Spatial and temporal density variation of microcrustacean assemblages in different systems of the upper Paraná River floodplain (PR/MS-Brazil)

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ABSTRACT. The present study evaluated the influence of water level fluctuations and the system type on the structure of planktonic microcrustacean assemblage, in different lagoons on the Upper Paraná River floodplain. Sampling was performed in pelagic region from 15 lagoons associated with three rivers, during flood (February 1999) and dry (October 1999) periods. Forty nine cladoceran species and sixteen copepods species were identified. Null model ANOVA results did not show significant differences in microcrustacean densities among systems. Only *B. hagmanni, B. deitersi* and Calanoid nauplii densities were significantly different between periods. Differences between periods in each system and among systems in each hydrological period were not significant either. Thus, spatial differences were not superior in microcrustacean structuring. However, some temporal differences were observed for bosminids and Calanoid nauplii.

Key words: cladocerans, copepods, lagoons, Upper Paraná River floodplain.

RESUMO. Variação espacial e temporal da densidade da assembléia de microcrustacécos em diferentes sistemas da planície de inundação do alto rio Paraná (PR/MS-Brasil). Este estudo avaliou a influência do nível hidrométrico e do tipo de sistema na estrutura da assembléia de microcrustáceos planctônicos, em diferentes lagoas da planície de inundação do alto rio Paraná (PR/MS). As coletas foram realizadas na região pelágica de 15 lagoas associadas a três rios, nos períodos de cheia (Fevereiro/1999) e de seca (Outubro/1999). Foram registradas 49 espécies de cladóceros e 16 de copépodos. Os resultados da ANOVA do modelo nulo não indicaram diferenças significativas das densidades dos microcrustáceos entre os sistemas. Somente as densidades de *B. hagmanni, B. deitersi* e náuplios de Calanoida foram significativamente diferentes entre os períodos. Diferenças entre períodos hidrológicos em cada sistema e entre sistemas em cada período hidrológico também não foram significativas. Nesse sentido, as diferenças espaciais não foram preponderantes para a estruturação da comunidade de microcrustáceos. Algumas diferenças temporais, no entanto, foram observadas para os bosminídeos e para os náuplios de Calanoida.

Palavras-chave: cladóceros, copépodos, lagoas, planície de inundação do alto rio Paraná.

Introduction

Floodplains are peculiar ecosystems, whose water level fluctuations can act as flood pulse that maintains a dynamic balance in environments, since they modify physical and chemical characteristics of water. Consequently, there are also variations in the composition and abundance of aquatic communities. These ecosystems are compounded by lakes, channels and flood areas associated with the principal river (Junk *et al.,* 1989; Neiff, 1990).

The structure and dynamic of microcrustaceans (cladocerans and copepods) in the floodplain environments are a result of environmental conditions variation and also indicate the available standing crop for superior trophic levels, such as invertebrate and vertebrate larvae (Esteves, 1998). The microcrustacean densities variations in Brazilian floodplains were investigated by, Hardy (1980), Hardy *et al.* (1984), José de Paggi (1990), Bozelli (1994, 2000), Lima *et al.* (1998), Lansac-Tôha *et al.* (2004) and Alves *et al.* (2005).

This paper evaluates the hypothesis that planktonic microcrustacean densities in the lagoons are not influenced by the type of systems and hydrological periods in the Upper Paraná River floodplain.

Material and methods

Study area

This study was carried out in the Upper Paraná River floodplain, between Porto Primavera (SP) and Itaipu (PR) reservoirs, in the States of Mato Grosso do Sul and Paraná (22°40' - 22°50'S and 53° 10' - 53°40'W).

Fifteen lagoons were selected, with different connectivity degrees to the main channel of rivers (Paraná, Ivinheima and Baía). The distribution of lagoons in the systems is: 2 in Paraná River system (Clara and Garças lagoons), 6 in Ivinheima River system (Pintado, Joaninho, Patos, Finado Raimundo, Sumida and Escondida lagoons) and 7 in Baía River system (Guaraná, Carão, Boca Aberta, Pousada das Garças, Esperança, Gavião and Onça lagoons) (Figure 1).

Except Clara, all the other lagoons have a permanent communication with the river, through a channel, and they are all shallow. Littoral regions are colonized by multi specific macrophytes, with dominance of *Eichhornia azurea*, several species of *Salvinia* sp., *Polygonum* sp. and sedges (Cyperaceae). Riparian vegetation can also be observed, especially in Ivinheima and Paraná systems.

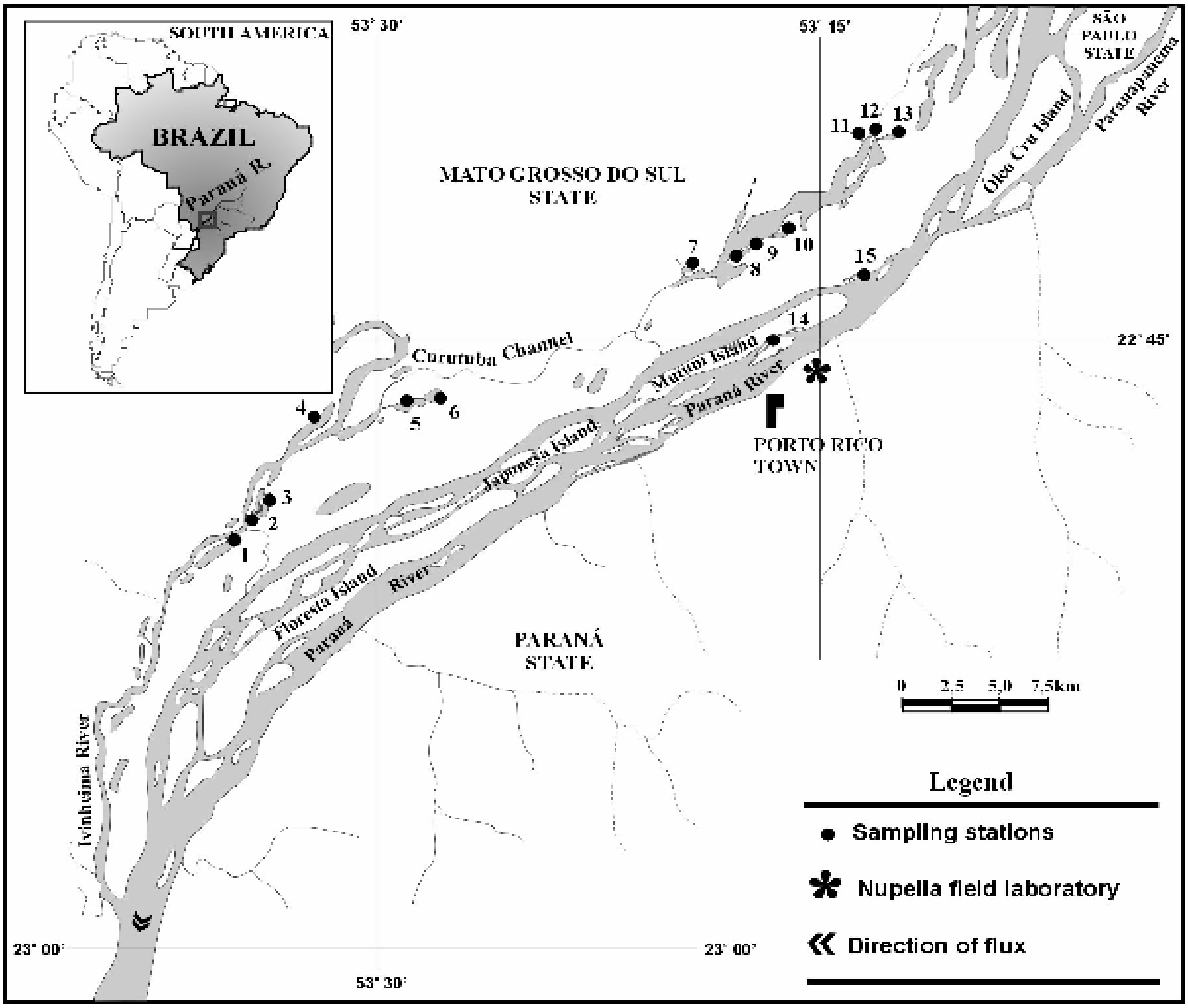

Figure 1. Study area. Ivinheima System - Pintado (1), Joaninho (2), Patos (3), Finado Raimundo (4), Sumida (5) and Escondida (6) lagoons; Baía System - Guaraná (7), Carão (8), Boca Aberta (9), Pousada das Garças (10), Esperança (11), Gavião (12) and Onça (13) lagoons; Paraná System - Clara (14) and Garças (15) lagoons.

Samplyng

Sampling was collected during the flood (February 1999) and dry periods (October 1999). These periods were established by the average of the Paraná River fluviometric level at each month (February = 450 cm; October = 301 cm).

Planktonic microcrustacean samples were taken by filtering 600 L of water at pelagic region surface from each lagoon, using a motorized pump and plankton net (68 μm).

Species were identified using the following bibliography: Paggi (1975 and 1979), Korinek (1981), Reid (1985), Santos-Silva *et al.* (1989), Korovchinsky (1992), Smirnov (1992 and 1996) and Elmoor-Loureiro (1997). Concerning copepods, just Cyclopoida females and Calanoida males were identified, and nauplii and copepodites were only quantified. Abundance was estimated by counting a minimum of 120 individuals in three subsequent sub-samples (Bottrel *et al.*, 1976), obtained with a Hensen-Stempell pipette (1.7 mL).

ANOVA null model was used to test the null hypothesis (Paes and Blinder, 1995) and it was significant when $p>0.05$. This analysis was carried out using an ECOSIM program (Gotelli and Entsminger, 2000) and the observed density with the most important numerically species - by place and by period - were randomized 10,000 times.

Results

Baía and Paraná lagoons present acid waters, lower turbidity values, and lower dissolved oxygen and chlorophyll-*a* concentration. On the other hand, Ivinheima lagoons show higher pH and turbidity values, and higher chlorophyll-*a* and dissolved oxygen concentration (Table 1) (Carvalho *et al.*, 2003).

Table 1. Limnological variables obtained in the three systems (Paraná, Ivinheima e Baía) during flood and dry periods (mean and standard deviation) (Carvalho *et al.,* 2003).

Variables	Flood (February 1999) Mean	SD	Dry (October 1999) Mean	SD
Paraná System				
Depth (m)	3.40	0.60	1.95	0.92
Total nitrogen ($mg.l^{-1}$)	0.28	0.02	0.18	0.02
Total phosphorus ($\mu m.l^{-1}$)	31.26	9.96	40.50	4.91
Chlorophyll-a ($\mu m.l^{-1}$)	5.98	4.03	6.69	1.74
Secchi disc (m)	1.60	0.15	0.80	0.14
Temperature (°C)	29.55	0.65	22.75	1.06
Dissolved oxygen ($mg.l^{-1}$)	4.93	3.10	6.35	0.71
Alkalinity ($\mu Eq.1^{-1}$)	335.00	0.10	433.90	68.73
pH	6.61	0.03	5.95	0.15
Turbidity (NTU)	6.51	1.85	11.66	0.59
Electrical conductivity ($\mu S.cm^{-1}$)	52.80	1.30	44.00	2.83
Ivinheima System				
Depth (m)	4.78	1.02	2.68	0.62
Total nitrogen ($mg.l^{-1}$)	0.35	0.08	0.22	0.09
Total phosphorus ($\mu m.l^{-1}$)	43.01	9.34	44.95	15.86
Chlorophyll-a ($\mu m.l^{-1}$)	6.09	3.97	18.34	11.15
Secchi disc (m)	0.90	0.14	0.73	0.23
Temperature (°C)	29.86	0.56	24.31	1.49
Dissolved oxygen ($mg.l^{-1}$)	2.14	1.48	7.66	0.94
Alkalinity ($\mu Eq.1^{-1}$)	265.44	31.10	388.69	77.74
pH	6.12	0.35	6.51	0.39
Turbidity (NTU)	7.77	2.83	20.08	9.75
Electrical conductivity ($\mu S.cm^{-1}$)	39.25	3.99	32.13	3.92
Baía System				
Depth (m)	3.71	0.36	2.19	0.12
Total nitrogen ($mg.l^{-1}$)	0.37	0.04	0.23	0.13
Total phosphorus ($\mu m.l^{-1}$)	39.99	13.47	37.21	22.62
Chlorophyll-a ($\mu m.l^{-1}$)	5.60	5.47	10.33	9.68
Secchi disc (m)	1.36	0.45	0.99	0.40
Temperature (°C)	30.26	1.12	24.21	1.13
Dissolved oxygen ($mg.l^{-1}$)	1.51	0.45	6.08	1.04
Alkalinity ($\mu Eq.1^{-1}$)	124.48	60.94	198.71	55.51
pH	5.95	0.27	5.59	0.37
Turbidity (NTU)	3.63	2.33	13.19	11.25
Electrical conductivity ($\mu S.cm^{-1}$)	20.52	3.84	22.29	4.86

Microcrustacean assemblage was represented by 64 species (48 cladocerans species and 16 copepods species) belonging to nine families, especially Chydoridae (cladocerans) (24 species), and Cyclopidae (copepods) (9 species) (Table 2).

Copepods were generally more abundant than cladocerans in the three systems, especially during the dry period. During this period, microcrustacean did not show densities differences in Ivinheima and Baía lagoons, although copepods were more abundant in Paraná lagoons. In the other period, copepods and cladocerans presented similar density values in the Paraná lagoons, and copepods were more abundant in the Ivinheima and Baía lagoons (Figure 2). However, cladoceran and copepods densities did not show significant differences among systems and between hydrological periods (Table 3).

Table 2. Cladocera and Copepoda species registered in the different lagoons studied in February and October 1999.

Cladocera	
Bosminidae	Daphniidae
Bosmina hagmanni Stingelin, 1904.	*Ceriodaphnia cornuta* Sars, 1886
B. tubicen Brehm, 1939	*Daphnia gessneri* Herbst, 1967
Bosminopsis deitersi Richard, 1895	*Simocephalus serrulatus* Koch, 1841
Chydoridae	*S. vetulus* Schodler, 1852
Acroperus harpae Baird, 1843	Ilyocryptidae
Alona cambouei Guerne and Richard, 1853	*Ilyocryptus spinifer* Herrick, 1884
A. dentifera Sars, 1901	Macrothricidae
A. glabra Sars, 1901	*Grimaldina brazzai* Richard, 1892
A. monacantha Sars, 1901	*Guernella raphaelis* Richard, 1892
A. rectangula Sars, 1861	*Macrothrix spinosa* King, 1953
A. verrucosa Sars, 1901	*M. triserialis* Brady, 1886
Alona sp.1	*Onchobunops tuberculatus* Fryer and Paggi, 1972
Alona sp.2	Moinidae
Alonella brasiliensis Bergamin, 1935	*Moina minuta* Hansen, 1899
A. dadayi Birge, 1910	Sididae
A. excisa Fischer, 1854	*Diaphanosoma birgei* Korinek, 1981
Biapertura sp.	*D. brevireme* Sars, 1901
Chydorus eurynotus Sars, 1901	*D. fluviatile* Hansen, 1899
C. sphaericus Mueller, 1785	*D. polyspina* Korovchinky, 1982
Dunhevedia odontoplax Sars, 1901	*D. spinulosum* Herbst, 1975
Ephemeroporus barroisi Richard, 1984	*Diaphanosoma* sp.1
Euryalona brasiliensis Brehm and Thomsen, 1936	*Diaphanosoma* sp.2
E. occidentalis Sars, 1901	*Latonopsis* sp.
Kurzia latissima Kurz, 1974	*Sarsilatona* sp.
Leydigia ciliata Gauthier, 1939	*Pseudosida* sp.
Leydiopsis curvirostris Sars, 1901	
Notoalona globulosa Daday, 1898	
Phryxura leptorhyncha Smirnov, 1996	
Copepoda	
Cyclopidae	Diaptomidae
Eucyclops sp.	*Argyrodiaptomus azevedoi* Wright, 1935
Mesocyclops longisetus Thiébaud, 1914	*A. furcatus* Sars, 1901
M. meridianus Kiefer, 1926	*Idiodiaptomus* sp.
M. ogunnus Onabamiro, 1957	*Notodiaptomus amazonicus* Wright, 1935
Metacyclops mendocinus Wierzejsy, 1892	*N. isabelae* Wright, 1936
Microcyclops anceps Richard, 1897	*N. spiniger* Brian, 1925
Paracyclops sp.	*N. spinuliferus* Dussart, 1985
Thermocyclops decipiens Kiefer, 1929	
T. minutus Lowndes, 1934	

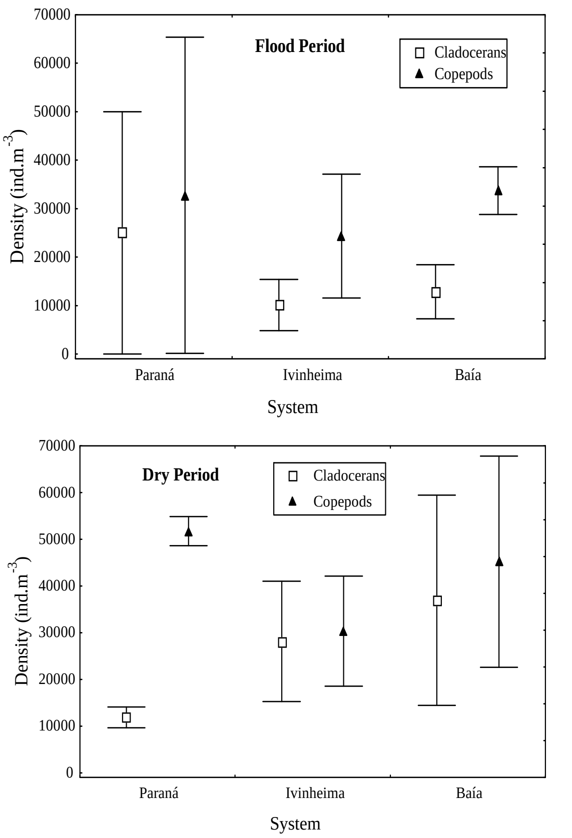

Figure 2. Microcrustacean densities in the three systems lagoons (Paraná, Ivinheima e Baía) during the flood and dry periods (symbol = mean; bar = minimum and maximum).

Table 3. Observed Index (Oi), randomized index average (Ri), randomized index variance (Riv) and the *p* value for each category of comparison of the total densities of cladocerans and copepods. (PR=Paraná, BA= Baía, IV= Ivinheima).

Categories of Comparison	Oi	Ri	Riv	*p*
		Cladocerans		
PR flood x PR dry	0.28	1.19	0.58	1.00
BA flood x BA dry	1.08	1.03	0.44	0.38
IV flood x IV dry	1.67	1.11	1.36	0.22
PR flood x BA flood	0.63	1.45	9.35	0.60
PR flood x IV flood	0.96	1.73	15.76	0.46
BA flood x IV flood	0.12	1.21	3.85	0.70
PR dry x BA dry	0.32	1.42	5.25	0.58
PR dry x IV dry	0.48	1.43	5.96	0.57
BA dry x IV dry	0.11	1.11	1.17	0.84
		Copepods		
PR flood x PR dry	0.34	1.15	0.50	1.00
BA flood x BA dry	0.25	1.04	0.76	0.84
IV flood x IV dry	0.12	1.23	3.48	0.71
PR flood x BA flood	0.03	1.33	4.25	0.94
PR flood x IV flood	0.09	1.94	30.95	0.86
BA flood x IV flood	0.53	1.19	3.32	0.50
PR dry x BA dry	0.02	1.42	5.54	0.92
PR dry x IV dry	0.99	1.37	4.01	0.32
BA dry x IV dry	0.31	1.09	1.38	0.70

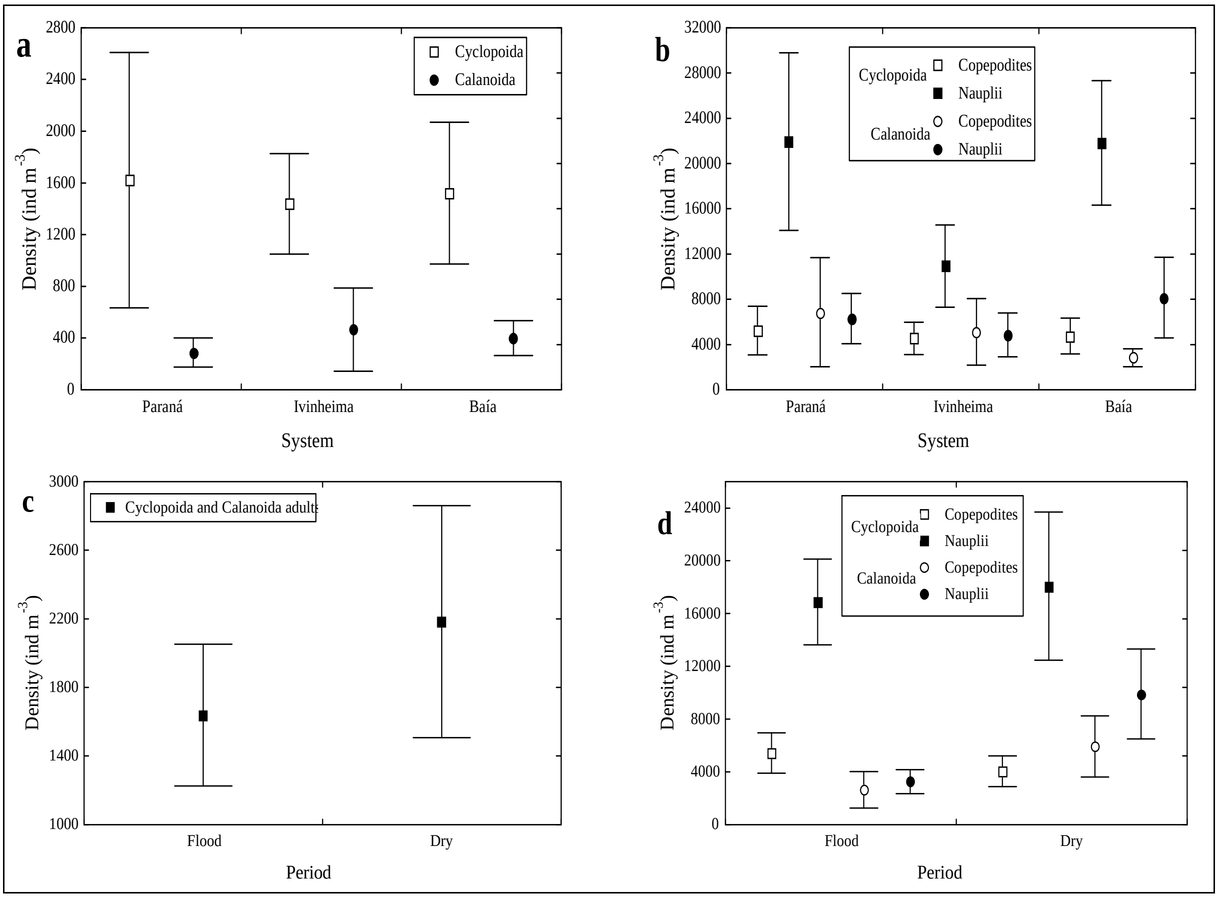

Figure 3. Copepods densities (young and adult) in different systems (**a** a nd **b**) during both hydrological periods (**c** and **d**) (symbol = mean; bar = minimum and maximum).

Cyclopoida was more abundant than Calanoida, especially nauplii and copepodites. More copepods were generally observed (young and adult forms) in Paraná lagoons than in the other lagoons. Copepods densities did not present significant differences among systems (Figure 3a and b). Temporally, copepods were numerically important during the dry period, and Cyclopoida were also dominant, especially nauplii. However, Cyclopoida nauplii densities were not significantly different between hydrological periods (Figure 3c and d). Expressive difference was observed for Calanoida nauplli density, which presented more individuals during the dry period (Table 4 and Figure 3d).

Moina minuta, Bosmina hagmanni, Bosminopsis deitersi and *Ceriodaphnia cornuta* were the most abundant cladoceran species. During the flood period, *M. minuta* showed higher density values in Baía and Paraná lagoons. *C. cornuta*, *B. hagmanni* and *B. deitersi* were also registered with higher densities in the latter lagoons. During the dry period, *M. minuta* occurred with higher densities in Baía and Ivinheima lagoons. *C. cornuta* was also abundant in the latter lagoons, and *B. hagmanni* and *B. deitersi*, in Baía and Paraná lagoons (Figure 4). Only *B. hagmanni* and *B. deitersi* presented significant density differences between the hydrological periods (Table 4), but these species did not show significant density difference among systems (Figure 4).

Table 4. Observed Index (Oi), randomized index average (Ri), randomized index variance (Riv) and the p value for each of the six most important species of cladocerans and copepods; young and adult copepods in the systems, considering the hydrological period. Significant values ($p<0.05$) in bold.

Species/Groups	Oi	Ri	Riv	*p*
M. minuta	0.13	1.08	2.12	0.72
C. cornuta	2.60	1.04	0.90	0.08
B. hagmanni	2.51	1.00	0.16	0.00
B. deitersi	3.75	1.03	1.03	0.01
T. minutus	0.69	1.07	2.14	0.42
N. amazonicus	0.62	1.01	0.40	0.68
Cyclopoid nauplii	0.03	1.03	1.80	0.87
Cyclopoid copepodit	0.51	1.06	2.33	0.48
Cyclopoid adult	0.09	1.08	2.31	0.78
Calanoid nauplii	3.55	1.03	0.99	0.03
Calanoid copepodit	1.50	1.03	1.25	0.28
Calanoid adult	1.65	1.03	1.05	0.22

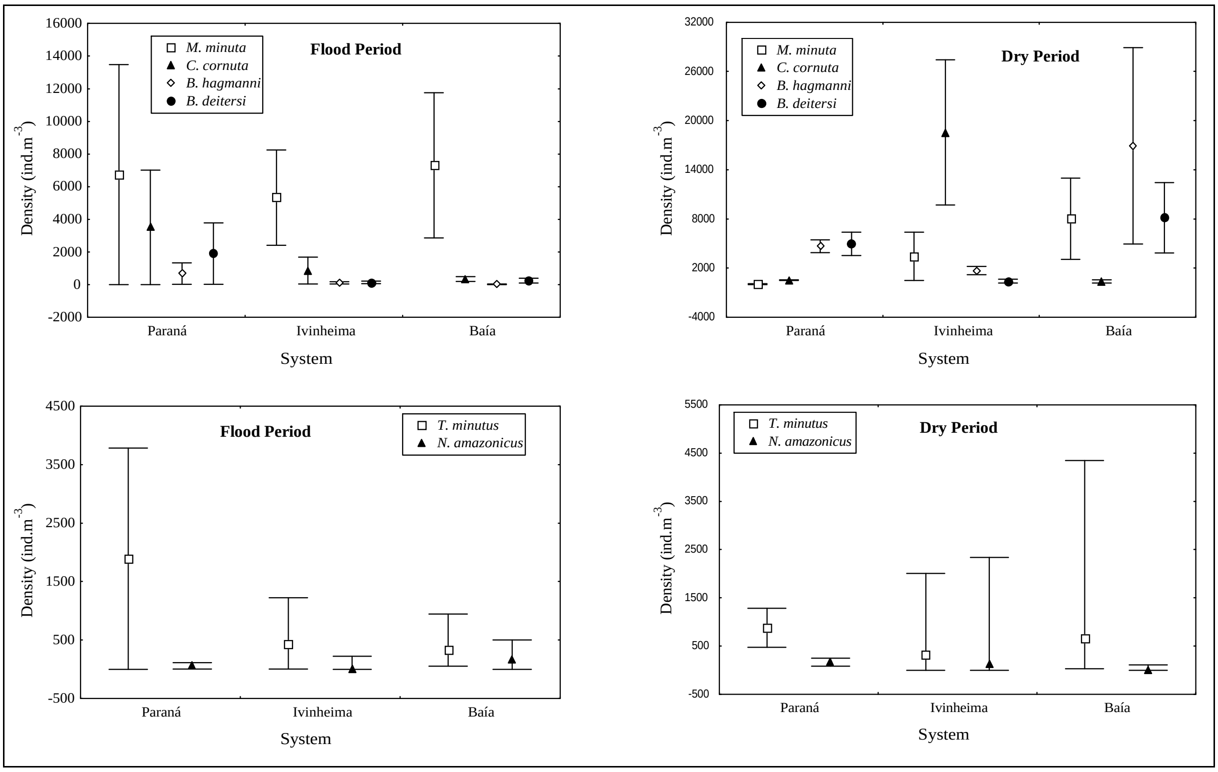

Figure 4. Densities of *Moina minuta, Ceriodaphnia cornuta, Bosmina hagmanni, Bosminopsis deitersi* (cladocerans), *Thermocyclops minutus* and *Notodiaptomus amazonicus* (copepods) registered in the Paraná, Ivinheima and Baía systems during the flood and dry periods (symbol = mean; bar = minimum and maximum).

Thermocyclops minutus and *Notodiaptomus amazonicus* were the most abundant copepods species. Generally speaking, these species showed a different spatial distribution during both hydrological periods. During the flood period, *T. minutus* presented higher densities in Paraná lagoons and *N. amazonicus* in Baía lagoons. On the other hand, *T. minutus* was numerically important in the latter lagoons during the other period, and *N. amazonicus* in Ivinheima lagoons (Figure 4). Densities of these species were not significantly different among systems and between hydrological periods (Table 4).

Discussion

Higher microcrustacean densities during the dry period were also observed by Carvalho (1983) and Bozelli (1994) in floodplain lagoons in Amazon, and by Serafim (1997) in the Paraná River floodplain. These authors attributed this fact to a high contribution of young forms of copepods (nauplii and copepodites). However, Lima *et al.* (1998) and Lansac-Tôha *et al.* (2004) observed higher densities of microcrustaceans during the flood period also due to the copepods.

Another factor that could influence the decrease of microcrustacean densities, especially cladocerans, during the flood period is the plankton dilution effect, as well as verified to the planktonic crustacean assemblage in lake Batata (Amazonia) (Bozelli, 2000).

The most abundant cladocerans species registered in the present study (*M. minuta, C. cornuta, B. hagmanni* and *B. deitersi*) were also dominant in other environments in the study area (Lima *et al.*, 1998; Lansac-Tôha *et al.*, 2004; Serafim, 1997), as well as in other floodplains in Brazil (Brandorff *et al.*, 1982; Carvalho *et al.*, 1983).

Some distribution patterns of these species were verified among systems, although these differences have not been significant. *C. cornuta* presented higher density in Ivinheima lagoons, where the highest turbidity values occurred. Maia-Barbosa (2000) also observed an increase of *C. cornuta* density when this population was exposed to conditions of turbidity increase and attributed this direct relationship to superior ability of this species to avoid visual predation. Besides that, Vanni (1987) also mentioned the high capacity of *C. cornuta* in increasing its population accrual rate in high food availability conditions. Higher chlorophyll-*a* concentrations were observed in Ivinheima lagoons (Carvalho *et al.*, 2003).

On the other hand, bosminids presented lower density values in Ivinheima lagoons, probably, because they are exposed to higher pH values (Carvalho *et al.*, 2003) and many authors mentioned these cladocerans as typical acidophylic organisms (Heredia-Seixas, 1981; Brandorff *et al.*, 1982; Serafim, 1997; Lima *et al.*, 1998).

B. hagmanni and *B. deitersi* densities were significantly different between hydrological periods and the number of individuals increased during the dry period. Carvalho (1983), Serafim (1997), Lima *et al.* (1998) and Lansac-Tôha *et al.* (2004) also observed this temporal distribution in different environments from South America floodplains. These results could be related to the plankton effect dilution during the flood period. According to Junk (1996), the flood pulse is an important factor on aquatic communities structuring, due to its influences over the alteration of the available habitats for colonization, over the quality and amount of available food, and over the physical and chemical characteristics from the environment. In this study, *M. minuta* did not present clear density differences between the hydrological periods, probably due to a better adaptation to the stress conditions, as considered by Maia-Barbosa (2000).

Cyclopoida and Calanoida nauplii, copepodites and adults presented similar densities in the systems, which suggests that limnological characteristics of the lagoons in the three systems (Carvalho *et al.*, 2003) did not influence remarkably on the copepods distribution, as showed by null model ANOVA results. Temporally, only Calanoida nauplii densities were significantly different between hydrological periods, with higher values during the dry period.

Among the most abundant copepods species, Reid and Moreno (1990) argued that *Thermocyclops minutus* is frequently dominant among the cyclopoid copepods in lentic environments. Sendacz (2001), studying lagoons in the Upper Paraná River (SP), upstream of our study area, also verified that this species is frequent, eurytopic and found in all environments and hydrological periods.

According to our hypothesis, the fluviometric level differences between the hydrological periods were more important to the structure of microcrustacean assemblage in the lagoons than the limnological characteristics of the three systems. It could probably have occurred due to the similar hydrodynamic of environments studied at each system (lagoons).

Acknowledgments

We thank Dra. Barbara Ann Robertson, Dr. Luiz Felipe Machado Velho and MSc. Rita de Cássia Rodrigues for helping in cladoceran and copepods identifications; MSc. Erica Mayumi Takahashi for the English review. PELD/CNPq for financial support and Capes for scholarships.

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Received on Decemberr 15, 2004.
Accepted on August 17, 2005.