Hydrobiologia **325**: 137–150, 1996.

Community structure of rotifers in two environments of the upper River Paraná floodplain (MS) – Brazil

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Received 1 March 1995; in revised form 17 May 1995; accepted 29 November 1995

Key words: Zooplankton, Rotifera, River Paraná floodplain, community, species diversity, canonical correlation analysis

Abstract

We evaluate the influence of abiotic and biotic factors on the community structure of rotifers across a regional hydrological cycle in lotic and lentic environments of the upper River Paraná. Depth, transparency, temperature, pH, electrical conductivity, dissolved oxygen, chlorophyll *a* and densities of rotifers were measured at two stations in Lake Guaraná (littoral and open water regions) and at one station in the River Baía (open water region). Highest densities of rotifers were found at the lake littoral. Canonical correlation analysis related environmental variables with the densities of the most abundant rotifers. The strongest relationship was with chlorophyll *a*, dissolved oxygen, hydrological level and water temperature. Diversity of rotifers at each station was mainly explained by fluctuations in hydrological level. Results of grouping analysis suggested the formation of groups according to phases of the hydrological cycle.

Introduction

Floodplains are systems composed of lakes, channels and terrestrial zones associated with great rivers. Junk (1980) states that terrestrial zones (ATTZ – aquatic transition terrestrial zone) must be considered special environments whose water levels function as a pulse maintaining the dynamic equilibrium of the floodplain. They modify the physical and chemical properties and consequently, cause variations in the composition and density of the aquatic communities.

The River Paraná between the mouth of the River Paranapanema and the Reservoir Itaipu is an anastomosed channel with low declivity, sometimes with an extensive floodplain, sometimes with big islands and a narrow floodplain (Souza Filho, 1993). This floodplain belongs to the second largest hydrological basin of South America (Paiva, 1982). According to Welcomme (1985), it is a fringing floodplain, with a narrow strip of floodable land. It can be included in the upper Paraná basin of the division proposed by Maack (1981).

Studies of community structure of zooplankton in floodplains in the neotropics have been undertaken by various authors, among whom Paggi & José de Paggi (1990) (Argentinian stretch of the Paraná) Lansac-Tôha et al. (1992, 1993) and Sendacz (1993) (Brazilian stretch of the Paraná), Green (1972), Brandorff et al. (1982) and Bozelli (1992) (Amazon); and Twombly & Lewis Jr (1987), Saunders III & Lewis Jr (1989) (The Orinoco, Venezuela).

Rotifers are opportunistic organisms whose density is characterized by temporal variations related to changing environmental conditions (Allan, 1976). The ecological importance of these small filter-feeders in energy flux and in nutrient cycling is large, as emphasized by Ruttner-Kolisko (1974) who stressed the nutrient value of these organisms and their role in the food web.

The present work aims at evaluating the influence of abiotic and biotic factors on the community structure of rotifers across a regional hydrological cycle in lentic and lotic environments of the upper Paraná floodplain

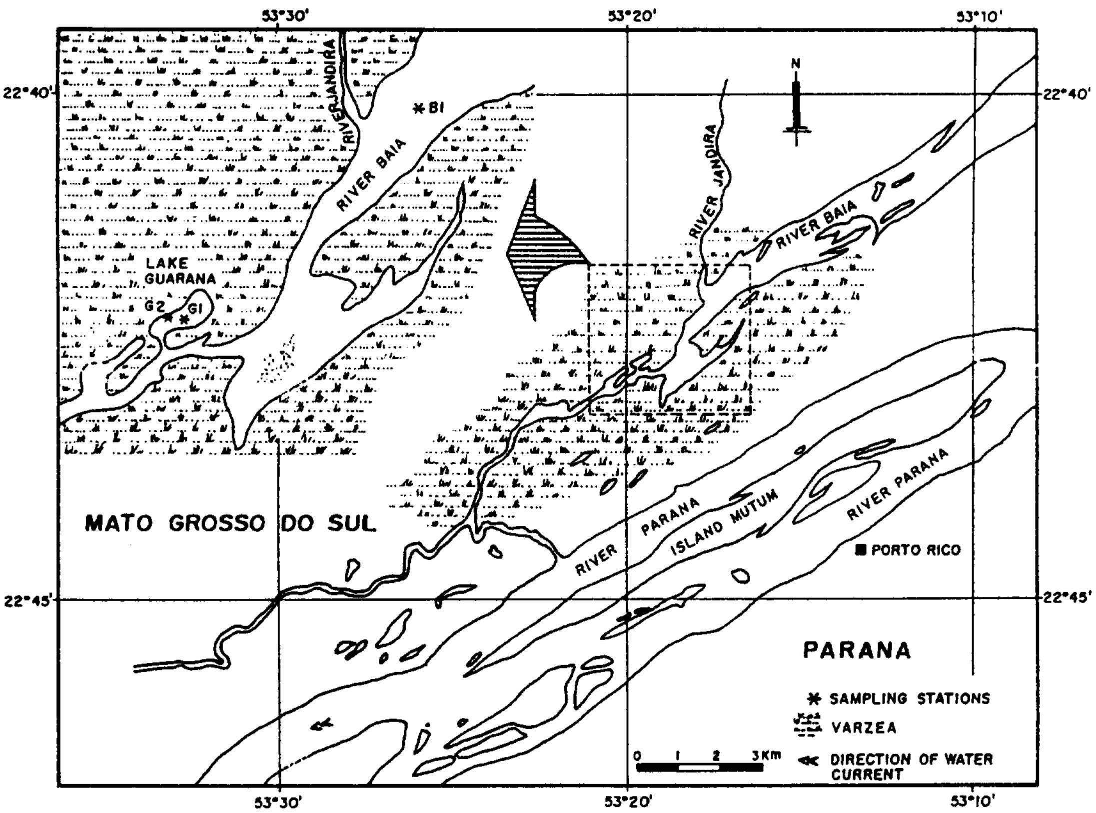

Figure 1. The site of sampling stations.

and on the diversity, richness and equitability of their communities.

Study area

The River Baía (22° 43′ S and 53° 17′ W) in the floodplain on the right of the River Paraná, Mato Grosso do Sul, is directly influenced by the hydrological level of the River. However, the low velocity of its current and the small declivity of its bed give the River Baía characteristics of a floodplain river. Along the sampled stretch, a number of grasses, chiefly *Panicum pernambucense* (Spreng) (Thomaz et al., 1991) and low margins are present (Figure 1).

Lake Guaraná (22° 43′ S and 53° 18′ W), situated on the right bank of the Baía, communicates with the river during the whole year by means of a channel. In the low water period, the varzea often floods (Thomaz et al., 1992). Aquatic macrophytes, chiefly *Eichhornia azurea* (Schwartz) Kunth, are predominant in the channel and in the littoral region. The margins are covered with grasses, chiefly *Panicum pernambucense* (Spreng) (Figure 1).

The River Baía and Lake Guaraná have warm temperatures, a pH acid to neutral, low electrical conductivity and low concentration of dissolved oxygen (Thomas et al., 1991, 1992).

Materials and methods

Physical, chemical and biological variables

Monthly samples of physical, chemical and biological variables were undertaken in the littoral of the lake with aquatic macrophytes, mainly *Eichhornia azurea* (Station G2), in its open water (Station G1) and in the open water of the river (Station B1) from March 1992 to March 1993. Samples were obtained at different depths of the water column: at the surface of Station G2 and at the surface, middle and bottom of Stations G1 and B1.

Monthly data of fluviometric levels (cm) of the River Paraná, taken at the district of Porto São José (municipality of São Pedro do Paraná, River Paraná basin, PR), were given by the National Department of Water and Electric Energy (DNAEE). Analyses of environmental variables, depth (m), water transparency (m), water temperature (°C), pH, electrical conductivity (μS cm^{-1}), oxygen (% sat) and concentration of chlorophyll a ($\mu g\ l^{-1}$) were taken by researchers of the Limnology Laboratory (NUPELIA/UEM) whose methodologies were described by Thomaz et al. (1992).

Rotifers

Samples were taken monthly during 13 months (March 1992 to March 1993) at each station, with a motor pump from open water (Stations G1 and B1), and from *Eichhornia azurea* (Station G2) using a plankton net of 70 μm mesh size. The end of the 6-cm diameter tube of motorpumb was protected by plastic to avoid big debris.

Rotifers (ind m^{-3}) were quantified by counting subsamples in a Sedgwick-Rafter cell; at least 200 individuals of each sample were counted. Identification was based on Koste (1978), Koste & Robertson (1983) and José de Paggi (1989).

Diversity

Species diversity (H') was calculated by the Shannon-Wiener index (Pielou, 1975): $H' = -\Sigma Ni/N \log_2 Ni/N$, with Ni the number of individuals of ith species and N the total number of individuals.

Equitability (E) (Pielou, 1966) was computed from $E = H'/H_{max}$, where H' is Shannon's diversity and H_{max} is the diversity under maximum uniformity condition.

Species richness (D) was evaluated using Margalef's index (Odum, 1983): $D = (s - 1)/\log N$, where s is the number of the taxa and N is the total number of specimens of all taxa.

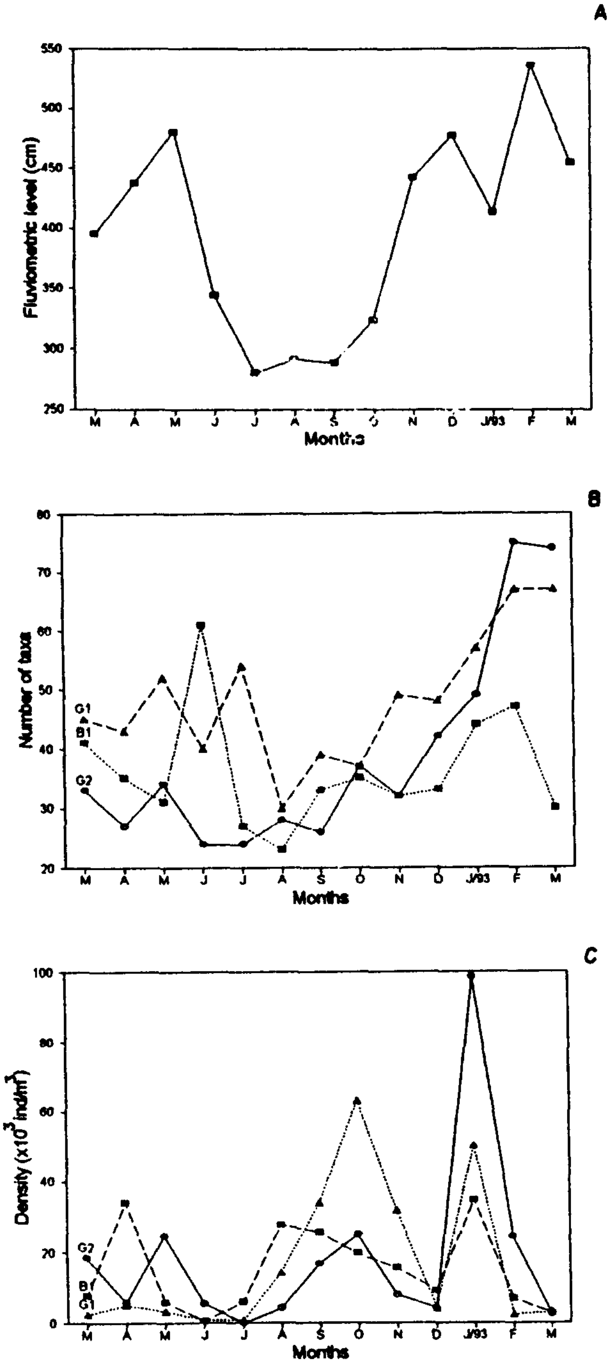

Figure 2. Datas of fluviometric levels (cm) of the river Paraná (A), number of taxa registered at each station (B) and seasonal density of the dominant taxa at each stations (G1 = open water of region of the lake Guaraná; G2 = littoral region of the lake Guaraná and B1 = open water of the river Baía) (C) measured between March 1992 and March 1993.

Grouping analysis

To compare rotifer composition at different stations and seasons (high and low water), grouping analysis was carried out, using Morisita's coefficient (Krebs, 1989) to construct a similarity matrix for each station and period. From this, an ascending hierarchical classification was developed using Unweight Pair-Group Method Average (UPGMA) (Sneath & Sokal, 1973). This permitted construction of a dendrogram. The degree of distortion on the matrix of original similarity was determined by the coefficient of cophenetical correlation (statistics package NTSYS-PC (vs. 1.5); Rholf, 1989).

Interpretations of taxa groupings in dendrograms were made by Pontin's classification (1978) of planktonic or semi-planktonic and littoral, periphytic or benthic taxa.

Canonical correlation analysis

We tested the relationship between environmental and biotic (the densities of the 17 most abundant taxa) variables over all stations, temporal and spatial variation, by canonical correlation analysis to find the best linear relationship between the two groups of variables (Digby & Kempton, 1991) using SYSTAT (vs. 0.3) (Wilkinson, 1990).

All variables, except pH, were log (KH) transformed.

Results

The monthly data of the level of the River Paraná (cm) show two periods: high (March–May, 1992 and October 1992–March 1993) and low water (June–September 1992) (Table 1 and Figure 2).

For maximum, minimum, mean and standard deviation for environmental variables, see Table 1 (PADCT/CIAMB, 1993).

Spatial variation

More individuals were recorded at station G2 (386,474 ind m^{-3}) than at station B1 (329,230 ind m^{-3}) and G1 (293.288 ind m^{-3}). The density of the 18 most abundant taxa of G2 represented 74.2% of total density at this station. At G1, the 16 most abundant taxa totalled 82.5% of total density. At B1 91.8% of total density was represented by 16 taxa. Among these, those considered for canonical correlation analysis are: *Ascomorpha saltans* (Bartsch), *Brachionus calyciflorus* Pallas, *B. mirus* (Daday), *Euchlanis dilatata* Ehrenberg, *Epiphanes clavulata* (Ehrenberg), *Filinia longiseta* (Ehrenberg), *Hexarthra* spp (chiefly *H. mira* (Hudson)), *Keratella cochlearis* Gosse, *Lecane (Monostyla) bulla* (Gosse), *L. proiecta* Hauer, *L. leontina* (Turner), *L. curvicornis* (Murray), *Ploesoma truncata* Levander, *Testudinella mucronata haueriensis* (Gillard), *T. patina* (Hermann), Conochilidae (chiefly *Conochilus unicornis* Rousselet and *C. natans* (Seligo)) and Bdelloidea.

Seasonal variation

A higher number of taxa occurred during high water, mainly at the lake stations (G1 and G2). In general, the density of the 17 most abundant taxa at the three stations increased too (Figure 2).

Canonical correlation analysis revealed a significant correlation ($P < 0.05$) among the physical, chemical and biological variables. Scores are presented in Figures 3 and 4.

The multiple regression of each environmental variable and population density of principal rotifers shows that the densities of the 17 most abundant taxa in all samples presented a relationship with the linear combination of all environmental variables. This suggested an influence, especially of chlorophyll *a* ($P = 6.009, P < 0.01$), fluviometric level ($F = 4.465, P < 0.01$), dissolved oxygen ($F = 0.423, P < 0.01$) and water temperature ($F = 0.591, P < 0.01$) on density. The first canonical axis mainly suggested an influence of dissolved oxygen ($r = 0.741$) and chlorophyll *a* ($r = 0.690$) and a spacial separation of stations (dotted line) (Figure 3). On the second canonical axis, water temperature ($r = 0.767$) and fluviometric level ($r = 0.639$) were discriminated sampling stations (Table 2). This axis suggests a separation of sampling stations according to fluviometric level (solid line) (Figure 3).

Multivariate analysis between population density of each taxon and all environmental variables suggested a relationship with the linear combination of density of the 17 most abundant taxa, especially *Ascomorpha saltans* ($F = 3.438, P < 0.01$), *Brachionus calyciflorus* ($F = 10.433, P < 0.01$), *Euchlanis dilatata* ($F = 7.330, P < 0.01$), *Hexarthra* spp ($F = 8.710, P < 0.01$), *Lecane (Monostyla) bulla* ($F = 8.428, P < 0.01$), *Ploesoma truncata* ($F = 5.318, P < 0.01$) and *Testudinella pati-*

Table 1. Fluviometric level of the river Paraná, average values (x), standard deviation (s), maximum (max) and minimum (min) abiotic and biotic variables obtained in 3 sampling stations in the period March 1992–March 1993. For station G2 only surface data are presented (Source: Report PADCT/CIAMB, 1993)

	M	A	M	J	J	A	S	O	N	D	J/93	F	M
Fluviometric level (cm)/month	395.	437.	480.	344.	280.	291.	288.	323.	442.	477.	413.	536.	454.

Station G2 Littoral region of lake/month	M	A	M	J	J	A	S	O	N	D	J/93	F	M
Depth (m)	1.80	1.60	2.60	1.80	0.80	0.80	0.80	0.80	2.00	2.80	1.80	2.00	3.20
Water transparency (m)	0.85	0.38	0.65	0.55	0.55	0.35	0.60	0.45	1.55	1.40	0.80	1.10	1.50
Water temperature (°C)	27.00	24.60	24.10	20.90	18.90	18.00	19.50	22.90	29.10	27.40	27.40	27.90	30.00
Oxygen (% sat)	33.80	9.00	11.20	8.60	81.80	101.60	73.70	60.60	31.40	28.70	62.60	11.50	20.00
Electrical conductivity (μS/cm)	49.00	34.00	28.00	23.00	24.00	20.00	17.00	25.00	50.00	35.00	31.00	33.00	38.00
pH	6.50	5.70	5.60	5.40	5.50	5.80	6.70	5.80	6.50	6.20	6.60	6.20	6.40
Chlorophyll *a* (μg/l)	14.56	6.83	14.68	1.37	9.10	9.83	16.38	9.56	4.10	7.51	1.83	9.10	8.68

Station G1 Open water region of lake/month	M	A	M	J	J	A	S	O	N	D	J/93	F	M
Depth (m)	3.40	3.00	4.40	3.20	2.40	1.60	2.20	2.50	3.40	4.00	3.10	3.40	4.60
Water transparency (m)	0.70	0.45	0.95	0.55	0.65	0.70	0.75	0.40	1.65	1.00	1.00	1.10	2.00
Water temperature (°C)													
x	26.33	24.50	23.40	20.97	19.13	17.87	19.00	23.30	26.27	26.63	26.53	27.23	28.47
s	0.25	0.29	0.49	0.05	0.05	0.12	0.57	0.22	0.79	1.23	1.16	0.66	1.33
max	26.60	24.60	24.00	20.90	19.20	18.00	19.40	23.50	27.10	27.60	27.40	27.70	29.60
min	26.00	24.10	22.80	21.00	19.10	17.70	18.20	23.00	27.20	24.90	24.90	26.30	26.60
Oxygen (% sat)													
x	37.37	7.20	11.31	6.37	82.83	98.03	69.17	59.07	46.37	22.87	46.87	25.40	0.91
s	5.75	1.68	3.42	0.29	0.68	0.63	1.87	0.87	19.92	8.91	7.48	6.58	0.44
max	45.50	9.30	15.90	6.70	83.80	98.90	71.00	60.20	61.00	30.00	52.60	30.20	1.28
min	33.33	5.20	7.70	6.00	82.40	97.40	66.60	58.90	18.20	10.30	36.30	16.10	0.29
Electrical conductivity (μS/cm)													
x	49.00	36.67	28.33	23.67	24.00	20.33	17.33	24.33	46.00	37.33	28.67	32.67	39.65
s	0.82	1.70	3.40	0.47	0.00	0.47	0.47	0.47	1.63	1.89	0.94	0.94	3.09
max	50.00	39.00	33.00	24.00	24.00	20.00	18.00	25.00	48.00	40.00	30.00	34.00	44.00
min	48.00	35.00	25.00	23.00	24.00	21.00	17.00	24.00	44.00	36.00	28.00	32.00	37.00
pH													
x	6.53	5.53	5.63	5.40	5.70	5.77	6.67	5.90	6.43	6.12	6.43	6.30	6.30
s	0.12	0.09	0.09	0.08	0.80	0.05	0.05	0.00	0.29	0.09	0.09	0.14	0.14
max	6.70	5.60	5.70	5.50	5.80	5.80	6.70	5.90	6.50	6.20	6.50	6.50	6.40
min	6.40	5.40	5.50	5.30	5.60	5.70	6.60	5.90	6.30	6.00	6.30	6.20	6.10
Chlorophyll *a* (μg/l)													
x	8.92	8.02	2.91	2.36	9.71	12.38	10.56	10.13	5.99	10.21	13.62	10.01	10.32
s	2.45	0.85	1.36	0.26	0.43	1.52	0.51	5.19	0.80	3.73	3.07	2.57	6.74
max	12.01	8.74	4.37	2.73	10.01	13.11	10.92	17.47	6.83	15.47	17.75	13.65	19.83
min	6.01	6.83	1.09	2.18	9.10	12.01	9.83	6.55	4.91	7.28	10.38	8.19	4.95

Table 1. Continued

Station B1 Open water region of river/month	M	A	M	J	J	A	S	O	N	D	J/93	F	M
Depth (m)	4.80	4.40	5.40	4.20	2.00	2.80	3.00	3.20	4.20	4.80	4.00	4.80	5.60
Water transparency (m)	0.85	0.95	1.15	1.25	0.55	0.80	0.80	0.45	1.25	1.00	1.00	1.10	1.90
Water temperature (°C)													
x	26.83	26.00	23.88	22.33	19.30	18.73	20.60	23.73	29.13	28.43	28.17	28.73	30.17
s	0.25	0.08	0.57	0.09	0.00	0.12	0.08	0.09	0.46	0.12	0.21	0.21	1.23
max	27.10	26.10	24.60	22.40	19.30	18.90	20.70	23.80	29.60	28.60	28.40	29.00	31.90
min	26.50	25.90	23.30	22.20	19.30	18.60	20.50	23.60	28.50	28.30	27.90	28.50	29.20
Oxygen (% sat)													
x	60.93	72.50	42.73	70.90	104.30	113.50	113.60	95.97	105.30	92.47	94.57	76.27	39.70
s	5.41	0.50	7.58	2.12	3.94	0.57	1.66	0.33	9.40	0.33	2.62	2.51	18.10
max	65.10	72.90	51.50	73.80	107.40	114.30	115.90	26.40	112.00	92.70	97.60	78.10	64.60
min	53.30	71.80	33.00	68.80	98.80	113.10	112.20	25.60	92.00	92.00	91.20	72.70	22.10
Electrical conductivity (μS/cm)													
x	44.00	25.67	23.67	20.00	20.33	20.00	20.00	21.00	45.33	34.33	24.00	29.00	36.50
s	0.00	0.47	0.47	0.00	0.47	0.00	0.00	0.00	1.25	0.47	0.00	0.00	0.50
max	44.00	26.00	24.00	20.00	21.00	20.00	20.00	21.00	47.00	35.00	24.00	29.00	37.00
min	44.00	25.00	23.00	20.00	20.00	20.00	20.00	21.00	44.00	34.00	24.00	29.00	36.00
pH													
x	6.60	6.27	5.83	5.03	6.47	6.43	6.90	6.67	7.07	6.87	6.97	6.60	6.80
s	0.00	0.05	0.09	0.09	1.05	0.05	0.00	0.05	0.17	0.05	0.05	0.00	0.10
max	6.60	6.30	5.90	6.00	6.50	6.50	6.90	6.70	7.30	6.90	7.00	6.60	6.90
min	6.60	6.20	5.70	5.80	6.40	6.40	6.90	6.60	6.90	6.80	6.90	6.60	6.70
Chlorophyll *a* (μg/l)													
x	7.96	7.74	4.01	1.21	6.07	12.97	35.68	8.37	8.92	9.65	20.70	9.33	5.18
s	1.70	0.64	1.80	0.00	0.43	0.96	1.36	0.61	1.03	0.68	0.85	1.64	1.91
max	10.24	8.19	6.01	1.21	6.37	14.33	37.13	8.87	10.38	10.38	21.84	11.60	7.09
min	6.14	6.83	1.64	1.21	5.46	12.29	33.86	7.51	8.19	8.74	19.79	7.80	3.27

na ($F = 5.662, P < 0.01$) (Table 2). On the first canonical axis, the taxa with the greatest contribution to a spatial discrimination of the stations were *Ascomorpha saltans* ($r = 0.308$), *Brachionus calyciflorus* ($r = 0.434$), *Hexarthra* spp ($r = 0.606$), *Lecane (Monostyla) bulla* ($r = 0.382$), *Ploesoma truncata* ($r = 0.328$) and *Testudinella patina* ($r = 0.564$) (dotted line) (Figure 4). On the second canonical axis, the taxa *Brachionus calyciflorus* ($r = 0.445$), *Euchlanis dilatata* ($r = 0.442$), *Lecana (Monostyla) bulla* ($r = 0.501$) and *Ploesoma truncata* ($r = 0.501$) contributed most to temporal discrimination of the stations (solid line) (Figure 4).

In the two distributions of scores (Figures 3 and 4), variations of dissolved oxygen and chlorophyll *a* and to densities of *A. saltans, B. calyciflorus, Hexarthra* spp, *L. (M) bulla, P. truncata* and *T. patina* (axis 1), cause a spatial separation of G2 (littoral of the lake) and B1 (open water of the river) ocurred; however, G1 did not clearly separate from the others (dotted line). Observing the influence of variation in water temperature, fluviometric level and of the densities of *B. calyciflorus, E. dilatata, L (M) bulla* e *P. truncata* (axis 2), there may exist a direct relationship between these and the temporal distribution of the stations. Stations were thus found either aggregated or dispersed along the canonical axis.

The occurrence of *A. saltans, B. calyciflorus, Hexarthra* spp, *L (M) bulla, P. truncata* and *T. patina* had a direct relationship with dissolved oxygen and chlorophyll *a* (axis 1 – dotted line). Both variables had greater values in the open water of the river (B1) than in the littoral of the lake (G2) (Table 2). We suppose these variables to be limiting factors for *A. saltans*, because it did not occur in the lake. On the other hand, occurrence of *E. dilatata, B. calyciflorus, L (M) bulla* e *P. truncata* had a direct relationship with water temperature and fluviometric level (axis 2 – solid line), especially

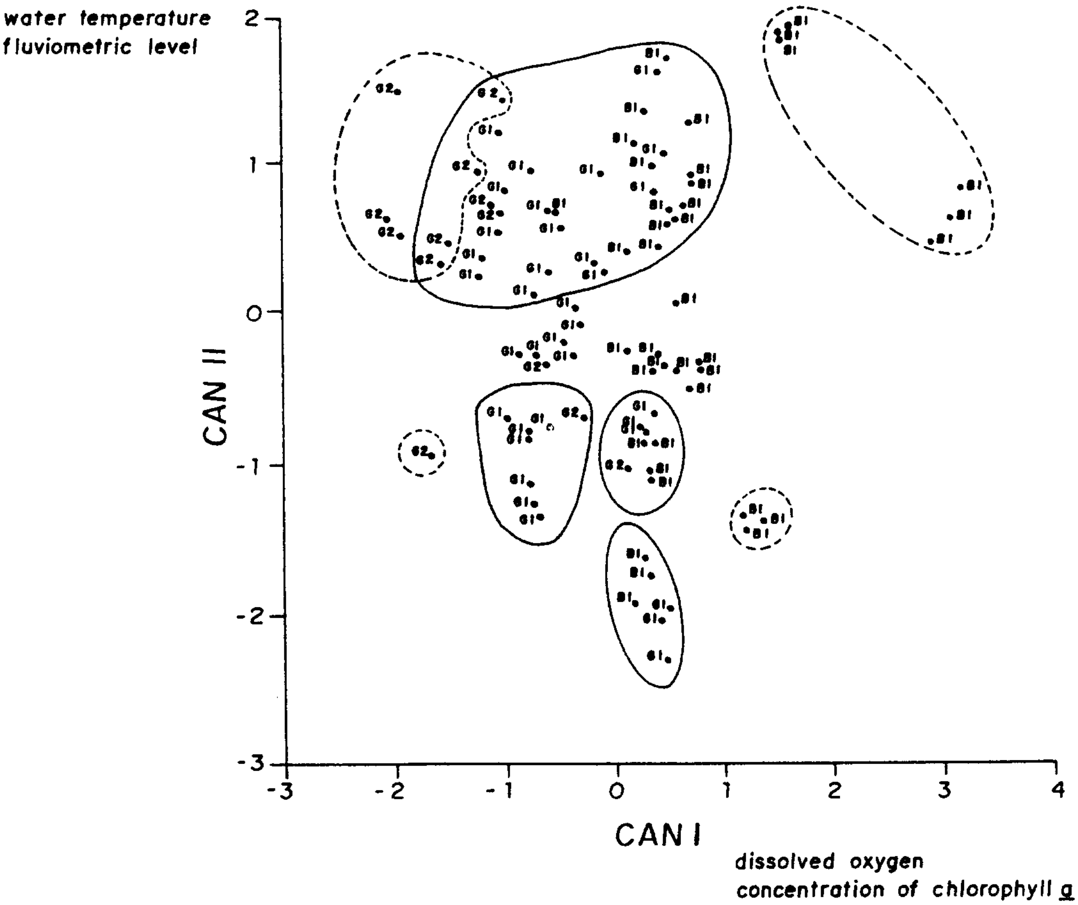

Figure 3. Score distribution of sampling station along the canonical axes defined by environmental variables in the analysis of canonical correlation (G1 = open water region of the lake Guaraná; G2 = littoral region of the lake Guaraná and B1 = open water region of the river Baía) (- - - = first axis; — = second axis).

during high water, when higher values of water temperature and fluviometric level were observed (Table 2).

Diversity

Species diversity, equitability and richness calculated for different stations depths (G1 and B1) are presented in Figure 5.

At G2 higher values of specific diversity fall in December (high water), and smaller values in August (low water), coinciding with equitability and richness. Species diversity at this station exhibited smaller seasonal variation than at the other two stations.

At G1, higher species diversity and equitability were observed from March 1992 to May (high water), together with a tendency of high abundance. The lowest diversity, equitability and richness at this station were recorded in October and November (high water).

Finally, at B1, higher species diversity was recorded in June (low water). The lowest species diversity, equitability and richness occurred in July (low water).

Grouping analysis

By grouping, the dendrograms may be considered a good representation of the original similarity matrix, since all coefficients of cophenetical correlation were higher than 0.80 (Valentin, 1990) (Figure 6).

At G2 during low water, one group with littoral, periphytic or benthic and semi-planktonic taxa (group

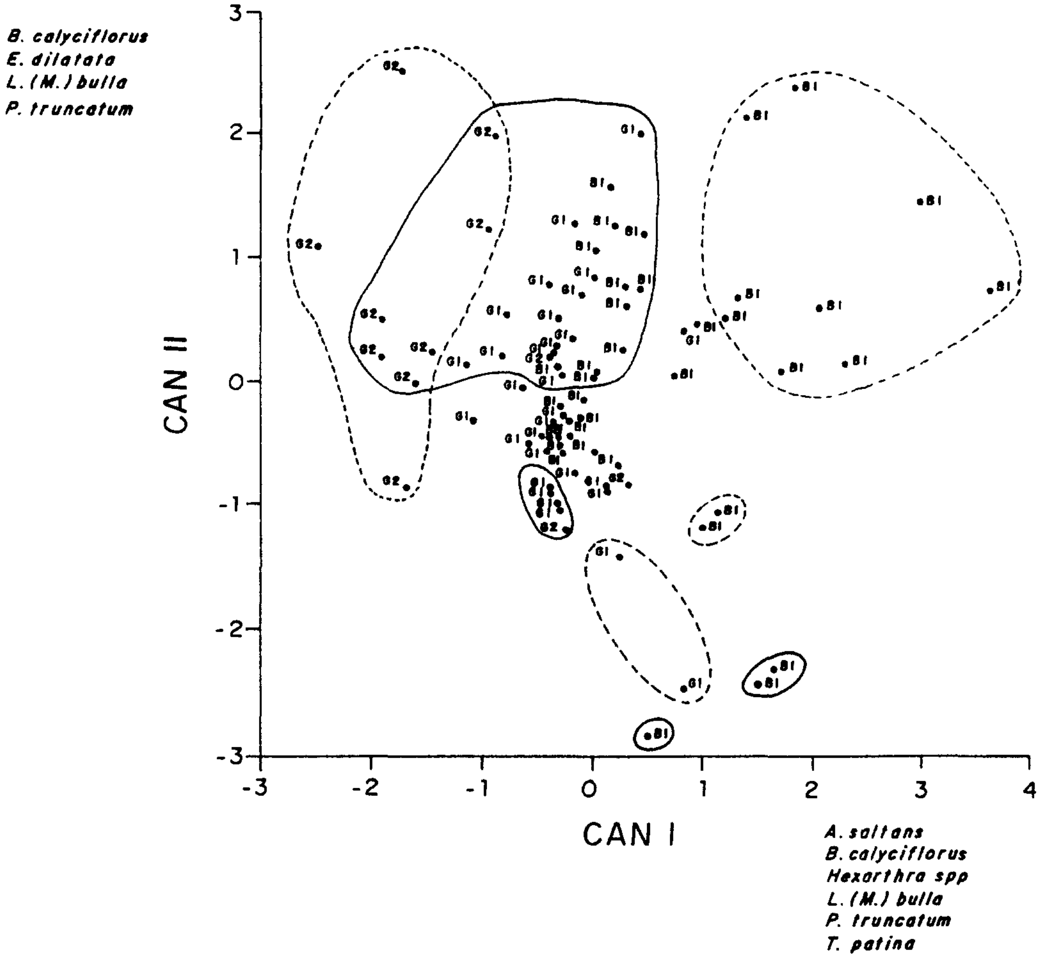

Figure 4. Score distribution of sampling station along the canonical axes defined by the densities of the principal taxa in the analysis of canonical correlation (G1 = open water region of the lake Guaraná; G2 = littoral region of the lake Guaraná and B1 = open water of region of the river Baía) (- - - = first axis; — = second axis).

A) and two planktonic or semi-planktonic groups (groups B and C) were formed, perhaps due to their closeness to the aquatic macrophytes. During high water, a richer species mixtures was observed at this station, especially in group A *(Brachionus calyciflorus* and *Plationus patulus).* Four groups with an association among the taxa (groups A, B, C and D) and five groups with only a single taxon *(Lecane luna, L. lunaris, L. doryssa, Testudinella mucronata hauriensis* and *Platyias quadricornis)* were formed (Figure 6).

At G1 during low water, three groups formed, with planktonic or semi-planktonic and littoral, periphytic or benthic taxa (groups A, B and C). Some taxa did not associate with this group *(Polyarthra vulgaris, Filinia saltator, Plationus patulus, Brachionus mirus, Lecane (Monostyla) bulla* and *L. curvicornis).* At high water, two groups of planktonic or semi-planktonic and littoral, periphytic or benthic taxa formed (groups A and B) together with taxa characteristics of the littoral, such as *Lecane (Monostyla) bulla* and *L. curvicornis* (Figure 6).

At B1, a large group of planktonic or semi-planktonic taxa formed at high water (group A), whilst at low water four groups of planktonic or semi-planktonic and littoral, periphytic or benthic taxa (groups A, B, C and D) and four isolated groups

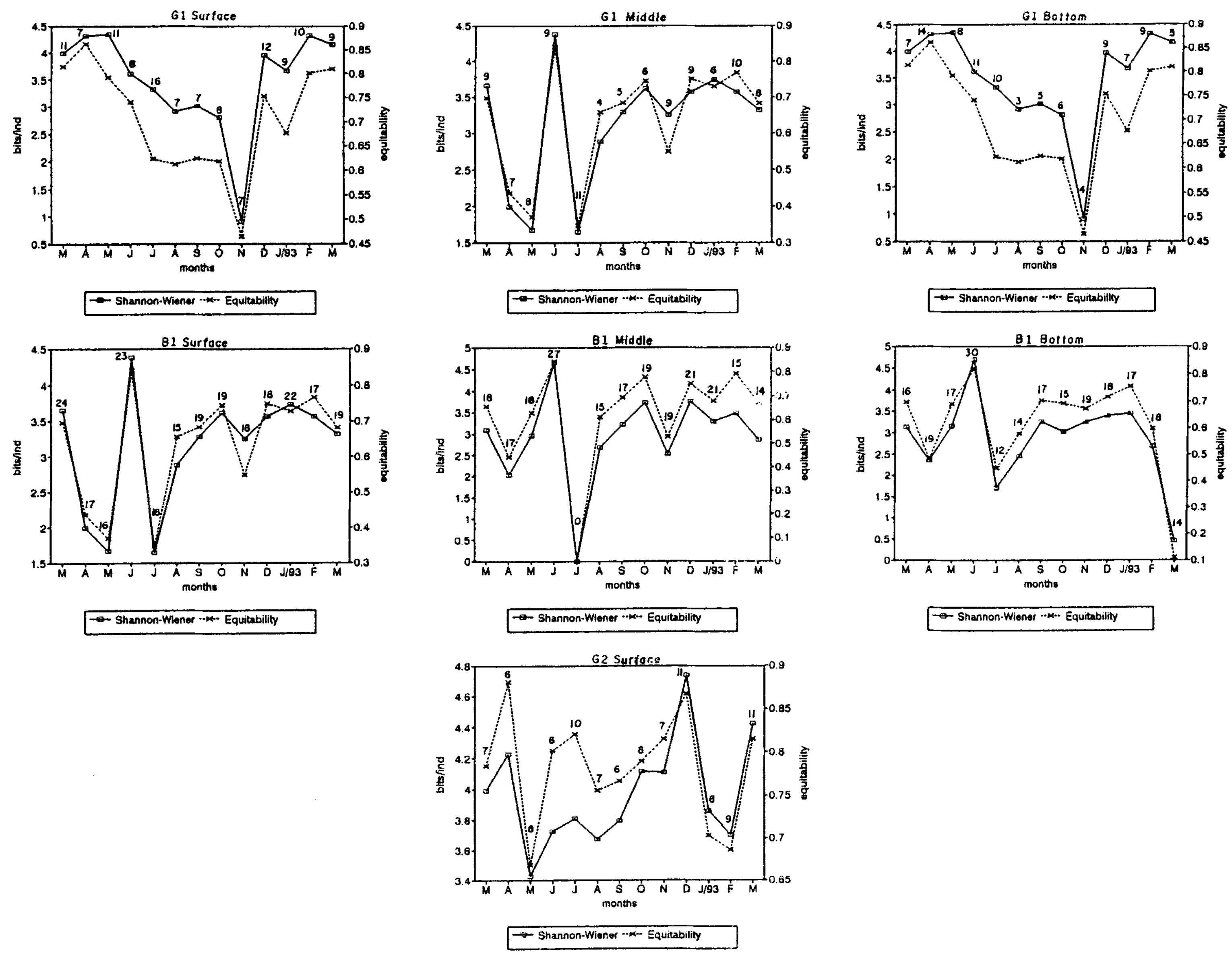

Figure 5. Species diversity and equitability of rotifers in each sampling station. The numbers represent the species richness (G1 = open water region of the lake Guaraná; G2 = littoral region of the lake Guaraná and B1 = open water region of the river Baía).

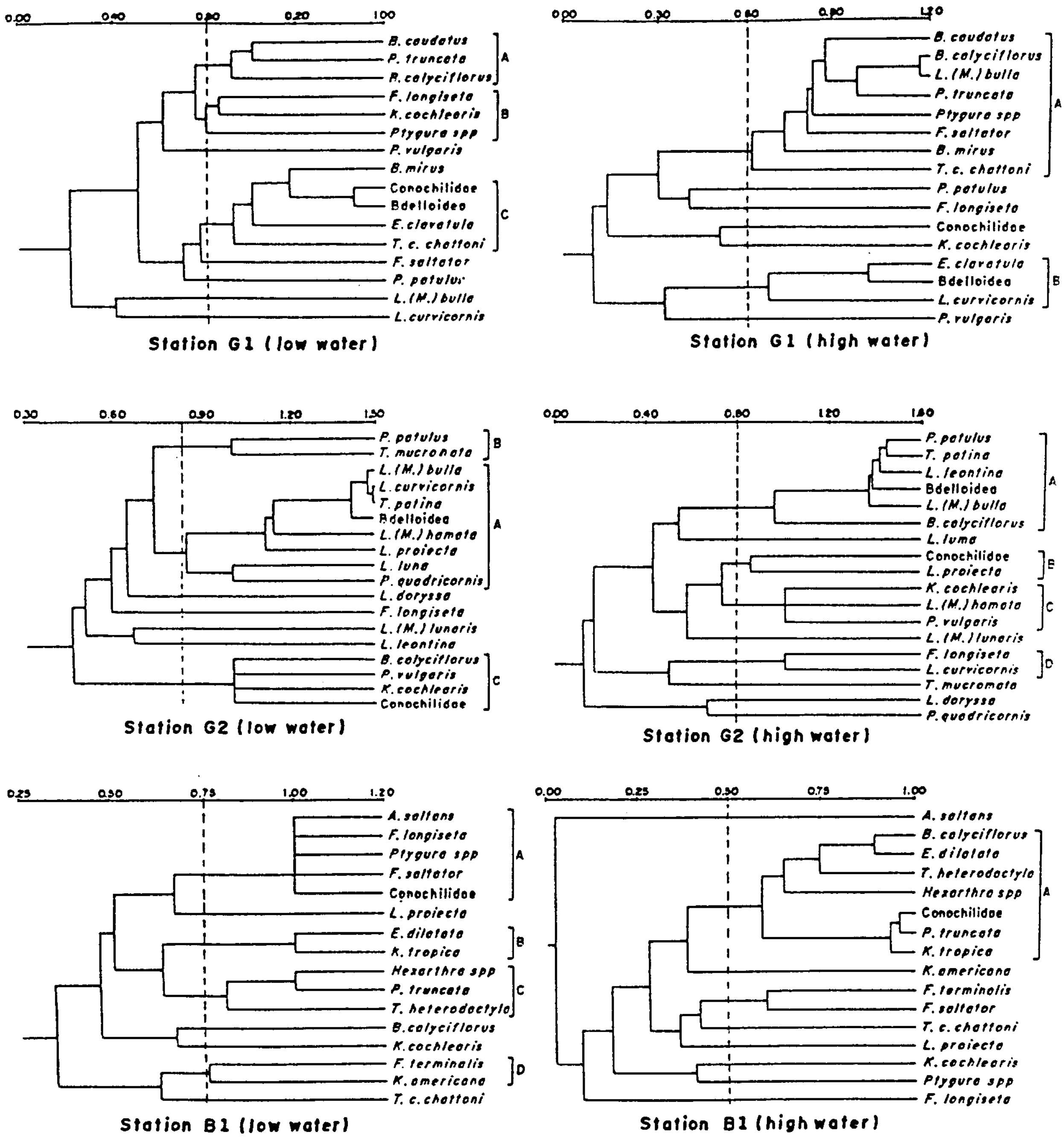

Figure 6. Dendrogram grouping the principal taxa of each station from density values using Morisita's index for the different stations according to the hydrological cycle.

Table 2. Result of the analysis of canonical correlation relating the 17 taxa to the environmental variables

Canonical correlation		0.848	0.774	($P < 0.05$)
		I	II	
	$F(P < 0.01)$	r	r	
Environmental variables				
Water temperature	3.591	-0.217	0.767	
Oxygen (% sat)	4.423	0.741	-0.103	
Electrical conductivity	2.869	-0.426	0.367	
pH	3.163	0.511	0.306	
Chlorophyll *a*	6.009	0.690	0.329	
Fluviometric level	4.465	-0.387	0.639	
Depth	3.054	0.239	0.332	
Biotic variables				
A saltans	3.438	0.308	0.171	
B. calyciflorus	10.433	0.434	-0.445	
E. dilatata	7.330	0.520	0.442	
Hexarthra spp	8.710	0.606	0.229	
L. (M.) bulla	8.428	-0.382	0.501	
P. truncatum	5.318	0.328	-0.501	
T. patina	5.662	-0.564	0.143	

F = Analysis of variance for linear regression; r = relation of original variables to the canonical axes (structure coefficient).

(Lecane proiecta, Brachionus calyciflorus, Keratella cochlearis and *Trichocerca cylindrica chattoni)* (Figure 6).

Some taxa such as *Keratella tropica, K. americana* and *Filinia terminalis* were more important at B1. In the lake, the most abundant taxa occurred at both stations. However, at G2, the genus *Lecane* (littoral or periphytic) was predominant whilst *Brachionus* (planktonic or semi-planktonic) was predominent at G1.

Discussion

Mean rotifer densities were similar between the open water of the lake and the river, and lower than those found at the lake littoral. Paggi & José de Paggi (1990) too recorded higher densities of zooplankton in the littoral of lentic environments of the middle River Paraná floodplain. The presence of extensive aquatic macrophytes in the littoral of such environments offers a greater number of habitats to microorganisms such as rotifers. In the Reservoir Lobo, São Paulo, Camargo et al. (1983) argue that the live biomass and detritus, originating chiefly from decomposition of aquatic macrophytes, is an important source of organic material upon which many consumers depend.

Among the common taxa found at all stations, *Keratella cochlearis, Lecane proiecta, Brachionus calyciforus, Filinia longiseta* and *Ploesoma truncata* were also important in other parts of the middle Paraná (José de Paggi, 1981, 1988 and Paggi & José de Paggi, 1990). In similar environments in the upper Paraná, the occurrence of *Brachionus calyciflorus* and *Conochilus unicornis* (Sendacz, 1993); *Keratella cochlearis, Lecane (Monostyla) bulla, L. proiecta, Filinia longiseta* and *Polyarthra vulgaris* in the Amazon (Hardy, 1980 and Bozelli, 1991) and *Keratella cochlearis, Lecane proiecta* and *Filinia longiseta* in Venezuela (Váquez, 1984; Vásquez & Rey, 1989 and Twombly & Lewis Jr, 1987) should be emphasized.

Canonical correlation analysis suggests a relationship between the open water of the lake and its littoral and the open water of the river, comparing abiotic variables (mainly dissolved oxygen and chlorophyll *a*) and the densities of abundant taxa (mainly *Ascomorpha saltans, Brachionus calyciforus, Hexarthra* spp, *Lecane (Monostyla) bulla, Ploesoma truncata* and *Testudinella patina*). This probably reflects the influence of these regions on the open water of the lake and occurs because of the tighter relationship between the littoral and open water when the lake shrinks during low water (0.014 km^2 – Jabour, unpublished data). On the other hand, during high water its size increases (1.43 km^2 – Jabour, unpublished data) and 'várzea' vegetation is incorporated to the littoral region. Brandorff et al. (1982) considered the occurrence of littoral zooplankton in the open water of Amazon lakes to be due to their shallowness and to the influence of the littoral.

Also, the occurrence of some rotifer taxa (mainly *Ascomorpha saltans, Brachionus calyciforus, Hexarthra* spp, *Lecane (Monostyla) bulla, Ploesoma truncata* and *Testudinella patina*) directly related to dissolved oxygen and chlorophyll *a*, mainly in the open water of the river during high water. According to Berzins & Pejler (1989), oxygen is an important factor in the seasonal distribution of rotifers. The occurrence of *E. dilatata* at all stations was directly related to variation in water temperature and fluviometric level. Mikshi (1992) verified the occurrence of this taxon at higher temperatures, which Mengeston et al. (1991) suggested that, although this taxon is littoral, it is frequently observed in plankton.

Values of species diversity, richness and equitability in this study were higher than those of Hardy (1980) for lakes of the open Amazon but similar to those recorded by Paggi (1980) and José de Paggi (1981) in the middle Paraná; by Sendacz (1993) in the littoral lakes of the upper Paraná; by Green (1972) in lakes of the alluvial valley of the River Suiá-Missú (Amazon), and by Vásquez (1984) in the River Caroni and some lakes in its floodplain (Venezuela).

A higher diversity in the littoral and open water of the lake at high water reflects the contribution of allochthonous fauna and an increase in number of habitats due to a widening of the lake's margin. The intensive communication between the littoral and open water of the lake during high water allows an exchange of taxa. Hardy (1980) recorded more diversity in rotifers in lake Jacaretinga (Amazon) at high water, not only at the margin but also in the center. Koste & Robertson (1983) and Hardy et al. (1984) observed higher diversity values of rotifers in lake Camaleão at high water and attributed this fact to its fluctuation in water level. Corrales de Jacobo & Frutos (1985) add that in studies on zooplankton in a lake of the middle Paraná floodplain, a great variety of species, chiefly characteristic of vegetation, occurred after an increase in water level.

At low water, the lowest diversity registered in the littoral was probably due to the slight isolation of this region from the rest of the lake. Lower diversity in the open water of the lake were recorded at high water and may relate to the rise in water level and consequently an increase concentration of suspended material. Brandorff & Andrade (1978) discuss the almost total disappearance of planktonic microcrustaceans in lake Jacaretinga after the entry of water from the Amazon. Studies undertaken by Hardy (1980) in the Amazon discuss lower diversity values of rotifers in the margin of lake Cristalino at low water and a lower diversity in the open water of lake Castanho at high water.

Higher diversity values in the river during low water are probably due to input of organisms from surrounding floodplain lakes. Corrales (1979) described an increase in zooplankton diversity during low water in the high River Paraná. José de Paggi (1981) added that the zooplankton of secondary channels of the middle River Paraná, showed higher diversity values at the low water. Bonetto & Corrales de Jacobo (1985) refer higher values in species diversity of zooplankton after high water to the great number of species that come from the alluvial valley and return to the river.

Low values of species diversity in the river during low water are possibly related to instability of the environment. José de Paggi (1981) finds that the zooplankton carried from lakes to the river during low water soon die in lotic conditions, even though some rotifers present certain adaptations such as the globular form of *Lecane proiecta* to survive in lotic conditions. It should be emphasized that this taxon was one of the principal taxa recorded in the open water of the river.

The agglomeration of taxa described by the dendrograms of the principal taxa at each station suggests an influence of hydrological level of the River Paraná on taxa distribution. Generally, during high water, a formation of groups with both planktonic and nonplanktonic taxa was observed. This is probably due to the mixture of the water of river and lake.

Hardy (1980) affirms that the structure of the zooplankton in lakes of the open water Amazon is periodically altered by flood pulses.

Acknowledgements

Thanks are due to researchers Dr Walter Koste and Dr[a] Susana José de Paggi for the identification of some taxa; Dr[a] Suzana Sendacz, Dr Jean Louis Valentin and Dr Angelo Antonio Agostinho for their valuable suggestions; to the researchers of the Limnology Laboratory (NUPELIA) for the collection and analysis of environmental variables; to Luis Mauricio Bini, Luiz Felipe Machado Velho and Dr[a] Evanilde Benedito-Cecilio for their help in data analysis; to the staff of the Nucleus for Research in Limnology, Ichthyology and Aquiculture (NUPELIA) of the Universidade Estadual de Maringá for their technical and scientific support; to CAPES for the granting of scholarships, to PADCT/CIAMB for the necessary financial support.

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