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Influence of environmental variables and anthropogenic perturbations on stream fish assemblages, Upper Paraná River, Central Brazil

Nicelly B. Araújo[1] and Francisco L. Tejerina-Garro[2]

The Ouvidor River, a tributary of the Upper Paraná River, drains areas covered by cerrado vegetation in Central Brazil. We collected data for environmental variables (water temperature, dissolved oxygen, pH, conductivity, turbidity, water velocity, luminosity, channel substrate and width) and anthropogenic perturbations (industry, reservoirs, urban areas) that may structure the fish assemblage in ten stream sites of the Ouvidor River basin. In each stream we delimited one 50 m long site where fish were captured by electrofishing and abiotic data were collected every two month between August 2004 and June 2005. Co-inertia analysis indicated that pH, water velocity, channel width and water temperature most strongly structured the fish assemblages. The interactions of water velocity and channel width with the fish assemblage were not directly affected by wet and dry seasons but the opposite was true for pH and water temperature.

O rio Ouvidor é um tributário do Alto rio Paraná, Brasil Central, que drena áreas cobertas por vegetação do tipo Cerrado. Em dez cursos d'água da bacia do referido rio foram coletados dados referentes às variáveis ambientais (temperatura de água, oxigênio dissolvido, pH, condutividade, turbidez, velocidade da água, luminosidade, substrato do canal e largura) e perturbações antropogênicas (indústria, represas, área urbana) que poderiam estruturar as assembléias de peixes. Em cada curso d'água foi delimitada uma estação de 50 m de comprimento, onde bimestralmente entre agosto de 2004 e junho de 2005 os peixes foram capturados utilizando-se a pesca elétrica e coletados os dados abióticos. A análise de co-inércia indicou que o pH, a velocidade da água, a largura do canal e a temperatura da água são os fatores que mais fortemente estruturaram as assembléias de peixes. A interação da velocidade da água e a largura do canal com as assembléias de peixes não foram afetadas diretamente pelo regime hidrológico regional (chuva e estiagem), enquanto que o contrário é observado para as variáveis pH e temperatura da água.

Key words: Neotropical fish, Goiás State, Cerrado.

Introduction

The structural and functional characteristics of aquatic communities respond to environmental oscillations that differ in spatial and temporal scales (Matthews, 1998). Four physical habitat characteristics are widely recognized as directly important for fish species distribution and abundance in streams: water depth (Angermeier & Karr, 1994; Penczak *et al.*, 1994), current velocity (Mendonça *et al.*, 2005), composition of the channel substrate (Cunico *et al.*, 2006) and riparian vegetation cover (Ferreira & Casatti, 2006a; Mérigoux *et al.*, 1998; Penczak *et al.*, 1994). Metrics representing these characteristics aid analyses of habitat modification on fish assemblages (Tejerina-Garro *et al.*, 2005). However, fish assemblages are also influenced by other characteristics of the aquatic environment such as the historic/biogeographic conditions, water temperature, flow regime, predation, competition, and diseases (Poff *et al.*, 1997; Jackson *et al.*, 2001).

In the Neotropical region, interest in stream fish ecology is relatively recent (Oliveira & Bennemann, 2005), including the influence of environmental variables on fish assemblage structure (Fialho *et al.*, 2008). Consequently, there have been few studies concerning this subject in the upper Paraná River basin. Abes & Agostinho (2001) reported that the variable set of channel width, depth, water and air temperature, dissolved oxygen, conductivity, pH and substrate influenced fish richness and assemblage composition. Penczak *et al.* (1994) found that pH, conductivity, depth, channel width, and pres-

[1]Programa de Pós-graduação em Ecologia e Produção Sustentável, Universidade Católica de Goiás - Campus II, Avenida Engler s/n, Jardim Mariliza, 74605-010, Goiânia, Goiás, Brazil. nicellybraudes@gmail.com
[2]Centro de Biologia Aquática, Universidade Católica de Goiás - Campus II, Avenida Engler s/n, Jardim Mariliza, 74605-010, Goiânia, Goiás, Brazil. garro@ucg.br

ence of macrophytes structured fish assemblages. Conductivity, water temperature, pH, dissolved oxygen (Braga & Andrade, 2005) and pH, water temperature, conductivity, chemical dissolved oxygen, and turbidity (Fialho *et al.*, 2008) were also related to differences in fish assemblage structure. However, these relationships were also affected by anthropogenic impacts related to different land uses (Penczak *et al.*, 1994) such as domestic sewage, agriculture, ranching, and urbanization (Fialho *et al.*, 2008). Despite their similarities in stream hydromorphology, neotropical streams are historically and geomorphologically different. Also, any environmental modification, natural or anthropogenic, can influence local fish zoogeography and modify the fish assemblage composition to some degree via local species extirpations (Gorman & Karr, 1978; Tonn, 1990) and introductions (Lomnicky *et al*., 2007). The lack of knowledge about fish faunas and environmental change in neotropical regions like those of the Central Brazil are of concern to ichthyologists and ecologists because regional biodiversity is unknown and some species appear to be disappearing of some streams even before it is possible to establish their spatial distribution (Tejerina-Garro, 2008)

The aim of this article is to identify which environmental variables (water temperature, dissolved oxygen, pH, conductivity, turbidity, water velocity, luminosity, channel substrate and width) and anthropogenic perturbations (industry, reservoirs, urban area) most structure the fish assemblages in streams sites of the Upper Paraná River, Central Brazil.

Material and Methods

Study area. The Ouvidor River basin is located in southern Goiás State, Central Brazil, and is a tributary of the Upper Paraná River, the second largest drainage basin of South America (Lowe-McConnell, 1999). The climate is semi-arid with marked wet and dry seasons, and air temperature varying between 16.9°C and 37.2°C. The predominant soil in the basin is red latosol (IBGE, 2005). The sampled stream sites (Table 1) have narrow (< 8 m) and shallow (< 1 m) channels. Their substrate is formed predominately by sand and gravels (Buraco, Olhos d'água, Posse dos Rodrigues, Riacho streams), bedrock (Lagoa, Ouvidor and Taquara II), or mud (Taquara I). The sites were bordered by riparian vegetation typical of the cerrado biome (Ribeiro, 1998), pasture (Ouvidor, Posse dos Rodrigues, Riacho, Olhos d'água streams) or industrial areas (Taquara II and Santo Antônio). Some channels were fragmented by reservoirs (Taquara I, Buraco, Sapê streams), received domestic sewage (Santo Antônio) or drained urban areas (Lagoa).

Sampling protocols. Fish, environmental variables and anthropogenic perturbations data were collected from one site in each of nine streams and one upper reach of the Ouvidor River main channel (Fig. 1, Table 1) every two months between August 2004 and June 2005 to assess changes in the fish assemblages associated with seasonality (Welcomme, 1979). In each stream, a 50 m long site was delimited based on easy access conditions, its geographic coordinates (Garmin 12) were obtained, and six transects every ten meters were marked.

Table 1. Streams sites sampled in the Ouvidor River basin and their geographic coordinates.

Site	Code	Geographic coordinates S	Geographic coordinates W
Taquara II	TII	18°09'16.6"	47°52'37.1"
Taquara I	TI	18°09'32.3"	47°51'08.5"
Buraco	B	18°09'40.2"	47°49'46.1"
Santo Antônio	SA	18°12'18.6"	47°52'34.9"
Lagoa	L	18°15'16.7"	47°49'25.6"
Ouvidor	Ouv	18°17'47.6"	47°52'48.7"
Posse dos Rodrigues	PR	18°18'09.0"	47°52'49.8"
Riacho	R	18°18'48.2"	47°55'15.8"
Sapê	S	18°21'28.2"	47°53'30.0"
Olhos d'água	Od	18°23'21.3"	47°54'28.8"

Fish were sampled by electrofishing, which is efficiently for collecting small fish species (Severi *et al.*, 1995) in lotic environments (Mazzoni *et al.*, 2000). The electrofishing equipment was powered by a portable generator (HONDA, 1800 W, 220 V) connected to a DC transformer then two electrified net rings (anode and cathode). Output voltage varied from 100 to 600 V. Each reach was fished three times from downstream to upstream by three people following the protocol suggested by Esteves & Lobón-Cerviá (2001). Collected fish were fixed in 10% formalin and identified to species or genus in the laboratory. Voucher specimens of each species were deposited in the Museu de Ciências e Tecnologia, Pontifícia Universidade Católica do Rio Grande do Sul, Brazil.

Channel width, substrate, water velocity and luminosity (total luminous flux incident on the channel surface) and the anthropogenic perturbations were measured at each transect. Water temperature and dissolved oxygen were measured at the first, third and sixth transects and the pH, conductivity and turbidity were measured at the center of each reach (Table 2).

Data analysis. The data matrices consisted in presence/absence values aiming to treats dominant species equally than rare species (McCune & Grace, 2002), qualitative variables values (channel substrate and anthropogenic perturbations), and average quantitative variables values for each reach. All data were grouped by season (wet and dry). The fish and qualitative and quantitative data matrices were submitted separately to Principal Component Analysis (PCAs). In the case of the quantitative data, the PCA was performed using the correlation method recommended when data collected was measured in different unities, whereas covariance was used for the fish and qualitative data because it was measured in the same unit (Dolédec & Chessel, 1991). Then the results of each PCA were submitted to a co-inertia analysis (COI) separately (fish *vs.* quantitative variables; fish *vs.* qualitative). We used multivariate ordination of COI because it is sensitive to a small number of samples (10 sites; Dolédec & Chessel, 1994) and aids identification of fish assemblage patterns resulting from the influence of the variables considered

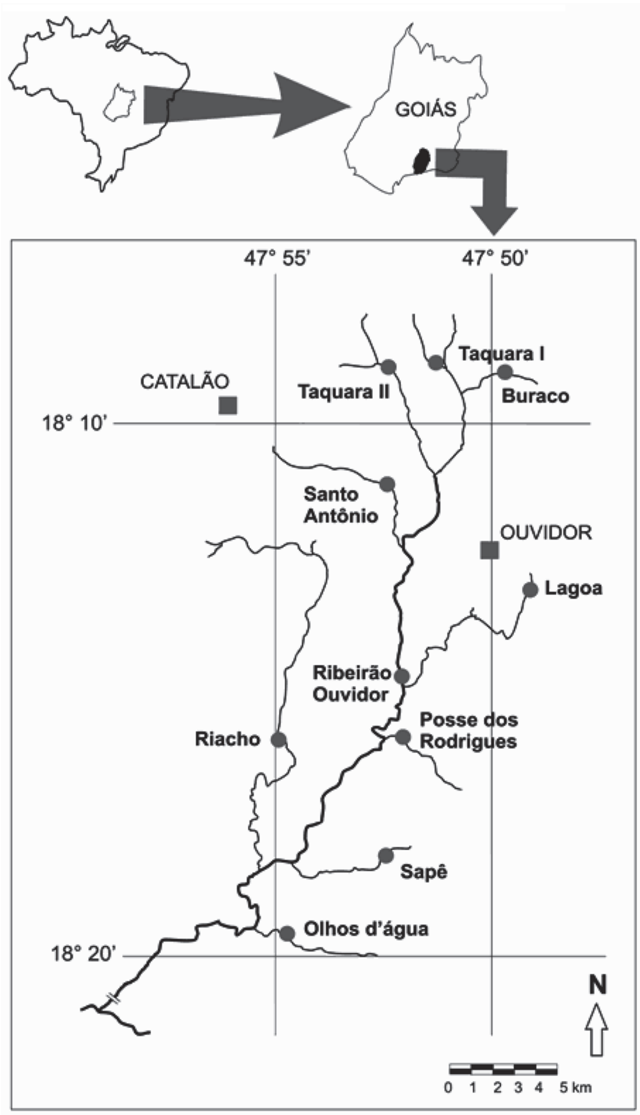

Fig. 1. Locations of the sampled sites (dots) in the streams of the Ouvidor River, Goiás State, Brazil. Squares indicate the main cities.

(McCune & Grace, 2002). The co-structure between fish assemblages and variables resulting from the co-inertia analysis was tested using a Monte Carlo test (1000 iterations). The collinearity between quantitative variables resulting from the PCA was tested using a Pearson correlation test (Zar, 1998). All analyses were performed using ADE-4 software (Thioulouse *et al.*, 2001).

Results

We collected 4049 specimens and 35 fish species (Table 3). Fish abundance was high at the Buraco site during the dry (601 specimens) and wet (641) seasons. Conversely, low abundance was observed at the Lagoa (76, dry season) and Taquara I (11, wet season) sites.

The COI analysis indicated that the co-structure between the fish matrix and the quantitative variables was significant ($p = 0.000$; characin *P. argentea* and the catfish *C.* cf. *iheringi*, *Hisonotus* sp., *Hypostomus* sp. and *H. margaritifer*) but not with the qualitative variables ($p = 0.084$; Table 4). In the first case, two axes explained 70.74% of the total inertia and the correlation (r) between the fish assemblage and the quantitative variables was significant (axis 1 = 0.86; axis 2 = 0.90; Table 4). On axis 1, the ordination of fish assemblages and stream reaches was related to water velocity and channel width in the dry and wet seasons (Fig. 2). The fish assemblages represented by these species were associated with reaches with the higher water velocities and wider channels observed in the Ouvidor River and Riacho stream (right sides of Figs. 2a-b; Table 5). By contrast, fish species such as the characin *H.* aff. *malabaricus* and the cichlid *T. rendalli* were related to stream reaches with low water velocities and narrow channel widths as observed in the Buraco and Sapê streams during dry season (Fig. 2; Table 5).

On axis 2, fish assemblages and sites were discriminated by pH and water temperature seasonally (Fig. 2; Table 4). In the dry season, the characins *Bryconamericus* sp.2, *P. myersi*, *A. eigenmanniorum*, *A. piracicabae*, *Bryconamericus* sp.1

Table 2. Qualitative and quantitative variables measured in the Ouvidor River and its tributaries.

Local	Type	Variable	Code	Category	Method/Equipment
Landscape	Qualitative	Anthropogenic perturbation	-	City	Visual
			-	Industry	
			-	Reservoir	
Channel	Qualitative	Channel substrate	-	Sand	Visual
			-	Gravel	
			-	Mud	
			-	Rock	
	Quantitative	Channel width (m)	CW	-	Tape measure
		Water velocity (cm/s)	WV	-	General Oceanic 2030 Series
		Water temperature (°C)	WT	-	Lutron DO-5510
		Luminosity (lux)	LU	-	Polaris
		Dissolved oxygen (mg/L)	DO	-	Lutron DO-5510
		pH	pH	-	Lutron PH-206
		Conductivity (µS/cm)	CO	-	WTW315i
		Turbidity (UTN)	TU	-	LaMotta2020

and the catfish *H. nigricans* were associated with sites, except Olhos d'água and Lagoa, where the water was acidic and the temperature low (superior side of Figs. 2a-b; Table 5). In the wet season *H. margaritifer* and *P. nasus* were associated with sites characterized by elevated water temperature and alkaline pH such as displayed by the streams Posse dos Rodrigues, Olhos d'água and Lagoa (Fig. 2; Table 5).

Discussion

One goal of ecosystem ecology is to establish how assemblages of organism, in this case fish, are related to environmental oscillations (Braga, 2004). Such relationships are characterized by the simultaneous influence of multiple environmental variables on assemblages (Bini, 2004). This also was the case in this study, where four variables (water velocity, channel width, water temperature and pH) structured fish assemblages to the greatest degree among the variables measured.

In our study, water velocity and the channel width were little affected by seasonality as normally occurs in natural conditions (Poff *et al.*, 1997; Tejerina-Garro & Mérona, 2001).This situation is often related to modification of stream hydrology by reservoirs, but reservoirs did not significantly influence many of our sites and fish assemblage ordination results. Reservoirs are known to regulate water velocity and channel width downstream (Mérona *et al.*, 2005), increase water residence time (Thomaz *et al.*, 1997), increase downstream substrate size (Oliveira & Lacerda, 2004), and consequently alter biotic communities (Agostinho *et al.*, 1992). This likely only occurred in sites with low water velocities and narrow channel such as Taquara I, Buraco and Sapé, each of which were located upstream of a reservoir.

In this study the relationship of catfish (*C.* cf. *iheringi*, *Hisonotus* sp., *Hypostomus* sp. and *H. margaritifer*) and characin (*P. argentea*) to sites with elevated water velocities and wide channels can be explained in part by the interaction of environmental filters and the functional characteristics of these species (Poff, 1997). Some of the sites sampled had rocky substrates and pools; both of which provide habitat for algae (Esteves, 1988; Bennemann *et al.*, 2005) and subsequently herbivorous catfish species such as *Hisonotus* and

Table 3. Relative abundance of fish species by site. B = Buraco; L = Lagoa; Od = Olhos d'água; Ouv = Ouvidor; PR = Posse dos Rodrigues; R = Riacho; S = Sapê; SA = Santo Antônio; TI = Taquara I; TII = Taquara II.

Species	Code	Stream site																				Total
		Dry season										Wet season										
		B	L	Od	Ouv	PR	R	S	SA	TI	TII	B	L	Od	Ouv	PR	R	S	SA	TI	TII	
Apareiodon ibitiensis	Apaibi	-	-	-	-	-	-	-	0.02	-	-	-	-	-	0.07	0.1	-	-	-	-	-	0.19
Apareiodon piracicabae	Apapir	-	-	0.02	-	0.17	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	-	0.24
Astyanax altiparanae	Astalt	-	-	-	0.05	2.89	0.27	3.21	2.32	2.84	0.89	-	0.07	-	0.12	1.28	0.05	1.06	0.59	0.12	0.27	16.03
Astyanax cf. *fasciatus*	Astfas	5.21	0.2	0.07	0.17	0.12	0.62	0.77	1.48	0.02	1.43	7.09	0.3	0.27	0.07	0.15	0.02	0.1	0.4	-	0.32	18.81
Astyanax eigenmanniorum	Asteig	1.43	0.02	0.07	0.12	0.05	0.12	-	-	-	0.05	-	-	-	-	-	-	-	-	-	-	1.86
Bryconamericus sp.1	Brysp1	-	0.05	-	0.15	0.35	0.32	-	0.1	0.02	0.2	-	-	-	1.38	0.02	-	0.1	0.05	-	-	2.74
Bryconamericus sp.2	Brysp2	-	-	-	0.1	-	-	0.12	0.15	0.02	-	-	-	-	-	-	-	-	-	-	0.02	0.41
Cetopsorhamdia cf. *iheringi*	Cetihe	-	0.07	0.77	0.05	-	0.05	-	0.02	-	-	-	0.05	0.1	-	-	-	-	-	-	-	1.11
Characidium fasciatum	Chafas	1.53	-	-	-	-	0.02	-	-	0.02	-	2.54	-	-	0.02	-	-	-	-	-	-	4.13
Characidium gomesi	Chagom	-	-	-	-	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	-	-	0.05
Cichlasoma paranaense	Cicpar	0.47	-	-	0.12	0.42	0.07	1.98	0.84	1.19	0.27	0.72	-	-	0.12	0.12	0.02	1.48	0.4	0.12	0.05	8.39
Cyphocarax modestus	Cypmod	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
Gymnotus carapo	Gymcar	-	0.25	-	0.05	0.1	0.02	0.05	0.05	1.53	0.4	-	0.79	-	0.02	0.07	-	0.05	-	-	0.25	3.63
Hisonotus sp.	Hissp	-	0.02	0.17	0.02	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.23
Hoplias aff. *malabaricus*	Hopmal	0.12	-	-	-	0.15	-	0.22	0.02	0.07	-	0.35	-	-	-	0.02	-	0.12	-	-	0.05	1.12
Hyphessobrycon sp.	Hyphsp	-	-	-	-	-	-	-	-	-	-	0.25	-	0.07	-	-	-	-	0.02	-	-	0.34
Hypostomus ancistroides	Hypanc	-	-	-	0.07	-	-	0.07	-	-	-	-	-	-	-	-	-	-	-	-	-	0.14
Hypostomus margaritifer	Hypmar	-	0.17	0.22	0.35	-	-	-	-	-	-	-	0.07	0.25	0.07	0.1	0.15	0.07	-	-	-	1.45
Hypostomus nigricans	Hypnig	-	0.1	0.02	0.07	-	-	0.05	0.07	-	-	-	-	-	-	0.05	-	-	-	-	-	0.36
Hypostomus regani	Hypreg	-	0.02	-	0.07	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.14
Hypostomus sp.	Hypsp	-	0.17	-	0.15	-	0.02	-	-	-	-	-	-	-	-	0.12	-	-	-	-	-	0.46
Imparfinis sp.	Impsp	-	-	-	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	-	-	-	0.05
Laetacara sp.	Laesp	-	-	-	-	-	-	-	0.02	-	0.07	-	-	-	0.02	-	0.05	-	0.02	-	0.02	0.20
Leporinus microphthalmus	Lepmic	-	-	-	0.02	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	0.12
Neoplecostomus paranensis	Neopar	-	-	-	-	-	-	-	0.07	-	-	-	-	-	0.02	0.02	-	0.02	0.1	-	-	0.23
Parodon nasus	Parnas	-	0.1	2.05	0.05	-	0.02	0.15	0.07	-	0.1	-	0.05	1.26	0.12	0.05	-	0.07	0.12	-	0.02	4.23
Phenacorhamdia sp.	Phesp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	-	0.02
Piabina argentea	Piaarg	-	0.62	0.07	0.15	0.05	0.74	0.32	2.35	-	0.22	-	0.12	0.15	0.79	1.06	0.27	0.17	1.28	-	0.22	8.58
Pimelodus sp.	Pimsp	-	0.02	-	-	-	-	-	-	-	-	0.02	0.05	0.17	-	0.02	-	-	-	-	-	0.28
Planaltina myersi	Plamye	0.05	-	-	-	-	-	-	-	-	-	0.17	-	-	-	-	-	-	-	-	-	0.22
Poecilia reticulata	Poeret	4.62	-	-	0.17	0.62	-	1.88	3.01	0.05	0.22	3.46	0.05	-	0.57	0.2	-	1.14	1.73	0.02	0.17	17.91
Rhamdia quelen	Rhaque	0.2	0.02	0.67	0.4	0.1	0.05	0.1	0.15	0.59	0.07	0.59	0.02	0.37	0.15	0.07	0.02	0.05	0.05	-	-	3.67
Synbranchus marmoratus	Synmar	-	-	-	-	0.02	-	-	0.02	-	-	-	0.02	-	-	-	-	-	0.02	-	-	0.08
Tilapia rendalli	Tilren	0.32	-	-	-	-	-	-	0.37	-	-	0.02	-	-	-	-	-	-	0.05	-	-	0.76
Trichomycterus sp.	Trisp	0.89	-	0.02	-	-	-	-	-	-	-	0.57	-	-	-	-	-	-	-	-	-	1.48
Total		14.84	1.88	4.17	2.35	5.09	2.37	8.92	11.16	6.37	4.03	15.83	1.65	2.69	3.58	3.48	0.59	4.45	4.87	0.27	1.41	100.00

Table 4. Fish species, quantitative and qualitative variables contribution (%) to axes and statistics of the co-inertia analysis. Boldface values indicate major contributions.

Description	Variable			
	Quantitative		Qualitative	
	Axis 1	Axis 2	Axis 1	Axis 2
Species' contribution (%)				
Apareiodon ibitiensis	1.21	0.00	0.92	2.73
Apareiodon piracicabae	0.24	**8.02**	0.28	15.29
Astyanax altiparanae	2.04	1.68	1.28	8.77
Astyanax cf. *fasciatus*	0.21	0.18	9.38	4.36
Astyanax eigenmanniorum	3.21	**13.80**	2.46	0.02
Bryconamericus sp.1	6.32	**7.31**	0.18	9.80
Bryconamericus sp.2	0.03	**12.18**	2.60	2.32
Cetopsorhamdia cf. *iheringi*	**10.20**	0.25	9.84	0.11
Characidium fasciatum	0.00	3.51	0.12	3.69
Characidium gomesi	0.53	0.56	0.00	1.46
Cichlasoma paranaense	0.04	2.81	3.14	2.38
Cyphocarax modestus	0.45	0.01	0.16	0.98
Gymnotus carapo	0.56	1.32	2.59	0.09
Hisonotus sp.	**7.36**	0.82	5.07	0.01
Hoplias aff. *malabaricus*	**15.88**	0.04	21.04	0.05
Hyphessobrycon sp.	1.21	1.93	3.42	0.11
Hypostomus ancistroides	2.16	3.23	0.00	0.00
Hypostomus margaritifer	**6.44**	**6.46**	3.38	11.00
Hypostomus nigricans	0.29	**8.77**	0.57	4.61
Hypostomus regani	0.21	0.00	0.01	2.90
Hypostomus sp.	**15.17**	2.60	10.35	0.10
Imparfinis sp.	0.21	0.11	0.23	0.99
Laetacara sp.	0.60	0.24	0.00	1.46
Leporinus microphthalmus	1.53	2.55	2.10	0.31
Neoplecostomus paranensis	0.00	0.13	0.64	0.20
Parodon nasus	0.54	**4.56**	2.32	3.47
Phenacorhamdia sp.	0.21	0.11	0.23	0.99
Piabina argentea	**7.49**	0.05	10.83	7.58
Pimelodus sp.	0.00	0.89	2.88	7.57
Planaltina myersi	3.48	**13.76**	2.09	0.42
Poecilia reticulata	3.46	0.09	0.27	0.06
Rhamdia quelen	0.21	0.11	0.23	0.99
Synbranchus marmoratus	0.01	0.83	0.23	0.04
Tilapia rendalli	**5.80**	0.71	0.92	0.19
Trichomycterus sp.	2.56	0.31	0.06	4.79
Variables' contribution (%)				
Water temperature	2.76	**34.66**	-	-
Dissolved oxygen	9.77	14.26	-	-
pH	0.96	**28.5**	-	-
Conductivity	10.85	2.58	-	-
Turbidity	12.19	15.52	-	-
Luminosity	9.24	1.77	-	-
Water velocity	**26.05**	0.71	-	-
Channel width	**28.14**	1.97	-	-
Sand	-	-	0.00	0.00
Gravel	-	-	39.02	21.06
Rock	-	-	18.99	1.58
Mud	-	-	28.23	2.77
Anthropogenic perturbations	-	-	13.75	74.57
Statistics				
Eigenvalues	1.4983	0.9766	1.5009	9.0450
Correlation (r)	0.86	0.9	0.74	0.75
Explained inertia (%)	42.46	27.68	51.52	31.05
Total explained inertia (%)	70.14		82.57	
Monte Carlo test (1 000 permutations)	p = 0.000		p = 0.084	

Hypostomus (Casatti, 2002; Fialho & Tejerina-Garro, 2004; Hahn *et al.*, 1998; Melo *et al.*, 2005; Santos *et al.*, 2004). Also, these catfish display body shapes and morphological adaptations of the pectoral fins that aid them in maintaining position in high velocity areas of streams (Casatti, 2002; Melo *et al.*, 2005). In addition, the catfish *C.* cf. *iheringi* is reported to be invertivorous (Casatti & Castro, 1998; Froese & Pauly, 2008; Oliveira *et al.*, 1997), feeding predominantly on aquatic insect larvae such as those of the family Leptophlebiidae, Hydropsychidae, Hydroptilidae (Casatti & Castro, 1998), which are present in streams of the Upper Paraná River (Oliveira *et al.*, 1997). In the case of the characin *P. argentea*, its fusiform body, terminal mouth position (Fialho & Tejerina-Garro, 2004), small size and opportunistic feeding behavior facilitate its exploitation of different lotic habitats along the margins of water courses (Ferreira & Casatti, 2006b; Ferreira *et al.*, 2002; Gomiero & Braga, 2005).

In our study, the characin *H.* aff. *malabaricus* and the cichlid *T. rendalli* are associated with sites having narrow channels and low water velocities. Such habitats favor *H.* aff. *malabaricus*, a piscivorous species (Resende, 2000; Santos *et al.*, 2004) that ambushes prey (Fialho & Tejerina-Garro, 2004) or *T. rendalli*, which consumes phytoplankton and zooplankton (Dias *et al.*, 2005; Lazzaro, 1991). In addition, low water velocities favor reproduction of *H.* aff. *Malabaricus*, which prefers lentic and muddy waters for spawning (Araújo-Lima & Bittencourt, 2001; Nakatani *et al.*, 2001) as well as *T. rendalli* (Fialho & Tejerina-Garro, 2004; Oliveira & Bennemann, 2005).

The dry and wet seasons (IBGE, 2005) accentuate physicochemical water characteristics, particularly pH and water temperature (Esteves, 1988; Gordon *et al.*, 1995; Melo *et al.*, 2003). During dry seasons the fish assemblages represented by the characins *A. eigenmanniorum*, *Bryconamericus* sp.1, *Bryconamericus* sp.2, *P. myersi*, *A. piracicabae* and the catfish *H. nigricans* are associated with sites having acidic water (average pH = 6.12) and relatively low water temperatures (average = 22.31 °C), whereas in wet seasons the catfish *H. margaritifer* and the characin *P. nasus* are linked with sites having relatively basic water (average = 8.08) and higher water temperatures (average = 24.37 °C).

The influence of pH on fish assemblage structure was also observed by Abes & Agostinho (2001), Braga & Andrade (2005), Fialho *et al.* (2008) and Penczak *et al.* (1994), in streams of the Upper Paraná River. In our study the pH influence seemed to be related mostly to regional soil characteristics and land uses. The Ouvidor River basin drains Cerrado regions characterized by naturally acidic soils (Ratter *et al.*, 1997), where the main economic activity is farming and cattle ranching (Nepstad *et al.*, 1997). These activities require the addition of calcium before the rainy season to reduce soil acidity sufficiently to enable profitable agricultural activities (Ratter *et al.*, 1997). This fertilization introduces Mg and Ca ions into the water courses during the wet seasons and results in more basic pH of the water (Carvalho *et al.*, 2000). However, it is not possible to determine from our study weather the preference of the fish species for basic or acidic water is related to the influence of pH on reproduction (Dei Tos *et al.*, 2002) or growth and development (Esteves, 1988; Ferreira *et al.*, 2001).

Esteves (1988) stated that one ecological consequences

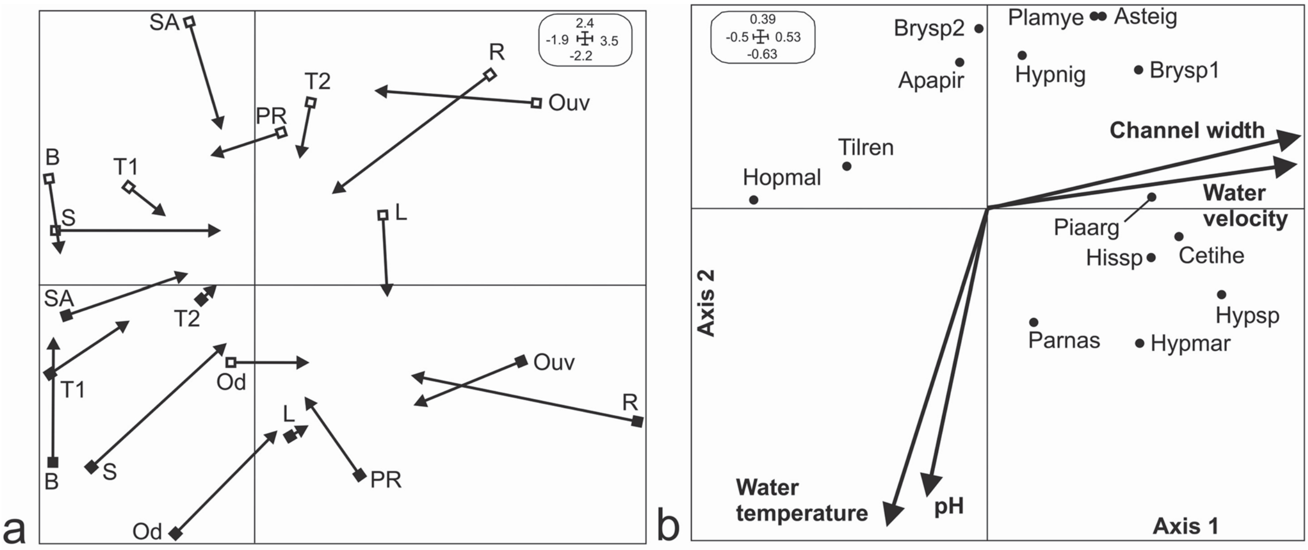

Fig. 2. Ordination of the co-structure between (a) fish assemblages (arrows) and stream sites (squares) and (b) fish species and environmental variables resulting from the co-inertia analysis. Only species that most contributes to each axis are displayed. Black and white squares represent stream sites sampled in the wet and dry season, respectively. Codes correspond to names listed in Tables 1 and 2. Small boxes indicate the graphic scale.

Table 5. Averages values of the quantitative variables by stream and season. DS = dry season; WS = wet season.

Stream	Water temperature (ºC)		DO (mg/L)		pH		Conductivity (µS/cm)		Turbidity (UTN)		Luminosity (lux)		Water velocity (cm/s)		Channel width (m)	
	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS
Taquara II	20.47	22.93	7.40	7.78	6.08	7.72	40.77	50.67	7.06	20.33	8.44	8.44	34.69	6.15	3.36	3.18
Taquara I	24.13	26.00	6.25	5.76	5.68	8.25	31.27	24.98	12.48	18.33	12.50	12.50	36.46	22.30	1.97	2.36
Buraco	23.50	24.20	6.50	8.80	6.19	8.62	91.70	115.10	3.75	50.30	10.94	10.94	24.58	11.71	1.07	1.19
Santo Antônio	19.10	23.07	6.50	7.52	6.39	8.66	110.77	142.17	10.69	17.45	10.50	10.50	32.02	8.11	4.67	4.51
Lagoa	22.37	24.63	7.90	8.42	6.39	8.14	20.43	24.83	5.50	48.09	9.83	9.83	55.97	27.88	3.92	3.96
Ouvidor	20.30	23.25	8.25	8.06	6.54	7.65	65.83	77.20	11.37	300.21	9.56	9.56	64.85	44.87	8.90	8.88
Posse dos Rodrigues	21.33	23.07	7.45	9.64	5.98	8.36	43.17	40.93	6.92	126.69	9.39	9.39	34.11	26.75	3.47	3.70
Riacho	20.37	22.10	7.50	8.08	5.93	7.36	29.90	29.35	23.30	504.10	9.17	9.17	69.79	68.17	5.78	5.83
Sapê	24.93	25.63	6.55	7.65	5.92	8.24	68.30	70.40	20.26	100.33	13.06	13.06	5.85	12.10	4.25	3.94
Olhos d'água	26.57	28.85	7.95	8.13	6.08	7.79	34.70	45.65	32.47	36.00	12.06	12.06	47.18	44.87	2.50	2.34

of the specific heat of water is relatively high thermal stability of aquatic ecosystems, and Wetzel (1993) suggested that thermal radiation into and from water reservoirs is predominantly a superficial phenomenon that is, restricted to the top centimeters of the water column. In this way, water courses with less water volume (*e.g.*, streams) tend to gain and lose heat more rapidly than ones with more volume (*e.g.*, river). This seemed to be the situation in our study when comparing the Ouvidor River with the Buraco and Sapê streams during the wet season, and all stream sites in both seasons. However, streams with riparian vegetation cover have lower water temperatures than uncovered ones (Ferreira & Casatti, 2006b), which seems to be the case of the Olhos d'água and Posse dos Rodrigues streams, where *H. margaritifer* and *P. nasus* are predominant. Generally, the influence of water temperature on fish is related to their metabolism (Silva & Araújo-Lima, 2003), which was not measured in our study. In sites lacking vegetation cover, the availability of light in the water column increases (Tejerina-Garro & Mérona, 2001). The increased light and additional nutrients from wet season run off favored increased periphyton production, which is consumed by *H. margaritifer* (Casatti, 2002; Hahn *et al.*, 1998; Melo *et al.*, 2005; Santos *et al.*, 2004;) and *P. nasus* (Fialho & Tejerina-Garro, 2004).

In conclusion, we found that fish assemblages of Ouvidor basin streams sites were structured by water velocity, channel width, pH and water temperature. Although we did not detect direct effects of anthropogenic perturbations on fish assemblages in this study, it does not mean that they were absent. Our results aids predictions of the responses of Ouvidor fish assemblages to environmental modifications, including those that take place at a large temporal and spatial scale such as air temperature.

Additional studies are necessary to verify if the fish-habitat relationships observed for our Ouvidor stream sites prevail at the larger spatial scale of the Paranaíba River basin in

Goiás, where streams were modified without prior knowledge of the structure and composition of the aquatic assemblages, including fish.

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