SPECIES COMPOSITION AND ABUNDANCE OF ROTIFERS IN DIFFERENT ENVIRONMENTS OF THE FLOODPLAIN OF THE UPPER PARANÁ RIVER, BRAZIL

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ABSTRACT. The purpose of this study was to describe the composition and abundance of rotifers in different environments: one lotic (the Ivinheima River) and another lentic (the Patos Lake) located in the floodplain of the Upper Paraná River. The influence of limnological variables on the structure and dynamics of rotifers was also examined. Samples were taken monthly from March 1992 through February 1993, in the open water region of the lake and river and in the channel between them and, in the littoral region of the lake and river. Of the 96 species identified, the best represented families were: Brachionidae (20 species), Lecanidae (18 species), and Trichocercidae (15 species). 55 species were widely distributed, 13 were pantropical, 16 neotropical (8 endemic to South America). *Trichocerca gracilis* was a new record for this floodplain. *Dipleuchlanis propatula propatula*, *Lecane curvicornis*, *L. leontina*, *L. bulla*, *Plationus patulus patulus*, *Platyias quadricornis quadricornis*, *Testudinella patina*, and *T. mucronata hauriensis* were consistently present. More species were recorded during the high water period, probably because of the interconnection among the different environments of the floodplain that allows fauna exchange and an increase in available habitats. Rotifer densities were higher mainly in the lake, during the high water. Using principal components analysis, was identified four variables that influence the seasonal variation in the rotifer densities: water level, dissolved oxygen, chlorophyll-a concentration, and water temperature.
KEY WORDS. Rotifera, Paraná River, floodplain, neotropics

On a floodplain, the seasonal variation in the hydrological conditions, characterized by the occurrence of high water and low water periods, is a fundamental ecological factor. Water level variations cause changes in the abiotic and biotic features of the whole system and regulate the exchange of matter and energy between the main river and the adjacent environments (JUNK *et al.* 1989).

The Paraná River has areas of floodplain in some of its stretches; in this environment and others, the zooplankton community varies in its composition and abundance in relation to changes in physical, chemical, and biological characteristics (VÁSQUEZ 1984a,b; ROBERTSON & HARDY 1984; PAGGI & JOSÉ DE PAGGI 1990; LANSAC-TÔHA *et al.* 1997). Among the zooplankton, the rotifers are notably most the abundant and diverse. This community richness, allied to their high turnover, indicates the ecological importance of rotifers in energy flow and nutrient cycling (ALLAN 1976).

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The aim of this paper is to describe the composition and abundance of rotifers in a lotic environment (Ivinheima River) and a lentic environment (Patos Lake), located in the floodplain of the Upper Paraná River, Mato Grosso do Sul State, as well as to identify the influence of physical, chemical, and biological variables on the rotifer community structure and dynamics.

MATERIALS AND METHODS

Study area

The Ivinheima River (22°49'33"S and 53°33'46"W) has a meandering pattern and turbulent waters. Its margins are covered by grasses (*Polygonon* sp.) and, in part, occupied by aquatic macrophytes (*Eichhornia azurea* Kunth). The Ivinheima communicates with the Paraná River by a channel (Fig. 1).

The Patos lake (22°43'12"S and 53°17'37"W) is located on the right bank of the Paraná River and on the left bank of the Ivinheima River, communicating with the latter throughout the year by a channel. This channel contains large beds of aquatic macrophytes along its length and its bank is dominated by grasses. The flow direction and water speed in the channel vary according to the flood stage of the river. The irregular shore at the lake is covered by grasses and small beds of aquatic macrophytes, predominantly *E. azurea* (Fig. 1).

Sampling stations

For this study, was established five sampling stations (Fig. 1): two in the lake (Stations 1 – open water region and 2 – littoral region), one in the channel between the river and the lake (Station 3 – open water), and two in the river (Stations 4 – littoral region and 5 – open water region).

Physical, chemical, and biological variables

We collected monthly samples for physical, chemical, and biological variables, always during the morning, from March 1992 to February 1993, at all stations. At stations 1 and 3 were collected the samples at three depths of the water column (surface, middle, and bottom), at station 5, at two depths (surface and bottom), and at stations 2 and 4, only on the surface.

Water level data for the Paraná River were supplied by DNAEE (National Department of Water and Energy). Analyses of the abiotic and biotic variables: water temperature (°C), water column transparency (m), dissolved oxygen (mg/l), pH, electrical conductivity (µS/cm), and chlorophyll-a concentration (mg/l) were conducted according to the methodology described by THOMAZ *et al.* (1992).

Rotifers

We obtained the rotifer samples with a motorized pump filtering 1000 liters of water for each sample through a 70 µm mesh plankton net.

Rotifers (ind/m^3) were quantified by counting sub-samples in a Sedgwick-Rafter cell; at least 200 individuals of each sample were counted. Identification was based on KOSTE (1978), KOSTE & ROBERTSON (1983) and SEGERS (1995).

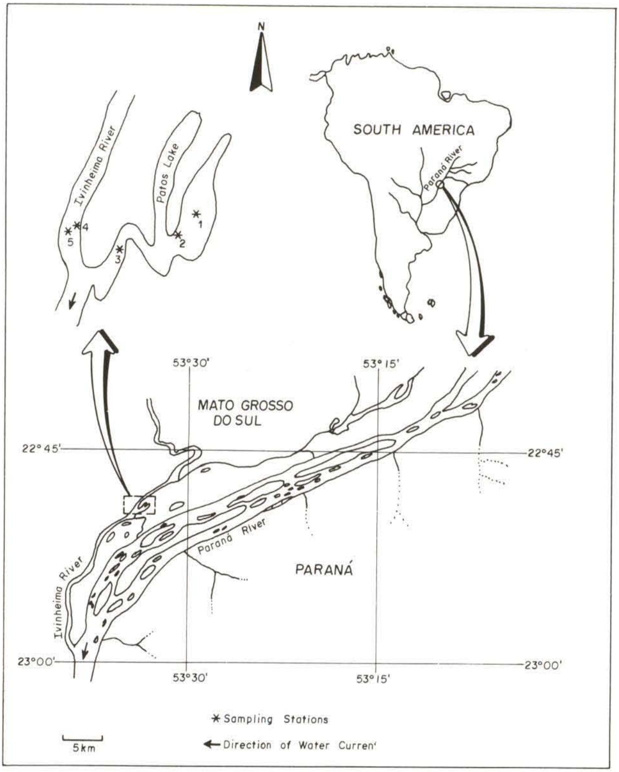


Fig. 1. Sampling stations.

Constancy Index and Geographical Distribution

A Constancy Index (c) for each species recorded at the five sampling stations, was determined by the expression c = (n x 100)/N, where "n" is the number of samples containing the species and "N" is the total number of samples collected (DAJOZ 1973). According to the results of this index, the species were considered constant when they occurred in more than 50% of the samples; accessory, when recorded in 25%-50% of the samples, and accidental when present in less than 25% of the samples.

From the data on geographic distribution for each species (KOSTE 1978; JOSÉ DE PAGGI 1990; BONECKER *et al.* 1994), the species were classified as having a widespread distribution, as pantropical, neotropical, or neotropical and endemic to South America.

Principal components analysis (PCA)

To evaluate the influence of the temporal and spatial variation of the environmental factors on the total densities of the rotifers and the principal species, were conducted a multivariate analysis of the data. PCA examines the interdependence among the variables and, from the data, discovers models that allow us to formulate hypothesis as a function of the estimated variables (PLA 1986).

From this analysis was derived a data matrix with all the limnological variables (Tabs I, II). The data, except for pH, were log transformed [Log (x+1)], and standardized since were dealing with variables with distinct units of measurement.

PCA was performed using *Statistica* software (STATSOFT 1991). To interpret the analysis was considered the axis that explained in total 50% or more of the variability of the data. Only those variables with structure coefficients = 0.5 were considered.

Table I. Water level of the Paraná River. Average values (x), standard deviation (s), maximum (max) and minimum (mim) environmental variables obtained at five sampling stations in March 1992 – February 1993. For stations 2 and 5 only surface data are presented. These data were used in the PCA.

Variables per Station	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Water level (m)	4.20	4.60	4.80	3.44	2.80	2.91	2.88	3.23	4.42	4.77	4.13	5.36
Station 1												
Depth (m)	4.20	4.60	6.60	5.80	4.20	3.60	3.80	4.40	4.80	5.60	4.00	4.60
Water transparency (m)	1.20	0.80	0.50	1.40	1.70	0.90	0.60	0.60	1.10	1.80	1.40	1.00
Water temperature (°C) $\bar{x}$	26.43	25.56	23.96	23.36	18.13	18.30	20.80	23.36	26.53	29.10	26.83	27.93
s	0.58	0.05	0.05	0.15	0.30	0.20	0.26	0.11	1.45	0.36	0.25	0.20
Max	27.10	25.60	24.00	23.50	18.40	18.50	21.00	23.50	28.00	29.40	27.10	28.10
Min	26.00	25.50	23.90	23.20	17.80	18.10	20.50	23.30	25.10	28.70	26.60	27.70
Dissolved oxygen (mg/l)	55.50	22.43	27.66	16.36	37.13	94.90	93.83	16.60	67.36	18.43	46.40	25.90
s	0.58	0.05	0.05	0.15	0.30	0.20	0.26	0.11	1.45	0.36	0.25	0.20
Max	67.60	24.00	29.50	17.40	41.70	97.00	96.40	18.20	97.80	23.10	50.30	27.90
Min	32.60	20.70	25.50	14.70	30.20	92.40	90.70	13.90	32.00	14.40	43.50	22.50
Electrical conductivity (µS/cm)	49.33	40.66	35.00	45.66	39.66	31.66	33.00	41.33	38.33	36.00	36.00	37.00
s	3.21	0.57	0.00	1.52	0.57	1.15	0.00	0.57	1.52	0.00	0.00	0.00
Max	53.00	41.00	35.00	47.00	40.00	33.00	33.00	42.00	40.00	36.00	36.00	37.00
Min	47.00	40.00	35.00	44.00	39.00	31.00	33.00	41.00	37.00	36.00	36.00	37.00
pH $\bar{x}$	6.60	6.10	6.26	6.13	6.23	6.36	7.50	6.33	6.76	6.43	6.53	6.40
s	0.14	0.00	0.11	0.05	0.05	0.15	0.17	0.05	0.11	0.05	0,05	0.00
Max	6.70	6.10	6.40	6.20	6.30	6.50	7.70	6.40	6.90	6.50	6.60	6.40
Min	6.50	6.10	6.20	6.10	6.20	6.20	7.40	6.30	6.70	6.40	6.50	6.40
Chlorophyll -a (µg/l)	2.73	3.21	1.91	1.09	1.21	5.27	28.91	4.12	6.96	2.65	8.51	5.46
s	1.44	2.78	1.93	0.00	0.60	0.31	5.50	1.16	0.49	0.72	0.34	1.82
Max	4.37	6.37	3.28	1.09	1.82	5.46	33.70	5.46	7.51	3.12	8.87	7.28
Min	1.64	1.09	0.55	1.09	0.61	4.91	22.93	3.28	6.55	1.82	8.19	3.64
Station 2												
Depth (m)	1.60	2.20	3.20	3.00	1.20	1.00	1.40	1.80	2.00	2.80	1.40	2.00
Water transparency (m)	1.30	0.80	0.50	1.70	1.10	0.70	0.60	0.70	1.10	1.30	1.10	1.00
Water temperature (°C) $\bar{x}$	28.10	25.40	24.10	23.40	18.70	18.60	20.60	23.70	27.80	29.30	26.70	28.30
Dissolved oxygen (mg/l)	66.50	31.40	28.50	20.00	44.20	101.80	120.80	36.60	76.80	18.10	23.70	27.70
Electrical conductivity (µS/cm)	49.00	38.00	35.00	48.00	40.00	32.00	33.00	41.00	38.00	36.00	37.00	37.00
pH $\bar{x}$	6.70	6.00	6.40	6.20	6.40	6.50	7.50	6.40	6.90	6.40	6.40	6.40
Chlorophyll -a (µg/l)	0.00	3.28	0.55	0.55	2.43	5.46	32.22	6.55	6.67	2.73	7.89	3.64
Station 3												
Depth (m)	4.40	5.00	7.00	6.40	4.40	4.00	4.40	4.80	5.20	5.00	4.40	5.00
Water transparency (m)	1.10	0.90	0.50	1.40	1.10	1.00	0.60	0.70	1.00	1.40	1.10	1.00
Water temperature (°C) $\bar{x}$	26.80	25.73	23.96	23.30	19.13	17.86	20.46	23.66	26.83	29.26	27.83	27.96
s	0.87	0.11	0.05	0.17	0.11	0.35	0.49	0.23	0.70	0.23	0.35	0.05
Max	27.80	25.80	24.00	23.40	19.20	18.20	20.80	23.80	27.60	29.40	28.20	28.00
Min	26.20	25.60	23.90	23.10	19.00	17.50	19.90	23.40	26.20	29.00	27.50	27.90
Dissolved oxygen (mg/l) $\bar{x}$	72.73	33.16	36.76	22.33	55.60	100.30	108.80	26.40	72.30	18.90	59.30	14.83
s	21.23	0.20	1.17	1.00	2.66	1.10	4.42	0.34	10.71	0.17	1.69	0.75
Max	95.20	33.40	38.10	23.10	58.60	101.40	112.70	26.60	81.20	19.00	60.50	15.70
Min	53.00	33.00	35.90	21.20	53.50	99.20	104.00	26.00	60.40	18.70	58.10	14.40

Cont.

Table I. Continued.

Variables per Station	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Electrical conductivity (µS/cm) $\bar{x}$	47.60	40.60	35.30	47.00	42.30	41.00	40.00	44.30	45.30	36.30	36.60	40.00
s	1.52	0.57	0.57	0.00	0.57	2.64	0.00	0.57	0.57	0.57	0,57	1.00
Max	49.00	41.00	36.00	47.00	43.00	43.00	40.00	45.00	46.00	37.00	37.00	41.00
Min	46.00	40.00	35.00	47.00	42.00	38.00	40.00	44.00	45.00	36.00	36.00	39.00
pH $\bar{x}$	6.60	6.16	6.16	6.33	6.53	6.83	7.16	6.50	6.80	6.53	6.63	6.40
s	0.10	0.05	0.05	0.11	0.05	0.05	0.05	0.10	0.00	0.15	0.05	0.00
Max	6.70	6.20	6.20	6.40	6.60	6.90	7.20	6.60	6.80	6.70	6.70	6.40
Min	6.50	6.10	6.10	6.20	6.50	6.80	7.10	6.40	6.80	6.40	6.60	6.40
Chlorophyll -a (µg/l) $\bar{x}$	2.55	3.09	1.09	0.55	2.30	2.36	7.82	3.70	1.82	3.07	9.10	6.52
s	2.57	0.62	0.00	0.00	0.84	0.62	1.37	0.91	1.37	1.27	0.52	1.83
Max	5.46	3.82	1.09	0.55	3.28	2.73	9.28	4.55	3.28	4.37	9.71	8.19
Min	0.55	2.73	1.09	0.55	1.82	1.64	6.55	2.73	0.55	1.82	8.74	4.55
Station 4												
Depth (m)	3.00	2.00	4.60	4.20	3.00	1.60	1.80	2.60	5.50	3.20	2.60	3.00
Water transparency (m)	0.50	0.80	0.50	1.70	0.80	0.80	0.60	0.40	0.90	1.20	0.60	0.60
Water temperature (°C)	26.70	25.30	24.30	23.30	18.20	18.90	20.40	23.80	27.30	29.20	28.00	28.50
Dissolved oxygen (mg/l)	88.30	59.80	47.20	30.30	99.40	106.90	96.70	81.60	61.90	15.80	86.10	82.90
Electrical conductivity (µS/cm)	41.00	43.00	37.00	47.00	50.00	45.00	41.00	42.00	43.00	37.00	46.00	44.00
pH	6.60	6.10	6.60	6.20	6.80	6.70	7.10	6.80	6.70	6.40	7.00	6.90
Chlorophyll -a (µg/l)	2.73	7.64	0.00	1.09	0.00	1.37	2.18	1.09	3.28	0.91	4.55	2.18
Station 5												
Depth (m)	4.60	5.00	7.40	6.50	6.00	5.00	5.00	6.50	2.80	6.00	4.20	5.00
Water transparency (m)	0.40	0.90	0.50	1.10	0.80	0.70	0.60	0.40	0.80	0.90	0.50	0.50
Water temperature (°C) $\bar{x}$	26.70	25.25	24.20	23.70	20.60	18.35	19.35	22.30	26.10	27.70	28.30	28.45
s	0.14	0.07	0.00	0.07	3.39	0.07	1.62	2.82	2.54	0.07	0.14	0.07
Max	26.80	25.30	24.20	24.20	23.00	18.40	20.50	24.30	27.90	28.20	28.40	28.50
Min	26.60	25.20	24.20	23.20	18.20	18.30	18.20	20.30	24.30	27.70	28.20	28.40
Dissolved oxygen (mg/l) $\bar{x}$	97.80	78.25	47.00	59.75	96.90	107.80	96.20	85.50	93.00	79.90	91.50	91.45
s	0.98	0.77	1.27	0.21	0.28	1.06	0.42	1.34	0.28	0.56	2.12	0.07
Max	98.50	78.80	47.90	59.90	97.10	108.60	96.50	86.50	93.20	80.30	93.00	92.00
Min	97.10	77.70	46.10	59.60	96.70	107.10	95.90	84.60	92.80	79.50	90.00	90.90
Electrical conductivity (µS/cm)	41.50	41.50	38.00	47.00	51.50	44.00	41.00	42.00	44.50	43.00	46.00	45.50
s	0.70	0.70	0.00	2.82	0.70	1.41	0.00	0.00	0.70	0.00	0.00	0.70
Max	42.00	42.00	38.00	49.00	52.00	45.00	41.00	42.00	45.00	43.00	46.00	46.00
Min	41.00	41.00	38.00	45.00	51.00	43.00	41.00	42.00	44.00	43.00	46.00	45.00
pH $\bar{x}$	6.45	6.50	6.45	6.25	6.90	6.75	7.15	7.00	7.00	6.90	7.10	7.10
s	0.07	0.00	0.21	0.07	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00
Max	6.50	6.50	6.60	6.30	6.90	6.80	7.20	7.00	7.00	6.90	7.10	7.10
Min	6.40	6.50	6.30	6.20	6.90	6.70	7.10	7.00	7.00	6.90	7.10	7.10
Chlorophyll -a (µg/l) $\bar{x}$	0.00	6.55	0.00	1.09	1.63	0.00	1.09	1.76	2.45	1.21	3.18	1.09
s	0.00	0.00	0.00	0.00	0.77	0.00	0.00	0.94	0.38	0.00	0.64	0.00
Max	0.00	6.55	0.00	1.09	2.18	0.00	1.09	2.43	2.73	1.21	3.64	1.09
Min	0.00	6.55	0.00	1.09	1.09	0.00	1.09	1.09	2.18	1.21	2.73	1.09

RESULTS

Water level

The fluctuations in the water level of the Paraná River are shown in figure 2. The hydrological cycle had two phases: high water period (March 1992 to May 1992 and October 1992 to February 1993) and low water period (June 1992 to September 1992).

Composition

Table III lists rotifers recorded, including their constancy and known geographic distributions. Were identified 96 rotifer species belonging to 21 families, of which the most representative were: Brachionidae (20 species), Lecanidae (18 species), and Trichoceridae (15 species). The most representative genera were *Lecane* (18 species), *Trichocerca* (15 species), and *Brachionus* (11 species). Among the bdelloids, which include periphytic and benthic species, were identified two species: *Dissotrocha aculeata* Ehrenberg, 1832 and *D. macrodactyla* (Ehrenberg, 1838) (Philodinidae).

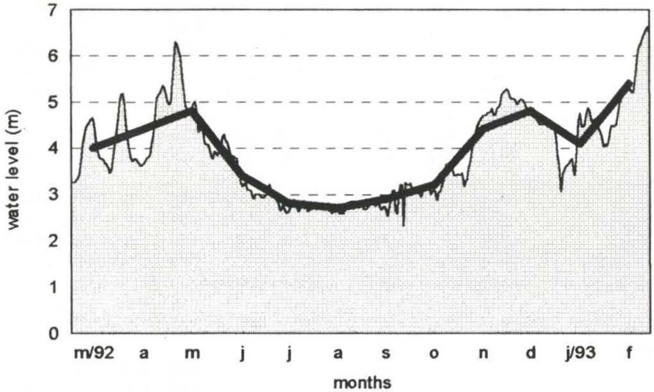


Fig. 2. Water level (m) of the Paraná River measured between March 1992 and February 1993. Dotted line = average and solid area = daily measuraments.

Table II. Densities of the principal species (ind/m^3) collected at each sampling station. These data were used in the PCA.

Species	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Station 1												
L. bulla	327	1097	336	147	181	0	0	1287	758	13117	3767	8150
L. curvicornis	903	10333	47	26	38	0	28	148	2667	12867	7633	4167
L. luna	35	56	5	0	0	0	0	0	0	0	0	0
L. elsa	25	917	2	0	5	0	0	69	0	550	733	2467
L. leontina	36	111	68	9	2	0	0	0	33	300	100	100
L. papuana	63	28	0	0	0	0	0	0	33	617	2683	50
D. p. propatula	54	1306	0	7	31	0	28	74	633	1183	3000	817
P. p. patulus	125	2306	10	9	9	0	0	2009	117	67	17	750
P. q. quadricornis	204	694	38	20	7	0	9	148	167	5517	217	1400
T. pusilla	0	0	0	6	27	1630	3000	56	17	17	50	0
F. terminalis	21	917	56	0	2	111	185	1324	117	50	450	600
B. calyciflorus	1	0	5	0	0	2512	1537	56	17	17	33	0
K. tropica	16	0	108	23	61	923	4685	250	100	50	150	0
T. patina	121	750	17	0	2	0	28	19	100	83	1133	550
Bdelloidea	488	1028	65	77	54	0	102	713	333	767	3050	783
Station 2												
L. bulla	1639	3000	1370	361	3037	556	500	833	53		625	9650
L. curvicornis	28	7167	74	181	333	0	0	0	825	9300	1088	9700
L. luna	222	0	0	0	37	0	111	111	0	0	0	0
L. elsa	0	167	0	0	0	0	0	0	0	14000	38	1650
L. leontina	333	333	593	14	148	111	167	75	1150	63	1050	93
L. papuana	0	0	0	0	0	0	0	0	125	0	38	950
D. p. propatula	28	750	37	14	111	0	56	0	0	300	25	1000
P. p. patulus	0	0	444	0	0	0	111	111	500	100	75	1200
P. q. quadricornis	167	83	297	97	148	0	56	56	0	2500	0	1150
T. pusilla	0	0	0	0	0	0	0	0	0	0	0	0

Cont.

Table II. Continued.

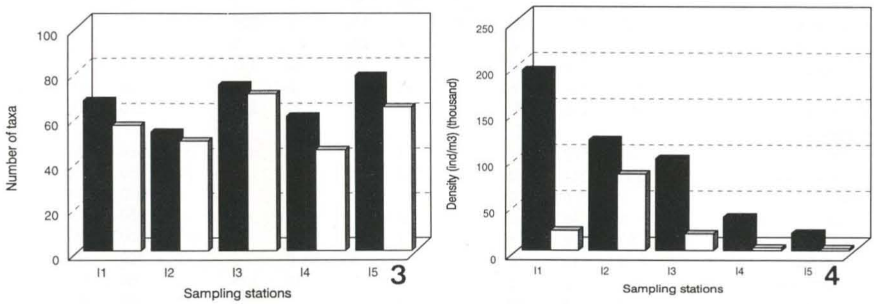
Species	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
F. terminalis	0	0	0	0	0	0	1056	556	0	0	0	1650
B. calyciflorus	0	0	0	0	0	0	2000	1389	1111	0	0	0
K. tropica	0	0	37	0	0	38444	600	5278	0	0	0	0
T. patina	0	833	630	14	667	333	56	0	0	150	88	750
Bdelloidea	139	1833	704	0	630	333	444	0	250	1200	125	850
Station 3												
L. bulla	528	1100	2177	127	262	28	194	753	599	9133	4375	1300
L. curvicornis	1343	1156	28	64	76	32	1851	90	235	1717	7467	1792
L. luna	153	0	19	74	3	5	0	37	28	1117	0	0
L. elsa	51	239	4	4	8	0	6	0	23	167	383	200
L. leontina	93	89	230	1	3	0	0	19	54	617	167	50
L. papuana	23	6	0	2	0	0	0	0	3	242	1192	633
D. p. propatula	130	191	0	27	113	0	0	31	57	825	808	15676
P. p.patulus	583	1042	28	3	38	0	5	479	174	583	4166	275
P. q. quadricornis	204	178	39	23	30	9	0	772	34	1892	200	408
T. pusilla	0	0	0	23	758	1167	0	0	0	0	0	0
F. terminalis	102	117	100	16	0	116	125	926	19	17	1333	1233
B. calyciflorus	5	0	0	1	4	258	560	0	6	17	0	0
K. tropica	144	14	96	10	8	375	2744	191	17	0	0	0
T. patina	264	183	76	44	63	5	23	34	66	208	450	125
Bdelloidea	482	139	127	76	54	111	120	228	173	275	1100	500
Station 4												
L. bulla	142	172	111	33	34	25	56	611	433	7850	850	2050
L. curvicornis	258	44	0	30	158	30	29	0	67	50	50	75
L. luna	8	0	0	0	0	0	7	56	0	1050	917	1625
L.elsa	8	43	0	4	26	0	3	37	17	50	33	225
L. leontina	17	39	111	0	21	0	0	20	167	500	83	125
L. papuana	0	15	0	0	0	0	0	0	0	100	67	825
D. p. propatula	33	0	0	0	0	20	10	19	33	50	117	0
P. p. patulus	8	83	56	15	4	0	7	74	250	150	150	200
P. q. quadricornis	75	103	167	59	30	46	26	37	33	100	33	300
T. pusilla	0	0	0	0	0	0	7	0	0	0	0	0
F. terminalis	42	20	42	11	9	0	10	129	0	0	17	0
B. calyciflorus	25	5	0	0	43	51	13	19	0	0	0	0
K. tropica	33	29	125	7	9	76	160	19	17	0	17	0
T. patina	192	64	694	200	325	56	26	148	50	600	250	25
Bdelloidea	233	29	13	37	30	71	33	148	100	800	317	350
Station 5												
L. bulla	290	640	264	147	80	69	146	1331	454	2000	275	268
L. curvicornis	12	170	21	2	3	6	15	31	158	288	567	52
L. luna	285	39	46	35	43	39	22	0	138	363	103	73
L. elsa	5	10	0	0	0	0	0	22	25	75	30	0
L. leontina	12	12	72	4	6	0	2	9	56	275	28	5
L. papuana	24	10	9	0	0	0	0	9	0	25	33	12
D. p. propatula	102	47	0	35	8	13	8	6	81	163	36	41
P. p. patulus	24	19	12	0	6	0	29	17	54	25	125	89
P.q. quadricornis	54	24	5	26	2	34	2	19	17	75	58	15
T.pusilla	0	0	0	4	2	0	0	22	0	0	0	0
F. terminalis	219	0	287	8	6	9	8	10	17	37	131	21
B. calyciflorus	0	0	5	0	17	4	4	0	0	0	0	0
K. tropica	26	6	61	32	7	73	64	18	202	75	25	0
T. patina	146	194	141	54	12	35	9	0	48	75	64	0
Bdelloidea	248	55	368	89	65	51	81	42	85	213	94	93

The greatest number of species in the lake occurred in the open water region (72 species), and 61 species were found in the littoral region. Similarly in the river, 85 species were recorded in open water, and 67 species in the littoral. 82 species were identified in the connecting channel between the river and the lake.

The Constancy Index suggested that a larger number of constant species were present in the river, chiefly in the littoral region, than in the channel, followed by the lake (Tab. III). Only eight species were constant at the five sampling stations: *Dipleuchlanis propatula propatula* (Gosse, 1886), *Lecane curvicornis* (Murray, 1913), *L. leontina* (Turner, 1892), *L. bulla* (Gosse, 1851), *Plationus patulus patulus* (Müller, 1786), *Platyias quadricornis quadricornis* (Ehrenberg, 1832), *Testudinella patina* (Hermann, 1783) and *T. mucronata hauriensis* (Gillard, 1967).

Over all, 55 species are of widespread distribution, 13 are pantropical, and 16 neotropical. Of these, 8 are endemic to South America (Tab. III). *Trichocerca gracilis* (Tessin, 1890) is a new record for the floodplain of the Upper Paraná River.

The greatest diversity of species was recorded at all stations in the high water period (Fig. 3).



Figs 3-4. (3) Number of species in each period of the hydrolical cycle by sampling station; (4) density of rotifers (thousand ind/m^3) in each period of the hydrolical cycle by sampling station. □ Low water, ■ high water.

Density

Comparing the total rotifer densities at the five sampling stations, considering only the mean of the stations with more than one collection depth, the greatest abundance occurred in the lake, followed by the channel, and then the river. Rotifer densities fluctuated from month to month at each station, with higher densities during the high water period (Fig. 4).

The most numerous species, in the whole system were *Lecane bulla, L. curvicornis, L. luna* (Müller, 1776), *L. elsa* Hauer, 1931, *L. leontina*, *L. papuana* (Murray, 1913), *Dipleuchlanis propatula propatula*, *Keratella tropica* (Apstein, 1907), *Plationus patulus patulus*, *Platyias quadricornis quadricornis*, *Brachionus calyciflorus* Pallas, 1776, *Trichocerca pusilla* (Lauterborn, 1898), *Testudinella patina*, and *Filinia* cf *terminalis* (Plate, 1886). Bdelloids were numerous at all stations (Tab. II). All these species were considered for the PCA.

Principal components analysis

The results obtained by PCA showed that the principal components (CPI and CPII) explained 60.42% of the total variability of the data.

Table III. Occurrence of species, Constancy Index and geographical distribution (Gd) in Patos Lake and the Ivinheima River between March 1992 and February 1993. (Wd) Widespread distribution, (Trop/p) pantropical, (Trop/n) neotropical and (end) endemic to South America (KOSTE 1978; JOSÉ DE PAGGI 1990; BONECKER *et al.* 1994). (C) Constant, (A) Accesory, (Ac) Accidental.

Species	Sampling stations					
	1	2	3	4	5	GD
Monogononta						
Brachionidae						
Brachionus angularis Gosse, 1851			Ac		Ac	Wd
B. budapestinesis Daday, 1885			Ac			Wd
B. dolabratus Harring, 1915	Ac			Ac	Ac	Trop/n
B. calyciflorus Pallas, 1766	A	Ac	A	A	Ac	Wd
B. falcatus Zacharias, 1898	Ac	Ac	A	C	Ac	Wd
B. quadridentatus quadridentatus Hermann, 1783	Ac	Ac	A	Ac	Ac	Wd
B. q. mirabilis (Daday, 1897)	Ac		Ac	Ac	Ac	Tro/p
B. mirus Daday, 1905	Ac		A	Ac	A	Trop/n, end
B. urceolaris (Müller, 1773)	A	Ac	A	Ac	Ac	Wd
B. caudatus Barrois & Daday, 1884	Ac	Ac	Ac	C	Ac	Trop/p (?)
B. caudatus v. personatus Ahlstrom, 1940					Ac	Wd
Keratella americana Carlin, 1943	Ac	Ac	Ac	C	A	Trop/p
K. cochlearis Gosse, 1851	A	Ac	A	C	A	Wd
K. tropica (Apstein, 1907)	C	A	C	C	C	Trop/n
K. lenzi (Hauer, 1853)	Ac	Ac	Ac	C	A	Trop/n
Plationus patulus patulus (Müller, 1786)	C	C	C	C	C	Wd
P. macracanthus (Daday, 1905)	A	A	C	C	C	Trop/n
Platyias quadricornis quadricornis (Ehrenberg, 1832)	C	C	C	C	C	Wd
P. q. brevespinus (Daday, 1905)	A	Ac	A	A	C	Wd
P. leloupi Gillard, 1957	Ac		Ac		Ac	Trop/n
Lecanidade						
Lecane monostyla (Daday, 1897)	Ac	Ac	Ac	Ac	Ac	Trop/p
L. quadridentata (Ehrenberg, 1832)	Ac	Ac	Ac	Ac	A	Trop/p
L. amazonica (Murray, 1913)	Ac		Ac	Ac	Ac	Trop/n, end
L. closterocerca (Schmarda, 1859)	A	Ac	A	Ac	A	Trop/p
L. bulla (Gosse, 1851)	C	C	C	C	C	Wd
L. lunaris (Ehrenberg, 1832)	Ac	A	A	C	C	Wd
L. cornuta (Müller, 1786)	A	C	Ac	C	A	Wd
L. papuana (Murray, 1913)	A	Ac	A	A	A	Trop/p
L. curvicornis (Murray, 1913)	C	C	C	C	C	Trop/p
L. leontina (Turner, 1892)	C	C	C	C	C	Trop/p
L. elsa Hauer, 1931	A	A	A	C	A	Wd
L. ludwigi (Eckstein, 1883)	Ac	C	A	C	C	Trop/p
L. proiecta Hauer, 1956	Ac		Ac	Ac	Ac	Trop/n, end
L. luna (Müller, 1776)	A	A	A	A	C	Wd
L. stichaea Harring, 1913	Ac	A	A		Ac	Wd
L. signifera (Jennings, 1886)	Ac		Ac		Ac	Wd
L. aculeata (Jakubski, 1912)		Ac			Ac	Trop
Lecane sp.		Ac			Ac	
Trichocercidae						
Trichocerca (Diurella) bidens (Lucks, 1912)					Ac	Wd
T. (D) similis (Wierzejski, 1893)			Ac		Ac	Wd
T. (D) similis grandis (Hauer, 1965)			Ac	Ac		Wd
T. (D) insignis (Herrick, 1885)				Ac		Wd?
T. (D) porcellus (Gosse, 1886)	Ac		Ac	Ac	Ac	Wd
T. cylindrica chattoni De Beauchamp, 1907	Ac	Ac		A	A	Wd
T. bicristata Gosse, 1887	Ac	Ac	A	Ac	C	Wd
T. gracilis (Tessin, 1890)	Ac	Ac		Ac	Ac	Wd
T. scipio Pejler, 1962			Ac	Ac		Wd
T. capucina Wierzejski & Zacharias, 1893			Ac		Ac	Wd
T. elongata (Gosse, 1886)	Ac	Ac	Ac	Ac	A	Wd
T. pusilla (Lauterborn, 1898)	A		Ac	Ac	A	Wd
Trichocerca sp 1	Ac	Ac	Ac	Ac	Ac	
Trichocerca sp 2			Ac	Ac	Ac	
Trichocerca sp 3	Ac					

Cont.

Table III. Continued. (C) Constant, (A) Accesory, (Ac) Accidental.

Species	Sampling stations					
	1	2	3	4	5	GD
Euchlanidae						
Euchlanis dilatata Ehrenberg, 1832	Ac	Ac	Ac	A	Ac	Wd
E. incisa Carlin, 1939		Ac	Ac		Ac	Wd
Dipleuchlanis propatula propatula (Gosse, 1886)	C	C	C	C	C	Wd
D. propatula f. macrodactyla (Hauer, 1965)	Ac	A	Ac		Ac	Trop/n, end
Manfredium eudactylotum (Gosse, 1886)	Ac	Ac	A	Ac	A	Wd
Mytilinidae						
Mytilina ventralis (Ehrenberg, 1832)	A	C	A	C	C	Wd
M. acanthophora Hauer, 1938	Ac		Ac		Ac	Trop/n, end
M. macrocera (Jennings, 1894)	Ac	Ac	Ac	Ac		Trop/n
Synchaetidae						
Synchaeta stylata Wierzejski, 1893			Ac			Wd
Synchaeta sp.	Ac	Ac	Ac		Ac	
Polyarthra vulgaris Carlin, 1943	C	A	C	A	A	Wd
P. remata (Skorikov, 1896)	Ac	Ac	Ac		Ac	Wd
Ploesoma truncata (Levander, 1894)		Ac	Ac	Ac	Ac	Wd
Testudinellidae						
Testudinella patina (Hermann, 1783)	C	C	C	C	C	Wd
T. mucronata hauriensis (Gillard, 1967)	C	C	C	C	C	Trop/n, end
T. tridentata amazonica Thomasson, 1971					Ac	Wd
T. ohlei Koste, 1972					Ac	Trop/n, end
T. ahlstromi (Hauer, 1956)					Ac	Trop/n, end
Conochilidae						
Conochilus unicornis Rousselet, 1892	C	A	A	A	A	Wd
C. coenobasis Skorikov, 1914	Ac		Ac		Ac	Wd
C. natans (Seligo, 1900)			Ac		Ac	Wd
C. dossuarius (Hudson, 1875)			Ac	Ac	Ac	Wd
Filiniidae						
Filinia pejleri Hutchinson, 1964			Ac			Trop/p
F. longiseta (Ehrenberg, 1834)	C	Ac	C	A	A	Wd
F. saltator (Gosse, 1886)	A	Ac	C	Ac	C	Trop/n
F. cf terminalis (Plate, 1886)	C	Ac	C	C	C	Wd
F. opoliensis (Zacharias, 1891)	Ac	Ac	Ac	Ac	Ac	Wd
Hexarthridae						
Hexarthra intermedia braziliensis (Hauer, 1953)	Ac		Ac	Ac	Ac	Trop/n
H. mira (Hudson, 1871)					Ac	Wd
Trichotriidae						
Trichotria tetractis (Ehrenberg, 1830)	A	C	A	C	C	Wd
Macrochaetus sericus (Thorpe, 1893)	Ac	Ac	Ac	Ac	A	Trop/p
Colurellidae						
Lepadella ovalis (Müller, 1786)	A	C	A	C	C	Wd
L. benjamini Harring, 1916	A	Ac	A	Ac	Ac	Trop/p
Epiphanidae						
Epiphanes clavulata (Ehrenberg, 1832)			Ac		Ac	Wd
Asplanchnidae						
Asplanchna (A) sieboldi (Leydig, 1854)	C		C	Ac	Ac	Wd
Proalidae						
Proales sp.	Ac	Ac	Ac			
Notommatidae						
Cephalodella sp.	Ac	A	Ac	Ac	Ac	
Flosculariidae						
Ptygura sp.		Ac	Ac		Ac	
Dicranophoridae						
Dicranophorus sp.	A		A	Ac	Ac	
Gastropodidae						
Ascomorpha ecaudis (Perty, 1859)	Ac	Ac	Ac	A	Ac	Wd
Collothecidae						
Collotheca sp.	Ac		Ac			
Bdelloidea						
Philodinidae						
Dissotrocha aculeata Ehrenberg, 1832	Ac	A	A	Ac	Ac	Wd
D. macrodactyla (Ehrenberg, 1838)				Ac		?

Analyzing the structure coefficients and the location of the sampling units at CPI (38.54%) and CPII (21.87%) together, was found that the highest rotifer densities occurred in the lake (a=1 and b=2), during the high water period (2=April, 9=November, 10=December, 11=January, 12=February), when the following limnological conditions predominated: high values of electrical conductivity and temperature; low concentrations of dissolved oxygen, and low pH values (CPI, solid line). Moreover, high rotifer densities also were associated with the higher concentrations of chlorophyll-a observed at the end of the low water period (7=September) and during the high water period (9=November and 11=January) (CPII, dotted line) (Fig. 5). The two principal components explained the spatial and temporal variations, where the CPI showed chiefly the influence of the water level and the CPII reflected the importance of chlorophyll-a. The sum of the three first principal components of PCA, employing the abiotic variables and the most abundant species, explained 58.58% of the total variability of the data.

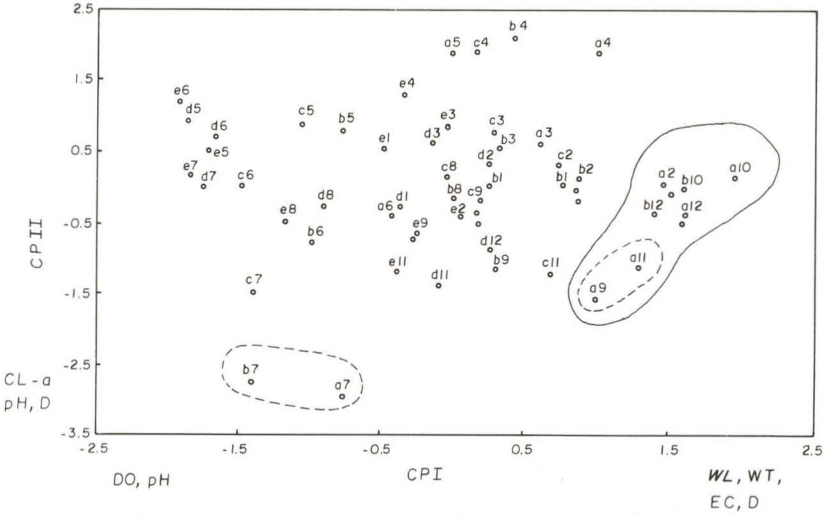


Fig. 5. Score distribution of sampling station (a=1, b=2, c=3, d=4 and e=5) and month (1=March, 2=April, 3=May, 4=June, 5=July, 6=August, 7=September, 8=October, 9=November, 10=December, 11=January and 12=February) among principal components defined by environmental variables. (—) First component, (- - -) second component.

The ordination of the stations and collection months along CPI (36.6%) indicates that most of the species negatively correlated with this component were more abundant in the lake (a=1 and b=2) and the channel (a=3), during the high water period (10=December, 11=January, 12=February) (solid line). These environments and collection months had high water levels, high temperature, and electrical conductivity values, and low concentrations of dissolved oxygen. *Brachionus calyciflorus* and *Keratella tropica* were more abundant in the open water region of the lake (a=I1) at the end of the low water period (6=August and 7=September), when the limnological characteristics were the opposite of those described above (Fig. 6).

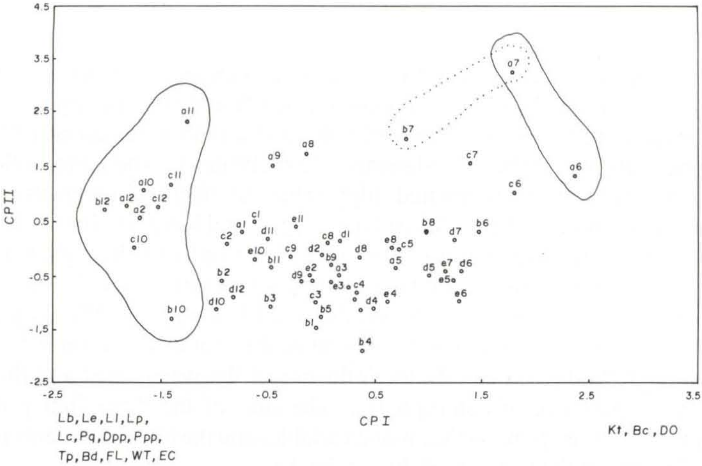


Fig. 6. Score distribution of sampling station (a=1, b=2, c=3, d=4 and e=5) and month (1=March, 2=April, 3=May, 4=June, 5=July, 6=August, 7=September, 8=October, 9=November, 10=December, 11=January and 12=February) among principal components defined by the densities of the principal species and environmental variables. (—) First component, (- - -) second component.

CPII (11.8%) showed that *Brachionus calyciflorus, Filinia* cf *terminalis* and *Trichocerca pusilla* predominated in the lake (a=1 and b=2), and in month when higher chlorophyll-a concentrations occurred (7=September) (dotted line) (Fig. 7). According to the CPIII (10.71%), in this environment *T. pusilla* was also important in the collection months with greater water transparency (4=June and 5=July) (dashed line), and *Lecane luna* in the month with high concentrations of dissolved oxygen and when the pH tended to the alkaline range (7=September) (dashed line) (Fig. 7).

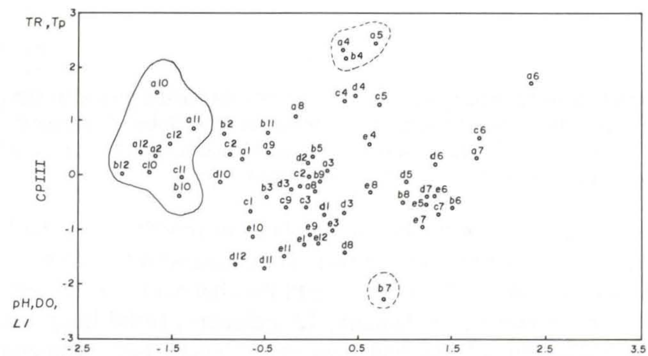


Fig. 7. Score distribution of sampling station (a=1, b=2, c=3, d=4 and e=5) and month (1=March, 2=April, 3=May, 4=June, 5=July, 6=August, 7=September, 8=October, 9=November, 10=December, 11=January and 12=February) among principal components defined by environmental variables. (—) third component.

DISCUSSION

Of the 28 genera identified, *Lecane*, *Brachionus*, and *Trichocerca* showed the highest richness of species, making up almost half of the number of records (46.4%). The richness of *Lecane* is well documented for tropical continental waters (KOSTE & JOSÉ DE PAGGI 1982; JOSÉ DE PAGGI 1990; ZOPPI DE ROA *et al.* 1993; BONECKER *et al.* 1994; LANSAC-TÔHA *et al.* 1997). *Brachionus* is also more representative in the tropics (PEJLER 1977; FERNANDO 1980; DUMONT 1983).

More species were found in the open water regions of these systems. These results differ from those verified for Guaraná Lake, also located on this floodplain (BONECKER *et al.* 1994). Guaraná Lake is small with extensive aquatic macrophyte beds which favor greater habitat diversity. On the other hand, Patos Lake has a larger area, with less developed macrophyte beds. Another fact that may explain these results is that in the open water region of Patos Lake, sampling was performed at three depths of the water column, whereas in the littoral region it was only conducted at the surface.

The composition of the rotifer fauna was influenced by the variations in the water level of the Paraná River, with more species recorded during the high water period. For example, at that time, species characteristic of the littoral region such as *Lecane signifera* (Jennings, 1886), *L. papuana*, and *L. proiecta* (Hauer, 1956) occurred in the open water. The rise in water level permits greater exchange of fauna between the littoral and open water regions. This influence of the hydrological regime on the composition of the rotifers has been observed in other environments of the floodplains of the Upper Paraná (LANSAC-TÔHA *et al.* 1992, 1997; BONECKER *et al.* 1994; CAMPOS *et al.* 1996) and the Middle Paraná (JOSÉ DE PAGGI 1988; PAGGI & JOSÉ DE PAGGI 1990), the Amazon basin (KOSTE & ROBERTSON 1983; KOSTE *et al.* 1984; BOZELLI 1992), and the Orinoco River (VÁSQUEZ 1984a).

Most of the rotifer species (57.3%) have a widespread geographical distribution. Several species endemic to the neotropical region and even to South America were present. Most neotropical endemics were members of the Brachionidae (*Brachionus dolabratus* Harring, 1915 and *Plationus macracanthus* (Daday, 1905), among others), as in other environments of this floodplain (BONECKER *et al.* 1994; LANSAC-TÔHA *et al.* 1997) and the floodplain of the Middle Paraná River, Argentina (PAGGI & JOSÉ DE PAGGI 1990).

The highest rotifer densities occurred in the lake, as evidenced by the PCA. Greater abundances of rotifers in lentic habitats were also seen in other studies in the floodplain of the Upper Paraná River (BONECKER & LANSAC-TÔHA 1996; LANSAC-TÔHA *et al.* 1997), the Middle Paraná River (PAGGI & JOSÉ DE PAGGI 1990), and in the Amazon basin (BOZELLI 1994).

In different aquatic environments subject to fluctuations in the water level, several studies have shown that greatest rotifer densities occur during the low water period (HARDY *et al.* 1984; VÁSQUEZ 1984b; VÁSQUEZ & SANCHEZ 1984; PAGGI & JOSÉ DE PAGGI 1990; BOZELLI 1994). The results of these studies contrast with ours, which recorded that the greatest abundances during high water, as illustrated by the PCA. This unusual occurrence may be related to the fact that the littoral region, during the high water period, is subject to strong mixing currents. During low water, in the open water of the lake and the channel typically planktonic species predominate: *Keratella tropica*, *K. cochlearis* Gosse, 1851, *Brachionus calyciflorus*, *Trichocerca pusilla*, and *Conochilus unicornis* Rousselet, 1892. In these same environments, during the high water, the most representative species were those typical of littoral regions, such as *Lecane curvicornis*, *L. bulla*, *L. elsa*, *Plationus patulus patulus*, *Platyias quadricornis quadricornis*, and *Dipleuchlanis propatula propatula*. This fact is shown by the PCA. According to FERNANDO (1980), opportunistic species typical of littoral regions may invade the open water region and become dominant temporarily.

The increment in the rotifer densities in the river during high water may also be caused by the contribution of fauna from the lake and other littoral lakes associated with the river. SAUNDERS & LEWIS (1988) observed that highest rotifer densities in the Caura River, Venezuela, also during high water, could be the result of the incorporation of animals from lentic habitats of the floodplain. Completing this reasoning, changes in the water volume activate backwaters or isolated areas, transporting animals to the river populations (JOSÉ DE PAGGI 1981). The higher densities during high water may also be explained by the fact that the rotifers are opportunistic organisms capable of producing large populations in unstable environmental conditions (ALLAN 1976).

The water level was not the only variable correlated with the seasonal fluctuations in the rotifer densities. PCA also showed that the highest total densities were correlated with high temperatures and lower concentrations of dissolved oxygen. For some species like *Brachionus calyciflorus*, *Lecane luna* and *Keratella tropica*, dissolved oxygen seems to be a limiting factor, as is pH. BÉRZINS & PEJLER (1989) affirm that oxygen concentration is an important factor in the temporal distribution of the rotifers. They recorded the occurrence of *Brachinous calyciflorus*, for example, at pH between 7.0 and 10.0, with highest abundance near 8.0 (BÉRZINS & PEJLER 1987). Was found this species more abundant at pH ca. 7.5. Temperature is also clearly important in the development of rotifer populations, especially for egg development, since the birth rate is different for each individual of the same species. HOFFMANN (1977) emphasized that temperature is very important for understanding changes in species abundance throughout the year.

Chlorophyll-a was also important in the seasonal variation of the total and specific rotifer densities, especially for *Filinia* cf *terminalis*, *Brachionus calyciflorus*, and *Trichocerca pusilla*. As the PCA showed, the greatest densities of these organisms were related to higher values of chlorophyll-a concentration. Most rotifers are omnivorous, filter-feeders, selecting food particles according to their size and quality (JOSÉ DE PAGGI 1978). *Brachionus calyciflorus* has a wide feeding spectrum, being an active consumer of algae and bacteria (POURRIOT 1977; PEJLER 1983; ROTHHAUPT 1990).

Densities of some species are weakly correlated with concentrations of chlorophyll-a: *Lecane elsa*, *L. curvicornis*, *L. leontina*, *Platyias quadricornis quadricornis*, *Dipleuchanis propatula propatula* and *Bdelloidea*. These species are typical of littoral regions with aquatic vegetation. Phytoplankton may not be the main food of these species, which may consume preferentially detritus and/or bacteria that, according to WETZEL (1990) are very abundant in these regions because of the decomposition of aquatic macrophytes. Species of the genus *Lecane* are detritus and bacteria feeders, and *D. propatula propatula* is exclusively detritivorous (POURRIOT 1977).

Studies undertaken by BONECKER & LANSAC-TÔHA (1996) in this floodplain also showed that the densities of the chief rotifer species were influenced mainly by chlorophyll-a, dissolved oxygen, the fluviometric level, and water temperature.

ACKNOWLEDGEMENTS. We thank Dr. Janet W. Reid for assistence with the English text. Thanks are due to our colleagues Dr. Susana José de Paggi for the identification of some species; Dr. Sérgio Luiz Costa Bonecker, Dr. Sidinei Magela Thomaz, Luiz Felipe Machado Velho and Luis Maurício Bini for their suggestions and their help in data analysis; to the staff of the Center for Research in Limnology, Ichthyology and Aquaculture (Nupélia, Universidade Estadual de Maringá) for technical and scientific support; to PADCT/CIAMB for the necessary financial support, to CAPES for several scholarships grants.

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Recebido em 27.III.1997; aceito em 14.V.1998.