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Influence of environmental parameters on fish assemblage of a Neotropical river with a flood pulse regime, Central Brazil

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This study aims to determine which of twelve environmental parameters (five physicochemical and seven hydromorphological) influence on the fish assemblage structure of the lower Mortes River basin located in the Bananal floodplain of the Araguaia River basin, Central Brazil. Sampling was conducted in six stretches of 1000 m each during the high and low waters. Fish were captured using gill nets and environmental parameters were measured by portable equipment or determined visually. The co-inertia analysis indicated that two physicochemical (dissolved oxygen and water transparency), and four hydromorphological (channel width and depth, riparian vegetation cover and type of the riverside substrate) parameters structure the fish assemblages, both driven by the regional hydrological patterns (flood pulse). These results are explained by fish-environmental parameters relationship characteristic of the aquatic Neotropical systems.

Este estudo determinou quais entre doze parâmetros ambientais (cinco físico-químicos e sete hidromorfológicos) influenciam na estrutura da assembleia de peixes do baixo rio das Mortes localizado na planície de inundação do Bananal, bacia do rio Araguaia, Brasil Central. As coletas foram realizadas em seis trechos de 1000 m cada durante os períodos de chuva e estiagem, nos quais 1036 peixes foram coletados utilizando-se redes de malhar e medidos os parâmetros ambientais utilizando equipamentos portáteis ou determinados visualmente. A análise de coinércia indicou que dois parâmetros físicos e químicos (oxigênio dissolvido e a transparência da água) e quatro hidromorfológicos (largura e profundidade da calha principal, cobertura da mata ripária e tipo de substrato da margem) estruturam a assembleia de peixes, ambos influenciados pelo regime hidrológico regional (pulso de inundação). Estes resultados são discutidos considerando a interação entre peixes e os parâmetros ambientais característicos dos sistemas aquáticos Neotropicais.

Key words: Ecological interactions, Physicochemical variables, Hydromorphology.

Introduction

One challenge in fish ecology is to obtain a functional knowledge of the response of populations and community to environmental variation and disturbances on a temporal and spatial scale (Winemiller *et al*., 2000). At a large-scale, studies emphasize abiotic factors structuring riverine fish assemblages in temperate and tropical regions (Tejerina-Garro *et al*., 2005). This situation is also observed in Neotropical rivers where the fish assemblage structure is reported to be influenced by geomorphological factors such as altitude (Suárez & Petrere Júnior, 2007), physicochemical water characteristics such as dissolved oxygen, pH (Jackson *et al*., 2001; Silva *et al*., 2007), water temperature (Cetra & Petrere, 2006), flow velocity (Willis *et al*., 2005) and discharge (Barretto & Uieda, 1998), conductivity, dissolved oxygen and pH (Araújo *et al*., 2009), or habitat availability (Melo, 2000) and heterogeneity (Towsend, 1996; Willis *et al*., 2005). In addition, the fish assemblages are influenced by the riparian vegetation, which provides food and increases the availability of aquatic refuges for small fish species through the falling of tree trunks and branches into the water course (Casatti *et al*., 2003). In addition, leaves incorporated into the channel substrate favor the establishment of a diverse fauna that can be used as food by fish (Uieda & Uieda, 2001).

Furthermore, the riparian vegetation hosts terrestrial

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arthropods who are predated by fish that jump out of the water such as *Osteoglossum bicirrhosum* (Cuvier, 1829) (Santos *et al*., 2004) or when they fall in the water (Melo *et al*., 2004).

Otherwise, in a river-floodplain system, such as that of the Mortes River, the periodic inundation and drought (flood pulse) is the driving force (Junk & Wantzen, 2003). It makes interactions between the aquatic and terrestrial environment possible (Junk *et al*., 1989), regulates the model of the aquatic communities (Quirós & Baigún, 1985; Townsend, 1996; Rodrigues *et al*., 2002), propitiates the high diversity of the lotic environment associated to the floodplain because of the elevated heterogeneity of the habitat (Luiz *et al*., 2004; Thomaz *et al*., 2007), including in clear water rivers (*sensu* Sioli, 1984), such as the Mortes River, characterized by a low concentration of nutrients, but that support a rich aquatic flora and fauna (Goulding, 1993). It also modifies the limnological characteristics of rivers because of the quantities of organic matter received from the floodplain (Townsend, 1996), and influences the fish-environmental parameter relationship (Lin & Caramaschi, 2005). However, Junk & Wantzen (2003) state that systematized and detailed studies about the influence of the hydrology and hydrochemical parameters on flora and fauna of Neotropical rivers with a floodplain are scarce.

This study aims to responds to the following question: which of twelve environmental parameters (five physicochemical and seven hydromorphological) influence fish assemblages of a river-floodplain system?

Material and Methods

Study area

The Mortes River is the main affluent of the Araguaia River, Amazon basin, Central Brazil (Fig. 1). Its lower section is located within the Bananal floodplain, which covers around 70,000 km² of the Mato Grosso State and extends along 600 km to the left of the Araguaia River (Brasil, 1982). The Mortes River basin is covered by Brazilian savanna (Cerrado), while some parts are used for agriculture and cattle raising. In its lower section the riparian vegetation may be continuous but interrupted occasionally by pasture. The right side of the river section sampled in this study borders the conservation unit of the Araguaia State Park. The regional climate is characterized by a rainy season (November to April) which causes annual flooding of the riparian vegetation and savanna (Lowe-McConnell, 1999) and allows the interconnection of the Bananal floodplain and the Araguaia and Mortes Rivers (Ribeiro *et al*., 1995). At low water levels, temporary sandy beaches are formed along the riverside and within the main channel.

Sampling protocol

Fish and environmental parameters were analyzed in six stretches located in the lower section of the Mortes River, Mato Grosso State (Fig. 1) during low (October 2004) and high (March 2005) water seasons. In each stretch (1000 m length), 11 transects were established every 100 m. This length corresponds to the category "stretch" of the classification of Imnhof *et al*. (1996). The geographic coordinates of the upstream and downstream bounds of each stretch and transect were taken using a GPS Garmin III.

Fish were captured using 20 gill nets (10 m length, 1.5 m width; mesh sizes of 30, 40, 60, 80 and 100 mm) following the protocol suggested by Tejerina-Garro & Mérona (2000) for tropical rivers. All gill nets were set from 17:30 to 7:30 with one inspection to reduce predation on captured fish. On site, collected fish were fixed in 10% formaldehyde solution and in the laboratory they were measured (standard length), weighed and identified. Voucher specimens for all species were deposited in the Ichthyology and Limnology Laboratory at the Universidade Estadual do Mato Grosso, Campus Nova Xavantina.

Water samples were collected using a Van Dorn sampler at 0.50 m depth in the center of the river channel in the first, fifth and eleventh transect of each stretch. Then, the variables pH (QUIMIS model Q-400 BC), conductivity (QUIMIS model Q-405 B2), water temperature (mercury thermometer),

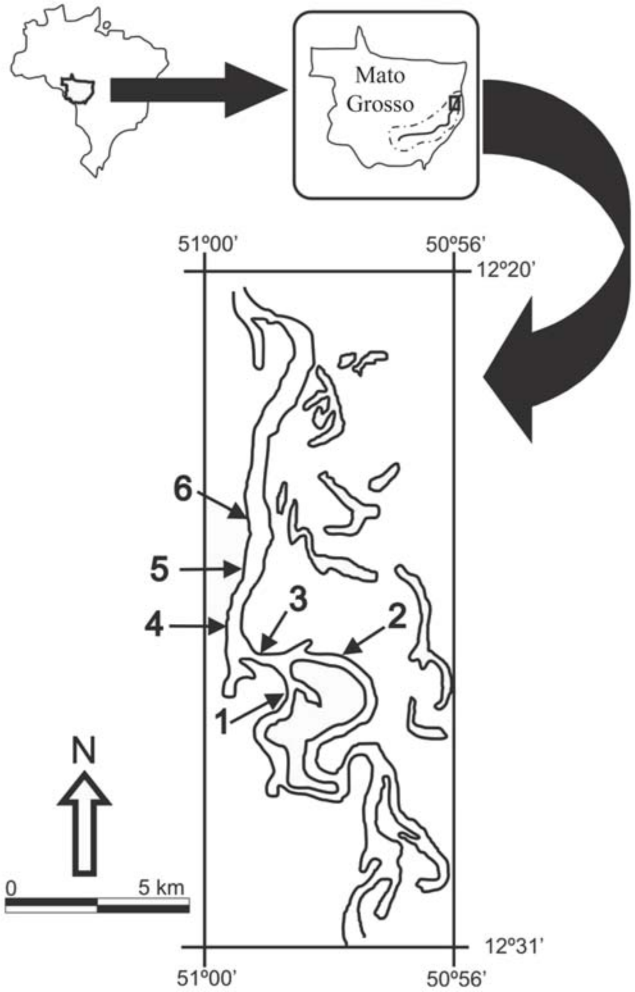

Fig. 1. Study area located in the lower section of the Mortes River, Bananal floodplain, Central Brazil. The boldface numbers correspond to the stretches sampled.

dissolved oxygen (Winkler method; Pinto-Silva, 2002) and Secchi transparency (Esteves, 1988) were measured. The water depth (scaled rope), water velocity (General Electronics Model 2030) and channel length (GPS Garmin III) were measured at each transect.

The qualitative variables, that is, the type of riverside inclination (steep, little inclined, no incline), riverside substrate (sand, clay, leaves, roots, flooded), riparian vegetation (trees, shrubs, herbs, grass, flooded) and the riparian vegetation cover over the river channel (high, little, absent, flooded) were estimated at each transect and on both riversides of the stretch.

Data analysis

The fish data matrix was formed by the abundance per species, the qualitative variables was composed by the dominant or co-dominant categories of each variable, and the quantitative variables were the average. In all situation data was organized per stretch and water season. Afterwards, the matrices were submitted to a multivariate analysis of ordination in order to find patterns in the fish assemblage structure related to environmental parameters (McCune & Grace, 2002). The following analyses were performed using the free ADE-4 software (Thioulouse *et al.*, 1997):

Principal component analysis (PCAs) - separately provided the ordination of the fish species using the covariance method which is recommended when faunistic data are counted using the same type of measurement (abundance in this study), and quantitative variables by means of a correlation method that allows the comparison of data measured in different units (Dolédec & Chessel, 1991).

Multiple component analysis (MCA) - used to ordinate multistate categorical variable arrays coded by qualitative criteria (Dolédec & Chessel, 1991).

Co-inertia analysis (COIAs) - provided the ordination of the co-structure between the fish species and environmental parameters. This analysis is sensitive even when the number of samplings is reduced (Dolédec & Chessel, 1994). Two COIAs were performed separately between the fish species ordination resulting from the PCA and the quantitative (PCA) and qualitative variables (MCA), both followed by a Monte Carlo test (1000 permutations; $p < 0.05$) in order to verify if the fish-environmental parameter co-structures founds were random.

Results

There were collected 1036 specimens represented by 72 species, 18 families and five orders (Table 1). The abundance and richness were higher in the low water (659 specimens and 66 species, respectively) than in the high water season (377 specimens and 41 species; Table 1).

Two axes of each COIA were retained for interpretation of the co-structure between the fish species assemblages and the quantitative (95.8% of total inertia explained) and qualitative (87.58%) variables. The co-structures found in both analyses have high correlation in two axes ($r = 0.79$ in axis 1, $r = 0.59$ in axis 2 for the quantitative variables; $r = 0.93$ in axis 1 and $r = 0.85$ in axis 2 for the qualitative variables) and are not random ($p = 0.001$ for the quantitative and $p = 0.021$ for the qualitative variables) (Table 2). In both ordinations, the co-structures found are influenced by seasonality (Figs. 2a-b).

In low waters, except stretches 2 and 4, the fish assemblage represented by *Serrasalmus gibbus*, *Serrasalmus eigenmanni*, *Triportheus auritus*, *Boulengerella cuvieri* and *Hydrolycus armatus* was related to an environment characterized by a high value of dissolved oxygen (average = 6.70 mg/l), high riparian vegetation cover, and a riverside substrate predominantly composed by sand, leaves and roots (Figs. 2a-b). In the same season and in stretch 2 the piranhas *Serrasalmus rhombeus*, *Serrasalmus eigenmanni* and *Pygocentrus nattereri* were related to low values of Secchi transparency (average = 78 cm), whereas in stretch 4 *P. nattereri*, *Hydrolycus tatauaia* and *Hemiodus unimaculatus* were correlated to the absence/high riparian vegetation cover and a riverside substrate composed of sand and leaves (Fig. 2b, Table 3).

In high waters, except for stretch 5, the fish assemblage represented by *Auchenipterichthys coracoideus*, *Agoniates halecinus*, *Ageneiosus inermis* and *R. vulpinus* was related to a deeper river channel (average = 397.85 cm) with a flooded riverside resulting in a high area of the river channel covered by vegetation (Fig. 2; Table 3). In stretch 5 only *A. halecinus* was associated to a high water transparency (101.67 cm) and a channel width (355.45 m) (Fig. 2a, Table 3).

Discussion

Dissolved oxygen (DO) is the most important gas in the dynamic and characterization of the aquatic ecosystem (Welcomme, 1979; Esteves, 1988). It displays elevated concentration variability along a water course and is influenced by wind and water velocity, thermal effects and organic matter decomposition throughout the hydrological cycle (Bayley, 1995). In this study the average concentration of DO measured at low waters was higher than that during high waters. Bayley (1995) indicates that when the water level increases at high waters the decomposition of organic matter increases, resulting in the decrease of DO concentration values. This occurs mainly in the floodplain because of the lateral inundation. The water present in the floodplain has low DO concentrations probably resulting from the combination of elevated amounts of organic matter and the inhibiting effects of the vegetation cover over the aquatic photosynthesis process (Kramer *et al.*, 1978). Like the DO concentration process, other modifications of the ecological conditions of rivers associated to floodplain occur resulting from periodic flooding and the intensity and duration of discharge, which creates transition zones between terrestrial and aquatic ecosystem (Junk & Wantzen, 2003). This annual flooding influence fish species with different life strategies causing modifications in the composition and structure of fish assemblage (Agostinho *et al.*, 2001) or single species (Castello, 2008), like in this study, where *Boulengerella cuvieri*,

Table 1. Absolute abundance of the fish species sampled in the lower Mortes River during low (L) and high (H) waters.

	Code	H	L		Code	H	L
CLUPEIFORMES				Alestidae			
Engraulidae				*Chalceus epakros* Zanata & Toledo-Piza, 2004	Chaepa	1	5
Lycengraulis batesii (Günther, 1868)	Lycbat	1	4	Cynodontidae			
Pristigasteridae				*Cynodon gibbus* (Agassiz, 1829)	Cyngib	0	6
Pellona castelnaeana Valenciennes, 1847	Pelcas	10	1	*Hydrolycus armatus* (Jardine & Schomburgk, 1841)	Hydarm	7	30
Pristigaster cayana Cuvier, 1829	Pricay	10	1	*Hydrolycus tatauaia* Toledo-Piza, Menezes & Santos, 1999	Hydtat	7	25
CHARACIFORMES				*Rhaphiodon vulpinus* Spix & Agassiz, 1829	Rhavul	48	18
Curimatidae				Ctenoluciidae			
Curimata cyprinoides (Linnaeus, 1766)	Curcyp	0	9	*Boulengerella cuvieri* (Agassiz, 1829)	Boucuv	28	67
Cyphocharax spiluropsis (Eigenmann & Eigenmann, 1889)	Cypspi	2	0	SILURIFORMES			
Prochilodontidae				Loricariidae			
Prochilodus nigricans Spix & Agassiz, 1829	Pronig	1	1	*Farlowella* sp.	Farsp	1	0
Semaprochilodus brama (Valenciennes, 1850)	Sembra	3	1	*Hypoptopoma* sp.	Hypsp	3	1
Anostomidae				*Hypostomus* sp.	Hypsp	0	2
Laemolyta fernandezi Myers, 1950	Laepet	3	3	*Loricaria* sp.	Lorsp	0	3
Laemolyta taeniata (Kner, 1858)	Laetae	2	0	*Pterygoplichthys* sp.	Ptesp	0	1
Leporinus affinis Günther, 1864	Lepaff	2	11	*Squaliforma emarginata* (Valenciennes, 1840)	Squema	2	14
Leporinus desmotes Fowler, 1914	Lepdes	0	1	*Sturisoma nigrirostrum* Fowler, 1940	Stunig	1	1
Leporinus friderici (Bloch, 1794)	Lepfri	0	4	Pimelodidae			
Schizodon vittatus (Valenciennes, 1850)	Schvit	1	4	*Hemisorubim platyrhynchos* (Valenciennes, 1840)	Hempla	0	3
Chilodontidae				*Pimelodus blochii* Valenciennes, 1840	Pimblo	0	9
Caenotropus labyrinthicus (Kner, 1858)	Caelab	1	4	*Pinirampus pirinampu* (Spix & Agassiz, 1829)	Pinpir	3	1
Hemiodontidae				*Pseudoplatystoma fasciatum* (Linnaeus, 1766)	Psefas	2	1
Anodus elongatus Agassiz, 1829	Anoelo	5	0	*Sorubim lima* (Bloch & Schneider, 1801)	Sorlim	1	6
Hemiodus argenteus Pellegrin, 1908	Hemarg	0	8	*Zungaro zungaro* (Humboldt, 1821)	Zunzun	0	1
Hemiodus microlepis Kner, 1858	Hemmic	0	6	Doradidae			
Hemiodus unimaculatus (Bloch, 1794)	Hemuni	4	20	*Hassar wilderi* Kindle, 1895	Haswil	0	5
Characidae				Auchenipteridae			
Agoniates halecinus Müller & Troschel, 1845	Agohal	23	1	*Ageneiosus inermis* (Linnaeus, 1766)	Ageine	49	16
Brycon falcatus Müller & Troschel, 1844	Bryfal	0	1	*Ageneiosus* sp.	Agesp	16	8
Brycon pesu Müller & Troschel, 1845	Brypes	0	8	*Auchenipterichthys coracoideus* (Eigenmann & Allen, 1942)	Auccor	13	1
Brycon sp.	Brysp	0	1	*Auchenipterus nuchalis* (Spix & Agassiz, 1829)	Aucnuc	16	16
Bryconops alburnoides Kner, 1858	Bryalb	0	2	BELONIFORMES			
Moenkhausia sp. 2	Moesp.2	0	1	Belonidae			
Myleus cf. *pacu* (Jardine & Schomburgk, 1841)	Mylpac	2	0	*Pseudotylosurus* sp.	Psesp	2	0
Myleus schomburgkii (Jardine & Schomburgk, 1841)	Mylsch	0	2	PERCIFORMES			
Myleus torquatus (Kner, 1858)	Myltor	1	7	Sciaenidae			
Pygocentrus nattereri Kner, 1858	Pygnat	40	101	*Pachypops fourcroi* (La Cepède, 1802)	Pacfou	0	1
Serrasalmus eigenmanni Norman, 1929	Sereig	3	31	*Plagioscion squamosissimus* (Heckel, 1840)	Plasqu	1	3
Serrasalmus geryi Jégu & Santos, 1988	Serger	2	11	Cichlidae			
Serrasalmus gibbus Castelnau, 1855	Sergib	19	53	*Cichla piquiti* Kullander & Ferreira, 2006	Cicpiq	0	1
Serrasalmus rhombeus (Linnaeus, 1766)	Serrho	35	59	*Crenicichla lugubris* Heckel, 1840	Crelug	0	1
Tetragonopterus argenteus Cuvier, 1816	Tetarg	0	4	*Crenicichla* sp.	Cresp	0	1
Tetragonopterus chalceus Spix & Agassiz, 1829	Tetcha	0	6	*Geophagus* sp.	Geosp	0	2
Tetragonopterus sp.	Tetsp	0	4	*Heros* sp.	Hersp	0	1
Triportheus albus Cope, 1872	Trialb	1	2	*Retroculus lapidifer* (Castelnau, 1855)	Retlap	0	1
Triportheus auritus (Valenciennes, 1850)	Triaur	5	21	*Satanoperca* sp.	Satsp	0	2
Triportheus trifurcatus (Castelnau, 1855)	Tritri	0	13				
TOTAL		176	406			201	253

Hydrolycus armatus, *Triportheus auritus* and *Serrasalmus gibbus* were related to oxygenated environments.

Changes in the river channel depth are related to oscillations of the hydrological cycle due to regional seasonality (Cellot *et al.*, 1994; Thomaz *et al.*, 2007). That was verified in this study, that is, the river channel was shallower during low waters than throughout high waters. This situation allied to the presence of the Bananal floodplain, promotes the migration of the littoral zones of the river (moving littoral *sensu* Junk *et al.*, 1989). During high waters the increase of river water volume raises the river channel depth and causes lateral flooding, thereby displacing the riverside into the floodplain (Junk & Wantzen, 2003). In this study *Ageneiosus inermis*, *Agoniates halecinus* and *Rhaphiodon vulpinus* were related to a deep channel. These are piscivorous species that inhabit the main river channel (Petry *et al.*, 2003), where they could prey on fish that enter or leave on the flooded region.

The influence of Secchi transparency on fish assemblage structure in this study was mainly related to stretch 5 during high waters. However, no pronounced differences were observed in this parameter in stretch 5 between high and low waters (average = 91.67 cm) as reported for the floodplain lakes of the Orinoco River (low waters = 5.00 cm; high waters = 130.00 cm; Rodriguez & Lewis-Jr, 1997) or for the Araguaia River (low waters = 18.00 cm; high waters = 132.00 cm; Tejerina-Garro *et al.*, 1998). This situation can be explained by the unidirectional

Table 2. Summary of the co-inertia analysis between the fish assemblages and quantitative (A) and qualitative (B) environmental parameters. Boldface numbers point to the more important contributions to the co-structure.

Environmental parameters		Axis 1	Axis 2
(A) Quantitative			
Dissolved oxygen		16.74	4.59
pH		10.19	1.78
Conductivity		8.78	14.29
Water temperature		12.72	6.01
Secchi transparency		1.24	50.87
Channel width		17.19	22.08
Water velocity		14.03	0.29
Channel depth		19.05	0.04
Statistics of the Co-inertia analysis:			
Eigenvalue		576.02	27.86
Explained inertia (%)		91.40	4.42
Total inertia explained (%)		95.82	
Correlation (r) fish species - environmental parameters		0.79	0.59
Monte Carlo test (1000 iterations)		0.001	
(B) Qualitative	Category		
Riverside inclination	No incline/little inclined	0.00	1.34
	Steep	9.96	2.26
	No incline	6.03	4.85
Riverside substrate	Sand/clay/leaves	0.21	1.61
	Sand/leaves	33.65	6.88
	Sand/leaves/flooded	1.56	6.45
	Flooded	4.89	6.45
	Sand/leaves/roots	0.18	25.91
Riparian vegetation	Flooded	3.26	0.21
	Trees/shrubs	0.29	0.01
Riparian vegetation cover	Little	1.14	0.02
	High	0.13	26.35
	Absent/high	33.65	6.88
	Flooded	4.98	10.13
Statistics of the Co-inertia analysis:			
Eigenvalue		121.25	26.53
Explained inertia (%)		71.83	15.75
Total inertia explained (%)		87.58	
Correlation (r) fish species - environmental parameters		0.93	0.85
Monte Carlo test (1000 iterations)		0.021	

flow characteristics of lotic systems (Esteves, 1988), which impedes the temporal and spatial constancy of similar quantities of suspended material in the water column. This condition is necessary for the response of fish assemblages to water transparency modification according to the PTM model (Piscivory-Transparency-Morphometry) described by Rodriguez & Lewis-Jr (1997). On the other hand, stretch 2 in both seasons showed low average values of Secchi transparency, channel width and channel depth in relation to the other stretches. This seems to be related to its similarity with a lentic environment, or a branch of a river with a lower water flow during both seasons. These conditions could favor the presence of prey species and could explain the presence of fish predators such as *Auchenipterichthys coracoideus*, *Rhaphiodon vulpinus*, *Ageneiosus inermis* and the piranhas *Serrasalmus rhombeus*, *Serrasalmus eigenmanni* and *Pygocentrus nattereri*, the latter associated with lentic waters (Goulding, 1980).

Aquatic environments are influenced by geology and vegetation (Allan & Johnson, 1997), the latter influencing the formation of the riparian vegetation (Bunn *et al*., 1999; Growns *et al*., 2003) that can totally or partially cover the river channel. In this study, the parameter riparian vegetation cover influences the fish assemblage structure. This influence seems to be related to the availability of refuges into the flooded vegetation (tree branch and trunk, and roots; Welcomme, 1979) and food represented by aquatic invertebrates and algae fixed to the substrate (Horeau *et al*., 1998; Naiman & Décamps, 1997; Barrella *et al*., 2001), arthropods (Goulding, 1993; Horeau *et al*., 1996) and fruits and seeds (Goulding *et al*., 1988; Goulding, 1993) falling from the flooded vegetation. This situation seems to explain the association of the insectivore *Triportheus auritus*, detritivore *Curimata cyprinoides* and omnivore *Brycon pesu* (Santos *et al*., 2004; Melo *et al*., 2005) with the riparian vegetation cover parameter in this study. Incidentally, other predator fish such as *Pygocentrus nattereri*, *Serrasalmus rhombeus* and *Hydrolycus tatauaia* were also related to this parameter. *Serrasalmus rhombeus* is reported to inhabit areas near the riverside in both seasons (low and high waters) displaying an ambush hunting strategy in both the main river channel and flooded areas (Goulding, 1980). The preference of *Boulengerella cuvieri* for sandy beaches where it hunts its prey (Arrington & Winemiller, 2003) could explain its association with stretches without riparian

Table 3. Average values and standard deviation (in parentheses) of the quantitative environmental parameters measured in the six stretches during low (L) and high (H) waters.

Stretch	Dissolved oxygen (mg/l)	pH	Conductivity (μS.cm^{-1})	Water temperature (ºC)	Secchi transparency (cm)	Channel width (m)	Water velocity (cm/s)	Channel depth (cm)
1L	6.60 (0.10)	6.87 (0.06)	8.20 (0.17)	30.00 (0.00)	84.67 (2.08)	222.73 (16.79)	28.82 (10.33)	145.86 (120.19)
2L	6.86 (0.01)	6.90 (0.10)	8.33 (0.23)	32.00 (2.89)	78.00 (12.12)	154.55 (17.53)	22.77 (4.70)	78.86 (40.19)
3L	6.93 (0.07)	6.40 (0.44)	8.90 (0.52)	32.50 (0.76)	87.33 (10.97)	212.73 (18.49)	22.00 (7.96)	110.73 (60.80)
4L	6.71 (0.00)	6.83 (0.06)	9.77 (1.59)	32.50 (0.50)	90.00 (1.73)	207.27 (11.91)	18.18 (3.42)	85.23 (27.17)
5L	6.41 (0.07)	7.00 (0.00)	9.30 (0.87)	33.00 (0.00)	91.67 (2.89)	285.00 (19.87)	28.00 (13.80)	136.64 (92.59)
6L	6.71 (0.22)	6.83 (0.06)	8.00 (0.10)	31.00 (0.29)	84.67 (5.13)	312.73 (10.09)	25.00 (7.02)	164.36 (81.25)
1H	4.96 (0.27)	6.17 (0.01)	13.00 (0.70)	22.00 (0.00)	86.00 (3.00)	378.18 (22.28)	29.86 (13.61)	339.27 (167.59)
2H	5.12 (0.01)	6.66 (0.03)	12.83 (0.21)	28.00 (0.00)	73.00 (0.58)	221.82 (22.28)	53.36 (16.10)	333.64 (53.30)
3H	5.11 (0.22)	6.07 (0.12)	12.50 (0.17)	29.00 (0.00)	80.00 (0.00)	325.45 (25.05)	54.14 (15.91)	413.86 (101.06)
4H	4.64 (0.17)	6.39 (0.05)	11.90 (0.36)	29.00 (0.00)	88.33 (2.89)	263.64 (15.02)	54.59 (18.09)	416.64 (109.62)
5H	5.17 (0.06)	6.56 (0.10)	10.63 (0.38)	28.00 (0.00)	101.67 (2.89)	355.45 (9.34)	49.41 (20.80)	381.23 (123.36)
6H	5.40 (0.06)	6.26 (0.04)	11.33 (0.67)	27.00 (0.29)	90.00 (0.00)	370.00 (11.83)	58.68 (18.80)	395.86 (105.54)

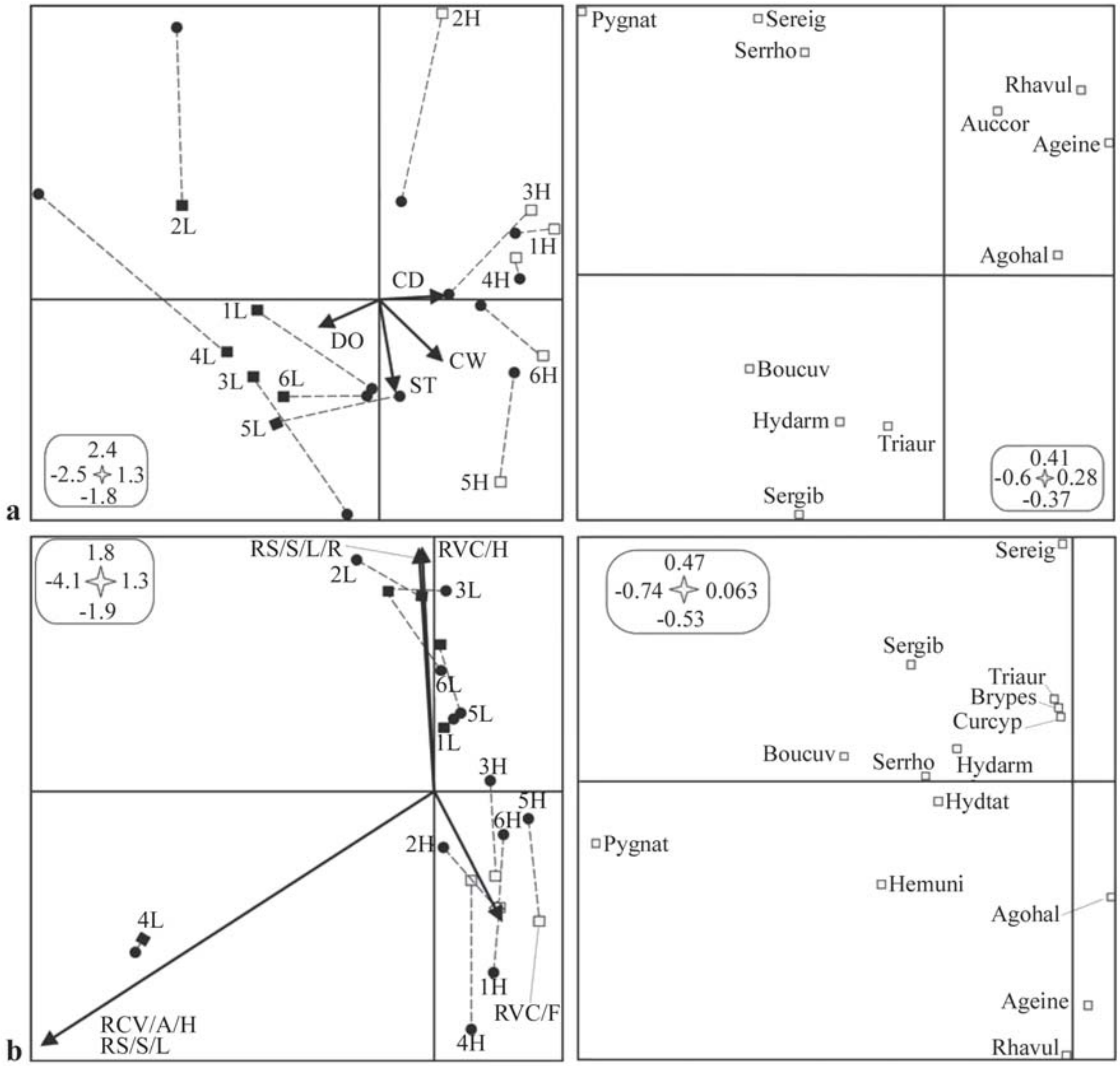

Fig. 2. Ordination of the co-structure resulting from the co-inertia analysis between the fish assemblages and quantitative (a) and qualitative (b) environmental parameters (square arrow edge = stretch; circle = fish assemblage). Numbers represent the stretch sampled at low (L) or high (H) waters. Letter codes correspond to the main fish species that contributed to the co-structure and are listed in Table 1. CD = channel depth; CW = channel width; DO = dissolved oxygen; ST = Secchi transparency; RS/S/L/R = river substrate/sand/leaves/roots; RVC/H = river vegetation cover/high; RVC/A/H = river vegetation cover absent/high; RS/S/L = river substrate/sand/leaves; RVC/F = river vegetation cover/flooded. Boxes indicate scales.

vegetation covers. However, the association of fish species to the riparian vegetation cover parameter can be related to shaded areas, where the decrease in water temperature caused by vegetation cover allows micro-habitats to be explored (Naiman & Décamps, 1997; Barrella *et al*., 2001; Growns *et al*., 2003).

In this study, of the twelve environmental parameters measured two physicochemical (dissolved oxygen and Secchi transparency) and four geomorphological (channel depth and width, riverside substrate and riparian vegetation cover) structure the fish assemblages, both driven by the flood pulse. These results are explained by fish-environmental parameter relationship characteristic of the aquatic Neotropical systems. However, the Secchi transparency does not show any pronounced contrast values between low and high waters, which is necessary for the response of fish assemblages according to the PTM model.

Studies like this may contribute to guide environmental management and efforts on conservation of the Mortes River basin, whose east side area until the Araguaia River constitutes one of the few regions of the Mato Grosso State, Central Brazil, not entirely transformed by anthropogenic activities (Anacleto *et al*., 2005).

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