Journal of Biotechnology and Biodiversity
journal homepage: *https://sistemas.uft.edu.br/periodicos/index.php/JBB/index*

Fish diversity in three tributaries of the São Francisco river, Brazil

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INFO

Keyworks
anthropogenic action
freshwater fishes
highway
ichthyofauna
streams

ABSTRACT

We evaluated fish diversity in three tributaries of the São Francisco River, one of the largest watercourses in Brazil. The study site is in the sub-basin of the Carinhanha River [Carinhanha, Cocos (I and II) and Itaguari Rivers], located in the South region of the Bahia state. These rivers are crossed by bridges of the federal highway BR-135. After sampling, upstream and downstream from each bridge, during drought and rain seasons, 3,520 specimens of fish (57 species, 21 families) were captured. The species with highest occurrence were *Deuterodon* cf. *taeniatus*, *Serrapinnus heterodon*, *Astyanax bimaculatus* and *Psalidodon* cf. *rivularis*. During drought season, the number of specimens captured was higher, leading to an increase of species dominance. In the rainy season, species diversity was higher with a greater distribution of individuals among species. The data indicate the maintenance of the fish faunal structure despite anthropogenic activities on the studied areas.

RESUMO

Diversidade ictiofaunística de três tributários do rio São Francisco, Brasil
O presente estudo fornece informações sobre a diversidade de peixes em três tributários do rio São Francisco, um dos mais importantes cursos d'água do Brasil e da América do Sul. A área de estudo, localizada na sub-bacia do rio Carinhanha (rios Carinhanha, Cocos segmento I e II e Itaguari), no estado da Bahia, envolve rios que estão em processo de interceptação pela rodovia federal BR-135. Amostragens realizadas tanto a jusante quanto a montante da rodovia, em períodos de seca e de chuva, levaram à captura de 3.520 exemplares (57 espécies; 21 famílias). As espécies de maior ocorrência foram *Deuterodon* cf. *taeniatus*, *Serrapinnus heterodon*, *Astyanax bimaculatus* e *Psalidodon* cf. *rivularis*. No período de seca houve maior número de capturas e dominância de espécies. No período chuvoso registrou-se maior diversidade de espécies e maior distribuição de indivíduos entre as espécies. Os dados indicam a manutenção da estrutura ictiofaunística, apesar das ações antrópicas sofridas pelos ambientes estudados.

Palavras-chaves
ação antrópica
ictiofauna
peixes dulcícolas
riachos
rodovias

Received 14 October 2019; Received in revised from 23 May 2020; Accepted 18 June 2020

ISSN: 2179-4804
DOI: https://doi.org/10.20873/jbb.uft.cemaf.v8n2.horodesky

INTRODUCTION

The São Francisco River, which is recognized as the largest basin entirely contained within the Brazilian territory (Koch et al., 2018), has a drainage area that includes the states of Minas Gerais, Bahia, Goiás, Pernambuco, Sergipe and Alagoas, which account for 7.5% of the country (Pereira, 2007).

In the western region of Bahia, the São Francisco River and its tributaries cross a very rich and complex biome, the Cerrado (Brazilian savannah). This biome is generally characterized by flat terrain and a semi-arid climate with conditions ranging from humid to sub-humid and from dry to sub-humid, and there are two well-defined seasons: wet and hot and dry and cold (Embrapa 2002). In this region, small rivers, streams and alluvial soils are exposed to periodic flooding and the presence of riparian formations (Embrapa, 2002).

The survival of the local fish fauna is strongly dependent on the allochthonous organic material imported from the marginal vegetation (Porto, 2008), which reinforces the need to preserve the environments around the streams. The rivers and streams with high physical complexity in the western region of Bahia tend to exhibit high species richness due to the greater availability and greater combinations of suitable habitats (Castro et al., 2015). However, degradation caused by anthropogenic factors may be responsible for reducing the abundance and diversity of native fish species (Teresa and Casatti, 2017).

It is estimated that the Cerrado regions have suffered, for at least the last 20 years, from the chronic effects of agricultural expansion including major changes in the landscape, especially in terms of land use and land cover (Embrapa, 2002). The rivers of this biome have also been affected by predatory fishing, damming and silting, deforestation of riparian forests and the introduction of exotic species (Costa-Neto et al., 2002). Other anthropogenic impacts include those caused by infrastructure development, such as the paving of a 160-km stretch (between the municipalities of Itacarambi and Cocos) of the federal highway BR-135, a 2.657 km-long highway that connects the North and Southeast regions of Brazil.

Progress in neotropical ichthyology, especially in poorly sampled areas, relies on biotic surveys, which contribute to the identification of regional fish diversity (Schaffer, 1998) and serve as registries of regional environmental vulnerabilities, thus supporting the development of environmental conservation public policies (Castro et al., 2015). The present study aimed to evaluate the possible anthropogenic effects of paving the BR-135 highway on the structure and diversity of the fish fauna, in both the dry and rainy seasons, in three tributaries of the São Francisco River in western Bahia that belong to the Carinhanha River sub-basin (the Carinhanha, Cocos, and Itaguari Rivers).

MATERIAL AND METHODS

Study site

Three rivers in the western state of Bahia were used in the study: the Carinhanha River (P1 - 14°18’39.48”S, 44°27’11.11”W; P2 - 14°18’38.42”S, 44°27’26.46”W), segment I (P1 - 14°14’21.82”S, 44°31’27.53”W; P2 - 14°14’25.87”S, 44°31’32.90”W) and segment II (P1 - 14°12’14.56”S, 44°32’39.45”W; P2 - 14°12’8.28”S, 44°32’30.63”W) of the Cocos River and the Itaguari River (P1 - 14°15’53.24”S, 44°31’13.45”W; P2 - 14°15’52.81”S, 44°31’25.59”W) (Figure 1). The sampling points in each river or river segment were defined based on their location relative to the BR-135 highway; they were located 200 m downstream (P1) and 200 m upstream (P2) from the points where these water bodies intercept the highway.

The Carinhanha and Itaguari Rivers are approximately 50 m wide and have a relatively well-preserved marginal vegetation with only a few areas degraded due to their use for watering livestock. The Cocos River, in both segments, is 10 m wide on average and is an anthropized area with sparse buildings and some patches of vegetation. When sampling during the dry season, segment I was completely dry, so it was not possible to collect any fish at that site.

Fish sampling

Two sampling campaigns were carried out during the rainy season (December/2016) and the dry season (June/2017). The campaigns lasted a total of four days and were conducted in the morning, afternoon and evening. The fishing gear included gill nets (10 m long and 2,0 m high with mesh size = 1,5 with 3,0 cm between adjacent knots), a cast net (mesh size = 0,5 with 2,5 cm between opposing knots and approximately 9 m in circumference), a trawl (mesh size = 0,5 cm between opposing knots and approximately 5 m long and 1,5 wide) and a dip net (mesh size = 0,5 cm). During collection, the following parameters were measured: water temperature (°C) and dissolved oxygen (mg/L) (YSI Oximeter, 550A, USA); pH (Sensoglass pH Meter, SP1400, Brazil); electrical conductivity (µs) (DDBJ-350 Conductivity Meter, China) and turbidity (NTU) (AT2K Turbidimeter, Alfakit, Brazil).

ISSN: 2179-4804
DOI: https://doi.org/10.20873/jbb.uft.cemaf.v8n2.horodesky

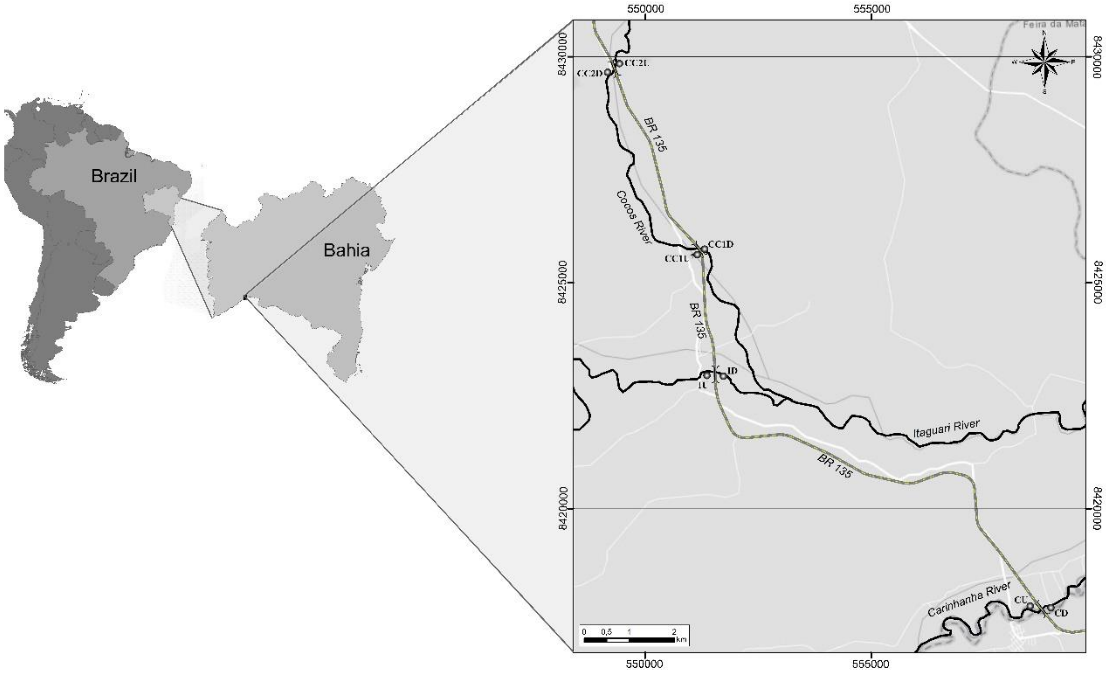

Figure 1 - Geographical location of the rivers and their respective sampling points. CC1U (Cocos I, Upstream); CC1D (Cocos I, Downstream); CC2U (Cocos II, Upstream); CC2D (Cocos II, Downstream); IU (Itaguari, Downstream); ID (Itaguari, Upstream); CD (Carinhanha, Downstream); CU (Carinhanha, Upstream).

The specimens were captured with permission (nr. 753/2016) of the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA). After capture, the fish were immediately identified, measured and released live into the river of origin. The specimens for which field identification was not possible were anaesthetized in benzocaine, desensitized (by spinal cord severing) and fixed in 10% buffered formalin. These animals were placed in plastic bags and stored in containers that were subsequently transported to the Museum of Natural History Capão da Imbuia in Curitiba, Paraná, Brazil, where they were identified to the species level according to Garavello (1979), Sato and Godinho (1999) and Oyakawa et al. (2006). Then, the specimens were quantified, preserved in 70% ethanol and deposited in the collection of the same institution.

Data analysis

The abiotic data measured during sampling as well as the total number of individuals were grouped, and normality was checked using the Shapiro-Wilk test. After confirmation of the non-parametric distribution (p>0,05), the differences between the seasons (dry and rainy) in the abiotic variables and the number of individuals collected were analysed by the Mann-Whitney method for comparisons between two independent groups.

The ecological attributes were determined by calculating the following indices: species richness, Shannon-Weiner diversity, Pielou’s equity and Berger-Parker. Past software, version 2.17, was used for the calculations.

RESULTS AND DISCUSSION

Abiotic variables

A large variation between the two campaigns was observed in the abiotic water parameters, mainly the dissolved oxygen, turbidity and temperature measured in the Carinhanha and Itaguari Rivers. The absolute concentrations of dissolved oxygen were lower in the two segments of the Cocos River compared to those in the other rivers, and they may have been directly related to the small volume of water at the two monitored points as well as the low flow and the low water turbulence (Kallenbach et al., 2018). In a stream such as Cocos, lower concentrations of oxygen may influence the integrity of local biochemical processes, thus directly and indirectly affecting the biota (Magoulick and Kobza, 2003) (Table 1).

Diurnal and seasonal fluctuations in physical and chemical variables are typical in rivers. The interaction among photosynthesis, respiration and gas exchange results in diurnal variations in

ISSN: 2179-4804
DOI: https://doi.org/10.20873/jbb.uft.cemaf.v8n2.horodesky

oxygen and carbon dioxide (Odum, 1956), whose relative concentrations are also affected by daily temperature variations (Drysdale et al., 2003, Null et al., 2017). The observed temperature variations occurred in response to the normal climate regime of the region, where water bodies present seasonal and diurnal variations and may even exhibit vertical stratification. Aquatic organisms have thermal tolerance limits and optimal temperatures for growth, presenting patterns of reproductive migration that tend to be regulated by water temperature (Calijuri et al., 2013). In addition, higher temperatures predispose equally higher rates of organic matter decomposition (Webster and Benfield, 1986) and increased concentrations of dissolved nutrients (Grattan and Suberkropp, 2001, Jalali and Kolahchi, 2009), with a consequent reduction in the concentrations of dissolved oxygen (Bjelke, 2005).

There was large variation in the turbidity values between the two campaigns that was caused by the increased water level of the rivers during the rainy season and the consequent increase in the amount of suspended particulate matter. According to Parra et al. (2018), increased turbidity can reduce the incidence of sunlight reaching the riverbed, reducing the rates of photosynthesis and even leading to the eggs of fish and benthic invertebrates being covered by the particulate matter. In addition, increased turbidity can interfere with feeding and defence of the fishes against predators (Wilber and Clarke, 2001).

Although it is known that the surrounding vegetation can alter many of the ecological characteristics of a water body by influencing variables such as luminosity, temperature, margin stability, allochthonous material (plants and animals) input and autochthonous productivity (Zhao et al., 2018), there is evidence that the measured abiotic variables were most influenced by the current, the type of substrate and the morphology of the studied rivers.

Table 1 - Mean values (max-min) of the abiotic variables measured during the sampling periods. Different letters indicate a significant difference (p<0,05) between periods. TU: turbidity; C: conductivity; DO: dissolved oxygen; T: temperature.

River	Point	Period	TU (NTU)	C (µs)	pH	DO (mg/L)	T (° C)
Carinhanha	**P1**	**R**	52,7 ^{a} (21,1-119,0)	37,6 (14-60)	7,4 (6,8-8,5)	7,5 ^{a} (7,4-7,7)	26,6 ^{a} (25,2-27,5)
		D	0,3 ^{b} (0,0-1,9)	38,0 (35-39)	7,8 (7,7-7,9)	6,1 ^{b} (5,9-6,3)	23,9 ^{b} (22,6-25,2)
	P2	**R**	96,4 ^{a} (19,8-319,0)	40,6 (33-49)	7,4 (6,4-8,4)	7,6 ^{a} (7,4-7,8)	26,7 ^{a} (25,3-27,5)
		D	0,13 ^{b} (0,47-1,88)	38,7 (37-39)	7,7 (7,7-7,9)	6,1 ^{b} (5,7-6,4)	24,0 ^{b} (22,7-25,2)
Cocos I	**P1**	**R**	9,1 (3,3-13,8)	402,7 (383-420)	7,1 (6,4-7,9)	6,3 (5,5-9,4)	26,5 (25,0-27,5)
		D	-	-	-	-	-
	P2	**R**	44,9 (4,6-719,0)	386,4 (164-423)	7,3 (6,3-8,0)	6,5 (5,0-7,1)	26,2 (24,5-27,2)
		D	-	-	-	-	-
Cocos II	**P1**	**R**	73,4 (4,9-476,0)	363,7 (155-436)	7,2 (5,9-7,7)	4,6 (3,6-5,7)	26,4 (23,5-28,1)
		D	16,6 (2,5-60,1)	389,6 (308-421)	7,9 (7,6-8,3)	5,1 (4,8-5,7)	22,6 (20,9-23,8)
	P2	**R**	13,2 (6,6-20,3)	395,5 (382-429)	6,8 (6-7,8)	4,5 (3,3-5,8)	26,7 (24,7-29,2)
		D	11,7 (0,7-44,7)	403,1 (376-421)	7,9 (7,3-8,2)	4,3 (3,7-4,8)	22,6 (21,0-23,6)
Itaguari	**P1**	**R**	42,5^{a} (10,4-135,0)	22,2 (14-34)	8,0 (6,7-8,5)	7,6 ^{a} (7,2-7,8)	25,8 ^{a} (23,8-26,5)
		D	1,1^{b} (0,0-6,2)	20,3 (19-21)	8,1 (7,9-8,3)	6,1 ^{b} (5,8-6,3)	24,2 ^{b} (22,8-25,0)
	P2	**R**	56,3^{a} (13,6-210,0)	21,0 (14-31)	7,3 ^{a} (6,6-8,2)	7,6 ^{a} (7,5-7,7)	25,9 ^{a} (24,7-26,6)
		D	2,9^{b} (0,0-14,0)	20,0 (19-22)	7,9 ^{b} (7,6-8,2)	6,0 ^{b} (5,8-6,4)	24,5 ^{b} (23,0-26,9)

ISSN: 2179-4804
DOI: https://doi.org/10.20873/jbb.uft.cemaf.v8n2.horodesky

Ichthyofaunistic community

Altogether, 3.520 individuals were captured representing 57 species of 21 families and five orders (Table 2). The most abundant orders in terms of the number of individuals were Characiformes (n=1.225) and Siluriformes (n=389). In turn, the most abundant families were Characidae (n=951) followed by Loricariidae (n=234) and Anostomidae (n=66). The predominance of the families Characidae and Loricariidae in the present study is consistent with the patterns expected for Neotropical rivers (Buckup et al., 2007, Lowe-McConnell, 1999). A previous study by Mattox et al. (2008) in rivers in the same study region (Itaguari, Corrente, Formoso, Lagoa Grande, Morro Furado and Riacho Verde) demonstrated a greater abundance of species belonging to such families.

Of the predominant species, those of the family Characidae stand out. According to Orsi et al. (2004), this family inhabits areas with abundant food that are suitable for reproduction and present adjacent refuges, thus demonstrating that the rivers evaluated here had the environmental characteristics required by these fish.

The most abundant species in the dry season were *Psalidodon* cf. *taeniatus* (n=902) and *Serrapinnus heterodon* (n=170), while those in the rainy season were *Astyanax bimaculatus* (n=215) and *Deuterodon* cf. *rivularis* (n=211). In the dry season, a greater number of captured specimens (n=1.929 individuals, 51 species) was recorded compared to the rainy season (n=1.591 individuals, 42 species), but no significant difference was observed between the two periods ($p>0.05$).

A total of 15 species endemic to the São Francisco River basin were found. During the sampling campaign in the dry season, a single specimen of *L. alexandri* was captured, a species that is on the ICMBio Red List of Threatened Species (ICMBIO, 2015) and is native to the São Francisco River basin. Popularly known in Brazil as "pacamã", it can weigh up to 8 kg as an adult (Sato and Godinho, 1999). It is considered a fish of high commercial value, and its production by aquaculture has been tested in the country (Tenório et al., 2006).

Photographs of the species with highest occurrence are presented in Figure 2.

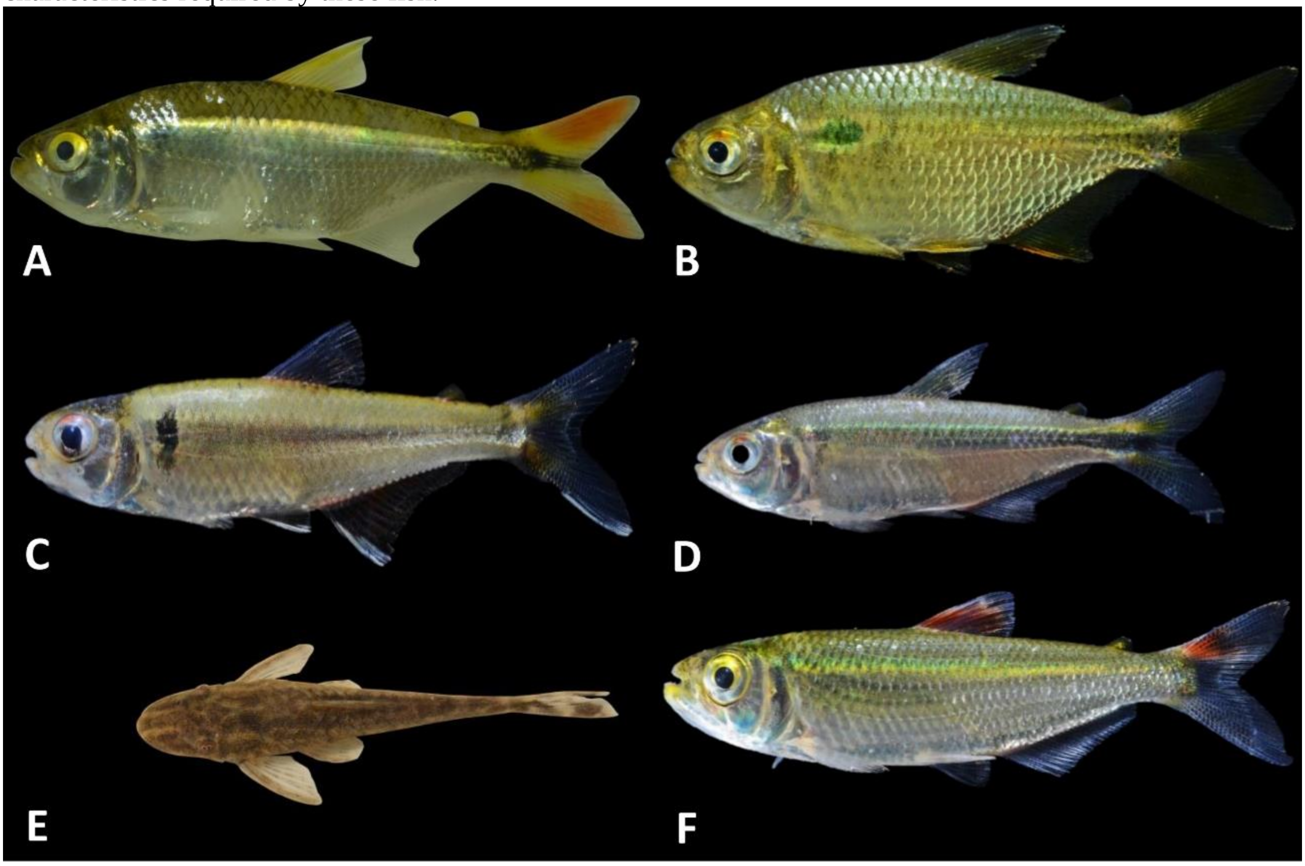

Figure 2 - Species with higher occurrence sampled in the Carinhanha, Cocos (segments I and II) and Itaguari Rivers. **a.** *Psalidodon taeniatus*; **b.** *Astyanax bimaculatus*; **c.** *Piabina argentea*; **d.** *Psalidodon fasciatus*; **e.** *Hisonotus vespuccii*; **f.** *Bryconops affinis*.

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Table 2 -List of families and species collected in the Carinhanha, Cocos (segments I and II) and Itaguari Rivers. R: rainy season; D: dry season; P1: downstream; P2: upstream. * endemic species; ** endemic and endangered species.

Family/species	**Carinhanha**				**Cocos I**		**CocosII**				**Itaguari**				**Total (n)**
	P1		**P2**		**P1**	**P2**	**P1**		**P2**		**P1**		**P2**		
	R	**D**	**R**	**D**	**R**	**D**	**R**	**D**	**R**	**D**	**R**	**D**	**R**	**D**	
Anostomidae															
Leporellus vittatus (Valenciennes, 1850)	0	4	3	4	1	0	1	0	0	0	0	0	0	2	**15**
Leporinus bahiensis (Steindachner, 1875)	3	0	5	0	1	1	4	0	7	0	0	2	0	2	**25**
Megaleporinus conirostris (Steindachner, 1875)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**1**
**Megaleporinus reinhardti* (Lütken, 1875)	1	0	3	1	0	0	0	0	0	0	0	0	0	1	**6**
**Leporinus taeniatus* (Lütken, 1875)	1	6	6	13	1	1	22	5	1	0	0	2	1	11	**70**
**Schizodon knerii* (Steindachner, 1875)	0	0	1	0	0	0	0	0	0	0	2	1	0	0	**4**
Apteronotidae															
Apteronotus brasiliensis (Reinhardt, 1852)	0	0	0	0	0	0	0	0	0	0	0	2	0	0	**2**
Aspredinidae															
**Bunocephalus* cf. *minerim* (Carvalho, Cardoso, Friele Reis, 2015)	4	0	0	1	0	0	0	0	0	0	0	0	1	0	**6**
Auchenipteridae															
Centromochlus bockmanni (Sarmento-Soares eBuckup, 2005)	4	2	0	0	0	0	0	0	0	0	1	0	0	0	**7**
Trachelyopterus galeatus (Linnaeus, 1766)	20	0	0	0	0	0	0	2	0	2	0	1	0	0	**25**
Bryconidae															
Brycon nattereri (Günther, 1864)	0	0	3	0	0	0	0	0	0	0	0	0	0	0	**3**
Salminus hilarii (Valenciennes, 1850)	1	0	1	0	3	0	0	0	0	0	0	0	3	0	**8**
Callichthyidae															
**Corydoras multimaculatus* (Steindachner, 1907)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**1**
Hoplosternum littorale (Hancock, 1828)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**

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Family/species	Carinhanha				Cocos I		CocosII				Itaguari				Total (n)
	P1		P2		P1	P2	P1		P2		P1		P2		
	R	D	R	D	R	D	R	D	R	D	R	D	R	D	
Characidae															
Astyanax bimaculatus (Linnaeus, 1758)	0	1	0	1	78	14	80	9	43	10	0	2	0	2	**240**
**Psalidodon fasciatus* (Cuvier, 1819)	82	0	62	0	2	0	11	0	2	0	20	0	21	3	**203**
Psalidodon cf. *rivularis* (Lütken, 1875)	2	0	4	0	43	42	40	0	77	0	0	0	3	0	**211**
Deuterodon cf. *taeniatus* (Jenyns, 1842)	0	147	0	187	0	0	0	183	0	84	0	211	0	90	**902**
Piabarchus stramineus (Eigenmann, 1908)	0	20	0	42	0	0	0	0	0	0	0	5	0	12	**79**
Bryconops affinis (Günther, 1864)	8	0	9	2	0	0	0	6	0	0	18	12	29	16	**100**
Hemigrammus marginatus (Ellis, 1911)	0	0	0	0	0	0	0	0	0	0	0	0	3	0	**3**
Moenkhausia sanctaefilomenae (Steindachner, 1907)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
**Phenacogaster franciscoensis* (Eigenmann, 1911)	0	1	4	3	0	0	15	22	0	5	4	12	3	0	**69**
Piabina argentea (Reinhardt, 1867)	81	27	43	14	0	0	0	0	0	0	20	5	17	15	**222**
Serrapinnus heterodon (Eigenmann, 1915)	0	8	0	75	11	8	4	48	0	1	2	27	0	11	**195**
Tetragonopterus chalceus (Spix and Agassiz, 1829)	0	0	1	0	0	3	38	7	0	4	1	3	3	1	**61**
Cichlidae															
**Cichlasoma sanctifranciscense* (Kullander, 1983)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	**2**
Crenicichla lacustris (Castelnau, 1855)	25	1	1	3	0	0	0	5	0	0	7	11	3	5	**61**
Crenuchidae															
Characidium cf. *fasciatum* (Reinhardt, 1867)	0	1	0	17	0	0	0	21	0	2	0	17	0	4	**62**
Characidium zebra (Eigenmann, 1909)	9	0	30	0	0	0	0	0	0	0	7	1	2	0	**49**
Curimatidae															
**Curimatella lepidura* (Eigenmann and Eigenmann, 1889)	0	0	0	0	0	0	0	14	0	1	0	0	0	0	**15**
Steindachnerina elegans (Steindachner, 1875)	0	0	2	0	2	0	20	9	16	3	4	3	1	0	**60**

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Family/species	Carinhanha				Cocos I		CocosII				Itaguari				Total (n)
	P1		P2		P1	P2	P1		P2		P1		P2		
	R	D	R	D	R	D	R	D	R	D	R	D	R	D	
Erythrinidae															
Hoplias aff. *malabaricus* (Bloch, 1794)	26	0	0	1	3	2	0	0	0	2	0	6	0	0	**40**
Gymnotidae															
Gymnotus aff. *carapo* (Linnaeus, 1758)	1	2	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Heptapteridae															
Cetopsorhandia iheringi (Schubart and Gomes, 1959)	0	1	0	2	0	0	0	0	0	0	0	4	0	0	**7**
Imparfinnis borodini (Mees and Cala, 1989)	0	0	3	8	0	0	0	0	0	0	0	0	0	0	**11**
Imparfinnis cf. *minutes* (Lütken, 1874)	10	4	11	2	0	0	0	0	0	0	0	0	0	0	**27**
Pimelodella cf. *lateristriga* (Lichtenstein, 1823)	0	1	8	0	0	0	0	1	0	0	0	0	0	0	**10**
Rhamdia quelen (Quoy and Gaimard, 1824)	0	0	0	0	7	17	3	0	2	0	0	0	0	0	**29**
Loricariidae															
Harttia cf. *Longipinna* (Langeani, Oyakawa and Montoya-Burgos, 2001)	0	0	7	1	0	0	0	0	0	0	0	0	0	0	**8**
**Hisonotus* cf. *vespuccii* (Roxo, Silva and Oliveira, 2015)	18	8	35	33	0	0	30	6	0	1	2	14	2	40	**189**
Hypostomus cf. *garmani* (Regan, 1904)	8	11	52	20	0	0	0	1	0	0	0	3	13	1	**109**
Hypostomus francisci (Lütken, 1874)	12	0	22	15	0	8	12	2	0	0	0	0	13	0	**84**
Hypostomus cf. *wuchereri* (Günther, 1864)	0	0	0	5	0	0	0	1	0	0	0	4	0	6	**16**
Hypostomus commersoni (Valenciennes, 1836)	0	6	0	7	0	0	0	2	0	0	0	1	0	2	**18**
Parodontidae															
**Apareiodon hasemani* (Eigenmann, 1916)	0	0	6	0	0	0	0	1	0	0	2	0	3	0	**12**
Apareiodon piracicabae (Eigenmann, 1907)	0	0	1	4	0	0	0	0	0	0	0	0	1	0	**6**
**Parodon hilarii* (Reinhardt, 1867)	16	0	2	6	9	0	0	0	0	0	0	1	6	2	**42**

ISSN: 2179-4804
DOI: https://doi.org/10.20873/jbb.uft.cemaf.v8n2.horodesky

Table 2 -List of families and species collected in the Carinhanha, Cocos (segments I and II) and Itaguari Rivers. R: rainy season; D: dry season; P1: downstream; P2: upstream. * endemic species; ** endemic and endangered species.

Family/species	Carinhanha				Cocos I		CocosII				Itaguari				Total (n)
	P1		P2		P1	P2	P1		P2		P1		P2		
	R	D	R	D	R	D	R	D	R	D	R	D	R	D	
Pimelodidae															
Pimelodus maculatus (Lacepède, 1803)	34	0	1	1	0	0	0	0	0	0	0	2	0	0	**38**
Pimelodus cf. *blochii* (Valenciennes, 1840)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Prochilodontidae															
Prochilodus costatus (Valenciennes, 1850)	1	0	0	0	0	0	0	1	0	0	0	0	0	0	**2**
Pseudopimelodidae															
**Pseudopimelodus charus* (Valenciennes, 1840)	0	0	21	0	0	0	0	0	0	0	4	0	0	0	**25**
***Lophiosilurus alexandri* (Steindachner, 1876)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Serrasalmidae															
**Myleus* cf. *micans* (Lütken, 1875)	0	3	19	21	0	0	0	0	0	0	0	3	0	8	**54**
Serrasalmus cf. *brandtii* (Lütken, 1875)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Sternopygidae															
Eigenmannia besouro (Peixoto and Wosiacki, 2016)	3	1	26	11	0	0	0	0	0	0	5	5	6	6	**63**
Sternopygus macrurus (Bloch e Schneider, 1801)	0	3	2	1	0	0	0	0	0	0	4	1	0	2	**13**
Synbranchidae															
Symbranchus aff. *Marmoratus* (Bloch, 1795)	0	1	0	0	0	0	0	0	0	0	0	0	0	1	**2**
Overall total	**370**	**260**	**394**	**503**	**161**	**96**	**280**	**349**	**148**	**115**	**104**	**361**	**134**	**245**	**3520**

ISSN: 2179-4804
DOI: https://doi.org/10.20873/jbb.uft.cemaf.v8n2.horodesky

Table 3 - Ecological attributes of the species sampled at the Carinhanha, Cocos I, Cocos II and Itaguari Rivers during the dry (D) and rainy (R) seasons.

Ecological attributes	**Carinhanha**				**Cocos I**				**Cocos II**				**Itaguari**			
	P1		**P2**		**P1**		**P2**		**P1**		**P2**		**P1**		**P2**	
	R	**D**	**R**	**D**	**R**	**D**	**R**	**D**	**R**	**D**	**R**	**D**	**R**	**D**	**R**	**D**
Species richness	23	23	31	31	12	9	13	22	7	11	17	28	20	25		
Absolute abundance (n)	370	260	394	503	161	96	280	349	148	115	104	361	134	245		
Relative abundance (%)	10,51	7,36	11,20	14,29	4,58	2,73	7,96	9,92	4,21	3,27	2,96	10,26	3,81	6,96		
Shannon-Weiner index	2,44	1,77	2,79	2,33	1,54	1,65	2,14	1,83	1,23	1,13	2,40	1,88	2,48	2,30		
Berger-Parker index	0,22	0,56	0,16	0,37	0,48	0,44	0,28	0,52	0,52	0,73	0,19	0,58	0,22	0,37		
Pielou's equity index	0,78	0,57	0,81	0,68	0,62	0,75	0,84	0,59	0,63	0,47	0,84	0,56	0,83	0,72		

ISSN: 2179-4804
DOI: https://doi.org/10.20873/jbb.uft.cemaf.v8n2.horodesky

The diversity index (Shannon-Weiner) showed that despite the greater number of individuals collected during the dry season, the greatest species diversity occurred in the rainy season, mainly in the Carinhanha and Itaguari Rivers. In the Cocos River (segment II), species dominance (Berger-Parker) was higher in the dry period, whereas the distribution of individuals among species (equity) was higher in the rainy season (Table 3).

The higher abundances recorded in the Carinhanha and Itaguari Rivers were probably related to the size of these water bodies and their physical and chemical characteristics (bottom type, marginal vegetation and water quality-related variables). Casatti and Castro (2006) reported that environments with characteristics similar to those found in these rivers exhibit quite varied habitats and microhabitats, which may directly influence the composition of the fish community.

Of the ecological attributes evaluated, it was evident that the Carinhanha and Itaguari Rivers had higher diversity indices and lower species dominance. The high dominance values found in the two segments of the Cocos River occurred due to the low number of species and the predominance of Astyanax. According to Allan e Flecker (1993), fish populations of rivers with characteristics such as the Cocos River (segments I and II) are more susceptible to human activities, such as fishing, the introduction of exotic species, alteration and destruction of the lotic and riparian ecosystem and pollution of aquatic ecosystems. Casatti et al. (2012) and Teshima et al. (2015) also reinforce that the dominance of fish species in streams is usually due to anthropogenic impacts, which lead to the loss of diversity by favouring the predominance of tolerant and opportunistic fish (r-strategists) that replace more sensitive and specialized species (k-strategists) that occur in smaller numbers. There is evidence that such a phenomenon is occurring, particularly in the Cocos River and less so in the other studied rivers.

CONCLUSIONS

In the present case, since the BR-135 expansion activities in the studied rivers are ongoing, it is not yet possible to discard the hypothesis that they may cause ecological, population or structural changes in the fish communities of the three sampled tributaries of the San Francisco River. However, based on the distribution, abundance and diversity index data from this study, the fish fauna are currently still relatively diversified, and the structure has been only slightly or not affected by the works already performed in that stretch of highway.

ACKNOWLEDGEMENTS

The authors thank the National Department of Transport Infrastructure (DNIT) for financial support and to the National Council for Scientific and Technological Development (CNPq) for the Research Productivity grant (Process 304633/2017-8).

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