P24, while P13, P21, P22 and P28 showed the highest values.

DISCUSSION

The high abundance of species belonging to the Characiformes and Siluriformes orders reflects the pattern observed in several studies in neotropical streams of the Paraná River basin (CASTRO et al., 2003; LANGEANI et al., 2007; ARAÚJO; TEJERINA-GARRO, 2007, CAETANO et al., 2016; BÉRGAMO et al., 2018; CAETANO et al., 2021; LARENTS et al.2022).

Table 3: List of fish species collected in 28 streams of the municipalities of Ribeirão Claro, Santo Antônio da Platina and Jacarezinho, Paraná, Brazil.

Tabela 3: lista das espécies coletadas em 28 riachos localizados nos municípios de Ribeirão Claro, Santo Antônio da Platina e Jacarezinho, Paraná, Brasil.

ORDER/Family/Species	Number of individuals
CHARACIFORMES	
Characidae	
Astyanax bockmanni Vari & Castro, 2007	801
Bryconamericus iheringii (Boulenger, 1887)	748
Astyanax lacustris (Lütken, 1875)	85
Astyanax paranae Eigenmann, 1914	70
Bryconamericus exodon Eigenmann, 1907	30
Serrapinnus notomelas (Eigenmann, 1915)	4
Oligosarcus paranensis Menezes & Géry, 1983	1
Parodonttidae	
Apareiodon ibitiensis Amaral Campos, 1944	307
Apareiodon piracicabae (Eigenmann, 1907)	60
Crenuchidae	
Characidium aff. *zebra* Eigenmann, 1909	105
Erythrinidae	
Hoplias sp.	4
SILURIFORMES	
Trichomycteridae	
Trichomycterus diabolus Bockmann, Casatti & de Pinna, 2004	42
Trichomycterus sp.	3
Callichthyidae	
Corydoras aeneus (Gill, 1858)	12
Loricariidae	
Hypostomus ancistroides (Ihering, 1911)	127
Hypostomus strigaticeps (Regan, 1908)	88
Hypostomus paulinus (Ihering, 1905)	68
Hypostomus hermanni (Ihering, 1905)	48
Hypostomus nigromaculatus (Schubart, 1964)	37
Hypostomus sp.	33
Otothyropsis biamnicus Calegari, Lehmann A. & Reis, 2013	20
Loricaria sp.	4
Heptapteridae	
Imparfinis schubarti (Gomes, 1956)	137
Rhamdia quelen (Quoy & Gaimard, 1824)	55
Imparfinis sp.	7
Imparfinis borodini Mees & Cala, 1989	4
PERCIFORMES	
Cichlidae	
Geophagus brasiliensis (Quoy & Gaimard, 1824)	56
Crenicichla britzkii Kullander, 1982	1
Crenicichla haroldoi Luengo & Britski, 1974	1
CYPRINODONTIFORMES	

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Poeciliidae	
Poecilia reticulata Peters, 1859	98
Phalloceros harpagos Lucinda, 2008	30
Xiphophorus hellerii Heckel, 1848	1
GYMNOTIFORMES	
Gymnotidae	
Gymnotus inaequilabiatus (Valenciennes, 1842)	16

Table 4: Significant values to the Index of Indicator Species (IndVal) of each species of fish for the category (c) of the physical and chemical variables, of the environmental parameters of streams of the rivers of the Cinzas and Paranapanema rivers, upper Paraná River* = p<0.05 and** = p<0.01. In bold higher values (range from 0 to 100) from IndVal to the associated category. To Mesoh. (Mesohabitat), 1 = riffle, 2= pool. Physical and chemical variables Oxy. (Dissolved oxygen), Salini. (Salinity), TDS (Total dissolved solids), and Temp. (Temperature), 1 = low, 2 = median, 3 = high values.

*Tabela 4: Valores significativos do Índice de Espécies Indicadoras (IndVal) de cada espécie de peixe para cada categoria (c) das variáveis físicas e químicas, dos parâmetros ambientais de riachos das bacias dos rios das Cinzas e Paranapanema, Alto rio Paraná * = p < 0,05 e** = p < 0,01. Em negrito maiores valores de IndVal para a categoria associada. Para a variável Mesoh. (Mesohábitat), 1 = corredeira, 2= remanso. Para as variáveis Oxi. (Oxigênio dissolvido), Salinid. (Salinidade), TDS (Sólidos totais dissolvidos), e Temp. (Temperatura), 1 = baixos, 2 = médios, 3 = altos valores.*

Species	Mesoh.		Oxi.		Salinid.		TDS		Temp.	
	C	IndVal	C	IndVal	C	IndVal	C	IndVal	C	IndVal
Astyanax lacustres	2	37.3*								
Astyanax bockmanni	2	65.7*	3	46.6*						
Astyanax paranae	2	46.4*								
Bryconamericus iheringii	2	82.2**								
Trichomycterus diabolus	1	26.5*								
Hypostomus nigromaculatus	1	23.0*								
Imparfinis schubarti	1	54.4*							1	55.9*
Phalloceros harpagos	2	17.9*			3	66.7*	3	66.7*		
Geophagus brasiliensis	2	33.2*			3	71.6*	3	71.6**		

However, in the present study, a positive correlation was found among species of the orders Characiformes and Siluriformes to the mesohabitats of pool and riffle respectively, allowing us to assume that such attributes possibly be related to the ecomorphological patterns of the species belonging to these orders. Siluriformes have back-ventral flattened bodies, ventral mouth

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and long peduncle, recurrent characteristics in organisms adapted to lotic waters and benthic habits, but also that allow feed in semi-pelagic areas. Differently, Characiforms present tall, flattened lateral bodies, and developed eyes, due to their eating habits of greater visual dependence in pelagic environments (MATTHEWS, 1998; CASATTI, CASTRO, 2006; MAZZONI et al., 2010).

Table 5: Values of ecological parameters for each collection point.

Tabela 5: Valores dos parâmetros ecológicos para cada ponto de coleta.

Point	Shannon Diversity (H')	Equitability (J)	Dominance (D)
P1	1.448	0.8994	0.26
P2	1.874	0.7814	0.2164
P3	1.412	0.7255	0.3334
P4	0.7651	0.4754	0.5043
P5	1.511	0.7268	0.2163
P6	1.638	0.7453	0.2722
P7	1.455	0.812	0.2898
P8	2.137	0.8913	0.1367
P9	2.185	0.9113	0.1254
P10	1.915	0.8315	0.1951
P11	1.614	0.776	0.2686
P12	1.851	0.8902	0.1784
P13	2.073	0.8343	0.1563
P14	1.96	0.9427	0.1586
P15	1.092	0.5249	0.4110
P16	2.164	0.9023	0.1276
P17	2.29	0.8627	0.1342
P18	1.765	0.7666	0.2228
P19	1.857	0.7744	0.2078
P20	1.94	0.7846	0.2147
P21	1.641	0.6604	0.2845
P22	2.203	0.8591	0.1404
P23	1.561	0.7102	0.2837
P24	1.325	0.6374	0.3098
P25	1.517	0.5749	0.4011
P26	1.262	0.5481	0.3423
P27	1.484	0.8285	0.2778
P28	2.077	0.8358	0.1687

On the environmental characteristics of the stretches, according to Rolla et al. (2009). Total Dissolved Solids (TDS) comprises all the inorganic and organic particulate material that is suspended in the water, so that the launch of domestic effluents and industrial tends to increase their concentrations in lotic environments, as well as erosive processes on margins surrounded by degraded or even absent riparian vegetation (MARTINELLI, FILOSO, 2007; DAGA et al., 2012; COLLIER et al., 2019). Like TDS, high concentrations of mineral salts in lotic environments disfavor species with specialized habits to the detriment of the increase in generalist species (FELIPE, SÚAREZ, 2010).

Based on the above information, it is possible to say that *G. brasiliensis*, can withstand elevated levels of anthropic changes, since it presented high values of IndVal for high concentrations of TDS, and salinity. These data suggest that *G. brasiliensis* may be an indicator for high salinity and TDS levels, as these data are like those described by Daniel et al. (2002) in urban streams highly impacted by the release of domestic and industrial effluents, which had salinity levels equal to 590 µS.cm-1, this value being higher than those recorded in the present study.

According to Daga et al. (2012), and Barbosa et al., (2020), physical-chemical changes (i.e. water temperature, salinity, nitrogen and phosphorus concentrations, and TDS) and morphometric changes (i.e. depth, water velocity, and substrate) in stream ecosystems can be directly associated with the removal of riparian vegetation. Therefore, when absent, there is a large input of allochthonous sediments, drastically altering the chemical characteristics of the water, as well as promoting the homogenization of the substrate, favoring detritivorous and small species such as *G. brasiliensis* (DAGA et al., 2012; COLLIER et al., 2019; BARBOSA et al., 2020). This condition was described by Caetano et al., (2021), in a study on the ichthyofauna of streams belonging to the Paranapanema river basin, in which *G. brasiliensis* was more abundant in stretches of streams with marginal vegetation composed exclusively of grasses.

Table 6: Values of physical and chemical variables (mean ± standard deviation = SD) for each collection point.

Tabela 6: Valores das variáveis físicas e químicas (média ± desvio padrão = DP) para cada ponto de coleta.

Point	Total Dissolved Solids [mg]	Oxygen [mg.L]	Temperature [°C]	Salinity [US/cm]
P1	86.01 ± 0.05	8,74 ± 0.04	13.95 ± 0.03	173.50 ± 0.02
P2	124.75 ± 1.75	8.62 ± 0.25	17.87 ± 0.07	251.5 ± 3.5
P3	206 ± 1.00	9.53 ± 0.18	18.17 ± 0.77	409.75 ± 3.25
P4	280.25 ± 0.17	8.21 ± 0.15	23.50 ± 0.17	560.75 ± 0.25
P5	191.50 ± 0.50	11.03 ± 0.67	16.12 ± 0.09	382.75 ± 0.25
P6	140 ± 0.01	9.66 ± 0.22	12.18 ± 0.21	279.5 ± 0.50
P7	139.5 ± 0.50	10.43 ± 0.12	18.75 ± 0.02	278.75 ± 1.25
P8	91. 01 ± 0.01	9.81 ± 0.42	17.98 ± 0.06	182.25 ± 0.75
P9	48.50 ± 0.50	10.27 ± 0.10	14.04 ± 0.18	97.01 ± 0.01
P10	72.02 ± 0.01	10.60 ± 0.04	14.94 ± 0.71	145.01 ± 0.2
P11	359.5 ± 0.50	10.25 ± 0.11	17.36 ± 0.13	259.5 ± 2.50
P12	33.25 ± 0.75	11.31 ± 0.16	14.33 ± 0.08	67.01 ± 1.01
P13	106.01 ± 1.00	12.08 ± 0.28	15.10 ± 0.04	212.02 ± 2.00
P14	80.25 ± 1.75	11.17 ± 1.01	17.77 ± 0.07	159.5 ± 2.50
P15	260.5 ± 3.50	10.77 ± 0.21	13.48 ± 0.05	520.00 ± 6.50
P16	267.5 ± 0.50	10.57 ± 0.04	13.13 ± 0,08	535.01 ± 1.01
P17	49.50 ± 0.50	9.27 ± 0.10	12.04 ± 0.18	97.01 ± 0.01
P18	93. 01 ± 0.01	9.85 ± 0.42	16.98 ± 0.06	153.25 ± 0.75
P19	267.5 ± 1.00	9.18 ± 0.21	13.13 ± 0.08	131.5 ± 2.50
P20	93. 01 ± 0.05	9.50 ± 0.60	21.29 ± 0.06	173.25 ± 0.75
P21	43.25 ± 0.22	11.50 ± 0.16	23.20 ± 0.60	57.01 ± 0.05
P22	45.05 ± 0.50	12.01 ± 0.16	18.52 ± 0.18	48.05 ± 0.10
P23	360.7 ± 0.32	9.50 ± 0.05	22.97 ± 0.53	269.5 ± 1.25
P24	198.50 ± 0.30	8.73 ± 0.15	17.40 ± 0.25	425.25 ± 0.25
P25	185.20 ± 0.20	10.05 ± 0.25	23.05 ± 0.02	352.25 ± 0.20
P26	271.5 ± 2.30	10.02 ± 0.05	23.75 ± 1.05	536.00 ± 0.50
P27	172.20 ± 0.15	9.05 ± 0.50	23.05 ± 0.05	373.35 ± 0.30
P28	46.41 ± 0.23	11.50 ± 0.18	19.35 ± 0.25	100.02 ± 0.05

Kennard et al. (2005) and Felipe, Súarez (2010) associate the occurrence of *P. harpagos* with low rates of biotic integrity, and resistance to various anthropic impacts, since in the present study this species presented high values of IndVal for TDS, and salinity, characteristic parameters of low environmental integrity (DAGA et al., 2012; SOUZA et al., 2013). This species presents broad dietary plasticity, being characterized as detritivorous, however, it can include fragments of leaves, fruits, and aquatic insects in its diet, especially Chironomidae larvae (MAZZONI et al., 2011; MONACO et al., 2014). In addition to broad food plasticity, *P. harpagos* presents great adaptability and tolerance to high levels of salinity, as described in Monaco et al. (2014), therefore this species can be anthropic alteration indicator (MARTINELLI, FILOSO, 2007; ROLLA et al., 2009; MONACO et al., 2014; VAZ et al., 2017).

Caetano et al. (2016) observed a greater abundance and frequency of occurrence of *I. schubarti* in stretches of more preserved streams. This characteristic was verified in the present study, since this species occurred predominantly in points with high diversity and equitability, besides low dominance values, demonstrating this species is associated with more healthy environments, besides presenting high IndVal values for low water temperatures.

According to Castro (1999), riparian vegetation plays an important role in stream ecosystems, as it provides allochthonous organic matter (e.g., large wood debris, leaf litter), in addition to totally or partially blocking the entry of light into the channel, reducing water temperature (CRUZ et al., 2013; COLLIER et al., 2019). A large availability of allochthonous organic matter favors the establishment of communities of benthic macroinvertebrates, which are the basis of the diet of members of Heptapteridae (PAGOTTO et al., 2011) and Trichomycteridae (UIEDA, PINTO, 2011), as is the case of *I. schubarti* and *T. diabolus* respectively (CRUZ et al., 2013). Therefore, despite the relationship between temperature and greater integrity of the environment are questionable, we can still say through ecological standards in which *I. schubarti* and *T. diabolos* was associated in the present work, and in other works (CASATTI et al., 2001; TERESA, CASATTI, 2010; CASATTI et al., 2012; 2015; ROLLA et al., 2009) that these species are possible indicators of more conserved environments.

The distribution of *A. bockmanni* varied between sample units with high and low diversity, equitability, and dominance, allowing us to say that it is a species associated with healthy environments preferably (SOUZA et al., 2013), able of also supporting high levels of habitat alterations (ROLLA et al., 2009). Araújo, Tegerina-Garro (2007) observed that *Astyanax eigenmanniorum* Cope, 1894, synonymy species of *A. bockmanni* (RAIO, BENNEMANN, 2010), presents omnivorous habits and generalist characteristics, capable of occupying environments of good and poor environmental quality.

Bryconamericus iheringii was abundant in stretches of low and high diversity, can be considered a generalist species, occupying impacted or not impacted habitats (ORICOLLI, BENNEMANN, 2006). Caetano et al. (2016) observed that *B. iheringii* was associated with stretches of streams of low environmental quality, being tolerant to several levels of anthropic changes. Furthermore, Oricolii, Bennemann (2006),

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in a study on the feeding of *B. iheringii* in streams of the Tibagi river basin, describe a wide dietary plasticity for this species, behaving as a generalist or specialist, depending on the availability of food resources in the environment. (e.g., plant remains, insects, benthic macroinvertebrates, and detritus), being a possible indicator of poor environmental quality.

During the works of Orsi et al. (2004) and Rolla et al. (2009) the association of *A. lacustris* was found to streams with high concentrations of total phosphorus, indicative of low environmental quality, possibly due to the release of sewage, being more abundant also in the present study in points endowed with poor ecological parameters, such as high dominance, low equitability and diversity. As observed, we can categorize *A. lacustris* as a possible indicator of poor environmental quality with the data mentioned above.

CONCLUSIONS

The IndVal analysis, rarely used in the way in the present study, made it possible to characterize *G. brasiliensis, P. harpagus, A. bockmanni, A. lacustris* and *B. iheringii* as possible indicators of poor environmental quality, and *I. schubart, T. diabolus* and *H. nigromaculatus* as species of fish indicators of more healthy environments. As shown, the use of ichthyofauna can be considered efficient in the indication of environmental quality in streams, specifically in the quantification of anthropic impacts. Finally, the present work can be used as a basis for future studies with bioindicators carried out in other watersheds, and even in other types of aquatic environments.

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