Influence of water level on periphytic meiofaunal abundance in six lagoons of the Upper Paraná River floodplain, Brazil.

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ABSTRACT: Influence of water level on periphytic meiofaunal abundance in six lagoons of the Upper Paraná River floodplain, Brazil. The role of the hydrological regime in periphytic meiofauna abundance on the Upper Paraná River floodplain was evaluated through a comparative study of six lagoons located in two systems of the floodplain, during two hydrological periods (maximum and minimum fluviometric levels). The substratum chosen was Eichhornia azurea Kunth petioles and they were sampled in treplicate taken at random. The community adhered to each petiole was scraped and fixed in formaldehyde solution. The dry weight of ash, the ash-free dry mass and the chlorophyll a of the periphyton were measured. The abiotic data (water transparency (Secchi disc), water temperature, dissolved oxygen, alkalinity, turbidity, pH, conductivity and total inorganic carbon) were also measured in the littoral region surrounding the macrophytes in each lagoon and period. The hydrological levels of the Paraná river were also obtained. Principal component analysis and Detrended Correspondence Analysis were used to understand the spatial and temporal variation of the limnological factors and periphytic meiofaunal abundance in the study. The two first axis scores of the DCA and PCA analyses were correlated using Regression Analysis. The most abundant organisms were rotifers and protozoa and the first group presented higher spatial and temporal variations than the second group of the periphytic meiofauna in the lagoons during the studied period. The hydrological regime and the hydrodynamic characteristics of the lagoons in the Ivinhema River and Baia River systems were the dominant factors in the organisms abundance in the periphytic meiofauna community.

Key words: periphyton, meiofauna, rotifers, lagoons, floodplain, water level.

RESUMO: Influência do regime hidrológico sobre a abundância da meiofauna perifítica em seis lagoas da planície de inundação do alto rio Paraná, Brasil. O papel do regime hidrológico sobre a abundância da meiofauna perifítica na planície de inundação ao alto rio Paraná foi avaliado a partir de estudos comparativos em seis lagoas durante dois períodos hidrológicos (níveis fluviométricos máximo e mínimo). O substrato escolhido foi o pecíolo de Eichhornia azurea Kunth. e foram amostrados em tréplicas em bancos selecionados randomicamente. Os organismos foram raspados lentamente dos pecíolos e fixados em solução de formaldeído. Os pesos secos das cinzas e livre de cinzas, e a biomassa perifítica foram medidos. Os dados abióticos (transparência da água (disco de Secchi), temperatura da água, oxigênio dissolvido, alcalinidade, turbidez, pH, condutividade elétrica e carbono inorgânico total) da região litorânea próximo aos bancos de macrófitas foram estimados em cada lagoa e período. Os dados do nível hidrológico do rio Paraná também foram obtidos. As análises de Componentes Principais e da Remoção do Efeito do Arco foram empregadas a fim de se avaliar a variação espacial e temporal dos fatores limnológicos e da abundância da meiofauna perifítica. Os dois primeiros eixos foram relacionados através de uma análise de Regressão Múltipla. Os organismos mais abundantes foram os rotíferos e os protozoários testáceos, e o primeiro grupo foi responsável pelas variações espaciais e temporais da meiofauna perifítica nas lagoas estudadas. O regime hidrológico do rio Paraná e as características hidrodinâmicas das lagoas foram fatores determinantes na abundância meiofauna perifítica.

Palavras-chave: Perifiton, meiofauna, rotíferos, lagoas, planície de inundação e nível de água.

Introduction

The river-floodplain systems present variations on water levels as a marked characteristic. The seasonality determines pulses of energy and material and is considered the main force function that governs the functioning of these ecosystems (Junk, 1996; Neiff, 1996), regulating physical, chemical and biological processes (Thomaz et al., 2004).

Alterations in water level, in dependence with morphometry and the degree of connection of the environments to the main river channel, influence the structure and distribution of various communities in the different lentic ecosystems of the floodplain (Takeda et al., 1991; Train & Rodrigues, 1998; Agostinho et al., 2000; Rodrigues & Bicudo, 2001; Lansac-Tôha et al., 2004). Periphyton is formed by autotrophic and heterotrophic organisms including periphytic meiofauna, that is composed by abundant and diverse community of organisms with different sizes (Robertson et al., 2000).

Investigations about periphytic meiofauna were rare in Brazil, especially on floodplains, where there are no abundance records of this community. Studies about these organisms are fundamental since they play an important ecological role inside the community. According to Nogrady et al. (1993) and Schmid-Araya (1993), the meiofauna may increase the transference of energy by feeding on particles inefficiently consumed by large invertebrates and fishes, and these resources are replaced to other trophic levels through a complex food web. Trophic relations between the components of the periphytic community are also important to know the composition and abundance of the meiofauna.

This study evaluated the influence of the water level as the main force function acting on the periphytic meiofaunal community, on the community and on main groups abundance, in different hydrological periods at six lagoons.

Materials and methods

Six lagoons were selected in the floodplain. Maria Luiza, Boca Aberta, and Onça lagoons are connected with Baia River and Boca do Ipoitã, Patos and Finado Raimundo lagoons with Ivinheima River (Fig. 1). The Baia River is a important tributary at the right bank of the Paraná River in Mato Grosso do Sul State, Brazil. This river presents a wide bed with a large wetland area and low marginal dikes and, is characterized as semilotic system due its low declivity and low current velocity (Takeda & Grzybkowska, 1997). On the other hand, the Ivinhema River, which is also located on the right bank of the Paraná River, presents a higher declivity and current velocity than the Baia River.

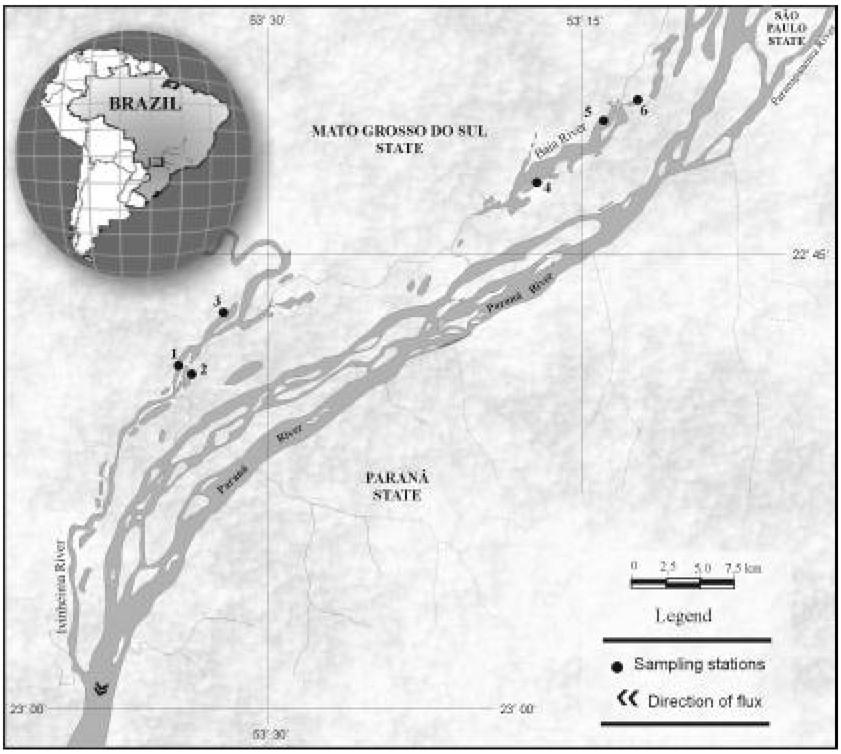

Figure 1: Study area in the Upper Paraná River floodplain (1 = Boca do Ipoitã lagoon, 2 = Patos lagoon, 3 = Finado Raimundo lagoon, 4 = Boca Aberta lagoon, 5 = Maria Luiza lagoon, 6 = Onça lagoon).

The Upper Paraná River floodplain is characterized by two distinct periods during the year. The maximum fluviometric and minimum fluviometric periods are observed between November and May, and between June and October, respectively (Thomaz et al., 2004). Samplings were carried out between 9 and 14 February 1999 (maximum fluviometric level) and between 30 September and 10 October 1999 (minimum fluviometric level).

The biotic data:

In order to determine periphytic meiofaunal community abundance, petioles of aquatic macrophyte Eichhornia azurea Kunth, a common macrophyte in Upper Paraná floodplain, were sampled in treplicate from branches taken at random. The cut petioles were transferred to glass bottles. The periphytic community adhered to each petiole was scraped.

The scraped samples were conditioned in containers with 4% formaldehyde solution. In the laboratory, the samples were diluted in 20 ml and, 10 ml of each sample was used to estimate meiofaunal organism abundance. This value was subsequently extrapolated for the unit of area of the petiole in square centimeters calculated from the geometric figure of a cylinder, corresponding to the E. azurea petiole.

The identification and abundance of the meiofaunal organisms were carried out using a Sedgwick-Rafter chamber (1 ml) under an optical microscope. The size classification proposed by Fenchel (1978) was used. The meiofauna is constituted by organisms that pass through a 500 mm mesh, but are caught in a 42 mm mesh. Protozoa (as testate amoebae) was also included in the periphytic meiofaunal community (Bott, 1996, Hakenkamp & Morin, 2000).

The dry weight of ash, the ash-free dry mass (Schwarzbold et al., 1990) and the chlorophyll a (Golterman et al., 1978) of the periphyton, together with the environmental variables, were measured in order to establish relationships with periphytic meiofaunal abundance.

The environmental variables

The fluviometric level (cm) considered was the average of the previous four sampling days. The fluviometric level of the Ivinhema River was measured in Porto Sumeca (Mato Grosso do Sul State) and, the Paraná River, in Porto São José (Paraná State). This last level was used to the Baia River system due the higher influence of the Paraná River to the tributary. Data were supplied by the National Agency of Electric Energy (ANEEL).

Environmental variables measured in the open water, surrounding the macrophytes, were transparency (m) (Secchi disc), temperature (°C) and dissolved oxygen (mg L^{-1}) (ISY field equipment), alkalinity (mEq L^{-1}) (Carmouze, 1994), turbidity (NTU) (LaMote, 2008 portable digital turbidimeter), pH and conductivity (mS cm^{-1}) (Cole and Palmer field potentiometer) and total inorganic carbon (mg L^{-1}) (Carmouze, 1994).

Data analysis

Principal component analysis (PCA) was used to reduce the dimensionality of the abiotic variables and to characterize the lagoons and the hydrological periods. The abiotic data were standardized (except pH) in order to linearize the bivariate relationships. This analysis was carried out using the statistical package Statistica version 5.0 (Statsoft Inc., 1996).

Organism densities were log (x+1) transformed. Detrended Correspondence Analysis (DCA) (Jongman et al., 1995) was used to order the sampling units based on organism density (Hill &Gauch, 1980) and also allow characterizing the lagoons and the hydrological periods. The axis scores first and second of these group analyses were correlated using Regression Analysis, throughout the statistical package PC-ORD 4.0 software (McCune & Mefford, 1995)

Results

Periphytic meiofauna and Environmental variables

Meiofaunal abundance in the lagoons of the Ivinhema River system was linked to water level variation, and the hydrological periods were distinct. The mean abundance values varied between 78 ind.cm^{-2} (in the maximum fluviometric level) and 38 ind.cm^{-2} (in the minimum fluviometric level). On the other hand, the meiofaunal abundance in the Baia River system lagoons was similar in both hydrological periods (50 ind.cm^{-2}, in the maximum, and 51 ind.cm^{-2}, in the minimum fluviometric levels) (Fig. 2).

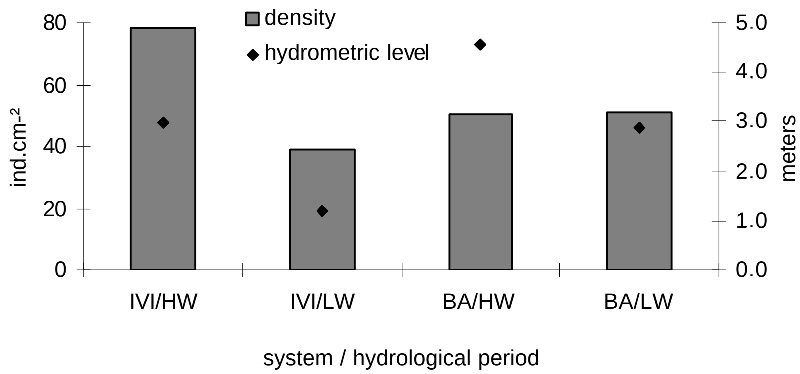

Figure 2: Relationship between the average density of the periphytic meiofaunal organisms (n = 9) and water level average (n = 4 days) in the Ivinhema (IVI) and in Baia systems (BA) during the two hydrological periods: maximum (HW) and minimum fluviometric levels (LW).

The difference of the depth in the lagoons of both systems between the hydrological periods (Fig. 3) promoted a difference in the meiofaunal abundance, mainly in the environments of Ivinhema River.

The fluviometric level variation registered in the Paraná River was higher than observed in the Ivinheima River. However, the water level variation in both river showed a maximum fluviometric level period in February and, a minimum fluviometric level in October (Fig. 4).

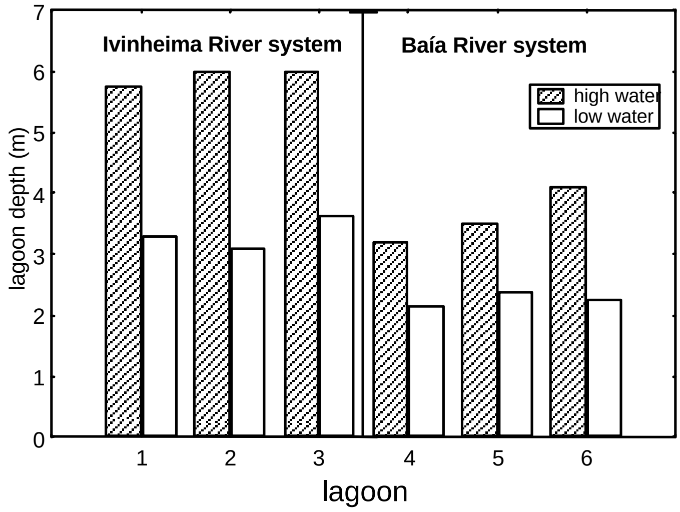

Figure 3: The lagoons depth of each river system (Ivinheima River system, 1 = Boca do Ipoitã lagoon, 2 = Patos lagoon, 3 = Finado Raimundo lagoon; Baia River system, 4 = Boca Aberta lagoon, 5 = Maria Luiza lagoon, 6 = Onça lagoon) in the maximum (February) and minimum fluviometric levels (October).

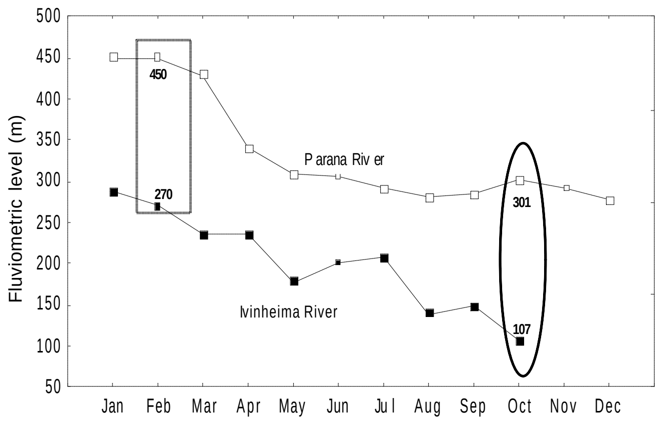

Figure 4: The fluviometric level of the Paraná River and Ivinheima River during 1999.

PCA results showed that the lagoons in each system of the floodplain (Baia River system = A and B, and Ivinheima River system = C and D) and hydrological period (high water = A and C and, low water = B and D) can be distinct by the environmental variables (Fig. 5 **I**). According the variables scores, the first PCA axis showed the temporal variation and it was detected by the water level, turbidity, dissolved oxygen, alkalinity, transparency, temperature and pH (r › 0.7). The other axis (PCA 2) showed the temporal variation in the lagoons of the Ivinheima system and it was described according to the temporal and spatial variation of the conductivity (r › 0.7) (Tab. I). The influence of the conductivity in the temporal variation was observed mainly in the high water period. In this time, waters of the river invade the wetlands, carrying a large quantity of organic material in decomposition to the lagoons.

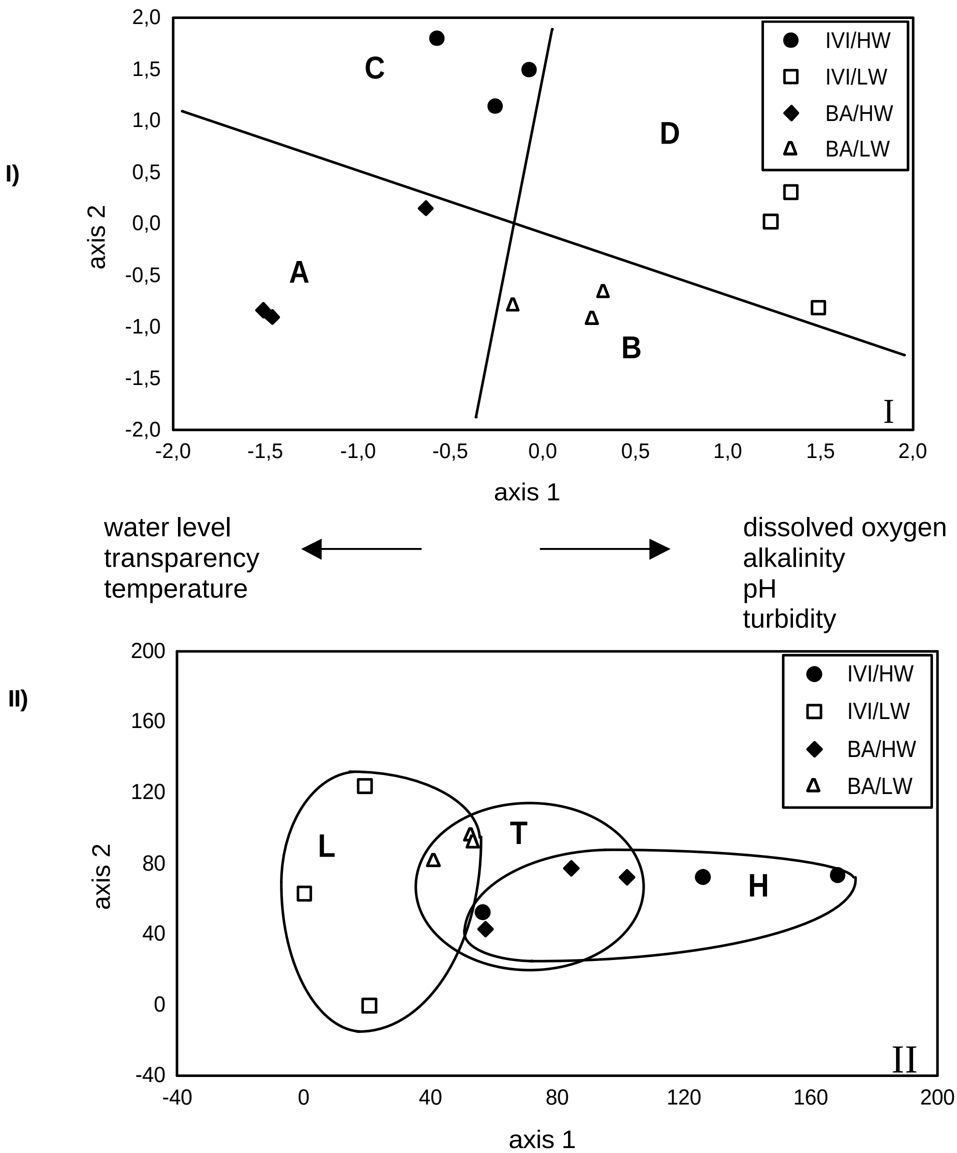

Figure 5: Scores of the PCA analyzes (I) and the DCA analyzes in the two first axes (II). I: quadrant A = lagoons of the Baia River system in high water period; quadrant B = lagoons of the Baia River system in low water period; quadrant C = lagoons of the Ivinhema River system in high water period and quadrant D = lagoons of the Ivinhema River system in low water period. II: L = low water period; H = high water period and T = lagoons of the Baia River system in both hydrological periods. Legends: IVI/HW and IVI/LW = Ivinhema River in maximum and minimum fluviometric levels, BA/HW and BA/LW = Baia River in maximum and minimum fluviometric levels.

Table I: PCA results from the first two axes according to the limnological variables from littoral region of the lagoons (values in bold are significant for r › 0.70).

Variables	**axis 1**	**axis 2**
water level	**-0.94**	-0.09
dry weight of ash	0.40	-0.23
transparency	**-0.75**	-0.39
water temperature	**-0.74**	0.54
dissolved oxygen	**0.82**	-0.42
alkalinity	**0.80**	0.44
pH	**0.74**	0.03
turbidity	**0.92**	-0.08
conductivity	0.32	**0.92**
total inorganic carbon	-0.24	0.40
autotrophic index	-0.09	0.50
% of variation explained	50.30	21.30

Water level was the most important factor (r = 0.94) affecting PCA 1 (50.3% of the total variance explication). Thus, this variable is the main force function of the floodplain and may directly and/or indirectly affect periphytic meiofaunal abundance.

The DCA scores showed the temporal and spatial difference of the community density in the lagoons/systems and the hydrological period (Fig. 5 II). According the DCA 1 scores, during the minimum fluviometric level (group L) the environments showed a distinct distribution, and the lagoons of the Baia River system were more similar to each other than those in the Ivinheima River system. On the other hand, during the maximum fluviometric level (group H), we also observed a separation between the environments, but less evident in the minimum fluviometric level (group L).

Considering the spatial variation, the DCA 1 results also showed that the lagoons in the Baia system presented similar density of the organism than the other lagoons (group T) during the two periods (Fig. 5 II).

Variation of some species of the periphytic meiofaunal (DCA 1) was significantly influenced by the following environmental variable: water level, transparency, water temperature dissolved oxygen, alkalinity, pH, turbidity (PCA 1) and conductivity (PCA 2) (Tab. II).

Main meiofaunal groups

The most abundant organisms in the periphytic meiofaunal community were

Table II: Regressions results between the PCA 1 scores (independent variable) and the DCA community scores (DCA 1 and DCA 2) and DCA rotifers scores (DCA rot 1 and DCA rot 2) (dependent variables) (values in bold are significant).

	Community		
	r (› 0.70)	$F_{(2,9)}$	p
DCA 1	0.85	11.4	0.0034
DCA 2	0.43	1.04	0.3911
	Rotifer		
	r (› 0.70)	$F_{(2,9)}$	p
DCA rot 1	0.85	11.4	0.0029
DCA rot 2	0.33	0.56	0.5892

rotifers and protozoa (Tab. III) and they changed the dominance in the community. Nematodes and microcrustaceans are presented in lower densities.

Table III: Average density (ind.cm^{-2}) of the periphytic meiofaunal groups in the environments and periods studied with standard deviation between parentheses (n = 9). (IVI/HW and IVI/LW = Ivinhema system in the maximum and minimum fluviometric levels; BA/HW and BA/LW = Baia system in the maximum and minimum fluviometric levels.

Groups	**IVI/HW**	**IVI/LW**	**BA/HW**	**BA/LW**
Rotifera	53.2 (67.8)	14.7 (9.3)	18.26 (13.27)	24.9 (21.65)
Protozoa	17.1 (13.4)	20.8 (22.34)	26.36 (32.05)	18.16 (21.12)
Microcrustacea	1.3 (0.99)	1.6 (1.87)	1.13 (0.75)	3.08 (3.37)
Nematoda	6.73 (10.5)	1.26 (1.003)	4.65 (4.9)	4.78 (5.89)

Among rotifers, Bdelloidea (Digononta) presented the highest densities and, among Monogononta, Lecanidae the highest abundance. Lecane bulla and L. furcata were the most abundant species, followed by L. lunaris, L. closterocerca, L. haliclysta and L. leontina. Other abundant taxa were Cephalodella sp., Epiphanes macrourus, Lindia spp., Notommata spp., Ptygura spp. and Testudinella patina.

Protozoa were represented by Codonella cratera and testate amoebae. Arcella discoides, Difflugia sp. and Centropyxis spp. were the most abundant taxa in all environments, mainly Centropyxis spp. Nematodes also showed higher density, except in Ivinhema river system, in the minimum fluviometric levels (Tab. III).

On the other hand, the microcrustacean taxa did not show high densities in all environments. The most abundant were cladoceran, especially Biapertura intermedia, Disparalona daday and Macrothrix spinosa. The ostracods presented the lowest abundance and the copepod adults of cyclopoid and calanoid also occurred with lower abundance. The highest densities were observed to the young forms of cyclopoids (nauplii).

Temporal and spatial dynamics of the main groups

Considering the groups density, the DCA rotifers scores showed that these organisms (R) presented the similar temporal and spatial distribution described to the community (Fig. 6).

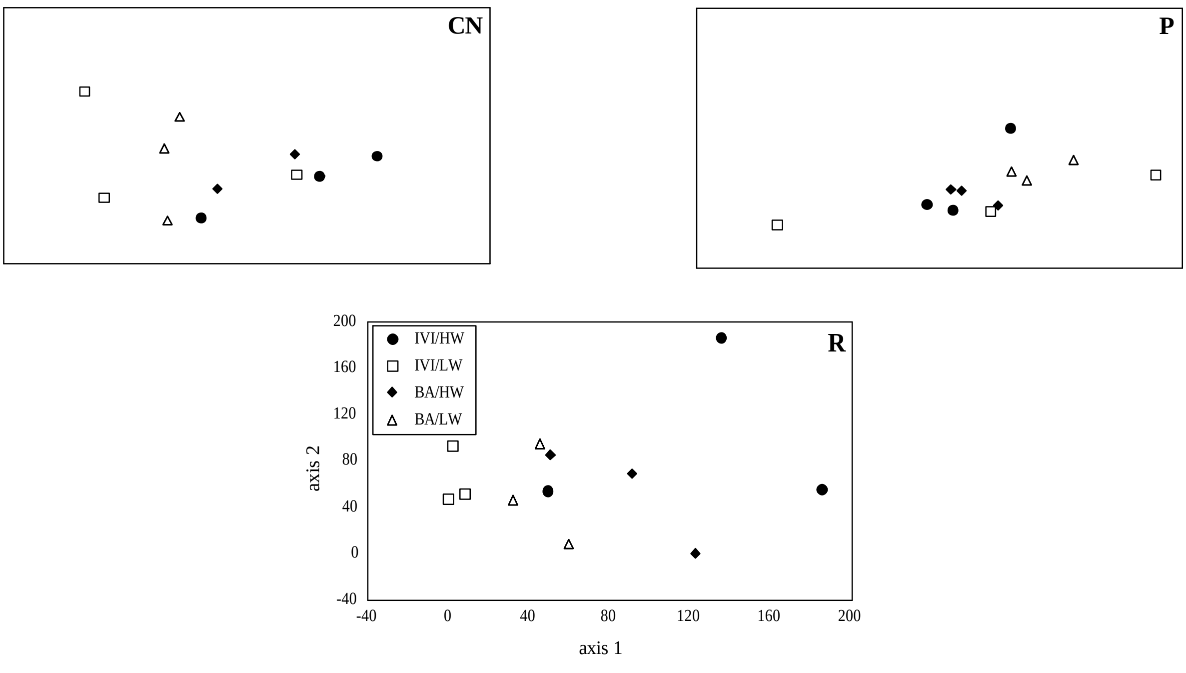

Figure 6: Scores of the DCA analyzes in the two first axes showed by the meiofaunal groups abundance: Microcrustacea + Nematoda (CN); Protozoa (P) and Rotifera (R). IVI/HW and IVI/LW = Ivinhema River in maximum and minimum fluviometric levels, BA/HW and BA/LW = Baia River in maximum and minimum fluviometric levels.

The regression results also showed that the temporal and spatial rotifers and community densities variation were influenced by the same environmental variables (Tab. II).

Moreover, the DCA microcrustaceans-nematodes scores showed a temporal density variation, especially during the minimum fluviometric level and in the Ivinheima lagoons. On the other hand, the DCA protozoan scores (P) did not show a clear temporal and spatial density variation. The DCA 1 scores were similar, except two data from the Ivinheima lagoons during the minimum fluviometric level (Fig. 6).

Discussion

The results showed that the composition and density of the periphyton meiofauna abundance were influenced by the hydrodynamic and limnological conditions of the different lagoons in the two studied period. According to Wetzel (1979), this community is influenced by water level and consequent variations in limnological characteristics of the environment.

The mean density of the periphytic meiofauna in the lagoons in the two hydrological periods (maximum and minimum fluviometric levels) was only different in the Ivinheima River system. The higher flow current and the connectivity between the lagoons and main channel of the river (high marginal dikes) determined the difference between the hydrological periods.

The connectivity between the river and the lagoon also influenced the exchange of material and energy between both the environments, as it was pointed out by Ward (1998). The change of water quality affected the communities such as periphytic meiofauna.

Variation of the abundance of periphytic fauna was also related to hydrological period determined by the Paraná river fluviometric level. Similar relationship was also verified in other environments (Lim & Furtado 1975; Duggan et al., 1998) and it was observed for other aquatic communities in the Upper Paraná River floodplain (Bonecker et al. 1998; Veríssimo 1999; Agostinho et al., 2000; Souza-Franco & Takeda, 2000; Train et al., 2000).

The conductivity was also a factor to discriminate the Baia and Ivinheima lagoons during the maximum fluviometric level, when the waters of the river invade the wetlands, a large quantity of organic material in decomposition is carried out to the lagoons. According to Esteves (1998), high conductivity may also be related to high rates of decomposition, as it was also observed for the Ivinhema River during the maximum fluviometric level by Thomaz et al. (1992).

Other variables (transparency, water temperature, alkalinity and turbidity) are important factors to describe the limnological difference among lagoons. They may be considered as having an indirect effect on periphytic meiofaunal abundance in tropical environments since they exert a marked influence on the algal community, a basic trophic source for periphytic invertebrates.

The similarity in organisms density between the environments in the maximum fluviometric level occurred due the effects of flood homogenization (Thomaz et al., 2007), increasing the linkage between the lagoons and river. Thus, the organisms abundance was influenced both by the hydrological regime and the hydrodynamic and limnological characteristics of the lagoons. In the Baia River system, the lagoons presented lower values of the total nitrogen, total phosphorus, pH, and conductivity than in the lagoons in the Ivinheima River system (Carvalho et al., 2003).

According to the most representative groups registered in the epiphytic meiofauna, Bdelloidea are common rotifers in the meiofauna of different freshwater aquatic microhabitats (Schmid-Araya, 1993). Their distribution is determined by the food availability (fine organic particles, bacteria and other unicellular organisms), predation, dissolved oxygen concentration and seasonal variation in the water level (Örstan, 1998, 2001). The other important rotifer group was Lecanidae and, according to Koste & Shiel (1990), this family is generally found in littoral habitats, in epiphyton or in epibenthos, and it is abundant in regions with aquatic macrophytes, as well as in floodplain environments. Rotifer is an important component of the periphyton and small species were supplied by food and shelter (Edmondson, 1944; Pejler & Berzin, 1993; 1994, Segers & Dumont, 1995).

The most important protozoan families recorded in the meiofauna (Arcellidae, Difflugidae and Centropyxidae) represent the major of testate amoebae in the different environments of the Upper Paraná River floodplain (Velho et al., 1996; Velho & Lansac-Tôha, 1996). Nematodes also occur in high densities in different aquatic environments (Giere, 1993). However, a more refined taxonomic classification is necessary. According to Traunspurger (2000), nematodes may act as predators/ omnivores in fixed habitats, as aquatic plants and periphyton.

Microcrustaceans were represented especially by cladoceran species and Dole-Oliver et al. (2000) considered that cladoceran use mechanical scraping to collect fixed particles in the periphyton. Ostracods were less representative, however in many records these organisms were found in periphyton (Lim & Furtado, 1975; Botts & Cowell, 1993; Galindo et al., 1994). Dominance of young forms (nauplii and copepodite) among copepods was also observed by Lansac-Tôha et al. (2004). Thus, some taxa may also use the periphytic environment in at least one period of their life cycle.

In conclusion, the hydrological regime and the hydrodynamic characteristics of the lagoons studied in the Ivinhema River and Baia River systems were the dominant factors in the organisms abundance in the periphytic meiofauna community. Rotifera was the most important group, both in abundance and in the temporal and spatial distribution and so they described the structure and the dynamic of the periphytic community.

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