Eight years of monitoring aquatic Oligochaeta from the Baía and Ivinhema Rivers

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(With 8 figures)

Abstract

The aim of this study was to analyze the factors that influence spatial and temporal variations of the Oligochaeta assemblage in the Baía and Ivinhema Rivers, located in the Upper Paraná River floodplain (Mato Grosso do Sul State, Brazil). Samples of Oligochaeta were collected between February 2000 and November 2007. A total of 27 Oligochaeta species were identified. A Principal Component Analysis (PCA) of the physical and chemical variables was used to summarize the total variation in the data and to identify major environmental gradients. Detrended Correspondence Analysis (DCA) was conducted to verify possible spatial and temporal gradients in the Oligochaeta species distribution. The highest Oligochaeta species densities and richness values were recorded during limnophases. The intensity and amplitude of the potamophase influenced the density, richness and composition of Oligochaeta since many species were transported by high water current velocities and/or died due to the low oxygen levels that are characteristic of this phase. *L. hoffmeisteri*, *P. descolei* and *A. pigueti* were recorded in the potamophase and in the limnophase and we concluded that they are adapted to different conditions of rivers (lotic and lentic) due to the presence of these species during the entire study period in both rivers. Nevertheless, these species were dominant in the potamophase periods of these rivers as they have body adaptations to survive in these conditions.

Keywords: Oligochaeta species, Baía and Ivinhema Rivers, flood pulse intensity and amplitude.

Oito anos de monitoramento de Oligochaeta aquáticas nos Rios Baía e Ivinhema

Resumo

O objetivo do estudo foi analisar os fatores que influenciam as variações espaciais e temporais da assembléia de Oligochaeta nos Rios Baía e Ivinhema, localizados na planície de inundação do Alto Rio Paraná. (Estado do Mato Grosso do Sul, Brasil). As amostras de Oligochaeta foram coletadas de fevereiro de 2000 a novembro de 2007. Um total de 27 espécies foi identificado. Análise de Componentes Principais (PCA) das variáveis físicas e químicas foi usada para sumarizar a variação total nos dados e identificar os principais gradientes ambientais. Para verificar possíveis gradientes espaciais e temporais na distribuição das espécies de Oligochaeta foi realizada uma Análise de Correspondência Dendrítica com remoção do efeito de arco (DCA). As maiores densidades e riqueza de espécies de Oligochaeta foram registradas nos períodos de águas baixas. A intensidade e amplitude da potamofase influenciaram a riqueza, densidade e composição de espécies, uma vez que muitas das espécies foram carreadas pela alta velocidade de corrente de água e/ou mortas devido aos baixos níveis de oxigênio que foram característicos dessa fase. *L. hoffmeisteri*, *P. descolei* and *A. pigueti* foram registradas nos períodos de potamofase e limnofase e nós concluímos que são adaptadas a diferentes condições de rios (lótico e lêntico) devido a preseça dessas espécies durante todo período estudado em ambos os rios. Contudo, essas espécies foram dominantes nos períodos de potamofase desses rios uma vez que elas apresentam adaptações corporais para sobreviver nessas condições.

Palavras-chave: espécies de Oligochaeta, Rios Baía e Ivinhema, intensidade e amplitude do pulso de inundação.

1. Introduction

Floodplains are areas that are periodically flooded by the lateral overflow of rivers or lakes, and/or direct precipitation or groundwater. Fluctuations in physical and chemical variables of the water in these environments causes the biota to respond through morphological, physiological, anatomical, phenological, and/or ethological adaptations and to produce characteristic community structures (Junk et al., 1989). The degree of connection between the river and its floodplain depends on the water level. The river and its wetlands must be considered one unit because its water, sediment and organic budgets are interrelated (Junk, 1980; Junk et al., 1989).

Physical and chemical variations in rivers and their floodplains are usually associated with fluctuations in the water levels, and this characteristic leads to the formation of the flood-pulse concept or the pulse concept (Junk et al., 1989; Neiff 1990a) encompassing both the dry and the flood phases. These phases are important for the biocenosis and regulation of environments (Neiff, 1990b; Neiff et al., 1994).

The flood pulse is the major force in floodplains, and it regulates community structure and ecosystem function (Junk et al., 1989; Neiff 2005; Casco et al., 2005; Agostinho et al., 2008; Takeda and Fujita, 2004). The main attributes of the pulse can be spatial, such as amplitude, intensity and tension, or temporal, such as frequency, recurrence and seasonality, which is also related to the historical behavior of the spatial attributes (Neiff, 1990a, Neiff et al., 1994, Neiff and Malvárez, 2004).

The hydrosedimentological dynamics of large rivers create a high degree of habitat heterogeneity, and this is reflected in the spatial and temporal structures of the benthic community (Marchese and Ezcurra de Drago, 1992). Oligochaeta is an abundant group of benthic organisms (Ezcurra de Drago et al., 2004), and this group is registered in almost all freshwater environments and is abundant in several environments in the Upper Paraná River (Montanholi-Martins and Takeda, 1998; Takeda, 1999; Takeda et al., 1997; Stevaux and Takeda, 2002; Takeda and Fujita, 2004).

This study investigated the hypothesis that the flood pulse modifies the Oligochaeta community structure, and aimed to analyze factors that influence spatial and temporal variations in Oligochaeta assemblages.

2. Materials and Methods

2.1. Study area and sampling stations

The alluvial floodplain of the Upper Paraná River has an asymmetric geometry, with a floodplain on only the right bank of the fluvial channel, and a grade that is about 6 km wide and 3 to 5 m above the mean river level. This floodplain is drained by an anastomosed system of channels (Stevaux and Santos, 1998) that is formed by the Baía River, the Curutuba and Araçatuba channels (which represent old Paraná River channels) and the lower section of the Ivinhema River (Santos, 2005) (Figure 1).

The Ivinhema River (22° 47' 59.64" S and 53° 32' 21.3" W) is an important right-bank tributary of

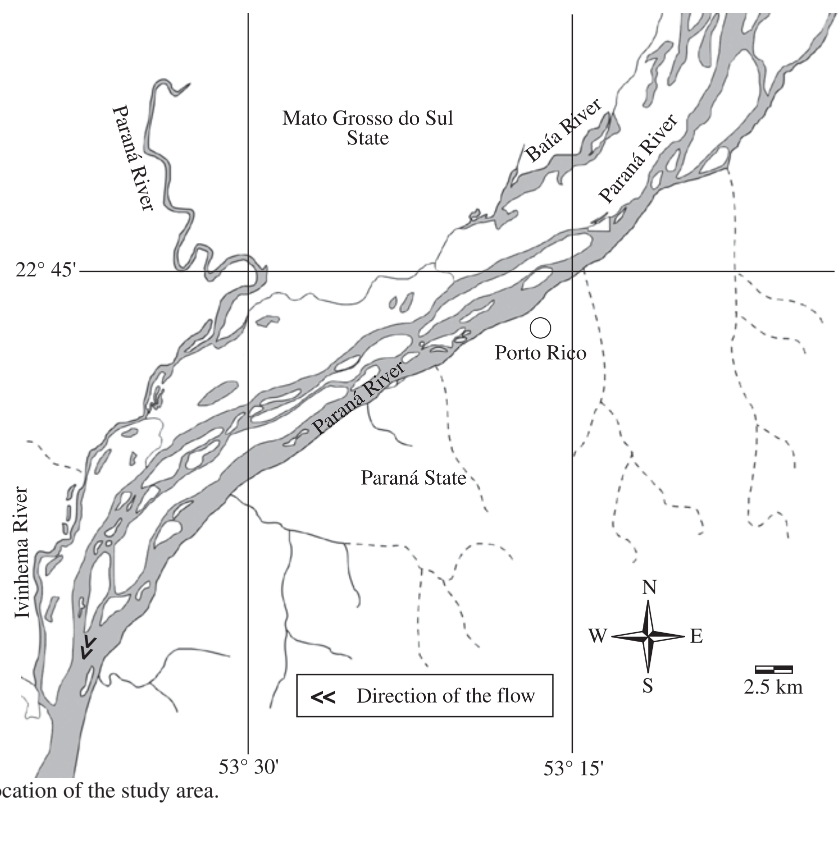

Figure 1. Location of the study area.

the Upper Paraná River, and it cuts a series of terraces, geomorphic surfaces, floodplains and associated features (Fortes et al., 2005).

The Baía River (22° 43' 23.16" S and 53° 17' 25.5" W) is situated on the right bank of the Paraná River in the Mato Grosso do Sul State. It is a sinuous channel and is considered to be a lentic environment because of its reduced water speed.

Water flow into this floodplain can occur due to floods of the Paraná and Ivinhema Rivers (Souza Filho, 2009). During the potamophase period of the Paraná River, water flow into the floodplain initially begins with groundwater elevation and continues until there is a connection with the lentic bodies, which occurs at a flood level of 3.5 m. The increase in river level elevation up to 4.6 m is provided by water entrance through the low banks of the fluvial channels and lakes, and initiates flooding in the "Curutuba/Ivinhema" area. The intermediate sections of the river overflow into the floodplain at a level of 6.0 m and cover the highest parts of the floodplain at a level of 7.0 m (Rocha, 2002; Meurer, 2004; Corradini, 2006; Souza Filho, 2009).

In floods of the Ivinhema River, water flow through the groundwater has not yet been determined, but the beginning of the floodplain occurs from the 2.5 m level of the Fluviometric Station of Ivinhema (Souza Filho, 2009).

2.2. Data collection

Samples for the study of Oligochaeta assemblages were collected quarterly from February 2000 to November 2007, except for November 2001, and March and September 2003. In 2001 and 2003, only three and two annual collections, respectively, were conducted. In the Ivinhema and Baía Rivers, samples were collected at three sites along a transect: two margins and one in the central part of the river. In each site, three samples were taken with a modified Petersen grab (0.0345 m^2) for biological analysis.

The sediment was washed in 2.0, 1.0 and 0.2 mm sequential sieves. The sediment retained on the last sieve was fixed in 70% alcohol, and was sorted using a stereomicroscope. Oligochaeta species were identified using an optical microscope and the key created by Brinkhurst and Jamieson (1971), Brinkhurst and Marchese (1991) and Righi (1984).

The hydrological data were provided by the Agência Nacional de Águas (ANA) and Itaipu Binacional, and the following variables were provided by Limnology Laboratory of Nupelia: conductivity (Digimed DM-3P), pH (Digimed DM-2P), temperature and dissolved oxygen (YSI-550A). The periods under the influence of La Niña and El Niño were defined according to McPhaden et al. (2006).

2.3. Data analysis

The water level data were analyzed from 2000 to 2007 using the attributes of f FITRAS (Neiff, 1990a) obtained with the PULSO program (Neiff and Neiff, 2003) (Table 1). The Fluvial Connectivity Quotient (FCQ) (Neiff and Neiff, 2003) refers to the intensity of the connectivity. The 4.6 m level required for the Paraná River to influence the Baía and Ivinhema Rivers and the 2.5 m level in the Fluviometric Station of Ivinhema were considered to be boundary levels between high water (potamophase - Neiff, 1990) and low water (limnophase - Neiff, 1990) phases (Souza Filho, 2009).

To assess the structure of the Oligochaeta assemblages, density (ind.m^{-2}) and species richness (S) were calculated. A non-parametric two-factor analysis of variance (Kruskal-Wallis test) (Zar, 1984) was used to test the difference between Oligochaeta species and sampling periods.

Principal Component Analysis (PCA) of the physical and chemical variables was used to summarize the total variation in the data and to identify major environmental gradients (Gauch, 1986). The abiotic data used were temperature, dissolved oxygen, conductivity, pH, organic matter (Table 2) and the hydrometric levels of the Ivinhema and Paraná Rivers. These data were analyzed using PC-ORD 4.0 (McCune and Mefford, 1999).

The mean density of Oligochaeta species was analyzed using Detrended Correspondence Analysis (DCA). The biotic data were log (x + 1)-transformed to minimize the effects of discrepant values. Rare species (less than two observations) were removed to improve data interpretation. Eight of the 27 species in the DCA met this criterion.

3. Results

3.1. Abiotic factors

Potamophase periods were generally observed during warmer months (December to March). However, in some years a second flood event was recorded between May and September in the Ivinhema River (Figures 2 and 3). The hydrosedimentological cycle of the Ivinhema River exhibited a bimodal pattern in most of the studied years, except for 2001 and 2004.

In the Paraná River floods did not occur in 2000, 2001 (La Niña years, in which low precipitation values were obtained) and 2004, and the hydrometric level in these years was always below 4.6 m. During this period, the Paraná River recorded the highest intensity (IL) and amplitude (AL) of the limnophase and the lowest values of FCQ (Table 1). On the other hand, higher hydrometric levels were recorded from January to March in 2002, 2003, 2005, 2006 and 2007, which combined with the occurrence of El Niño, when high precipitation values were also obtained.

A higher amplitude (AP) and intensity of the potamophase (IP) was recorded in the Ivinhema River in 2001 and in the Paraná River in 2007 and 2005, respectively (Table 1). Regarding the number of complete pulses (CP) and the FCQ, the greatest values were recorded in the Ivinhema River.

In the Principal Component Analysis (PCA), the first two axes explained 57% (axis 1 = 37% and axis 2 = 20%) of the total data variability.

Table 1. Attributes of *f* FITRAS measured in the Paraná River (Porto São José) and in the Ivinhema River (Porto Sumeca) between 2000 and 2007. AP, AL: Total Amplitude of Potamophase and Limnophase, IP, IL: Intensity of Potamophase and Limnophase. FCQ: Fluvial Connectivity Quotient. CP: number of Complete Pulses.

Attributes / Years	AL	IP	IL	AL	FCQ	CP
Ivinhema						
2000	28	338	3.83	0.84	0.08	1
2001	98	267	4.79	1.06	0.36	7
2002	18	347	3.18	0.8	0.05	1
2003	13	352	2.81	0.86	0.036	2
2004	50	316	3.44	0.82	0.15	4
2005	52	313	4.55	0.83	0.16	2
2006	41	324	2.91	0.94	0.12	4
2007	69	296	4.29	0.71	0.23	3
Paraná						
2000	3	363	5.07	2.04	0.008	1
2001	0	365	4.14	1.17	0	0
2002	10	355	5.3	1.89	0.028	2
2003	9	356	5.02	1.96	0.025	2
2004	0	366	4.34	1.95	0	0
2005	33	332	6.76	1.98	0.09	5
2006	13	352	5.16	2.2	0.03	3
2007	55	310	6.45	2.16	0.17	1

The attributes of FITRAS are defined as follows:
The **amplitude** of the phase is the duration of droughts and floods of a determined magnitude in a determined place on the floodplain.
The **intensity** of the phase is the intensity caused by a drought or an inundation.
The **fluvial Connectivity Quotient** = FD/ID
where FD is the number of flooding days (potamophase)
and ID is the number of isolated days (limnophase)
The **complete pulses** (potamophase + limnophase).

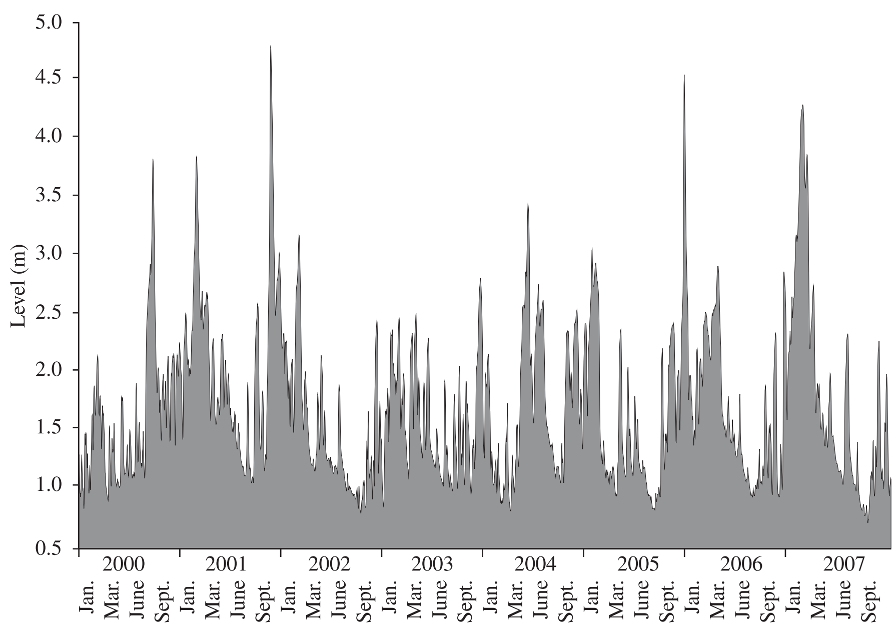

Figure 2. Hydrometric level of the Ivinhema River, obtained in the Fluviometric Station of Ivinhema from 2000 to 2007.

Table 2. Mean, maximum and minimum (in parentheses) of the abiotic variables of the water at the sampling sites from 2000 to 2007.

Variables / Years	Temperature (°C)	pH	Conductivity (μS.cm^{-1})	Dissolved oxygen	Organic matter (%)
Ivinhema					
2000	23.83 (18-26.8)	6.86 (6.46-7.16)	41.84 (39.0-44.0)	7.34 (6.28-8.55)	6.83 (0-16.3)
2001	25.46 (21.1-30)	6.57 (6.26-6.85)	43.28 (40.2-46.2)	7.36 (5.9-8.78)	9.94 (0.6-20.7)
2002	25.22 (20-27.6)	7.32 (6.61-8.44)	40.98 (32.7-57.3)	6.88 (5.42-7.75)	7.21 (0-21.29)
2003	27.45 (26.6-28.4)	6.58 (5.72-6.99)	40.23 (26.1-49.5)	7.12 (5.7-7.9)	10.5 (1.7-26.7)
2004	24.2 (17.2-28.4)	6.68 (5.94-7.94)	43.77 (37.2-50.2)	6.72 (5.6-7.7)	4.6 (0.5-9.6)
2005	24.28 (18.6-29.7)	7.13 (7.06-7.40)	45.8 (39.6-52.5)	7.34 (6.09-8.63)	6.72 (0-15.6)
2006	26.03 (20.8-29.3)	6.92 (6.18-7.72)	44.76 (42.7-49.0)	6.86 (5.46-8.15)	6.86 (0.52-16.29)
2007	25.85 (21.1-29.8)	7.06 (6.44-7.86)	45.30 (42.1-50.0)	6.26 (2.59-8.37)	4.56 (0.37-16.80)
Baía					
2000	23.9 (18.1-28)	6.54 (6.13-6.97)	31.65 (27.9-35)	7.10 (4.68-8.6)	1.22 (0.11-8.07)
2001	24.05 (20.8-29)	6.24 (5.9-6.76)	22.9 (19-25.7)	7.46 (5.94-9.3)	6.06 (2.69-14.17)
2002	24.84 (18.6-28.4)	6.54 (5.72-6.99)	32.1 (22.1-49.5)	7.33 (5.68-8.35)	5.32 (0.8-11.1)
2003	24.9 (20.3-30)	6.9 (6.6-7.2)	29.9 (25.0-41.0)	6.7 (4.5-8.8)	5.6 (0.5-13.8)
2004	24.5 (17.8-28.2)	5.8 (4.97-7.1)	31.3 (25.3-37.8)	6.3 (5.0-7.0)	7.1 (1.0-21.7)
2005	24.28 (19.3-28.8)	6.61 (6.29-6.99)	36.00 (26.8-57.1)	6.95 (5.05-8.8)	8.39 (1.60-50.74)
2006	26.05 (21.2-29.7)	6.57 (5.69-7.13)	32.1 (23.8-49.5)	6.52 (4.71-7.1)	10.47 (0.20-40.52)
2007	26.17 (21.5-29.9)	6.76 (6.41-7.14)	40.68 (29.6-51.8)	6.14 (2.35-7.9)	10.01 (0.87-37.03)

In the axis 1, dissolved oxygen contributed the highest positive correlation, while temperature and levels of the Paraná and Ivinhema Rivers had the highest negative correlations. On axis 2, the variables that correlated positively with the variability were pH and conductivity, and the level of the Ivinhema River had the largest negative correlation (Figure 4).

Axis 1 showed differences between the environments due to dissolved oxygen and temperature values that were different during the potamophase and limnophase periods. The limnophase periods in the Baía and Ivinhema Rivers occurred during the colder months (May to September), whereas the potamophase periods coincided with high temperatures. On axis 2, the two

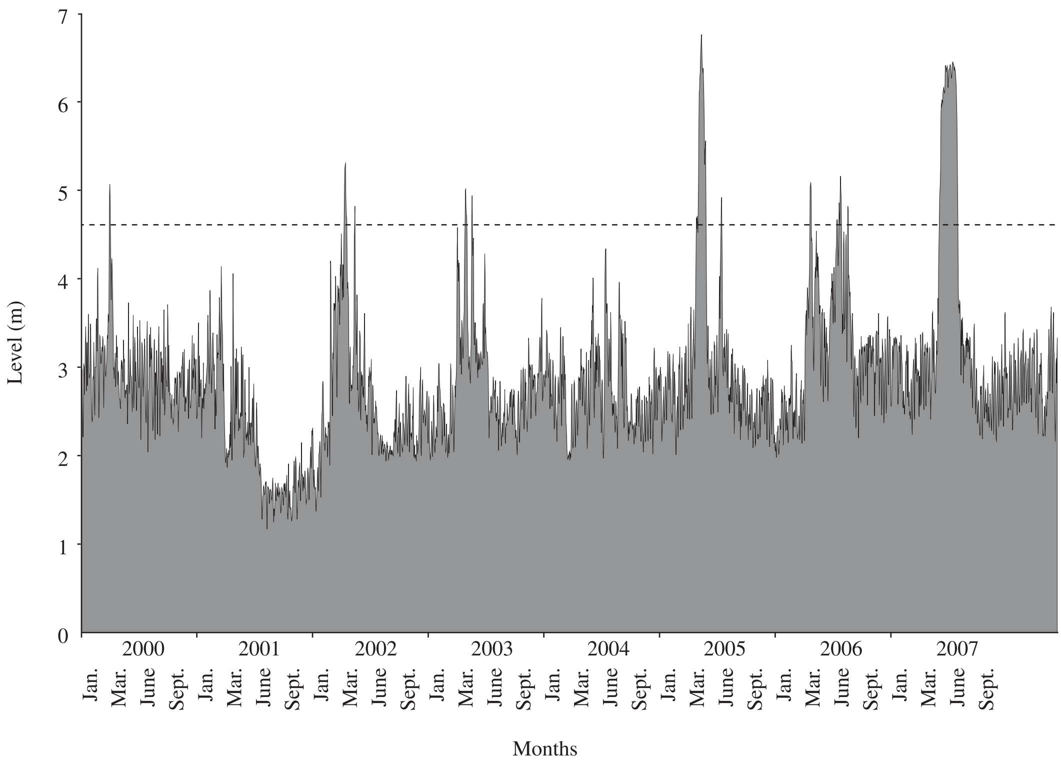

Figure 3. Hydrometric level of the Paraná River, obtained in the fluviometric station of Porto São José from 2000 to 2007.

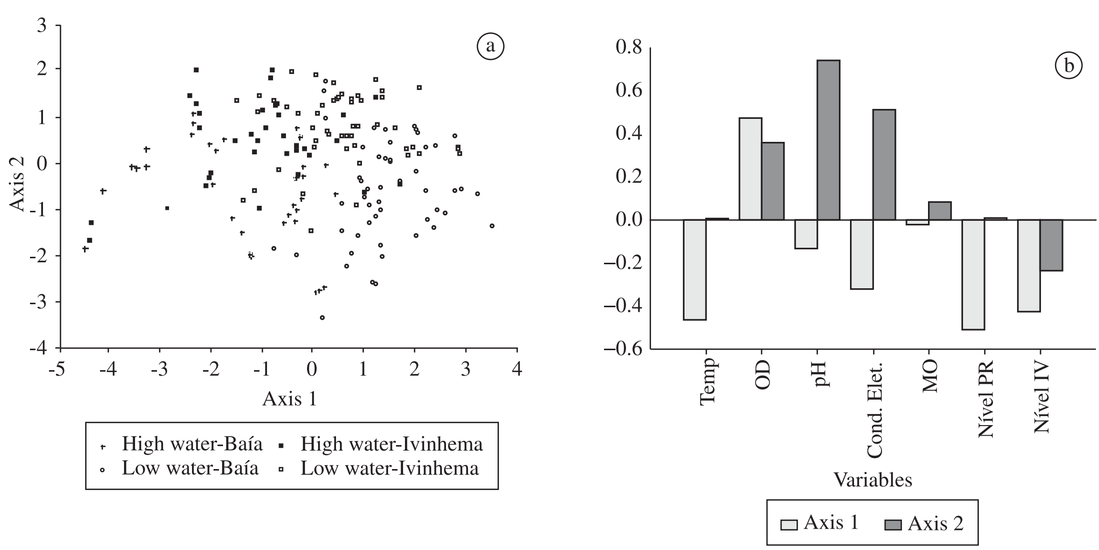

Figure 4. a) Ordination of the scores for each sampling station, in relation to axes 1 and 2 of the principal component analysis (PCA); and b) Autovector of the variables used in the principal component analysis.

environments differed based on high values of pH and conductivity recorded in the Ivinhema River and in the lower Baía River (Figure 4).

3.2. Aquatic oligochaeta composition

In this study, 7250 Oligochaeta individuals from seven families were recorded: Alluroididae, Enchytraeidae, Haplotaxidae, Narapidae, Opistocystidae, Naididae and Tubificidae. The Enchytraeidae individuals were not identified at the specific level and considered as species for the analysis. Naididae was responsible for 56% of the collected species in the Baía River and 52% in the Ivinhema River (Table 3).

Higher mean densities of Oligochaeta were recorded in February and May 2000 in the Ivinhema River and in May and August of the same year in the Baía River (Figure 5). A Kruskal-Wallis test showed that there was a significant difference only between the Oligochaeta density and the collection periods ($H = 50.95$; $p < 0.05$).

A higher percentage of *Narapa bonettoi* was observed in the Ivinhema River from 2000 to 2002. After 2005, *Limnodrilus hoffmeisteri*, *Paranadrilus descolei* and *Aulodrilus pigueti* dominated this river (Figure 6a). The Baía River had different dominant species during the years of the study (Figure 6b).

Table 3. Presence and absence of aquatic Oligochaete species during the flood (Potamophase) and drought (Limnophase) periods of the Ivinhema and Baía Rivers.

Station	**Baía**	**Baía**	**Ivinhema**	**Ivinhema**
Periods	**Drought**	**Flood**	**Drought**	**Flood**
ENCHYTRAEIDAE	+	–	–	–
HAPLOTAXIDAE				
Haplotaxis aedeochaeta (Brinkhurst and Marchese, 1987)	–	–	+	–
OPISTOCYSTIDAE				
Opistocysta funiculus (Cordero, 1948)	–	–	+	–
NARAPIDAE				
Narapa bonettoi (Righi and Varela, 1983)	+	–	+	+
NAIDIDAE				
Pristina americana (Cernosvitov, 1937)	+	–	+	+
P. macrochaeta (Cernosvitov, 1939)	+	–	+	–
P. leidyi (Smith, 1896)	–	–	+	–
P. aequiseta (Bourne, 1891)	+	–	+	–
P. proboscidea (Beddard, 1896)	+	–	+	–
P. osborni (Walton, 1906)	+	–	–	–
Bratislavia unidentata (Harman, 1973)	–	–	+	–
Dero sp.	+	–	+	–
Dero (Dero) plumosa (Naidu, 1962)	+	–	–	–
D. (D.) righii (Varela, 1990)	–	–	+	–
D. (D.) digitata (Muller, 1773)	+	–	+	–
D. (D.) sawayai (Marcus, 1943)	+	–	+	–
D. (D.) multibranchiata (Steiren, 1892)	+	–	–	–
Dero (Aulophorus) borellii (Michaelsen, 1900)	+	–	–	–
D. (A.) furcatus (Muller, 1773)	+	–	+	–
Nais communis (Piguet, 1906)	+	–	+	–
Slavina evelinae (Marcus, 1942)	+	–	+	+
Stephensoniana trivandrana (Aiyer, 1926)	+	–	+	+
TUBIFICIDAE				
Limnodrilus hoffmeisteri (Claparede, 1862)	+	+	+	+
Paranadrilus descolei (Gavrilov, 1955)	+	+	+	+
Aulodrilus pigueti (Kowalewski, 1914)	+	+	+	+
Bothrioneurum americanum (Beddard, 1894)	+	–	+	–
ALLUROIDIDAE				
Brinkhurstia americana (Brinkhurst, 1964)	+	–	+	–

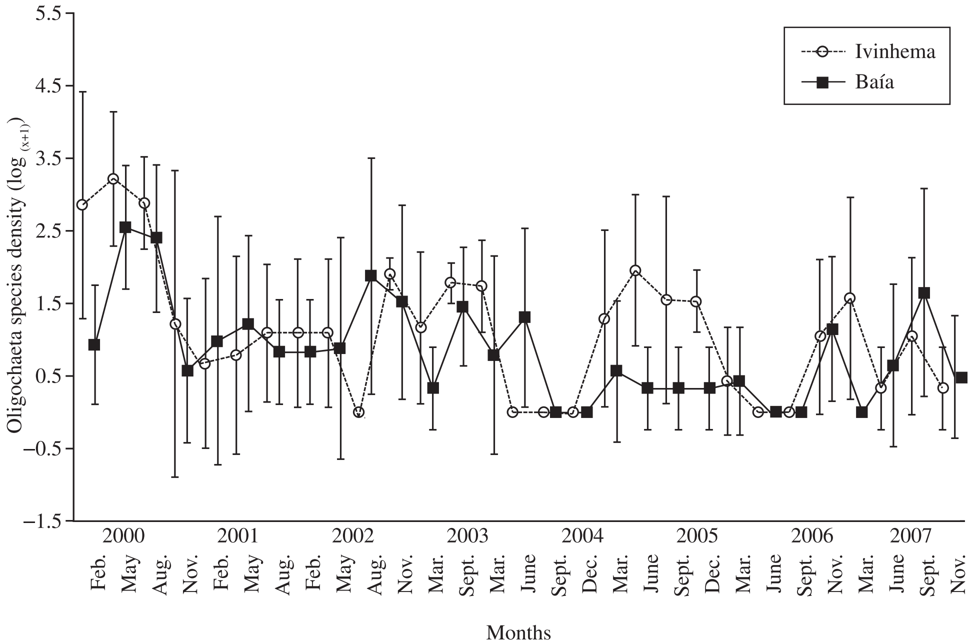

Figure 5. Oligochaete species density ($\log_{(x+1)}$) in the Ivinhema and Baía Rivers over an eight year period.

The highest value of species richness was observed in the Ivinhema River in June 2005 while the highest value in the Baía River occurred in August 2000 (Figure 7). A Kruskal-Wallis test showed a significant difference only between species richness and the collection periods ($H = 47.27$; $p < 0.05$).

To verify possible spatial and temporal gradients in the Oligochaeta species distribution, a Detrended Correspondence Analysis (DCA) (eigenvalues on axis 1 = 0.99 and on axis 2 = 0.53) was conducted, and indicated three separate groups. Group 1 was formed mainly in the limnophase periods of the Baía River, where a greater number of Oligochaete species was observed. Group 2 was observed during the limnophase and potamophase periods of the Ivinhema River and the potamophase period of Baía River, and included *P. descolei*, *L. hoffmeisteri* and *A. pigueti*. Group 3 comprised the limnophase periods of the Ivinhema River from 2000 to 2002 when higher densities of *Haplotaxis aedeochaeta* and *N. bonettoi* were observed (Figure 8).

4. Discussion

Early ecologists recognized that environmental conditions were temporally dynamic (McIntosh, 1985), and the temporal study contributed significantly to its generalizations and/or predictions. Observations distributed across several days or months may differ from those that span years or decades because longer studies have a greater probability of observing or helping to explain slow, rare, subtle or complex changes in natural environments (Likens, 1989; Elliott, 1990; Risser, 1991; Cody and Smallwood, 1996, Jackson and Füreder, 2006).

Long-term studies of lotic macroinvertebrates communities are rare (Jackson and Füreder, 2006), particularly over broad spatial scales, but the perspectives of such studies are valuable for identifying interactions between spatial and temporal variability (Collier, 2008). Few long-term studies have been conducted on the Oligochaeta community in fluvial systems (Nijboer et al., 2004). The absence of those studies does not allow us to understand or to assess environments with great variability, such as those found in areas that are sometimes flooded.

The pulse acts as a disturbance factor in fluvial macrosystems, removing organisms and allowing new spaces and resources to become available (Hildrew and Giller, 1994). The degree of disturbance is a function of the frequency, intensity, tension, regularity, amplitude and seasonality of the "pulses" (*f* FITRAS) (Neiff, 2001), of the connectivity (Ward et al., 1999) and, in general, of the fluvial dynamics (Ward et al., 2002), which are deeply influenced by climatic changes.

The interactions of such attributes, as well as the fluctuation between potamophase and limnophase periods, determine several effects on the community structure of benthic invertebrates (Neiff, 2001) and on floodplain ecosystems and provide a high spatial and temporal diversity (Ward et al., 1999).

Pulses of water discharge have a high degree of interannual variability in the Paraná River. The nature of these pulses is variable over a century, and even over a decade. Hydrological regularities are shown through long-term studies, which enables tendencies in hydrological variability to be determined (Neiff, 1996). Depetris et al. (2003) observed that extreme water phases do not

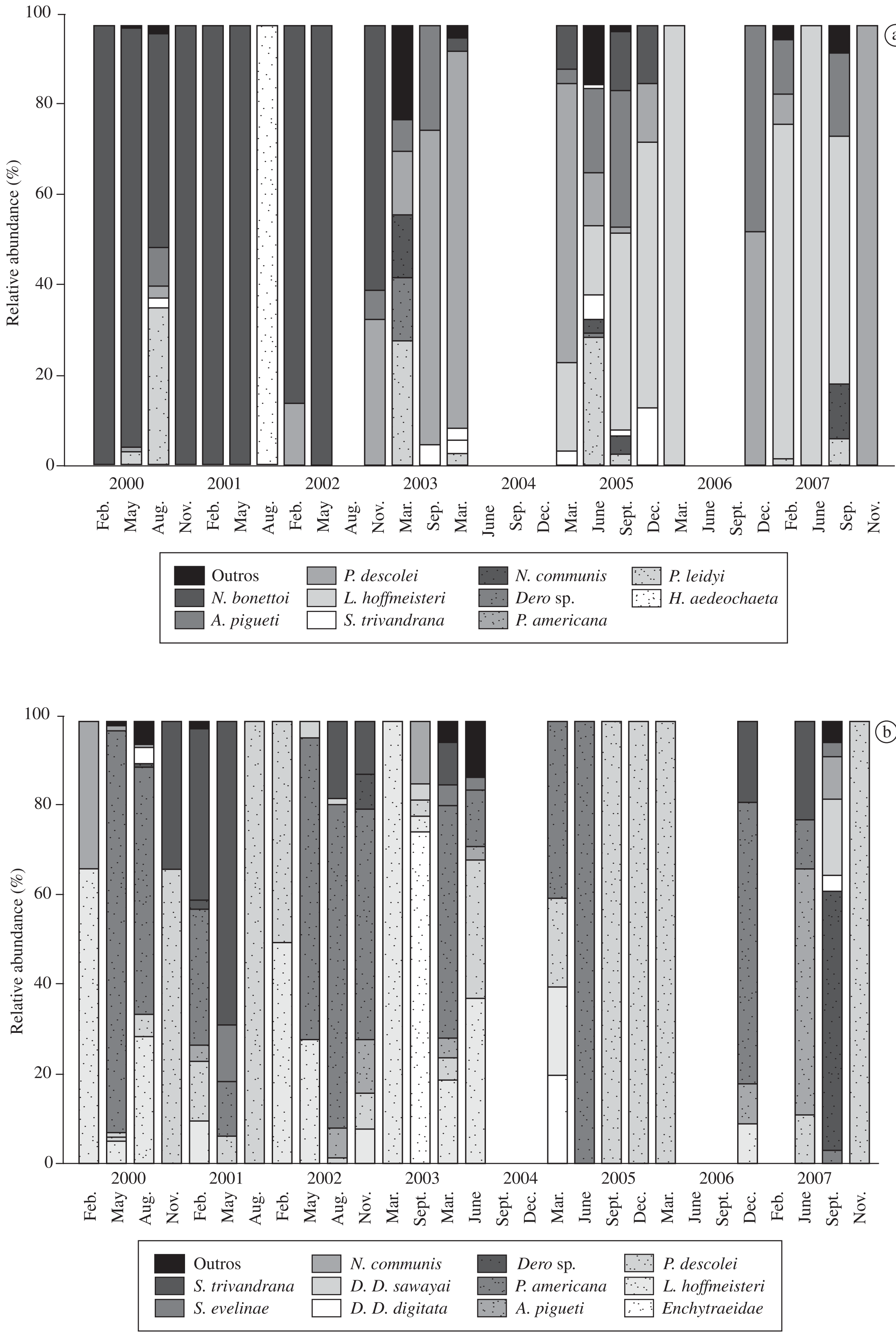

Figure 6. Relative abundance of oligochaete species in the a) Ivinhema and b) Baía Rivers.

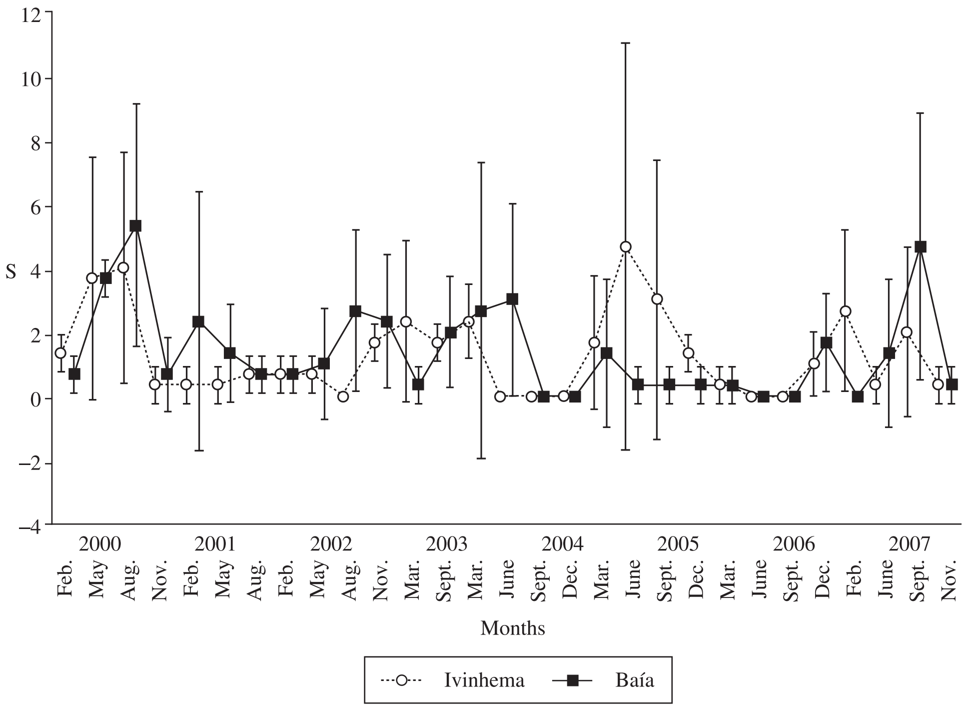

Figure 7. Species richness of the Ivinhema and Baía Rivers sampled over an eight year period.

always coincide with long-term hydrological records and that these phases are usually related to the global climatic phenomenon called ''El Niño Southern Oscillation'' (ENSO). The ENSO drives complex weather patterns such as wind direction and velocity, temperature, and the timing and amount of precipitation over cycles that return roughly every 3-7 years (Schonher and Nicholson, 1989). Future climate change may have uncertain effects on this cycle (Hoerling and Kumar, 2003).

The Paraná River recorded the lowest hydrometric levels in 2000 and 2001, possibly because of the influence of the La Niña and of the 2nd phase formation of the Engenheiro Sérgio Motta Reservoir. Those phenomena provided the lowest values of complete pulses, intensity and amplitude of the limnophase, and the fluvial connectivity quotient, in a way that decreased the influence of this river on the other rivers studied. On the other hand, 2005 and 2007 had the highest hydrometric levels, possibly because of the presence of El Niño. That fact provided the highest values of intensity and amplitude of the potamophase and of the fluvial connectivity quotient, which increased the influence over the analyzed rivers, modifying the richness and density of Oligochaeta species.

According to the scores of the PCA axes, the rivers and the potamophase and limnophase periods could be distinguished. In the floodplain, dissolved oxygen is low during the high water phase (potamophase) when the rivers overflow because of the decomposition of some plants and the backlog of organic matter alongside the banks, and the coincidence of this period with high temperatures accelerates this process (Thomaz et al., 1997). Under such conditions, thermal stratification may last longer than 24 hours (Thomaz et al., 2004).

The oligochaeta assemblage composition of the two rivers was also separated into three groups using DCA. Group 1, which consists of several species, is formed mainly in the limnophase period. The highest values of Oligochaeta density and richness were observed in 2000 during the limnophase period and could have resulted from a decreased influence of the Paraná River water on the Ivinhema and Baía Rivers. The lower connectivity of the Paraná River with the studied environments likely increased the species richness due to high oxygen concentration. The highest richness in the Ivinhema River was observed in 2005 after a high intensity potamophase period. This high richness value could have been the result of species drifting from other places into the Ivinhema River, and potentially even from the Paraná River, which remained higher than 4.6 m for 33 days during 2005. During the period of high water, the transport by drift and, consequently, the temporary colonization of habitats may increase the species richness immediately after the high water phase (Marchese et al., 2002).

In the group 2, the composition of the two rivers in the potamophase period was similar and was characterized by presence of Aulodrilus pigueti, Limnodrilus hoffmeisteri and Paranadrilus descolei. The first two species cited are found in sediments with abundant organic matter (Marchese, 1987; Montanholi-Martins and Takeda,

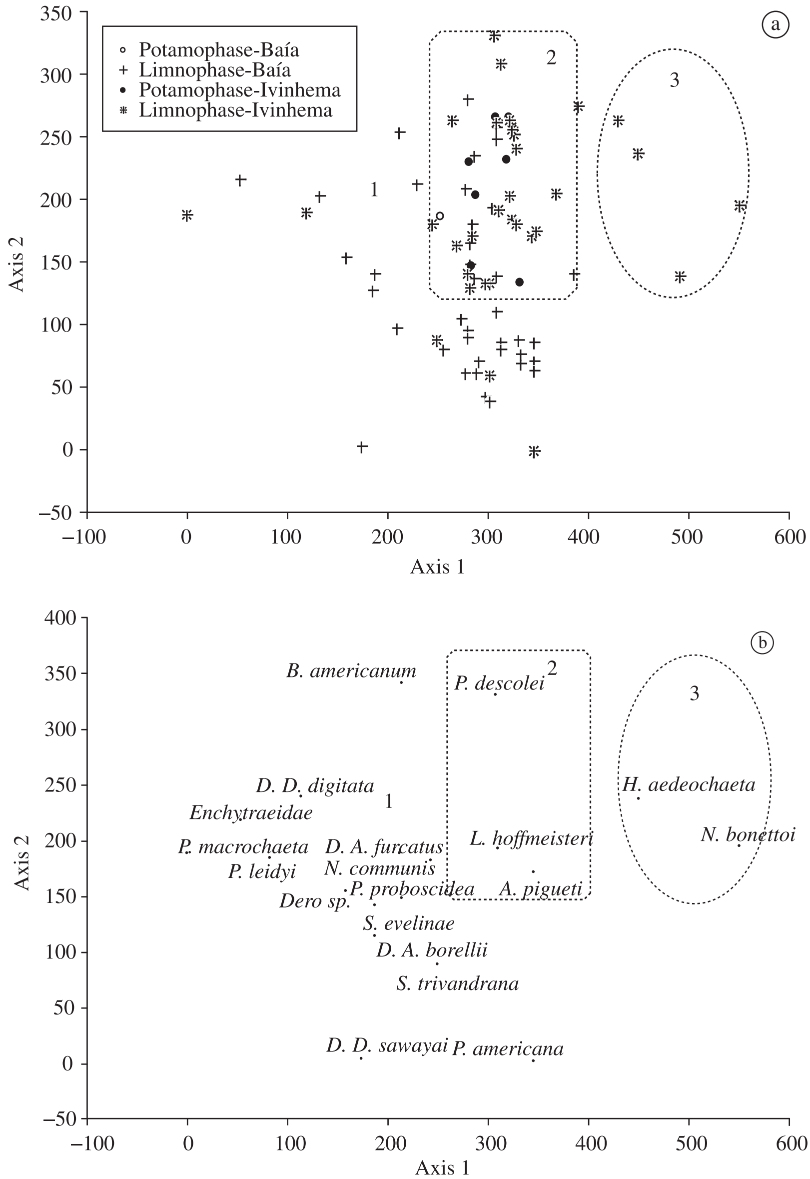

Figure 8. First two axes of the Detrended Correspondence Analysis (DCA) ordination diagram. a) Ordination of the environment/collection period scores and b) Ordination of the Oligochaete species.

1998) and possess respiratory pigments (hemocyanin), which can improve respiration in environments with low levels of dissolved oxygen (Misenderino, 1995).

Group 3 recorded high densities of *H. aedeochaeta* and *N. bonettoi* in the Ivinhema River from 2000 to 2002. According to Montanholi-Martins and Takeda (1998, 2001) and Takeda and Fujita (2004), the bed of the Ivinhema River is composed of pebble, gravel and sandy sediments. These two species are observed in sandy sediments of fluvial systems such as the Paraguay River (Ezcurra de Drago et al., 2004) and the Paraná River (Marchese and Ezcurra de Drago, 1992; Montanholi-Martins and Takeda, 1998; 2001; Marchese et al., 2002; and Takeda and Fujita, 2004; Bletter et al., 2008). In the limnophase periods, higher densities of *H. aedeochaeta* and *N. bonettoi* were observed due to the decreased influence of water currents in the sandy sediment transport these species.

In the present study, a decrease in the richness and density of Oligochaeta during the potamophase periods was observed due to the influence of the water current velocity that causes the transportation of species. However, we need more research to know how the intensity and amplitude of the potamophase influences Oligochaeta assemblage. *L. hoffmeisteri*, *P. descolei* and *A. pigueti* were recorded in the potamophase and in the limnophase and we concluded that they are adapted to different conditions of rivers (lotic and lentic) due to the presence of these species during the entire study period in both rivers. Nevertheless, these species were dominant in the potamophase periods of these rivers as they have body adaptations to survive in these conditions.

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