ZOOPLANKTON BIOMASS OF RESERVOIRS IN DIFFERENT TROPHIC CONDITIONS IN THE STATE OF SÃO PAULO, BRAZIL

SENDACZ, S.[1], CALEFFI, S.[2] and SANTOS-SOARES, J.[3]

[1]Instituto de Pesca, Secretaria de Agricultura e Abastecimento do Estado de São Paulo

[2]Petróleo Brasileiro SA, Refinaria de Capuava,
Av. Alberto Soares Sampaio, 2122 A, CEP 09380-904, Mauá, São Paulo, SP

[3]Fundação Parque Zoológico

Correspondence to: Suzana Sendacz, Instituto de Pesca,
Secretaria de Agricultura e Abastecimento do Estado de São Paulo,
Av. Francisco Matarazzo, 455, CEP 05001-900, São Paulo, SP, Brazil,
e-mail: sendacz@pesca.sp.gov.br

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ABSTRACT

This paper reports on a study involving an estimate of the biomass of rotifers, cladocerans, and cyclopoid and calanoid copepods found in reservoirs in different trophic conditions, comparing and relating numerical density data and pointing out differences between the dry and rainy seasons. In terms of numerical densities, both reservoirs were dominated by rotifers, although cladocerans represented a higher biomass in the oligotrophic environment in both seasons. In the eutrophic environment, higher biomass values were found for cyclopoids during the dry season and for cladocerans during the rainy one. Different biomass patterns were observed relating to both the trophic conditions and the rainy and dry seasons.

Keywords: biomass, zooplankton, trophic state, Alto Tietê Basin.

RESUMO

Biomassa de organismos zooplanctônicos em represas de diferentes condições tróficas do Estado de São Paulo, Brasil

Este trabalho descreve um estudo sobre a determinação dos valores de biomassa de rotíferos, cladóceros, copépodos calanóides e ciclopóides em represas de diferentes estados tróficos, com o objetivo de comparar e relacionar com dados de densidades numéricas, considerando os períodos chuvoso quente e estiagem frio. Verificou-se que, embora rotíferos tenham dominado numericamente em ambas as represas, em termos de biomassa os cladóceros predominaram no ambiente oligotrófico, em ambos os períodos considerados. No ambiente eutrófico, copépodos ciclopóides predominaram no período estiagem frio, e cladóceros, no chuvoso quente, evidenciando padrões diferenciados de biomassa tanto em relação às condições tróficas quanto aos períodos chuvoso e seco.

Palavras-chave: biomassa, zooplâncton, estado trófico, Bacia do Alto Tietê.

INTRODUCTION

The species of the zooplankton community display a wide array of sizes, so numerical population densities do not always provide useful information (Matsumura-Tundisi *et al.*, 1989), making comparative studies of tropical and temperate reservoirs or different hydrographic basins and trophic states difficult.

Several authors, among them Dumont *et al.* (1975), Bottrell *et al.* (1976) and Culver *et al.* (1985), have estimated the biomass of temperate lakes and reservoirs. As for tropical and subtropical water bodies, Burgis (1974), Saint-Jean (1983) and Hart (1987), among others, conducted studies on African lakes and reservoirs. In Brazil, studies on the zooplankton biomass of eutrophic and oligotrophic reservoirs have been undertaken by Matsumura-Tundisi & Tundisi (1986), Matsumura-Tundisi *et al*. (1989), Esteves & Sendacz (1988), Melão (1997), Melão & Rocha (2000) and Wisniewski (1998). Saunders & Lewis (1988) and Vásquez & Rey (1992) determined the zooplankton biomass of lakes in Venezuela.

The zooplankton communities of most tropical and subtropical lakes and reservoirs are dominated by rotifers, regardless of the trophic state, but due to their small size and weight, they often contribute little to the biomass.

Zooplankton biomass estimated from weight-length relationships reported in the literature should be avoided, since temperature, food quality and quantity, species genotype, seasons and differences in the physical conditions of habitats, among other factors, can lead to changes in the carbon content of each species (Dumont *et al*., 1975; Vijverberg, 1989).

The sites studied here, Ponte Nova (23° 33' S, 45° 50' W) and Guarapiranga (23° 43' S, 46° 32' W) reservoirs, are located in the Alto Tietê Hydrographic Basin (Fig. 1). The two reservoirs are part of the water supply system of metropolitan São Paulo, Brazil, and were among the 17 reservoirs studied in 1979 by researchers of the Instituto de Pesca (Institute of Fishery) as part of the project "Tipologia de reservatórios do Estado de São Paulo" (Typology of the reservoirs of the state of São Paulo), when abiotic and biotic variables were obtained (Maier & Takino, 1985a; 1985b; Sendacz *et al*., 1985; Xavier *et al*., 1985; Esteves & Sendacz, 1988). At that time, the Ponte Nova reservoir displayed a low trophic state compared with other studied reservoirs.

Ever since the 1930s, several researchers have been concerned about the eutrophication and pollution process that the Guarapiranga reservoir has suffered. Eutrophication has rendered treatment of the water supply increasingly difficult and expensive, and the use of copper sulfate to control algae blooms has been intensified since 1990. Aspects of the zooplankton community of the Guarapiranga reservoir, such as composition and seasonal fluctuation of numerical densities, have been studied by Sendacz & Kubo (1982, 1999), Sendacz *et al*. (1985), Domingos (1993), and Caleffi (1994, 2000).

The estimates of the zooplankton biomass in the present study will provide data to relate and compare different trophic states of the reservoirs under study, and to identify differences relating to the dry and rainy seasons.

METHODS

A sampling station was set up in each reservoir, in the limnetic zone near the dam (Fig. 1). During this study, it was found that the application of the algicide copper sulfate – a practice usually adopted in Guarapiranga to control algae blooms – had been suspended.

Water samples were collected at depths corresponding to the surface, 50%, 25%, 10% and 1% of light penetration, and at the bottom, using a 5-L Van Dorn bottle. The Modified Trophic State Index (MTSI) proposed by Toledo Jr *et al*. (1983) was calculated based on transparency (Secchi disk), chlorophyll *a* (Marker *et al*., 1980) and total phosphorus (Valderrana, 1981).

Zooplankton samplings were collected using plankton nets of 40 and 60 µm mesh for rotifers and crustaceans, respectively, through vertical hauls of the entire water column. Organisms were anesthetized by CO_2 (soda water) and preserved in 4% formalin.

A quantitative analysis of zooplankton was made by counting subsamples, using a Sedgwick-Rafter chamber for rotifers, and a counting chamber for crustaceans. Quadrants of a 7.5 cm Petri dish or whole samples were counted when the numerical densities were low.

The weights of the most abundant rotifers were determined indirectly, based on biovolumes calculated from formulas proposed by Ruttner-Kolisko (1977). Using a micrometric eyepiece, measurements were taken of at least 20 individuals of each rotifer species to determine their biovolumes. Dry weights were calculated considering 10% of the fresh weight estimated through biovolumes (Doohan, *apud* Bottrell *et al*., 1976).

The methodology proposed by Wetzel & Likens (1991) was adopted for the microcrustaceans: 10 to 50 individuals of the most abundant species were isolated according to their different developmental phases (Copepoda: nauplii, copepodids, males, females, ovigerous females;

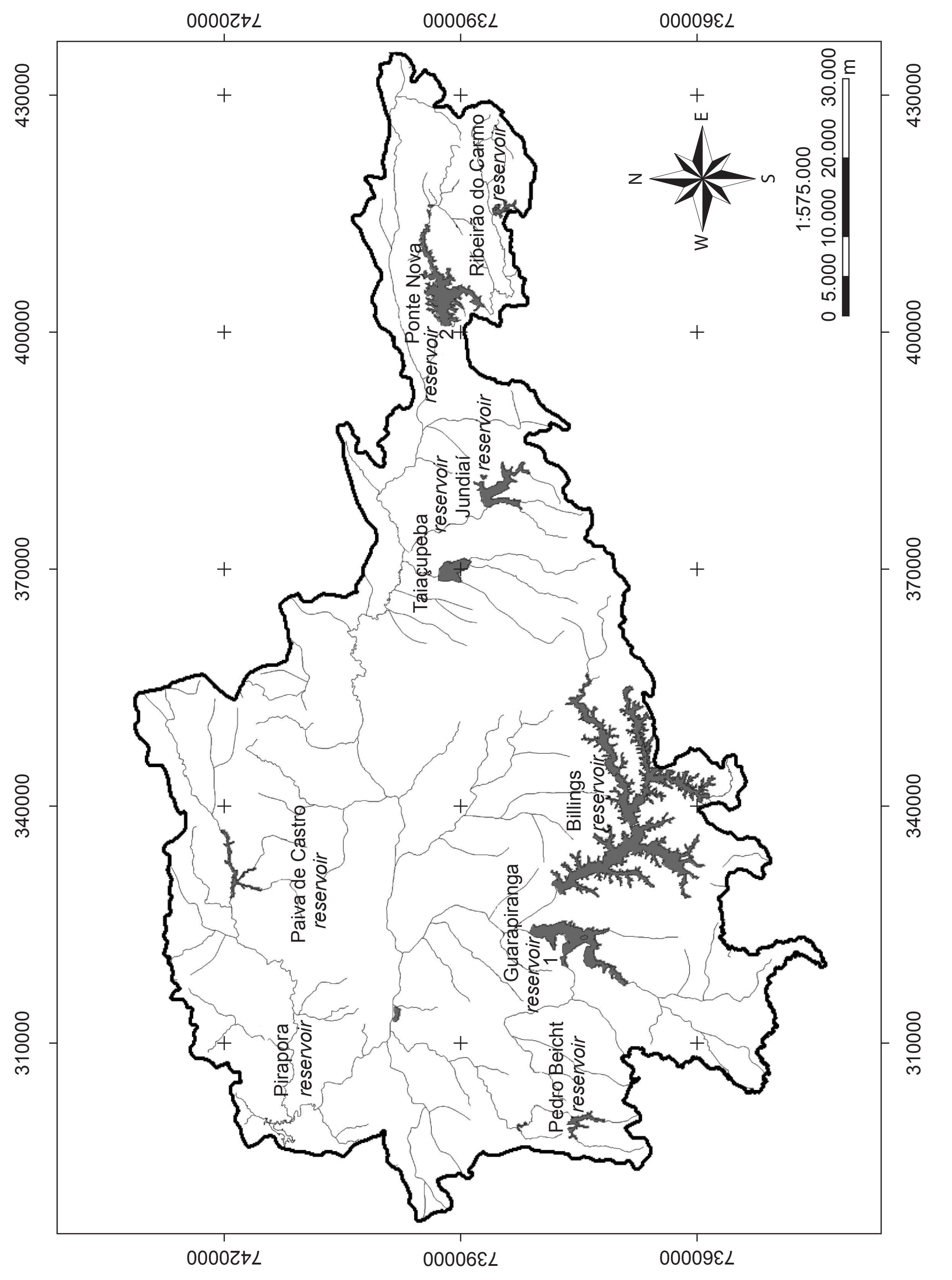

Fig. 1 — Alto Tietê Hydrographic Basin: 1) Guarapiranga reservoir; and 2) Ponte Nova reservoir.

Cladocera: young, adult females, ovigerous females). The organisms were rinsed three times in distilled water to remove the fixation material (formalin) and then dried at 60 °C for 24 h in small preweighed aluminum foil boats. To cool them, the animals were transferred to a desiccation chamber for 1 h, and then weighed on a Mettler UMT microbalance.

RESULTS

Monthly rainfall (in mm), considering the cold-dry (Apr to Sep 2001) and the warm-rainy (Oct 2001 to Mar 2002) seasons, are shown in Fig. 2. The mean rainfall in the dry season was 44.2 mm in Ponte Nova and 40.6 mm in Guarapiranga. The mean rainfall values in the rainy season were higher in Ponte Nova (227.6 mm) than in Guarapiranga (183.1 mm).

Table 1 shows water transparency, maximum depths, chlorophyll *a* and total phosphorus concentrations, and MTSI (Toledo Jr. *et al.*, 1983). With the exception of transparency and depths, the values were higher for the Guarapiranga reservoir, with slight differences found between the dry and rainy seasons.

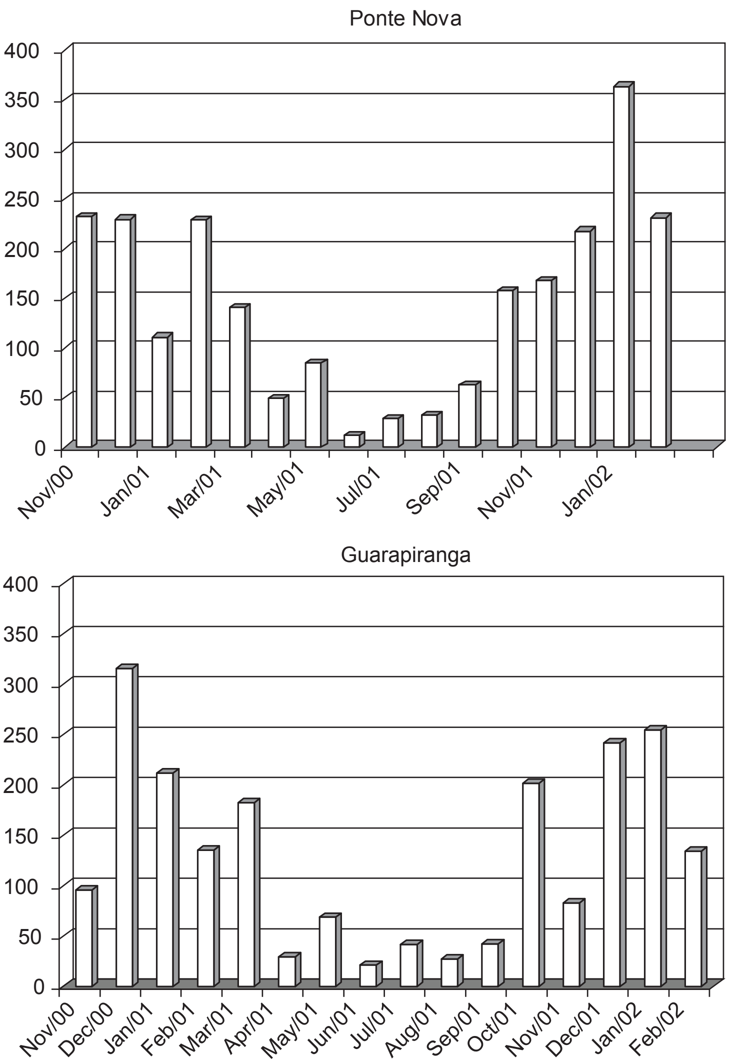

Fig. 2 — Total precipitation (mm) of Ponte Nova and Guarapiranga reservoirs from November 2000 to February 2002.

TABLE 1
Depth (m), transparency (m), chlorophyll (ug.L^{-1}), total phosphorus (ug.L^{-1}), and Modified Trophic State Index (MTSI) for Ponte Nova and Guarapiranga reservoirs, in Aug 2001 and Feb 2002.

Ponte Nova	Aug 2001		Feb 2002	
		MTSI		MTSI
Depth (m)	12.7		12.0	
Transparency (m)	2.6	36.98	1.9	41.51
Chlorophyll (ug.L^{-1})	5.89	48.35	5.26	47.21
Total phosphorus (ug.L^{-1})	12.2	32.81	14.2	35.00
MTSI	-	42.68	-	41.19

Guarapiranga	Aug 2001		Feb 2002	
		MTSI		MTSI
Depth (m)	5.0	-	7.0	-
Transparency (m)	0.9	52.29	0.8	53.99
Chlorophyll (ug.L^{-1})	31.18	65.06	25.94	63.21
Total phosphorus (ug.L^{-1})	64.00	56.72	53.47	54.13
MTSI	-	59.17	-	57.73

Differences were also observed in the composition of the reservoirs' zooplankton communities (Tables 2 and 3). *Collotheca ornata, Conochilus dossuarius, Conochilus unicornis, Kellicottia bostoniensis, Keratella cochlearis, Polyarthra vulgaris* and *Trichocerca pusilla* were common to both reservoirs. *Ascomorpha saltans, Brachionus mirus, Collotheca mutabilis, Filinia longiseta limnetica, Ptygura libera* and *Trichocerca sp* were restricted to Ponte Nova, and *Asplanchna sp*, *Brachionus calyciflorus, B. havanaensis, Filinia opoliensis, Synchaeta oblonga* and *Trichocerca capucina* to Guarapiranga.

Cyclopoids were represented in Ponte Nova by *Tropocyclops prasinus* and sporadically by *Mesocyclops longisetus* and *M. meridianus*. In Guarapiranga, the cyclopoid species found were *Thermocyclops decipiens*, *T. inversus* and *Tropocyclops prasinus*. *Odontodiaptomus paulistanus* was the only calanoid found in Ponte Nova, while *Notodiaptomus deitersi*, *N. iheringi*, *Notodiaptomus henseni* and, sporadically, *N. cearensis* occurred in Guarapiranga (Tables 2 and 3).

Several congeneric species of cladocerans were observed, such as *Bosmina longirostris, B. hagmanni* and *B. tubicen, Ceriodaphnia cornuta rigaudi* and *C. silvestrii, Daphnia ambigua* and *D. gessneri, Moina minuta* and *M. micrura* in Ponte Nova, and *Ceriodaphnia cornuta cornuta* and *C. silvestrii*, *Daphnia ambigua* and *D. gessneri* in Guarapiranga (Tables 2 and 3).

During the cold dry season (August 2001), the total zooplankton densities in Guarapiranga were about 10 times higher (677,501 organisms.m^{-3}) than in Ponte Nova (69,064 organisms.m^{-3}), while during the warm rainy season (February 2002), these differences were less important (Fig. 3). Considering both seasons, in Ponte Nova rotifers represented 86.2% of the total zooplankton, cyclopoids 2%, calanoids 0.4%, and cladocerans 21%. In Guarapiranga, rotifers represented 74.5% of the total zooplankton, cyclopoids 28%, calanoids 0.1%, and cladocerans 6%.

During the dry season *Polyarthra vulgaris, Ptygura libera, Conochilus unicornis* and *Collotheca ornata* predominated in Ponte Nova, and *P. vulgaris* and *Synchaeta oblonga* in Guarapiranga. In the rainy season *C. ornata* and *Kellicottia bostoniensis* predominated in Ponte Nova, while *Keratella cochlearis tecta*, *P. vulgaris cf. longiremis* and *Filinia opoliensis* predominated in Guarapiranga.

Though present in both reservoirs, *Tropocyclops prasinus* represented 10% of

TABLE 2
Ponte Nova reservoir: numerical densities (ind.m^{-3}), individual dry weights (μgDW) and biomass (μgDW.m^{-3}) of rotifers, cyclopoids, calanoids and cladocerans in Aug 2001 and Feb 2002 (♂, males; ♀, females; ♀ov, ovigerous females; y, young).

Rotifera		Aug 2001			Feb 2002		
		ind.m^{-3}	μgDW	μgDW.m^{-3}	ind.m^{-3}	μgDW	μgDW.m^{-3}
Ascomorpha saltans		1162	0.010	11.62	-	-	-
Brachionus mirus typicus		232	-	-	5645	0.0102	57.55
Collotheca mutabilis		1511	0.065	98.66	2880	0.0260	74.86
Collotheca ornata		10227	0.024	249.55	77882	0.0046	357.70
Conochilus dossuarius		232	-	-	691	-	-
Conochilus unicornis		11390	0.015	174.26	29263	0.0111	323.91
Filinia longiseta limnetica		-	-	-	3226	0.0357	115.16
Hexarthra intermedia		-	-	-	13364	0.0252	336.24
Horaella thomassoni		-	-	-	230	-	-
Kellicottia bostoniensis		116	-	-	40899	0.0042	170.92
Keratella americana		-	-	-	115	-	-
Keratella cochlearis		2441	0.001	3.17	20507	0.0012	24.85
Polyarthra vulgaris		11971	0.060	720.63	9447	0.0558	527.06
Ptygura libera		11971	0.018	209.49	230	-	-
Trichocerca pusilla		232	-	-	115	-	-
Trichocerca sp		465	-	-	-	-	-
Bdelloidea		1162	-	-	-	-	-
Subtotal		53111	-	1467.38	204495	-	1988.24
Copepoda Cyclopoida							
Nauplii		883	0.55	487.29	309	0.68	209.96
Copepodids		288	0.76	217.96	194	0.76	147.10
Mesocyplops meridianus	♂	9	-	-	-	-	-
	♀	79	8.77	692.83	-	-	-
	♀ov	1	-	-	-	-	-
Tropocyclops prasinus	♂	14	-	-	9	-	-
	♀	56	2.10	117.60	2	-	-
	♀ov	65	2.18	141.89	2	-	-
Subtotal		1395	14.36	1657.57	516	-	357.06
Copepoda Calanoida							
Nauplii		79	0.77	60.67	25	-	-
Copepodids		135	3.83	517.67	16	-	-
Odontodiaptomus paulistanus	♂	28	9.54	267.17	2	-	-
	♀	26	13.78	358.35	21	-	-
	♀ov	3	-	-	2	-	-
Subtotal		271	-	1203.87	67	-	-
Cladocera							
Bosmina longirostris	y	10227	0.33	3401.59	2212	0.44	973.29
	♀	1976	0.85	1686.19	747	0.73	544.99
	♀ov	407	0.93	376.48	1161	0.94	1091.63
Bosmina hagmanni	j	-	-	-	0	-	-
	♀	-	-	-	65	-	-
	♀ov	-	-	-	28	-	-

TABLE 2
Continued...

Bosmina tubicen	y	-	-	-	18	-	-
	♀	-	-	-	120	3.58	428.95
	♀ov	-	-	-	65	-	-
Bosminopsis deitersi	y	-	-	-	9	-	-
	♀	-	-	-	37	-	-
	♀ov	-	-	-	46	-	-
Ceriodaphnia cornuta rigaudi	y	260	2.17	564.20	-	-	-
	♀	232	2.71	628.72	-	-	-
	♀ov	214	2.95	631.30	-	-	-
Ceriodaphnia silvestrii	y	288	1.97	566.95	387	2.41	932.92
	♀	390	2.99	1164.29	129	2.81	362.59
	♀ov	205	3.78	774.52	55	4.20	232.26
Diaphanosoma birgei	y	-	-	-	65	-	-
	♀	-	-	-	9	-	-
	♀ov	-	-	-	28	-	-
Daphnia ambigua	y	37	-	-	378	1.23	464.80
	♀	62	-	-	55	4.46	246.64
	♀ov	0	-	-	175	8.64	1513.02
Daphnia gessneri	y	62	-	-	18	-	-
	♀	186	-	-	0	-	-
	♀ov	0	-	-	18	-	-
Moina minuta	y	-	-	-	1447	0.67	969.51
	♀	-	-	-	525	0.76	399.27
	♀ov	-	-	-	1014	1.09	1105.09
Moina micrura	y	-	-	-	0	-	-
	♀	-	-	-	46	-	-
	♀ov	-	-	-	9	-	-
Subtotal		14546	-	9794.23	8867	-	9264.95
Total		69323	-	14123.04	214069	-	11610.25

total cyclopoids in Ponte Nova but only 1% in Guarapiranga. *Thermocyclops decipiens*, commonly associated with eutrophic conditions, represented 10% of total cyclopoids in Guarapiranga, but was not found in Ponte Nova.

In Ponte Nova, cladocerans were represented by a larger number of taxa and higher relative abundance, mainly during the cold season. Both reservoirs were dominated by *Bosmina longirostris*. *Daphnia ambigua* was well represented in Ponte Nova, while *D. gessneri* was more abundant in Guarapiranga.

The total zooplankton biomass was about 25-fold greater in Guarapiranga during the dry season (356.8 mgPS.m^{-3}) than in Ponte Nova (14.1 mgDW.m^{-3}). During the rainy season the biomass was found to decrease in both reservoirs (80.7 and 11.5 mgDW.m^{-3}, Guarapiranga and Ponte Nova, respectively, see Fig. 3).

Cyclopoids represented 66.2% of the total biomass in Guarapiranga during the dry season (Aug 2001), but its relative importance declined substantially in the rainy season (21.9%). In Ponte Nova, cyclopoids occurred in low densities and biomass. Higher biomass contributions in Ponte Nova were due to cladocerans (73 and 80.6%), which also contributed considerably in terms of biomass in Guarapiranga (19.5 and 46.7%).

The calanoid biomass displayed a different pattern in each reservoir. During the dry season in Ponte Nova, this group represented 0.4% of the total densities and 8.5% of total biomass, but practically

TABLE 3
Guarapiranga reservoir: numerical densities (ind.m^{-3}), individual dry weights (µgDW) and biomass (µgDW.m^{-3}) of rotifers, cyclopoids, calanoids and cladocerans in Aug 2001 and Feb 2002 (♀, males; ♀, females; ♀ov, ovigerous females; y, young).

Rotifera		Aug 2001			Feb 2002		
		ind.m^{-3}	µgDW	µgDW.m^{-3}	ind.m^{-3}	µgDW	µgDW.m^{-3}
Asplanchna sp.		59474	0.223	13274.52	-	-	-
Brachionus calyciflorus		-	-	-	3854	0.2332	898.75
B. havanaensis havanaensis		-	-	-	3854	0.0170	65.55
Collotheca ornata		-	-	-	30834	0.0194	599.68
Conochilus dossuarius		-	-	-	6745	0.0246	165.70
Conochilus unicornis		54763	0.062	3378.88	7227	0.0396	286.22
Filinia opoliensis		-	-	-	79013	0.0691	5461.90
Hexarthra intermedia		-	-	-	4818	0.0269	129.50
Kellicottia bostoniensis		32387	0.004	139.26	2409	0.0038	9.06
Keratella cochlearis		11188	0.001	15.66	4336	0.0011	4.78
K. cochlearis tecta		-	-	-	109847	0.0015	165.80
P. vulgaris var. longiremis		196086	0.033	6529.68	84312	0.0274	2310.72
Synchaeta oblonga		79494	0.249	19778.23	-	-	-
Trichocerca capucina		8833	0.152	1341.69	-	-	-
Trichocerca pusilla		2944	0.029	85.68	7709	0.0378	291.21
Subtotal		445169	-	44543.59	344958	-	10388.86
Copepoda Cyclopoida							
Nauplii		141420	0.907	128253.31	30714	0.13	3992.79
Copepodids		27027	0.970	26211.90	22162	0.43	9529.70
Themocyclops decipiens	♂	4819	1.031	496728	366	0.98	358.83
	♀	8276	5.050	41793.80	424	3.95	1674.68
	♀ov	5657	5.705	32275.21	482	4.35	2095.76
Thermocyclops inversus	♂	-	-	-	39	-	-
	♀	-	-	-	39	-	-
	♀ov	-	-	-	0	-	-
Tropocyclops prasinus	♂	-	-	-	77	-	-
	♀	-	-	-	328	-	-
	♀ov	629	2.096	1318.38	77	-	-
Subtotal		188771	-	236188.62	54707	-	17651.77
Copepoda Calanoida							
Nauplii		113	5.388	-	2447	0.32	783.19
Copepodids		390	12.370	2101.13	1619	2.15	3480.41
Notodiaptomus cf deitersi	♂	77	15.260	946.93	-	-	-
	♀	82	-	1258.01	-	-	-
	♀ov	-	9.600	-			
Notodiaptomus iheringi	♂	3	14404	28.26	790	6.41	5064.71
	♀	56	14.929	805.77	414	10.36	4292.51
	♀ov	6	13.820	87.91	116	11.73	1356.32
Notodiaptomus henseni	♂	21	16.467	284.83	10	-	-
	♀	59	-	969.66	10	-	-
	♀ov	15	-	-	29	-	-
Subtotal		821	-	6482.49	5435	-	14977.15

TABLE 3
Continued...

Cladocera							
Bosmina longirostris	y	10790	0.60	6509.97	58	-	-
	♀	15713	1.41	22093.43	0	-	-
	♀ov	1362	1.64	2237.57	39	-	-
Bosminopsis deitersi	y	0	-	-	-	-	-
	♀	105	-	-	-	-	-
	♀ov	105	-	-	-	-	-
Ceriodaphnia cornuta cornuta	y	-	-	-	96	-	-
	♀	-	-	-	405	1.00	404.70
	♀ov	-	-	-	251	1.20	300.63
Ceriodaphnia silvestrii	y	1571	2.66	4177.43	2949	0.83	2447.27
	♀	4086	3.73	15236.83	1330	2.23	2965.29
	♀ov	629	5.61	3530.26	1253	3.70	4634.77
Daphnia ambigua	y	524	2.27	1187.31	-	-	-
	♀	524	3.19	1669.57	-	-	-
	♀ov	629	4.09	2572.45	-	-	-
Daphnia gessneri	y	314	3.36	1056.52	3006	2.51	7545.90
	♀	1152	5.35	6163.20	1021	5.93	6056.80
	♀ov	210	15.06	3163.26	1619	8.26	13371.26
Diaphanosoma birgei	y	210	-	-	19	-	-
	♀	105	-	-	39	-	-
	♀ov	0	-	-	39	-	-
Moina minuta	y	-	-	-	0	-	-
	♀	-	-	-	0	-	-
	♀ov	-	-	-	19	-	-
Subtotal		38029	-	69597.80	12141	-	37726.63
Total		672790	-	356812.49	417356	-	80744.41

disappeared in the rainy season. In Guarapiranga, the densities and biomass were higher during the rainy season, when they ranked second in total biomass, after cladocerans (Fig. 4).

In Guarapiranga, cyclopoid nauplii, adult and ovigerous females of *Thermocyclops decipiens*, adult females of *Bosmina longirostris* and *Synchaeta oblonga* contributed the most to the biomass during the dry cold season while, in the warm rainy one, copepodids of Cyclopoida, males and females of *Notodiaptomus iheringi*, young, adult and ovigerous females of *Daphnia gessneri*, and *Filinia opoliensis* exhibited high biomass values.

Young and adult females of *Bosmina longirostris*, adult and ovigerous females of *Ceriodaphnia silvestrii, Ceriodaphnia cornuta rigaudi*, and *Polyarthra vulgaris* were the major contributors in Ponte Nova, during the dry and cold season. During the rainy season, cladocerans were the only contributors, mainly young and ovigerous females of *Bosmina longirostris*, young of *Ceriodaphnia silvstrii*, ovigerous females of *Daphnia ambigua*, and young and ovigerous females of *Moina minuta*.

DISCUSSION

Variables such as chlorophyll and nutrients, which reflect the trophic state, were higher in

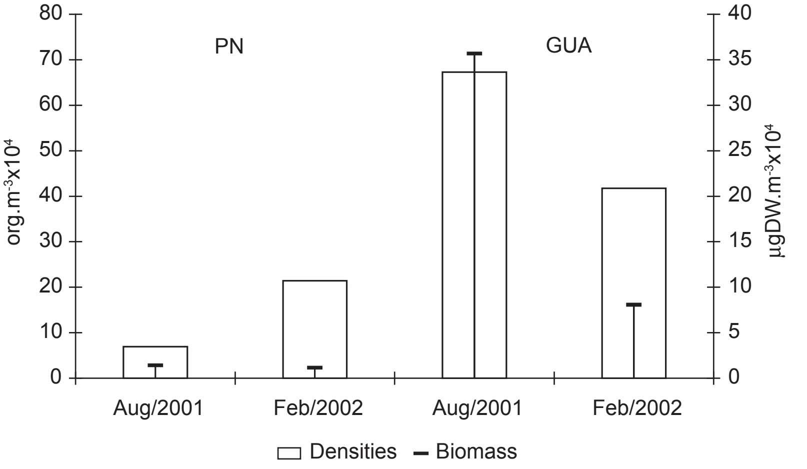

Fig. 3 — Zooplankton densities (number of organisms.m^{-3}) and biomass (µgDW.m^{-3}) in Ponte Nova (PN) and Guarapiranga (GUA) reservoirs, during the cold and dry (August 2001) and warm and rainy (February 2002) periods.

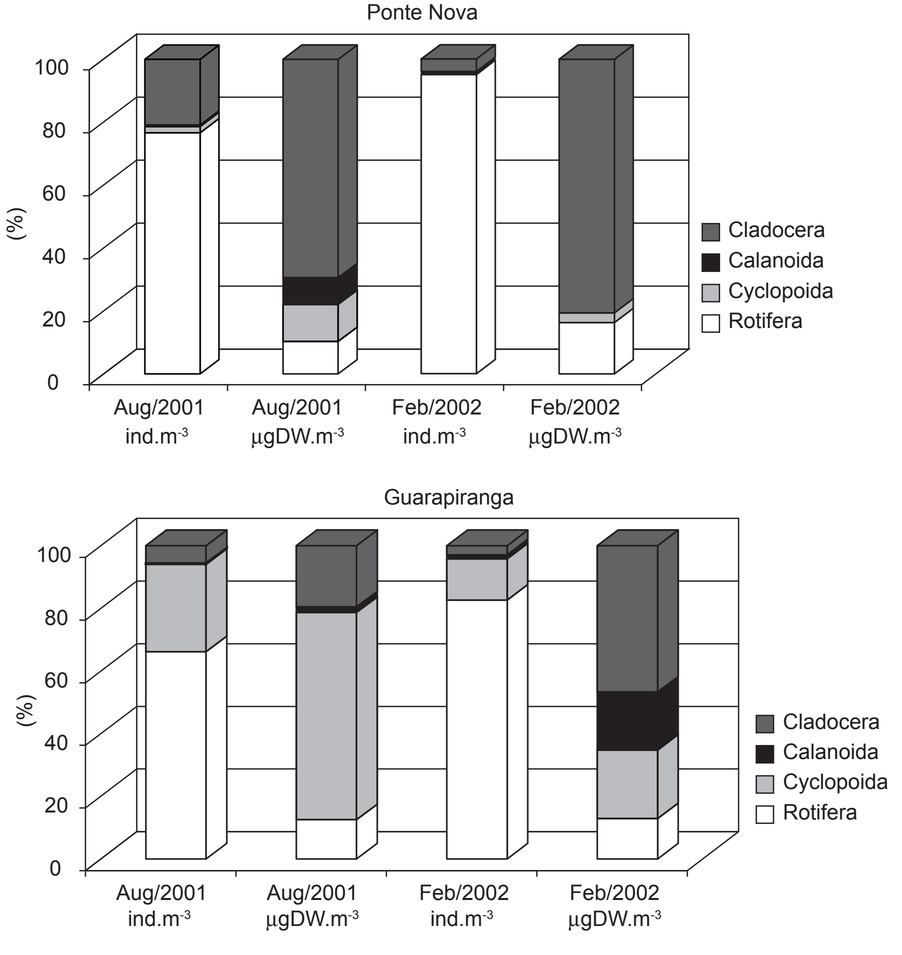

Fig. 4 — Relative contribution and numerical densities (ind.m^{-3}) and biomass (µgDW.m^{-3}) of rotifers, cyclopoids, calanoids and cladocerans in Ponte Nova and Guarapiranga reservoirs, in August 2001 and February 2002.

Guarapiranga reservoir. Along two decades of studies, this reservoir exhibited an intense process of eutrophication.

Both reservoirs also showed an increase in the chlorophyll concentration; a comparison with data obtained in the dry and rainy seasons by Maier & Takino (1985b) at the same sites shows an increase from 3.6 and 12.9 $\mu g.L^{-1}$ to 5.9 and 5.3 $\mu g.L^{-1}$ in Ponte Nova, and from 4.4 and 9.0 $\mu g.L^{-1}$ to 31.2 and 25.9 $\mu g.L^{-1}$ in Guarapiranga.

In this study, differences in physical and chemical variables associated with the dry and rainy seasons were observed at Guarapiranga, where nitrogen and phosphorus compounds and pigments were lower during the warm rainy season due to the dilution of superficial water.

Water bodies showing a trophic state index below 44 are oligotrophic, from 44 to 54 they are mesotrophic, and above 54 they are eutrophic. In the present study, the MTSI of Ponte Nova (42) and Guarapiranga (59) reflected, respectively, oligotrophic and eutrophic environments. Caleffi *et al*. (1994) obtained a TSI (Carlson, 1977) of 51 for Guarapiranga in previous studies; however, the TSI found in this study was the same as the MTSI, *i.e*., 59. The values found in the present study reflect the intensified eutrophication process as well as the input of the waters of Billings reservoir, transferred to Guarapiranga through the recent reversion of the Taquacetuba branch in August 2000.

As expected, in this study the two reservoirs were found to be numerically dominated by rotifers, a predominance that various authors have also found in other reservoirs in the state of São Paulo. Rotifers represented 78% of the total zooplankton in the Broa reservoir, which was oligotrophic at that time (Matsumura-Tundisi & Tundisi, 1976), and also predominated in 16 out of 17 reservoirs studied by Sendacz *et al*. (1985), and in the eutrophic Barra Bonita reservoir (Wisniewski, 1998).

As observed in Guarapiranga and in other eutrophic reservoirs (Domingos, 1993; Caleffi, 1994; 2000; Wisniewski, 1998; Piva-Bertoletti, 2001), zooplankton densities are usually lower during the warm rainy season, following a decrease of nutrients resulting from the dilution of superficial water. The opposite occurs in oligotrophic environments (Melão, 1997), where an increase in primary production is expected in the rainy season pursuant to the input of nutrients.

Ptygura sp, *Polyarthra sp* and *Collotheca sp* predominated in Ponte Nova both in 1979 (Sendacz *et al*., 1985) and in this study, as well in other oligotrophic reservoirs of the Alto Tietê basin, such as Cabuçu, Pedro Beicht and Taiaçupeba (Arcifa, 1984). Thus, the structure of the rotifer community has not changed over the years, following the trophic conditions of Ponte Nova. Guarapiranga showed the opposite pattern: changes in the zooplankton community relating both to the relative abundance of groups and to predominant species occurred in response to eutrophication.

Cyclopoids and calanoids were poorly represented in Ponte Nova while, in Guarapiranga, young stages represented 25% of the total zooplankton. Declining calanoid densities in Guarapiranga were probably due to lower water temperatures recorded during the cold season. *Notodiaptomus iheringi* was important due to its ability to replace other calanoid species in eutrophic waters (Coelho-Botelho *et al*., 1999; Rietzler *et al*., 2002).

Studies involving estimations of the dry weight and biomass of zooplankton organisms are rare. A comparative approach is difficult due to the use of different methodologies. Matsumura-Tundisi *et al*. (1989) and Melão (1997) estimated dry weights of microcrustaceans in the Broa reservoir (SP) and in the Lagoa Dourada reservoir (SP) using a microbalance. Wisniewski (1998) obtained data from the literature for the Barra Bonita reservoir. Also, comparisons were not always possible due to differences in the composition of species.

Some species recorded in this study were also found in the oligotrophic Lagoa Dourada reservoir (Melão, 1997), such as *Tropocyclops prasinus* and *Ceriodaphnia cornuta*, found in both reservoirs.

In Guarapiranga, *Bosmina longirostris* showed high dry weights during the dry season similar to those obtained at Barra Bonita by Wisniewski (1998), while the dry weights of *B. longirostris* were low in the oligotrophic Ponte Nova reservoir.

The dry weight of organisms of the same size may change according to the life cycle, nutritional state and reproductive conditions (Rocha, 1983), and the trophic conditions of the water (Andrew & Fitzsimons, 1992). Differences in the dry weight estimates of this study were attributed to both seasonal factors and each reservoir's trophic state, reflecting the nutritional state of the organisms.

The individual biomass should not be calculated from weight-length relationships found in the literature, since these relationships change according to temperature, food quality and availability, and genotype (Vijverberg, 1989).

The dry weight of *Ceriodaphnia cornuta rigaudi*, recorded in Ponte Nova during the dry and cold seasons, was higher than the dry weight of *Ceriodaphnia cornuta cornuta*, recorded in Guarapiranga in the warm rainy season and by Melão (1997) in Lagoa Dourada reservoir, but lay within the range established by Dumont *et al*. (1975).

As for calanoid copepods, the dry weight of *Argyrodiaptomus furcatus* was estimated earlier by Matsumura-Tundisi *et al*. (1989); however, this study adds an estimate of the dry weight of *Odontodiaptomus paulistanus* and of three *Notodiaptomus* species.

Although rotifers predominated numerically in both reservoirs and seasons, in terms of biomass in the cold dry season, cyclopoid copepods contributed more in Guarapiranga and cladocerans in Ponte Nova. In the warm rainy season, cladocerans represented the highest biomass in both reservoirs.

A comparison with oligotrophic data (Melão, 1997) reveals that Ponte Nova followed the same pattern, *i.e*., a higher contribution of cladocerans occurred in both seasons. The changes in biomass patterns in Guarapiranga were probably due to instable physical and chemical conditions.

The total zooplankton biomass in Ponte Nova (14.1 mgDW.m^{-3}) and Guarapiranga (354.6 mgDW.m^{-3}) in the cold dry season was higher than that reported by Melão (*op.cit*.) (4.6 and 5.9 mgDW.m^{-3}) and Wisniewski (*op.cit*.) (50.0 to 290.1 mgDW.m^{-3}, with a mean value of 88.5 mgDW.m^{-3}).

These levels of biomass lay within the limits of 3 to 355 mgDW.m^{-3} reported for African lakes and reservoirs by Allanson *et al*. (1990, *apud* Melão, 1999). The biomass values obtained for Guarapiranga were close to the upper levels in African aquatic systems.

The zooplankton biomass was found to decrease in the warm rainy season mainly in the Guarapiranga reservoir. During this season, both reservoirs showed lower values of total pigments and total suspended solids. The same trend was observed in Barra Bonita reservoir by Wisniewski (*op.cit*.), although Melão (*op.cit*.) recorded an increase of biomass values for the Lagoa Dourada reservoir.

The extent of seasonal variation can be characterized by the ratio of maximum to minimum biomass; ratios > 10 appear to be typical of zooplankton communities in the temperate zone (Saunders & Lewis, 1988). A ratio of < 10, detected in this study for both reservoirs, has also been found in other large tropical lakes, *e.g*., lakes Chad (Saint-Jean, 1983), George (Burgis, 1974) and Lanao (Lewis, 1979).

The total zooplankton biomass estimated for Ponte Nova corresponds to other environments with similar trophic conditions, such as the Carioca Lake, Doce River and Lobo reservoir, for which values of 10.9 and 11 to 16 mgDW.m^{-3} were estimated, respectively, by Matsumura-Tundisi & Tundisi (1986) and Matsumura-Tundisi *et al*. (1989).

The zooplankton biomass of Guarapiranga reservoir was much higher when compared with other eutrophic environments such as the Amarela Lake, Doce river (173.9 mgDW.m^{3}) (Matsumura-Tundisi & Tundisi, *op.cit*.) and Barra Bonita reservoir (Wisniewski, 1998).

The mean biomass of cyclopoid and calanoid copepods at Barra Bonita reservoir was 50.5 mgDW.m^{-3} (Wisniewski, *op.cit*). The cyclopoid copepods biomass in Guarapiranga was 236 mgDW.m^{-3} in the cold dry season, and 17.6 mgDW.m^{-3} in the warm rainy one.

With regard to oligotrophic environments, the rotifer biomass values reported by Melão (1997) (0.9 mgDW.m^{-3}) were lower than those estimated for Ponte Nova (1.5 mgDW.m^{-3}). As for eutrophic environments, the rotifer biomass values of Guarapiranga reservoir were higher (44.5 mgDW.m^{-3}) than those estimated by Wisniewski (*op.cit*.) (4.6 mgDW.m^{-3}).

The data reported here suggest different patterns of numerical densities and levels of biomass associated with trophic conditions. The biomass values for Ponte Nova were similar in the two seasons, while numerical densities increased in the rainy season. Higher numerical densities and biomass were observed in Guarapiranga in the dry season, when physical and chemical variables reflected highly eutrophic conditions.

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