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Fish as Indicators of Environmental Quality in a Stretch of the Cachoeira River, Bahia, Brazil

Flores-Lopes Fábio^{1*} and Silva Augusta M.²

¹Departamento de Ciências Biológicas, Universidade Estadual de Santa Cruz, Rodovia Ilhéus-Itabuna, km 16, CEP 45662-000, Ilhéus, BA, Brazil

²Bióloga, Mestre em Sistemas Aquáticos Tropicais, Universidade Estadual de Santa Cruz, Rodovia Ilhéus-Itabuna, km 16, CEP 45662-000, Ilhéus, BA, Brazil

*Corresponding Author

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Abstract: Fishes are representative of the biotic community assemblage of aquatic ecosystems and have been widely used as a tool in the study of monitoring environmental quality assessment. Indices of species richness, fish abundance and diversity per sample representing methodologies can assess different situations as the quality of the environment. Despite the poorly known ichthyofauna in the extreme south of Bahia, this study aimed to surveil the environmental quality in a stretch of Cachoeira River through the waterfall fish community. Samples were collected seasonally at five points of the river between the municipalities of Itapé and Ilhéus. The samples were taken over a period of one year (May 2007 to January 2008). The results of this study showed that the points 1, 2 and 5 had a better environmental quality in relation to others. In the first point the endemic species *Lignobrycon myersi* and *Nematocharax venustus* were found and taken as a reference. The points 3 and 4 indicated a further deterioration of environmental quality due to the high frequency of exotic species such as *Tilapia rendalli*, *Tilapia* sp. and *Poecilia vivipara* and the entry of effluents. The results of T test showed no significant difference between points 1 and 2 point 5. The results reflect the degradation of this stretch of river waterfall, which can be reflected in a decrease in diversity. The presence of endemic species in our samples in the most upstream points, reinforces the need for environmental preservation of the watershed for the maintenance of species characteristic of this environment and to maintain water quality to be used by the population.

Keywords: Diversity, Monitoring, *Tilapia rendalli*, Environmental quality, Integrated quality index

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Introduction

The aquatic ecosystem is considered the most susceptible to pollution (Cantanhêde *et al.*, 2014) and is extensively contaminated with admixtures of chemical compounds including heavy metals, persistent organic pollutants released from industrial and other anthropogenic sources, causing potent harm on the ecological equilibrium and organisms in particular due to the accumulation of these toxic compounds in their tissues (Bassey, 2019). According to Buss *et al.* (2009), the use of aquatic biota is an important tool in assessing water quality.

According to Ferreira *et al.* (2011), the main environmental problems responsible for the degradation of water quality, are caused by human activities. Ecological studies have used a variety of approaches to evaluate the water quality and the degradation degree of freshwater ecosystems in response to different levels of pollution. In the last few decades, Liebel *et al.* (2013) stressed that increasing of environmental degradation has contributed for the distribution of toxic chemicals to the environment, and consequently serious effects in wild aquatic organisms health can be noticed. Kopecka *et al.* (2006) stated that the aquatic environment is affected by different types of chemicals that are toxic to biota and originate from both natural and anthropogenic sources.

According to Bruschi Jr. *et al.* (2000), anthropogenic activities have a negative and profound influence on freshwater fish from the smallest streams to the largest rivers. The deterioration of the environment as a result of anthropic activities made necessary to develop and adapt methods to assess environmental quality, in addition to the need

for subsidies to regulate the use of water resources, enabling the development of alternatives to minimize the degradation of rivers (Teixeira *et al.*, 2005).

Aquatic organisms such as fish and molluscs are useful as bioindicators of pollution, due to a great deal of response and sensitivity to changes in the aquatic environment, which plays an increasingly important role in biomonitoring of environmental pollution (Bassey, 2019). Bruschi Jr. *et al.* (2000) suggested the use of fish as a taxocenosis representative of the biotic community of aquatic ecosystems and tool of environmental quality evaluation is based on some characteristics of this group. Teixeira *et al.* (2005) emphasized that fish assemblages and their spatial and temporal variation patterns is of great relevance in assessing environmental quality. The fish community has numerous advantages as indicator organisms in biological monitoring programs, like the availability of life cycle information for a large number of species, since they include a variety of trophic levels comprising both aquatic and terrestrial food.

According to Authman (2008), fishes are considered to be most significant biomonitors in aquatic systems for the estimation of metal pollution level. Bassey (2019) stated that studies on fish biomarker are of great significance as they can help to evaluate organ alterations, enzymatic responses and histological changes when exposed to polluted aquatic environment.

Karr (1981) described an evaluation of biotic integrity using a fish community. The biotic index takes into account the sensitivity or tolerance of a species or groups of species

to pollution and designates a value, and the sum of these values results in a pollution index for a particular site. Data may be qualitative (presence or absence) or quantitative (relative abundance or absolute density) (Mason, 1991). According to Bruschi Jr. *et al.* (2000), the number of species changes, if some of them are sensitive and disappear; the relative abundances are altered during the disappearance process or only as a result of the modification of a particular resource exploited by this or that species. In this way, the richness and abundance of fish species per sample and the diversity indexes represent methods of analysis that can evaluate different situations regarding the quality of the environment.

In spite of the extensive hydrographic network represented by the streams in the Brazilian water basins, few studies have been carried out involving the ichthyofauna (Castro and Casatti, 1997). The extreme south of Bahia is a region of varied environments for freshwater fish, interspersed by several small and medium sized hydrographic basins. In this region, the hydrological richness is contrasting with the still-unknown fish fauna and the presence of several species still to be described (Sarmiento-Soares, 2007).

From the point of view of the geographical area of study, the ichthyofauna of the extreme south of Bahia is still in the inventory phase, due to the recent recognition of new species. Cetra *et al.* (2009) added that the Cachoeira river basin in southern Bahia is a region with very little information about the composition, diversity and spatial distribution of the ichthyofauna. The region's water systems have a rich endemic ichthyofauna (Porto, 2007). These high-priority specimens exist in specific environments and are important in

determining conservation potential. Furthermore, many endemic species in the region are seriously at risk of disappearing without their existence being recorded by science (Sarmiento-Soares, 2006).

This study aimed to surveil the environmental quality in a section of the Cachoeira River through the fish community, characterize the ichthyofauna present in it, and measure the environmental influence through the Integrated Quality Index (IQI).

Materials and Methods

The Cachoeira river catchment area is located in the south of Bahia - Brazil, between the municipalities of Itapé and Ilhéus (14° 42'/15° 20'S and 39° 01'/40° 09' W) and its drainage area is about 4830 km², comprising thirteen municipalities: Firmino Alves, Floresta Azul, Santa Cruz da Vitória, Itajú do Colônia, Ibicaraí, Lomanto Junior, Itapé, Buerarema, Jussari, Itabuna, Ilhéus, Itororó and Itapetinga. The population is constituted around 530 thousand inhabitants (2007). It is bordered to the north by the Contas and Almada river basins; to the south by the Pardo and Una river basins; to the west by the Pardo river basin; and to the east by the Atlantic Ocean (Schiavetti *et al.*, 2002). This basin originates in the springs of the Colônia river, at an altitude of 800 m, in the Serra of Ouricana (Itororó) and reaches its lowest level on the littoral surface of the municipality of Ilhéus. The Colônia River extends for 100 km, bathes the municipalities of Itororó, Itapetinga and Itajú de Colônia, and has its confluence with the Salgado River in Itapé and then it is known as Cachoeira River.

After crossing 50 km, the Cachoeira River has its mouth at the place known as Coroa Grande (Ilhéus), where it mixes with the

waters of the Santana and Fundão rivers (Nacif, 2000)

The specimens were collected with "picaré" - type trawls (15 m x 1.5 m x 0.5 cm net) and "puçás" (Malabarba and Reis, 1987) in six seasonal samplings during May 2007 to January 2008. Three samplings were carried out in 2007 and another three in 2008. The material was collected in five points of the Cachoeira river, between Itapé and Ilhéus. Point 1 - Vila de Itapé (14° 52' 719" S and 39° 24' 772" W), point 2 - Santa Amélia (Itapé) (14° 52' 719" S and 39° 24' 772" W), point 3 - in front of Jardim das Acácias 47° 20' S and 39° 15'41" W), point 4 - next to the Pitú Restaurant (14° 47' 788" S and 39° 12' 107" W) and point 5 - Sesmarias Road - Banco da Vitória (14° 47' 072" S and 39° 06' 273" W) (Fig. 1).

The specimens were anesthetized with MS222 (3-Aminobenzoic Acid Ethyl Ester) and then fixed in 10% formaldehyde in the field. The material was screened in the laboratory of Zoology in the Universidade Estadual de Santa Cruz (UESC). The material was screened, identified up to the species level and preserved in 70% alcohol. Some specimens were sent to experts at Laboratory of Zoology at Universidade Federal do Rio Grande do Sul (UFRGS) and the Museum of Zoology of the Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS) for identification. The analyzed material was deposited in the scientific collection at Universidade Estadual de Santa Cruz (UESC).

In order to characterize the ichthyofauna present in the Cachoeira River, the Shannon Wiener Diversity Indexes (Pielou, 1975), species richness (Margalef, 1969) and the Pielou Equity Index (1975) were used. All

these indexes were calculated by the Divers program and carried out on a natural logarithm. The occurrence constancy index (Dajoz, 1983) was also used. Species are considered constant when present in more than 50%, accessory species when present from 25 to 50% and accidental species when present in less than 25% of the samples. A cluster analysis was performed based on abundance and species richness, in order to verify the degree of similarity between the sampling points. This analysis was performed using the software MVSP - Multi-Variate Statistical Package Version 3.11 (1999), by Kovach Computing Services.

To calculate the Integrated Quality Index (IQI), the total number of individuals per sampling site, the number of species and the Diversity Index were used. These three measurements were transformed in proportions from zero to 1 by dividing their values by the highest value obtained among the samples. The results were grouped in class intervals to establish the categories (high, medium and low quality), which were established if a decrease was made between the maximum value of the minimum value, and the result was divided by three. A linear regression analysis was performed to verify if there was a correlation between the Diversity and Richness Ratios with the Integrated Quality Index.

The non-parametric Mann-Whitney test for independent samples with $p < 0.005$ was used to compare the values of the Diversity, Richness, Equity and Integrated Quality Indexes (IQI). The differences between the points for each parameter were tested through a non-parametric ANOVA. The degree of significance was 95%. Past software version 1.11 was used for statistical analysis.

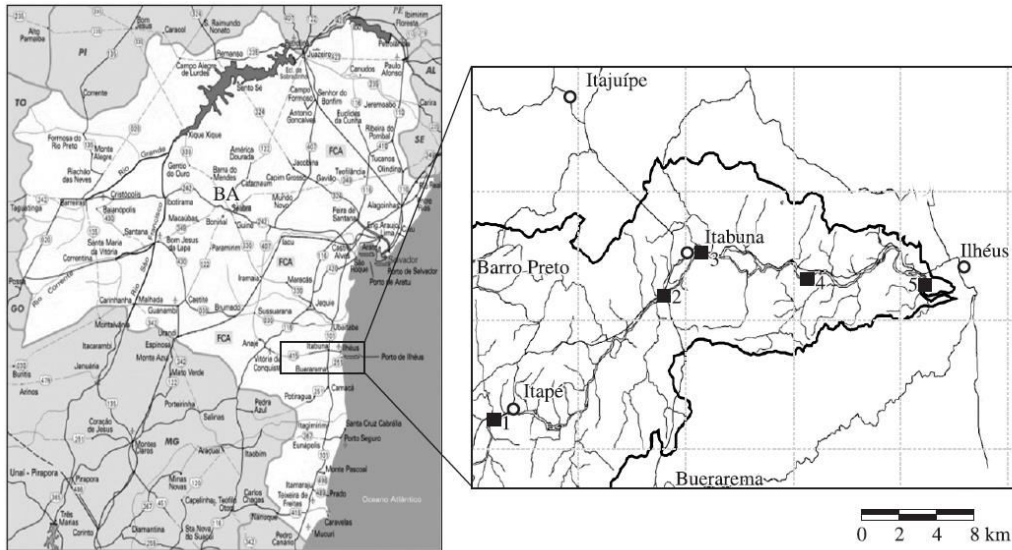


Figure 1: Maps of Brazil and Bahia and, in particular, the catchment area of the Cachoeira river, showing collection points. 1 - Vila de Itapé, 2 - Fazenda Santa Amélia, 3 - In front of the Jardim das Acácias, 4 - Next to Restaurante do Pitú and 5 - Estrada das Sesmarias.

Results

A total of 868 individuals were collected corresponding to 30 species, 13 families and 5 orders (Table 1), of which 21 specimens were captured in the first collection, 158 in the second, 267 in the third, and 422 in the fourth. From the total number of individuals observed at all sampling points, 68% belonged to the order Perciformes, 16% to Cyprinodontiformes, 14% to Characiformes and the other orders totaled 2%.

The analysis of the ichthyofauna structure showed that the most abundant families were Cichlidae with 63%, Poeciliidae with 16% and Characidae with 13% being the remaining 8% represented by the other families. The species that presented a higher percentage within the composition of the species observed in this study were *Tilapia rendalli* (Boulenger, 1897) 56%, *Poecilia vivipara* (Bloch and Schneider, 1801) 16%, *Lignobrycon myersi* (Miranda Ribeiro, 1918) 12%, *Geophagus brasiliensis* (Quoy and Gaimard, 1824) 4%, *Eleotris* sp.

Gmelin (1789) 2%, *Centropomus paralellus* Poey (1960) 2%, *Hyphessobrycon* sp. Eigenman (1908) 2%, *Nematocharax venustus* (Weitzman *et al.*, 1986) 1% and *Crenicichla* sp. Heckel (1840) 1%. The other species comprised 10% (Table 2).

According to the constancy index, the species that may be considered as potentially indicative were *Tilapia rendalli*, which occurred in 100% of the samplings, followed by *Poecilia vivipara* and *Tilapia* sp. (60%). The accessory species were *Astyanax fasciatus*, *Geophagus brasiliensis* and *Lignobrycon myersi* (40%).

When comparing the number of individuals and the species richness between the points sampled, it was possible to observe that points 1 and 4 presented the highest number of individuals and the highest wealth. Points 3 and 4 were the ones that showed the lowest species richness. Point 4 was the one that presented the largest number of individuals (325 = 38%), represented by 4

Table 1: List of classification of the species sampled in the Cachoeira river during the study period

Order	Family	Species
Characiformes	Characidae	<i>Astyanax bimaculatus</i> (Linnaeus, 1758)
		<i>Astyanax fasciatus</i> (Cuvier, 1819)
		<i>Astyanax</i> sp., Bird e Girard, 1854
		<i>Astyanax</i> sp. 1 Bird e Girard, 1854
		<i>Astyanax</i> sp. 2 Bird e Girard, 1854
		<i>Astyanax</i> sp. 3 Bird e Girard, 1854
		<i>Astyanax</i> sp. 4 Bird e Girard, 1854
		<i>Astyanax</i> sp. 5 Bird e Girard, 1854
		<i>Lignobrycon myersii</i> (Miranda Ribeiro, 1918)
		<i>Hypherssobrycom</i> sp. (Eigenman, 1908)
	<i>Nematocharax venustus</i> (Weitzman, Menezes & Britski, 1986)	
	Crenuchidae	<i>Characidium</i> sp. Reinhardt, 1867
		<i>Characidium</i> sp1 Reinhardt, 1867
		<i>Characidium</i> sp2 Reinhardt, 1867
	Curimatidae	<i>Cyphocharax</i> sp Fowler, 1906.
Clupeiformes	Engraulidae	<i>Lycengraulis grossidens</i> (Spix e Agassiz, 1829)
Cyprinodontiformes	Poeciliidae	<i>Phalloceros</i> sp. Eigenmann, 1907
		<i>Poecilia vivípara</i> (Bloch e Schneider, 1801)
Perciformes	Centropomidae	<i>Centropomus parallelus</i> (Poey, 1960)
	Cichlidae	<i>Gymnogeophagus</i> sp.(Miranda Ribeiro, 1918)
		<i>Geophagus brasiliensis</i> (Quoy e Gaimard, 1824)
		<i>Tilapia rendalli</i> (Boulenger, 1897)
		<i>Tilapia</i> sp. Smith, 1840
	<i>Crenicichla</i> sp. (Heckel, 1840)	
	Eleotridae	<i>Eleotris pisonis</i> (Gmelin, 1789)
	Mugilidae	<i>Mugil platanus</i> (Gunther, 1880)
	Carangidae	<i>Caranx</i> sp. 1 Lacépède, 1801
		<i>Caranx</i> sp. 2 Lacépède, 1801
Gobiidae		<i>Gobionellus</i> sp. Girard, 1858
Syngnathiformes	Syngnathidae	<i>Microphis brachyurus lineatus</i> (Kaup, 1856)

Table 2: Composition of the most abundant species during the sampling period

Species	Point 1	Point 2	Point 3	Point 4	Point 5	Total
<i>Caranx</i> sp. 1					1	1
<i>Caranx</i> sp. 2					1	1
<i>Astyanax bimaculatus</i>	1					1
<i>Astyanax fasciatus</i>	3	1				4
<i>Astyanax</i> sp.	5			1		6
<i>Astyanax</i> sp1	5					5
<i>Astyanax</i> sp2.		4				4
<i>Astyanax</i> sp3.	2					2
<i>Astyanax</i> sp4.		1				1
<i>Astyanax</i> sp5.		5			4	9
<i>Gobionellus</i> sp.					4	4
<i>Centropomus parallelus</i>					17	17
<i>Characidium</i> sp.	2	1				3
<i>Cyphocharax</i> sp.		1				1
<i>Eleotris pisonis</i>					19	19
<i>Geophagus brasiliensis</i>	30	2				32
<i>Geophagus</i> sp.	7					7
<i>Gymnogeophagus</i> sp.		1				1
<i>Hypherssobrycom</i> sp.		13				13
<i>Crenicichla</i> sp.		2	8		2	12
<i>Lignobrycon myersi</i>	22	30				52
<i>Paralichthys orbignyanus</i>					1	1
<i>Lycengraulis grossidens</i>					3	3
<i>Microphis lineatus</i>					10	10

<i>Nematocharax venustus</i>	10	2				12
<i>Phalloceros</i> sp.	3					3
<i>Poecilia vivipara</i>	93	33		9		135
<i>Poecilia</i> "sem pintas"	2					2
<i>Mugil platanus</i>					2	2
<i>Characidium</i> sp.1	1					1
<i>Characidium</i> sp.2	3					3
<i>Sphoeroides testudineus</i>					5	5
<i>Tilapia rendalli</i>	40	105	32	311	2	490
<i>Tilapia</i> sp.			1	4	1	6
Total	229	201	41	325	72	868
Number of species	16	14	3	4	14	

species. This point was followed by point 1, in which 229 specimens (26%) were observed, belonging to 16 species. Point 2 presented 201 specimens (23%) in 14 species; point 3 presented 41 specimens (10%) in 3 species, and point 5 presented 72 individuals (8%) in 14 species (Table 2).

Point 1 demonstrated the highest diversity index values at all samplings. Point 2 presented a lower value of diversity than that of point 1 during the entire study period presenting a much lower value in the last sampling. Point 5 also showed a lower value than point 1, but presented a distribution of values very similar to this point (Fig. 2). Points 3 and 4 showed the lowest values of the Diversity Index. Point 3 showed only the species *Tilapia rendalli* and *Crenicichla* sp. The results obtained by the 't' test showed that points 1 and 2 did not differ statistically from point 5 ($p = 0.1$ and $p = 0.4$, respectively), and point 3 did not differ statistically from point 4 ($p = 0.7$). The results showed that all other combinations between the points were statistically significant.

These results indicate that points 3 and 4 have the worst environmental quality based on species richness, because in addition to the low number of species, they have a high dominance of *Tilapia rendalli* and *Poecilia vivipara* in relation to the other species (Fig. 3). In the second, third and fourth sampling, point 4 presented the highest number of individuals (59, 91 and 175 individuals, respectively), with only four species (*Tilapia rendalli*, *Tilapia* sp., *Poecilia vivipara* and *Astyanax* sp.; *Tilapia rendalli* comprising 56% of the individuals sampled and *Poecilia vivipara* comprising 15%).

At point 1 were observed 52 specimens of *Lignobrycon myersi*, which is an endemic species in southern Bahia and 12 specimens of *Nematocharax venustus*, which is a common species in lighter and cleaner waters. It was possible to verify that points 1 and 2 presented the highest species richness during the sampling period and point 4 presented a frequency variation (Fig. 3).

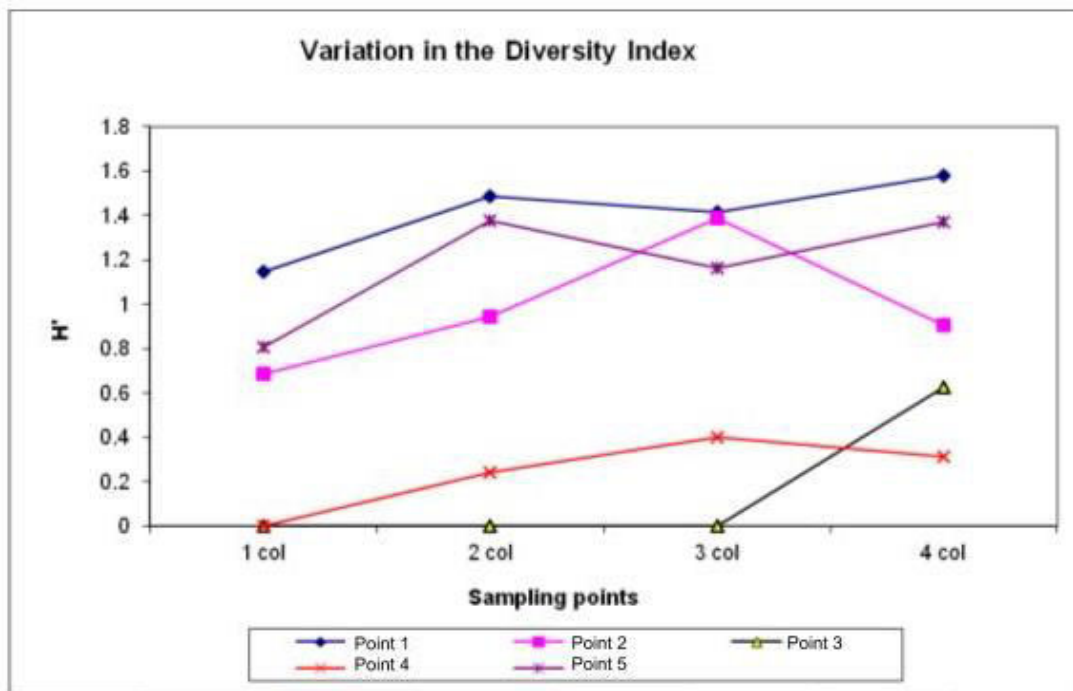


Figure 2: Variation of the diversity index per sampling point.

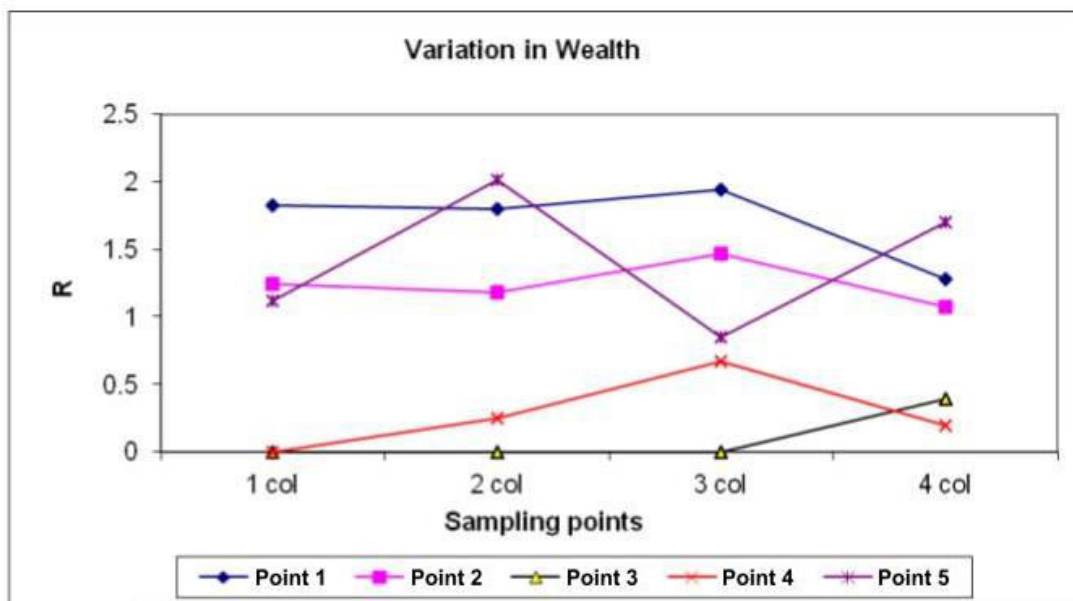


Figure 3: Variation of Richness per sampling point.

In relation to species richness, points 1 and 2 presented a very similar distribution being verified in these points the highest values. Point 5 presented the highest values of wealth in the second and fourth sampling

(2.01 and 1.69, respectively). Points 3 and 4 showed the lowest species richness values, and at point 3, due to the low number of specimens collected it was only possible to calculate the index in the fourth sample, and

point 4 presented the highest index value in the third sample (0.66) (Fig. 3).

The results for biomass and abundance showed that at points 3 and 5, the biomass was greater than the number of individuals, which indicates that the captured animals are mostly adults having medium to large size. However, at point 4, an inverse result was verified, indicating that the specimens captured at this point are very small, probably juveniles (Fig. 4).

The Integrated Quality Index (IQI) analysis showed that the highest values were obtained at point 1 (2.62) and point 2 (2.28), followed by point 5 (2.09), and that the values obtained at points 3 and 4 were 0.59 and 1.35, respectively. According to the results of this analysis, points 1, 2 and 5 were classified as high environmental quality, point 4 as medium quality and point 3 as low quality. The results also showed that at points 1, 2 and 5 the highest IQI values were verified during the entire study period (Fig. 5).

The results of the Cluster analysis demonstrated the formation of two clusters, one formed by points 1 and 2 and the other formed by points 3 and 4, indicating that based on species composition, these points are similar to each other. Point 5 presented the greatest dissimilarity in relation to the other points, occurring in isolation, which shows that the ichthyofauna of this place is very different from the other points (Fig. 6).

Discussion

Aquatic environmental contaminants by industrial effluents and urban sewage present as common characteristic the release of xenobiotic complex mixtures that potentially affects important aspects related with

physiological aspects in fish (Liebel *et al.*, 2013). For these authors, alterations indicated that fishes were affected by the exposure to pollutants presented in water and sediment. The higher incidence of those alterations corroborate the hypothesis that the lakes are affected by human activities.

Fish taxocenosis was defined by Karr (1981) and Karr and Dudley (1981) as the ability of the environment to support and maintain a balanced, integrated and adapted community of organisms having a species composition, diversity, and functional organization comparable to that of habitat of the region and was used in order to verify the biotic integrity. Fausch *et al.* (1990) and Bruschi Jr. *et al.* (2000) used it to verify the biological quality of certain environments. According to Al-Sabti and Metcalfe (1995), fish are important vehicles for the transferral of contaminants to human populations and may indicate the potential exposure to pollutants.

In the Cachoeira river, few studies are carried out with fish in order to verify the biotic integrity of the environment, mainly with the use of native species. Cetra *et al.* (2009) stated that the Cachoeira river Basin, in the south of Bahia, is a region with very little information about the composition, diversity and spatial distribution, pointing to the species *Nematocharax venustus* like endemic and suggesting the need for new surveys in the region. When evaluating the environmental quality of the Cachoeira river, Paulo *et al.* (2012) verified that a high frequency of histopathological alterations found in fish is probably associated with alterations in the aquatic environmental quality.

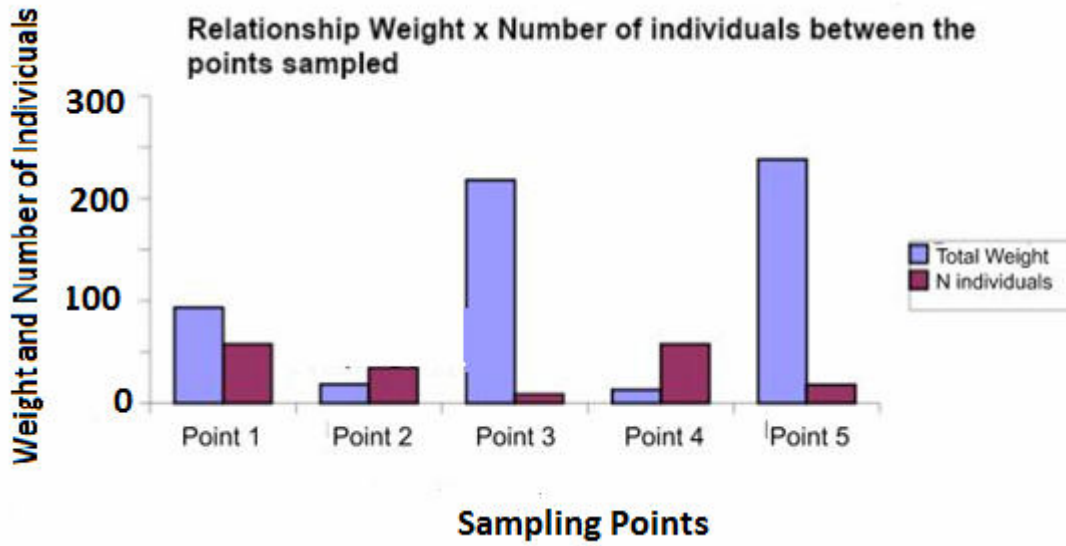


Figure 4: Relationship between biometric data and fish community data obtained for the species.

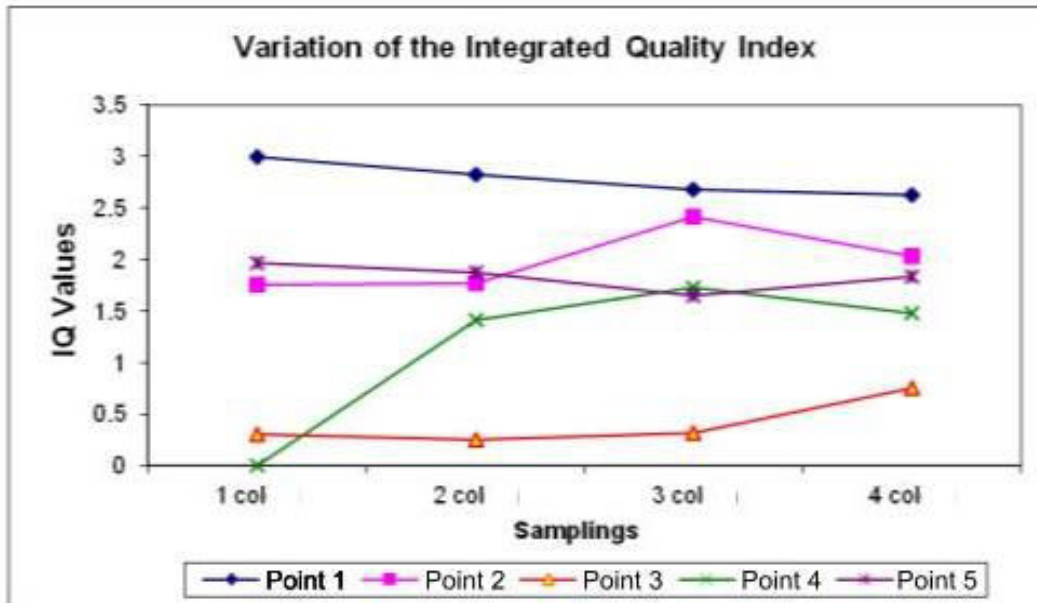


Figure 5: Variation of the quality index integrated by sampling point.

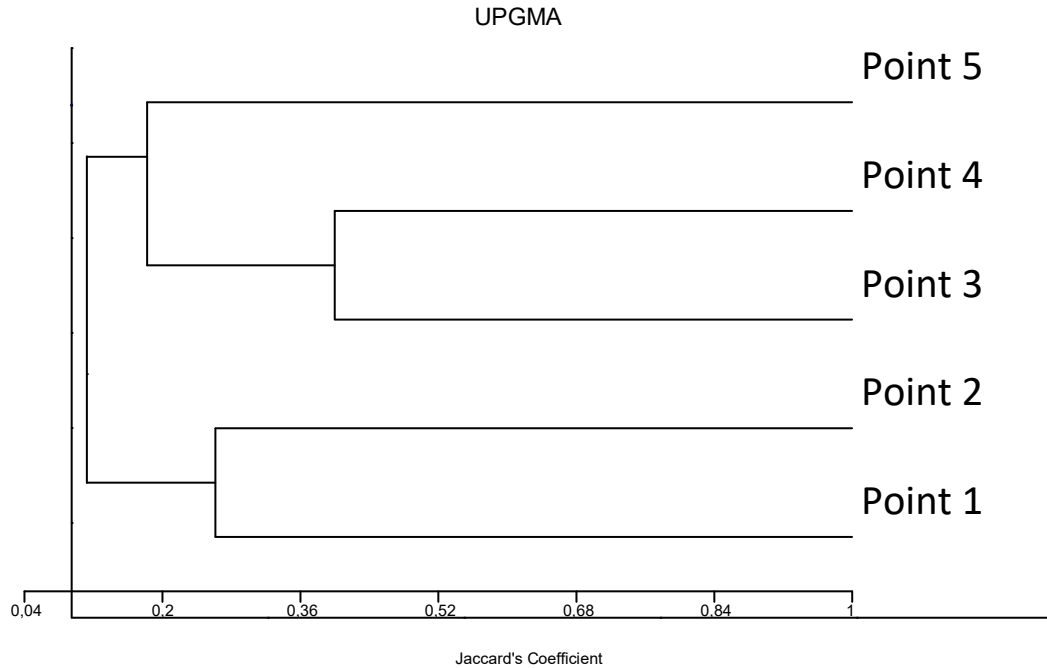


Figure 6: Dendrogram of the Cluster Analysis based on the composition of fish species captured in the Cachoeira river.

It can be observed from the present study that at the points 1 and 2, several individuals of the Characidae family were observed, specially the species *Lignobrycon myersi*, *Astyanax* sp., *Hyphessobrycon* sp. and *Nematocharax venustus*. Buckup *et al.* (2007) emphasized that the species *Nematocharax venustus* is classified as vulnerable in the list of endangered species. It is a species with few records in scientific collections, and its distribution has been extended in the region, since the distribution area was given as restricted to the Jequitinhonha Basin.

It is also important to emphasize the occurrence of the species *Lignobrycon myersi*, which is considered endemic to the Braço River (Malabarba *et al.*, 1998; Castro and Jucá-Chagas, 2008) and is categorized as high risk of extinction due to its limited geographic distribution and fragility of the environments

where it is found (Machado *et al.*, 2005). The occurrence of this species at points 1 and 2 associated with the results of the diversity, richness, quality (CI) and cluster analysis indices shows that these points and point 5 were the ones with the best environmental quality during the study period.

Points 3 and 4 have the lowest quality in relation to the other points studied according to diversity, richness and Integrated Quality Index (IQI) and the grouping analysis revealed that they form a group, being very similar between themselves and dissimilar in relation to the other points.

Mason (1991) pointed out that the index consider that the unpolluted environments present a large number of species, with none of them composing the majority of the community. The polluted environments are characterized by presenting few species, with

some of the species making up the majority of frequencies of occurrence of *Tilapia rendalli* and *Poecilia vivipara* was observed, species considered generalist, which indicates a strong relation with degraded environments. According to Bruschi Jr. *et al.* (2000), the occurrence of species known to be generalists corroborates the classification of low or medium quality sites.

The high frequency of these species at points 3 and 4, mostly juveniles, demonstrate their reproductive success in more degraded environments, due to the fact that these points are located after Itabuna, which discharges polluting residues into its domestic effluents, water courses and rainwater network.

Point 3 had the highest dominance, the lowest number of individuals and the lowest Diversity Index with samplings finding mostly *Tilapia rendalli*. The lack of sewage collection and treatment systems, plus the inadequate disposal of solid waste are characteristics of the localities around this basin, and can cause the environmental pollution.

This study verified a predominance of the families Cichlidae and Poeciliidae represented by the species *Tilapia rendalli* and *Poecilia vivipara*, respectively. Both are potentially indicative by the Constancy Index (Dajoz, 1983). These species are considered as bioindicators and they occur in practically all the samplings. They are exotic species that dominate the environment. These results are similar to observed by Zaganini (2009) and Teixeira *et al.* (2005), who verified that *Tilapia rendalli* is an opportunistic species quite resistant to diseases and great environmental variations, overpopulation and low levels of dissolved oxygen, besides using a great variety

the community. In points 3 and 4 the highest of foods. *Poecilia vivipara* is one of the main indicators of quality in streams, due to its tolerance to variations in the different types of habitats, including impacted ones (Aquino *et al.*, 2009).

The tools used in this work verified that the high frequency of exotic species such as *Tilapia rendalli*, *Poecilia vivipara* and *Tilapia* sp. in relation to native species is indicative of degradation of environmental quality. According to Araújo *et al.* (2003), they are widely known for their ability to tolerate altered environments, occurring in places where a large number of species have limited distribution.

The results of the Diversity, Richness and IQI Indexes showed that points 1, 2 and 5 have the best environmental quality, since they do not differ statistically, showing that they are similar to each other and different from the others in number of species and number of individuals per species. These samples showed a great variety of species and a small number of specimens of each one, which points to a higher quality of these sites, being the best places for the survival of these animals.

On the other hand, point 4 presented a greater number of individuals and a very small variation in the number of species. That demonstrates that this site does not have good environmental quality since it was not used by the species as a good quality point.

The results obtained by the aforementioned indexes were similar to the results of the IQI, which showed higher values at the same points. The results showed that the environments that were less impacted

by chemicals, pollution, garbage, and environmental destruction have a better environmental quality than those who suffered from this type of effect.

By the linear correlation analysis, points 1 and 5 had the best environmental quality, which is probably due to the fact that the IQI is influenced by the diversity index, whose value is used in the calculation of IQI. On the other hand, Paulo *et al.* (2012) verified that point 2 presented a high frequency of moderate and severe histopathological alterations, which are probably caused by stressors that are not detected in a physical-chemical analysis or by the type of analysis used in this study.

The results of the cluster analysis demonstrated that point 5 is the most dissimilar to the others, because this point is located in the estuarine region of the Cachoeira river, suffering in this way the influence of salinity from the ocean and, thus, modifying ichthyofauna composition of this environment. When evaluating the Cachoeira river water, Klumpp *et al.* (2002) observed an increase in the phosphate concentration after the village of Ferradas, and it increases considerably in the municipality of Itabuna, indicating a strong influence of urban waste in the concentration of this nutrient. These authors pointed out that the use of household detergents with high amounts of phosphate could contribute to the contamination of the river.

The results of the present study showed that the presence of *Lignobrycon myersi* and *Nematocharax venustus*, which are endangered, reinforces the idea of carrying out conservation actions in the studied basin. Such action is extremely important for the

maintenance of species characteristic of this environment, as well as maintaining the quality of water to be used by the populations of nearby cities. In this study it was proved that the presence of endemic species reinforces the need for environmental preservation of the watershed for the maintenance of species characteristic of this environment and to maintain water quality to be used by the population.

Teixeira *et al.* (2005) reported that the sections with the lowest diversity indexes are those with low environmental quality. Purcell *et al.* (2009) verified that the impacts changed the hydrology, geomorphology, chemistry and biology of the water. These authors also examined the effects of urbanization on stream condition using both stressor and response indicators.

According to Kennish (1991) the contamination of water bodies and non-target organisms by heavy metals occurs mainly as a consequence of the exploration and processing of ores, of the galvanizing industries, manufacture of paints and textiles, of waste discharges produced in vessels, deposition of sewage and dredging debris. According to this author, many of these industrial processes produce toxic effluents. Paiva *et al.* (2017) reported that many of the stressors are heavy metals and verified that the intense use of these metals and its environmental persistence both in soil and the aquatic environment are a matter of great concern due to the potential environmental impact.

Schuch *et al.* (2012) indicated that the streams are polluted by organic contamination and show advanced stages of eutrophication, mainly in the lower reaches.

All sampling sites were classified as “Class 4”, corresponding to the poorest water quality level, used only for navigation and harmonizing landscapes.

The Santa Cruz do Sul’s urban streams are heavily polluted by organic contamination and show advanced stages of eutrophication. Lins *et al.* (2010) reported that several studies have pointed out that the exposure of fish to oil hydrocarbons can interfere in the reproductive system and cause abnormalities during the development of fish embryos and larvae, changes in cardiac, respiratory and behavioral functions, immunotoxic, genotoxic, mutagenic and carcinogenic effects, in addition to histopathological lesions in the respiratory, digestive and excretory systems.

According to Khan *et al.* (2014), when exposed to Pb²⁺ fish exhibited abnormal behavior including erratic movement, jumping, excessive secretion of mucus and loss of balance which may be due to Pb neurotoxicity. Prolonged exposure to water pollutants even in very low concentrations have been reported to induce morphological, histological and biochemical alterations in tissue which may critically influence fish quality (Kaoud and El-Dahshan, 2010).

Conclusion

The results obtained in this study showed that points 1, 2 and 5 can be considered to have the best environmental quality, even with the presence of several stressors, and the other points had inferior environmental quality. Cluster analysis showed that point 5 was different from the other points analysed. The data from the tests carried out showed that the Cachoeira River is undergoing a process of environmental degradation, probably due to the presence of several stressing chemicals,

and human activities, which caused several types of problems for the environment and for species.

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