LONGITUDINAL PROCESSES IN SALTO GRANDE RESERVOIR (AMERICANA, SP, BRAZIL) AND ITS INFLUENCE IN THE FORMATION OF COMPARTMENT SYSTEM

ZANATA, L. H. and ESPÍNDOLA, E. L. G.

CRHEA, EESC, USP, Av. Trabalhador Sancarlense, nº 400, C.P. 292, CEP 13560-970, São Carlos, SP, Brazil

Correspondence to: Lucí Helena Zanata, CRHEA, EESC, USP, Av. Trabalhador Sancarlense, nº 400, C.P. 292, CEP 13560-970, São Carlos, SP, Brazil, e-mail: lhzanata@sc.usp.br

(With 5 figures)

ABSTRACT

Studies on the longitudinal processes in reservoirs, involving physical, chemical and biological processes have been thoroughly appraised, suggesting the existence of a longitudinal organization controlled by the entrance and circulation of water which inserts modifications in the structuring of the system. To evaluate this effect, the Salto Grande reservoir (Americana, SP) was analyzed in 11 sampling stations in its longitudinal axis, in the rainy and dry seasons of 1997 considering the physical chemical and biological variables. Analyzing the results in agreement with the declining concentration degree of the river–barrage direction, a more significant correlation was verified in the dry period for total phosphorus ($r^2 = 0.86$), dissolved total phosphate ($r^2 = 0.83$), nitrite ($r^2 = 0.93$), inorganic phosphate ($r^2 = 0.89$), ammonium ($r^2 = 0.84$) and suspended material ($r^2 = 0.85$). In the rainy period, only nitrite ($r^2 = 0.90$) and conductivity ($r^2 = 0.89$) presented correlation with the distance of the dam, which demonstrates the effects of precipitation and the operational mechanism of the dam, as well as the distinction among the physical (sedimentation), chemical (oxidation) and biological (decomposition) processes in spatial heterogeneity of the system. These factors were decisive in the organization of these communities, with higher occurrence of rotifers and copepods in relation to cladocerans, the first ones being more abundant in the entrance of the Atibaia river, decreasing towards the dam direction, while copepods presented an inverse pattern. A distribution pattern similar to Copepoda was also verified for the Cladocera, evidencing a tendency to increase the density of organisms in the stations distant to the entrance of the Atibaia river, not being registered, however, a distribution gradient in the longitudinal axis, as observed for rotifers and copepods. In relation to the trophic degree a longitudinal gradient was also verified from eutrophic to oligotrophic depending on the location of the sampling station in relation to the longitudinal axis and period of analysis. The differences obtained, relating to the distribution of the environmental variables, demonstrate a characteristic pattern for reservoirs, with a longitudinal gradient in the sense river–barrage that inserts changes in the physical and chemical composition of the water, contributing to the differentiated establishing of biological communities.

Key words: reservoirs, longitudinal gradients, formation of compartment.

RESUMO

Processos longitudinais no reservatório de Salto Grande (Americana, SP) e sua influência na formação de compartimentos do sistema

Estudos sobre os processos longitudinais em reservatórios, envolvendo os processos físicos, químicos e biológicos, têm sido amplamente avaliados, sugerindo a existência de uma organização longitudinal controlada pela entrada e circulação da água, a qual insere modificações na estruturação do sistema. Para avaliar esse efeito, o reservatório de Salto Grande (Americana, SP) foi analisado em 11 estações de amostragem de seu eixo longitudinal, nos períodos seco e chuvoso de 1997, considerando-se va-

riáveis físicas, químicas e biológicas. Analisando-se os resultados de acordo com o grau de decaimento das concentrações no sentido rio–barragem, verificou-se correlação mais significativa no período seco do que no chuvoso para fósforo total ($r^2 = 0,86$), fosfato total dissolvido ($r^2 = 0,83$), nitrito ($r^2 = 0,93$), fosfato inorgânico ($r^2 = 0,89$), amônio ($r^2 = 0,84$) e material em suspensão ($r^2 = 0,85$). No período chuvoso, apenas nitrito ($r^2 = 0,90$) e condutividade ($r^2 = 0,89$) apresentaram correlação com a distância da barragem, o que demonstra o efeito da precipitação e do mecanismo operacional da barragem, bem como a distinção entre os processos físicos (sedimentação), químicos (oxidação) e biológicos (decomposição) na heterogeneidade espacial do sistema. Esses fatores foram determinantes na organização das comunidades, com maior abundância de rotíferos e copépodos em relação aos cladóceros, sendo os primeiros mais abundantes na entrada do rio Atibaia, decrescendo em direção à barragem, enquanto copépodos apresentaram padrão inverso. Padrão de distribuição semelhante aos copépodos também foi verificado para os cladóceros, evidenciando tendência ao aumento da densidade de organismos nas estações distantes da entrada do rio Atibaia, não sendo registrado, porém, gradiente de distribuição no eixo longitudinal, como observado para rotíferos e copépodos. Em relação ao grau de trofia também se verificou gradiente longitudinal de eutrófico a oligotrófico, dependendo da localização da estação de amostragem em relação ao eixo longitudinal e período analisado. As diferenças obtidas quanto à distribuição das variáveis ambientais demonstram um padrão característico para reservatórios, com gradiente longitudinal no sentido rio–barragem que insere modificações na composição física e química da água, contribuindo para o estabelecimento diferenciado das comunidades biológicas.

Palavras-chave: reservatórios, gradiente longitudinal, formação de compartimentos.

INTRODUCTION

Artificial reservoirs are distinguished from other natural aquatic ecosystems because of operation mechanisms that alter the conditions of the setting, which together with functions of natural forces, cause the heterogeneous distribution of the organisms in the environment (Tundisi, 1988; Straskraba *et al*., 1993). In this system, the water time of residence and material contribution input a longitudinal zonation usually associated with the increase of particulate material sedimentation in the river–barrage direction (Thomaz *et al*., 1997), where each compartment will constitute a section along the longitudinal axis (lotic, transition and lentic) with differentiated characteristics, where the degree of space heterogeneity is influenced by morphometry, flow and stratification conditions, the hydrodynamic conditions are the main causes of the horizontal variability in most of the reservoirs (Straskraba & Tundisi, 1999).

Studies developed by Armengol *et al*. (1999) and Zanata (1999) suggest the existence of a longitudinal organization in reservoirs controlled by water circulation, which is related to the physical and chemical characteristics and to the biotic communities of the system. This spatial and temporal heterogeneity in the environmental conditions is a decisive factor in the continuous organization process of the communities in the aquatic environment (Espíndola, 1994), causing the diversity of habitats, which is considered fundamental for the occurrence of biological diversity (Tundisi *et al*., 1988).

Considering the importance of water resources, the present study seeks to characterize the physical, chemical and biological processes in the longitudinal axis of the Salto Grande reservoir (Americana, SP), during two seasons of the year (summer and winter), which influence the ecology of the system.

STUDY AREA

This work was developed in the Salto Grande reservoir, located in the eastern-central area of the State of São Paulo, in the municipal district of Americana, in the coordinates 22°44'S and 47°20'W, at 530 meters of altitude and inserted in the hydrographic basin of the Atibaia river (one of the tributaries of the Piracicaba river, in the headboard area of the upper basin of the Paraná river), which covers an area of 2,724 km². The reservoir area is 11.5 km², with a 64 km perimeter, 17 km of length, maximum volume of 106×10^6 m³, maximum depth of 9 m and a 30-day average water time of residence.

The Atibaia river basin presents high urban and industrial density, mainly in the inferior sector, causing a growing deterioration process of water quality, due mainly to the entrance of domestic and

industrial effluents from the cities of Paulínia and Campinas. Moreover, it receives significant contribution of organic load from small rivers and streams that receive sanitary sewers without treatment from other cities (Rocha, 1972; Carvalho, 1979; Shimizu, 1981), as well as the material contribution from agricultural activities.

MATERIAL AND METHODS

To evaluate the longitudinal processes in the reservoir of Salto Grande, 11 collection stations were horizontally distributed in the dam, taking into consideration mainly the longitudinal axis in direction to the entrance of the Atibaia river, main affluent towards the dam. The collecting was carried out on February 14 (higher temperature and higher precipitation) and June 30, 1997 (lower temperature and lower precipitation).

Samples were collected integrating the water column with a suction pump for analysis of physical, chemical and biological parameters, as well as suspended material (Teixeira *et al*., 1965; Tundisi, 1969), chlorophyll-a (Nusch, 1980) plus total and dissolved nutrients (Golterman *et al*., 1978; Standard Methods, 1995; Koroleff, 1976; Mackereth *et al*., 1978), conductivity, temperature and dissolved oxygen analysis were made through a HORIBA-U10 field meter, in all the collection stations. Water transparency analysis was accomplished by means of a Secchi disc, through which the limit of the euphotic zone was obtained (Cole, 1975). The obtained results were used for determination of the trophic state of the system in agreement with methodology of Toledo *et al*. (1983). The samples for analysis of zooplankton (Rotifera, Copepoda and Cladocera) were collected in both periods and in 9 stations with a suction pump and using a plankton net with 30 μm of mesh opening. The samples were conditioned in flasks and preserved with formaline 4% for subsequent analysis in laboratory, specialized methodology and bibliography was used considering the composition and density of the organisms.

RESULTS

Limnological characteristics of the Salto Grande reservoir

The results obtained for the limnological variables are presented in Tables 1 and 2; the diffe-

rentiation in the water quality in the longitudinal axis of the system was verified, with higher values for some variables in the stations closest to the entrance of the Atibaia river. The conductivity values, for instance, varied from 87 to 238 μS/cm and from 99 to 157 μS/cm in the dry and rainy period, respectively. Significant variation was also obtained for suspended material (from 2.79 to 12.50 mg/L in the dry period and from 9.33 to 64.9 mg/L in the rainy period), with higher organic fraction in the dry period (except in stations closer to the Atibaia river) and the inorganic fraction predominating in the rainy period. The higher carriage of aloctone material in the rainy period contributed to the reduction of the euphotic zone limit (from 0.6 to 2.1 m in the rainy period and from 1.8 to 6.5 m in the dry period), verifying that in the dry period all the stations presented more than 50% of the water column with light. The chlorophyll-a concentration was larger in the rainy period (from 1.95 to 11.86 μg/L) than in the dry period (from 0.46 to 6.51 μg/L). For total and dissolved nutrients, in general, a concentration decline in the Atibaia river-barrage direction was verified, mainly in the dry period. The concentrations of total phosphorus varied from 69.58 to 128.85 μg/L in the rainy period and from 39.63 to 244.22 μg/L in the dry period. Among the phosphate compounds, it was only during the rainy period that the total dissolved phosphate and inorganic phosphate did not present a decreasing distribution of concentration. It was also verified for the longitudinal pattern higher concentrations of nitrogen compounds in stations close to the entrance of the Atibaia river and lower concentrations in stations close to the barrage. For nitrite, for instance, a variation was verified from 13.68 to 162.86 μg/L in the rainy period, while that variation occurred from 49.30 to 274.76 μg/L in the dry season (Tables 1 and 2).

Composition and dominance of the zooplanktonic community

In both analyzed periods, Rotifers and copepods were the most abundant in the Salto Grande reservoir (Tables 3 and 4). In the rainy season the average percentile contribution of Copepoda, Cladocera and Rotifera was of 35.64%, 10.93% and 50.39% while in the dry period, the variation was of 26.83%, 11.25% and 61.31%, respectively, with differences in the longitudinal axis: Rotifera being the most abundant in stations close to the Atibaia

river, and Copepoda and Cladocera in stations intermediate and close to the dam.

The Cyclopoida copepods were the most abundant in the reservoir during the two analyzed periods. In the rainy period, this group represented 76.2% of a total of 898,607 ind./m³.

In the dry period, Cyclopoida contributed with 88.2% of a total of 1,481,051 ind./m³. Calanoida represented 23.8% and 11.8% of the copepods found in the rainy and dry periods, respectively. The occurrence of Harpacticoida copepods was only observed in the rainy period, in stations 1 and 2, with 20 ind./m³ and station 3, with 75 ind./m³ (Table 5).

In the rainy period, rotifers contributed with 50.39% of the total of individuals. Station 3 presented a larger abundance of organisms (306, 600 ind./m³), in which was also observed the largest relative abundance of rotifers (89.90%), while the smallest contributions occurred in stations 8, 10 and 11, where the relative abundance of rotifers varied from 15.79% to 28.95%. In those stations, the copepods were the dominant organisms (Table 3).

In the dry period, rotifers were more abundant in station 8, contributing with 831,600 ind./m³. The relative abundance of rotifers varied from 86.75% to 47.24% in stations 3 and 9, respectively. In spite of the heterogeneous distribution of the organisms in the system, the rotifers were dominant in all the collected stations during the dry period (Table 4).

TABLE 1

Comparison of limnological data in Salto Grande reservoir in the wet season.

Variable	Stations										
	1	2	3	4	5	6	7	8	9	10	11
Maximum depth (m)	4.0	2.5	1.7	5.0	10.0	3.7	5.5	7.0	2.7	13.5	19.5
Euphotic limit (m)	0.6	0.9	0.9	0.9	1.5	0.9	2.1	1.8	1.9	1.5	0.6
Conductivity (μS/cm)	145	148	157	130	123	117	108	108	105	103	99
Total suspended material (mg/L)	64.90	35.85	36.87	17.01	19.04	10.72	9.33	11.71	10.78	11.83	14.40
Organic material (mg/L)	22.5	13.7	10.3	5.9	5.3	3.8	3.0	3.8	4.1	4.1	3.6
Inorganic material (mg/L)	42.4	22.2	26.6	11.1	13.8	6.9	6.3	7.9	6.7	7.7	10.8
Chlorophyll-a (μg/L)	4.88	6.28	6.98	11.86	3.49	7.67	2.23	6.98	10.46	10.46	1.95
Total phosphorus (μg/L)	108.72	119.99	128.85	73.57	86.67	69.58	85.17	78.34	71.51	86.55	91.85
Total dissolved phosphorus (μg/L)	64.03	62.12	56.21	38.41	58.95	61.08	64.08	86.85	67.78	70.51	79.74
Inorganic phosphate (μg/L)	33.30	33.43	32.57	26.13	31.67	30.99	28.06	33.27	37.26	28.41	48.84
Total organic nitrogen (mg/L)	3.28	6.06	6.09	2.00	1.60	2.14	1.82	1.97	1.58	1.47	2.08
Ammonium (μg/L)	617.03	776.24	896.06	539.43	691.28	453.97	451.25	260.27	248.23	276.27	464.94
Nitrate (μg/L)	1,020.6	1,066.9	1,060.3	1,009.1	843.6	902.9	684.0	789.8	791.7	877.7	552.8
Nitrite (μg/L)	155.21	162.42	162.86	118.25	88.87	76.18	26.67	20.72	27.85	22.23	13.68
Silicate (mg/L)	5.58	5.14	5.22	5.37	4.33	3.83	3.59	3.38	4.46	3.70	4.31

TABLE 2

Comparison of limnological data in Salto Grande reservoir in the dry season.

Variable	Stations										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Maximum depth (m)	3	3	2	7.5	11	5.7	6.5	8.5	12	9	7.5
Euphotic limit (m)	2.4	2.4	1.8	6.3	6.3	5.7	6.5	6.3	6	6	
Conductivity (µS/cm)	225	238	219	87	91	154	157	158	163	116	111
Total suspended material (mg/L)	12.50	13.75	11.62	6.74	5.05	4.83	3.47	2.79	3.29	2.99	3.30
Organic material (mg/L)	6.0	6.2	4.5	3.9	2.6	2.4	2.3	2.1	1.6	2.3	1.7
Inorganic material (mg/L)	6.5	7.6	7.1	2.9	2.5	2.5	1.2	0.7	1.7	0.7	1.6
Chlorophyll-a (µg/L)	2.32	2.79	4.18	6.04	2.79	6.04	6.51	0.46	2.32	3.72	5.11
Total phosphorus (µg/L)	199.97	244.22	221.56	188.15	96.21	61.68	48.34	55.06	39.63	42.75	42.26
Total dissolved phosphorus (µg/L)	115.61	146.87	142.41	55.52	48.01	41.08	27.30	25.57	23.52	25.74	25.44
Inorganic phosphate (µg/L)	78.34	89.96	90.65	33.32	28.38	17.10	7.59	13.24	7.88	8.04	6.11
Total organic nitrogen (mg/L)	1.37	1.31	1.37	0.88	0.81	1.11	0.57	2.43	1.88	1.9	1.58
Ammonium (µg/L)	1,314.5	1,519.9	1,538.5	761.3	1,047.1	536.5	293.5	575.6	365.5	218.0	267.1
Nitrate (µg/L)	1,944.8	1,932.7	1,591.8	1,464.8	1,304.0	1,483.1	1,377.7	1,325.7	1,368.0	1,404.9	1,335.0
Nitrite (µg/L)	274.09	274.76	235.79	160.10	137.19	115.71	65.05	98.31	64.01	49.30	51.61
Silicate (mg/L)	6.87	6.26	6.88	5.95	4.90	4.71	4.93	2.34	5.06	3.47	5.00

TABLE 3

Density (ind./m³) and the relative abundance (%) of Copepoda, Cladocera, Rotifera and other organisms in the wet season.

Stations	Copepoda		Cladocera		Rotifera		Other organisms*		Total
	Density	**%**	**Density**	**%**	**Density**	**%**	**Density**	**%**	**Density**
1	3,600	2.48	70	0.05	115,600	79.77	25,650	17.70	144,920
2	5,150	2.77	120	0.06	148,800	80.09	31,710	17.07	185,780
3	10,125	2.97	7,885	2.31	306,600	89.90	16,445	4.82	341,055
5	145,578	35.87	31,455	7.75	228,480	56.30	315	0.08	405,828
6	131,983	39.50	72,715	21.76	129,285	38.70	109	0.03	334,092
8	150,624	54.45	51,912	18.77	74,100	26.79	0		276,636
9	145,299	45.29	33,260	10.37	142,200	44.32	86	0.03	320,845
10	191,488	56.41	47,900	14.11	98,280	28.95	1,760	0.52	339,428
11	114,800	66.35	30,229	17.47	27,310	15.79	672	0.39	173,011
Total	898,647		275,546		1,270,655		76,747		2,521,595
%	35.64		10.93		50.39		3.04		

*Insecta larvae, Annelida and Ostracoda.

TABLE 4

Density (ind./m³) and the relative abundance (%) of Copepoda,
Cladocera, Rotifera and other organisms in the dry season.

Stations	Copepoda		Cladocera		Rotifera		Other organisms*		Total
	Density	%	Density	%	Density	%	Density	%	Density
1	4,459	6.41	2,698	3.88	56,733	81.55	5,675	8.16	69,565
2	1,093	1.92	20	0.04	33,893	59.47	21,987	38.58	56,993
3	460	0.97	35	0.07	40,950	86.75	5,760	12.20	47,205
5	138,575	17.84	70,888	9.13	567,100	73.03	0		776,563
6	243,114	25.87	148,401	15.79	548,340	58.34	0		939,855
8	218,055	19.09	92,721	8.12	831,600	72.80	0		1,142,376
9	250,191	32.79	152,403	19.97	360,427	47.24	0		763,021
10	331,778	34.58	62,438	6.51	564,960	58.89	227	0.02	959,403
11	293,326	38.34	91,257	11.93	380,457	49.73	78	0.01	765,118
Total	1,481,051		620,861		3,384,460		33,727		5,520,099
%	26.83		11.25		61.31		0.61		

* Insecta larvae, Annelida and Ostracoda.

TABLE 5

Comparison of density (ind./m³) and the relative abundance (%) of Copepoda (Cyclopoida,
Calanoida and Harpacticoida) in the wet and dry season.

Stations	Wet season							Dry season				
	Cyclopoida		Calanoida		Harpacticoida		Total	Cyclopoida		Calanoida		Total
	Density	%	Density	%	Density	%		Density	%	Density	%	
1	3,500	95.6	140	3.8	20	0.5	3,660	2,282	51.2	2,178	48.8	4,460
2	5,130	99.6	0		20	0.4	5,150	1,060	97.0	33	3.0	1,093
3	10,005	98.8	45	0.4	75	0.7	10,125	445	96.7	15	3.3	460
5	105,374	72.4	40,204	27.6			145,578	111,485	80.5	27,090	19.5	138,575
6	91,434	69.3	40,549	30.7			131,983	198,275	81.6	44,839	18.4	243,114
8	93,600	62.1	57,024	37.9			150,624	207,545	95.2	10,509	4.8	218,054
9	120,790	83.2	24,409	16.8			145,199	235,043	93.9	15,148	6.1	250,191
10	156,904	81.9	34,584	18.1			191,488	283,071	85.3	48,707	14.7	331,778
11	97,828	85.2	16,972	14.8			114,800	266,743	90.9	26,583	9.1	293,326
Total	684,565		213,927		115		898,607	1,305,949		175,102		1,481,051
%	76.2		23.8		0.01			88.2		11.8		

The density of Cladocera varied from 70 ind./m³ (station 1) to 72,715 ind./m³ (station 6), in a total of 275,546 ind./m³, in the rainy season and of 20 ind./m³ (station 2) to 152,403 ind./m³ (station 9), in a total of 620,861 ind./m³, in the dry period, during the two analyzed periods cladocerans were less frequent than copepods and rotifers. Other organisms were found in the analyzed samples, such as larvae insects, annelids and some ostracods, which, in the rainy period and in the dry period (Tables 3 and 4) were more abundant in the stations close to the entrance of the river Atibaia.

In general, the densities were larger in the dry period, when Rotifer (3,384,460 ind./m³), Co-

pepoda (1,481,051 ind./m³), Cladocera (620,861 ind./m³) and other organisms (33,727 ind./m³) added to a total of 5,520,099 ind./m³, while in the rainy period the density of Rotifer (1,270,655 ind./m³), Copepoda (898,647 ind./m³), Cladocera (275,546 ind./m³) and other organisms (76,747 ind./m³) added to 2,521,595 ind./m³ (Tables 3 and 4).

DISCUSSION

Spatial and temporal characterization of the environmental variables in the Salto Grande reservoir

The distribution of all the presented environmental variables demonstrates a characteristic pattern for reservoirs, as thoroughly discussed by Armengol *et al.* (1999). According to these authors, nutrients can be diluted by water, resulting in the establishment of a longitudinal gradient in the composition of the water of a reservoir, which contributes to the qualitative and quantitative differentiated establishment of the biological communities.

As mentioned previously, in the Salto Grande reservoir an accentuated longitudinal gradient of distribution of some variables was verified, demonstrating the heterogeneity of the system and the variation of the conditions of the reservoir, in both study periods. To evaluate the variation and the decline degree in relation to the chemical composition of the water, an analysis similar to that developed by Armengol *et al.* (1999) was made, in which the author calculates the existent correlation between a certain variable and the distance of the barrage. The obtained results are presented in Fig. 1, verifying a more significant correlation in the dry than in the rainy period for total match ($r^2 = 0.86$), dissolved total phosphate ($r^2 = 0.83$), nitrite ($r^2 = 0.93$), inorganic phosphate ($r^2 = 0.89$), ammonium ($r^2 = 0.84$) and suspended material ($r^2 = 0.85$). In the rainy period, only nitrite ($r^2 = 0.90$) and conductivity ($r^2 = 0.89$) presented correlation with the distance of the barrage, which clearly demonstrates the outstanding effect of the precipitation and of the operational mechanism of the barrage in the space heterogeneity of the system.

As also presented by Armengol *et al.* (1999), it is possible, through the comparison of the exponents of the declining equation, to measure the efficiency of the processes involved in the reduction of the concentration of variables analyzed along the Salto Grande reservoir (Fig. 2). As shown in

Fig. 2, small variations occurred in conductivity (0.05 – rainy and dry period), demonstrating similarity with the results obtained by Armengol *et al.* (1999) in the Sau reservoir (Spain), this fact being attributed to the dilution by small tributaries, morphology of the basin or precipitation. Other components showed high rates of decrease in the longitudinal axis, such as suspended material (0.16-0.17 – rainy and dry period, respectively), probably due to the sedimentation process, already observed by Leite (1998) for that system. The results obtained for ammonium ion (0.10-0.20, in the rainy and dry periods, respectively) and phosphate compounds (0.20-0.30, in the dry period) were similar to those observed by Armengol *et al.* (1999), this being attributed to the precipitation that can happen to phosphate compounds and the chemical transformation, such as the case of ammonium nitrification, processes in which the activity of organisms is essential.

Through the calculation of the variation rate (Fig. 1) and of the analysis of the decline equation (Fig. 2) it is possible to verify if processes are of biological origin or not, evidenced by the role of the sedimentation, chemical transformation, precipitation and biological activity, although, for the most part, a combination of morphologic, climatological and trophic degree factors occurred, which serve as support so that other processes can take place in the system.

In the case of the Salto Grande reservoir, the depositional process is important for the improvement of the water quality, making it function as a sedimentation basin or play the part of a tertiary treatment in response to the entrance of polluted water from the Atibaia river. However, biological activities related to production and decomposition are also important for the establishment of a gradient in the reservoir, once the communities are organized in relation to a trophic gradient.

The Salto Grande reservoir is in advanced eutrophication process due to the constant discharge of industrial and domestic effluents that arrive to the system through punctual and diffuse sources.

In the rainy period, the material contribution for the reservoir is larger due to the high pluviometric indexes. Besides the carrying of aloctone material that enriches the system, it should also be considered a possible liberation of nutrients of the sediment through the removal of the water flow and by biological and chemical processes (Lijklema, 1994).
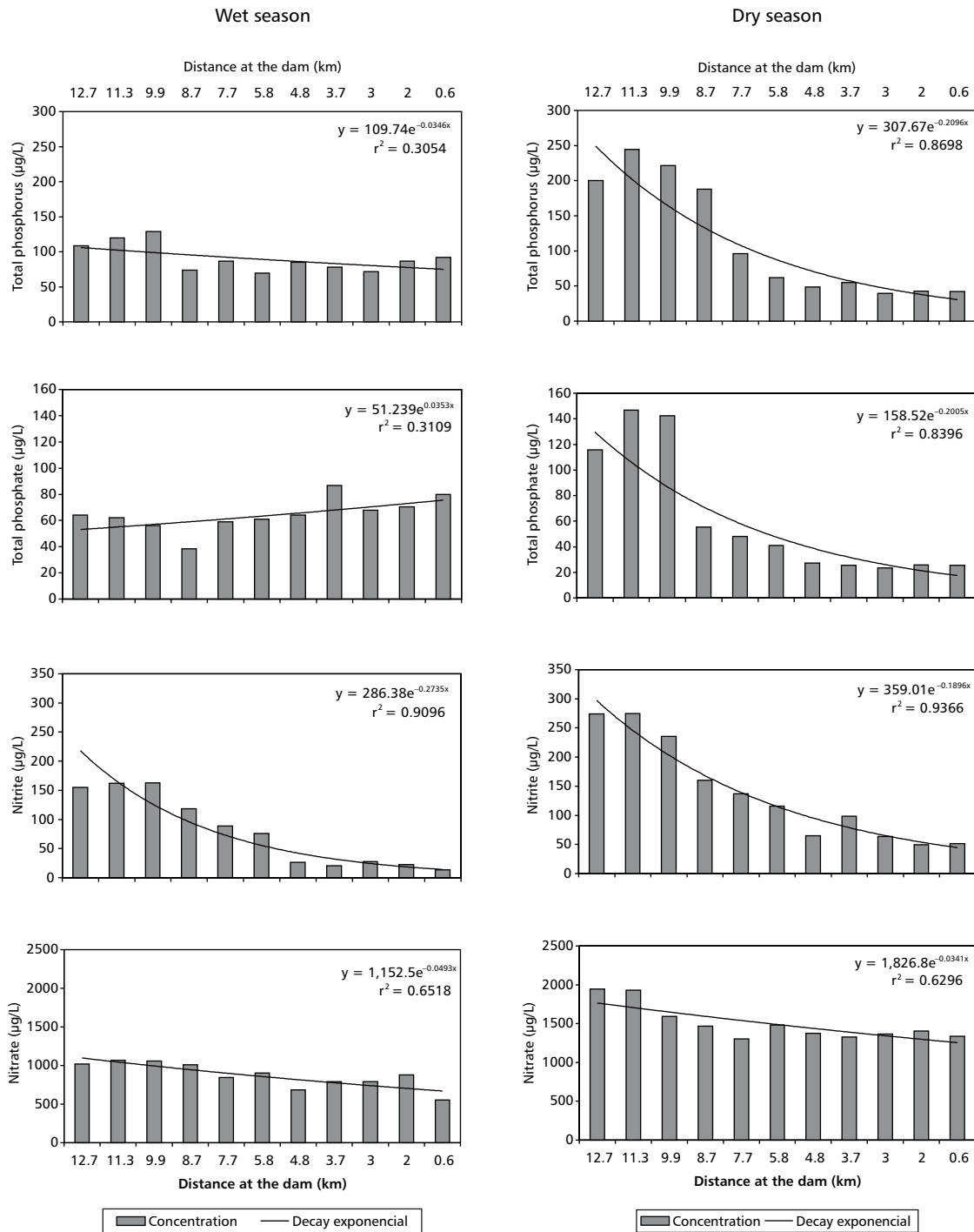
Fig. 1 — Evolution of the chemical, physical and biological variables in the Salto Grande reservoir from the Atibaia river to the dam. The equations are relating of each variable with the distance at the dam.
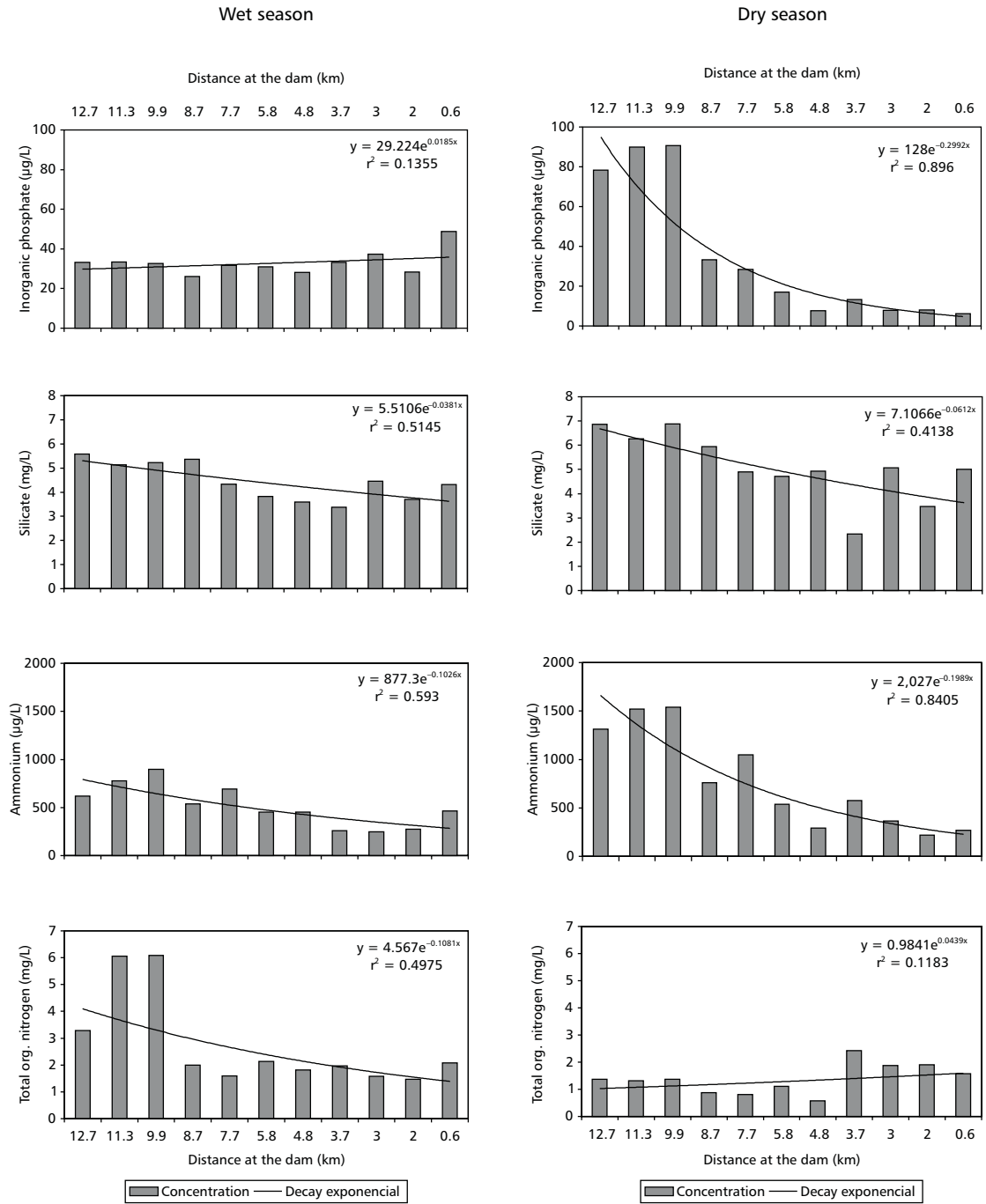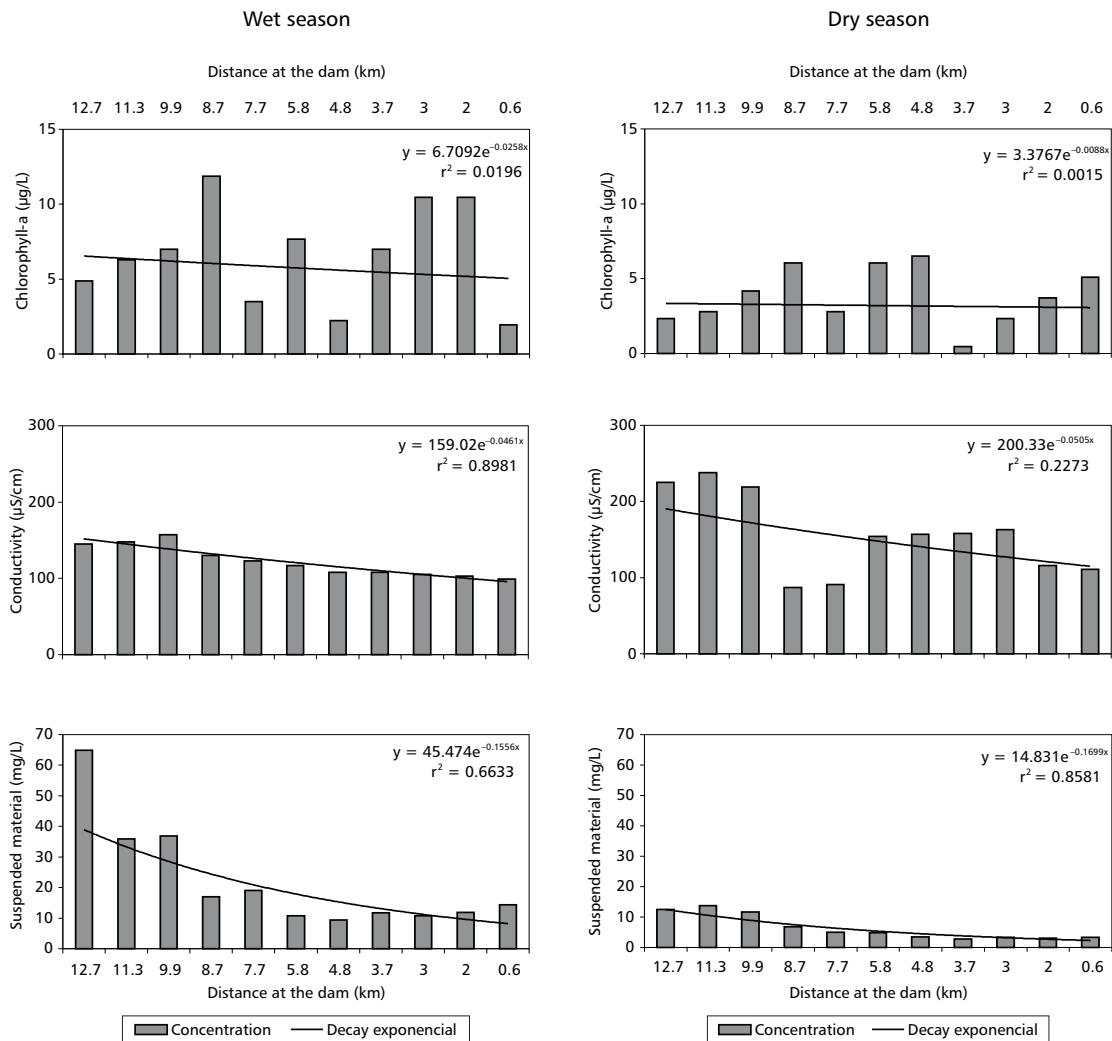
Fig. 1 — (*Continued*).

Wet season

Dry season

Distance at the dam (km)

Distance at the dam (km)

Fig. 1 — (*Continued*).

In the dry period, the lowest water flow and larger residence time (caused by low indexes of pluviosity), as well as the morphometry of the system, favored the sedimentation of the aloctone material that arrived mainly through the Atibaia river.

That process might have caused a longitudinal gradient in the reservoir, leading to a more eutrophic condition in areas close to the entrance of the Atibaia river to a less eutrophic condition close the barrage (Fig. 3).

Considering all the obtained information, it is verified that the Salto Grande reservoir is a highly impacted system by the punctual and

diffuse entrances of nutrients, sediment and metals (as presented by Tonissi, 1999), which present close relationship with functions of climatological forces (mainly precipitation) and antropogenics (use and occupation of the hydrographic basin and operational mechanisms of the barrage). Given the constant entrance of aloctone material and its effects in the physical, chemical and biological characteristics, the system is considered eutrophic with tendencies to mesotrophic and oligotrophic, depending on the location of the sampling stations in relation to the longitudinal axis and season (Fig. 3).
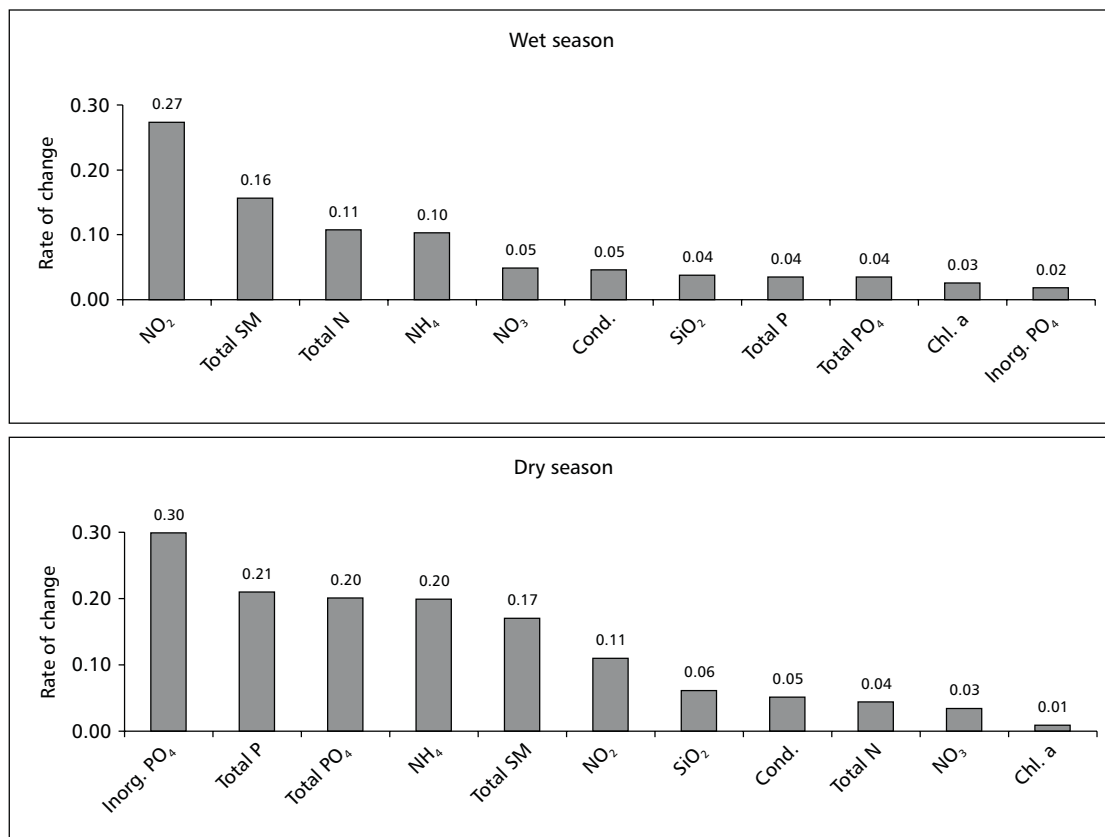
Fig. 2 — Measure of the efficiency of the processes involved in the reduction of the concentrations of the variables analyzed in the Salto Grande reservoir.
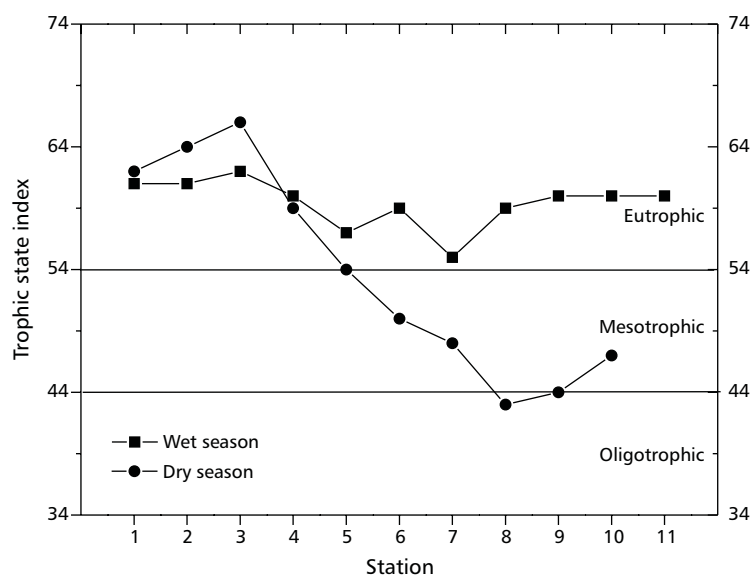

Fig. 3 — Trophic state index in the Salto Grande reservoir.

Space and temporal heterogeneity of the zooplanktonic community

In the Salto Grande reservoir, the heterogeneity did not only occur in the distribution, but also in the composition and density of organisms of the zooplanktonic community while comparing the analyzed periods. It can be observed that the physical, chemical and biological characteristics of the reservoir favored a larger abundance of Rotifer and Copepoda.

In the rainy period, in spite of the density of those organisms being similar, considering the longitudinal axis of the system, its spatial distribution was differentiated. Rotifers were more abundant in the entrance of the Atibaia river, presenting a decreasing gradient in direction to the barrage, while, in relation to copepods, an inverse distribution was verified, being these organisms more abundant in the stations distant to the river entrance (Fig. 4).

A dominance of rotifers took place during the dry period in the reservoir in relation to the density of organisms and copepod was the second most abundant group. In general, the density of organisms was larger in that period, but the distribution was similar to that observed in the rainy period. In relation to the cladocerans, the distribution pattern observed evidenced a tendency to the increase of organism density in the stations distant to the entrance of the Atibaia river. However, a distribution gradient was not registered in the longitudinal axis, as observed for rotifers and copepods. Other analyzed organisms (such as Dipteran larvae, annelids and ostracods) were more abundant in stations close to the entrance of the Atibaia river in the two analyzed periods, with inferior density for the other groups. The distribution of Rotifer, Copepoda and Cladocera in the located stations in the longitudinal axis of the reservoir can be observed in Fig. 4.
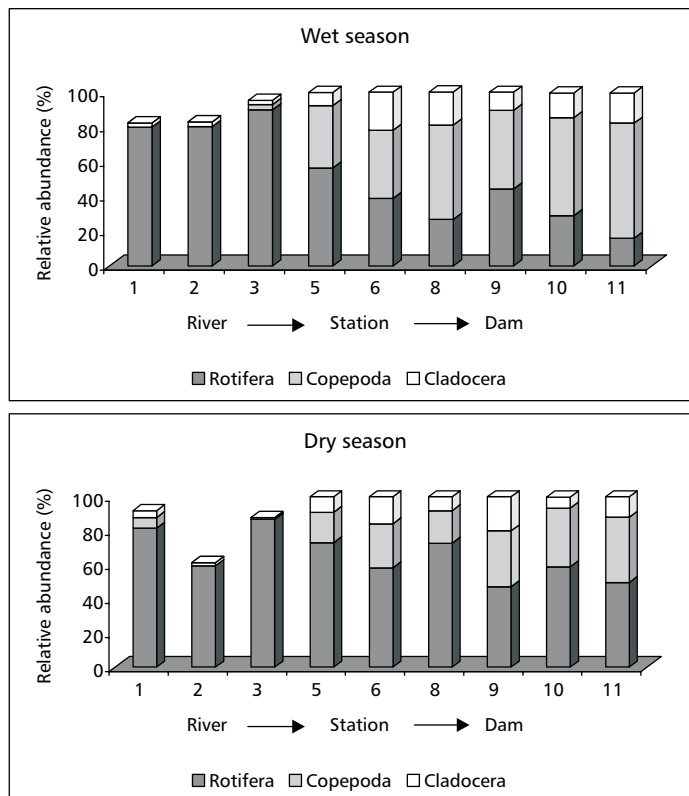
Fig. 4 — Longitudinal distribution of the relative abundance of zooplankton community in the Salto Grande reservoir

In relationship to rotifers, the literature has demonstrated that its dominance is associated to the increase of the trophic degree (Esteves & Sendacz, 1988), which is related to the feeding habits of this group, which include the ingestion of small particles such as bacteria and organic debris, usually abundant in eutrophic systems (Nogueira, 1996). In that way rotifer distribution in the Salto Grande reservoir might have been influenced by the suspension material concentration that also presented a decreasing gradient in the entrance of the reservoir in barrage direction. That sedimentation was directly related with the morphometry of the system (Leite, 1998).

However, the temporal variation in the density of the organisms was also sure for the operational regime of the reservoir. The smallest densities for rotifers were verified in the rainy season, in which the reservoir presents smaller time of residence of water. According to Rocha *et al.* (1999), organisms such as rotifers, protozoans and nauplii copepods are more susceptible to the intense flow due to their size and location in the water column.

The inverse distribution of copepods in relation to the rotifers possibly occurred as a function of food supply. Besides its distribution, the composition of this group can also be related to feeding habits. In the Salto Grande reservoir the dominance of Cyclopoida in relation to Calanoida took place during the rainy and dry period. In general, the distribution of copepods in the longitudinal axis of the Salto Grande reservoir evidenced a better adaptation of the organisms in the stations distant to the entrance of the Atibaia river (Fig. 4). However, considering the horizontal distribution of Cyclopoida and Calanoida (Fig. 5) in the rainy period, a better adaptation tendency of Calanoida was observed in the stations distant to the entrance of the river Atibaia, while Cyclopoida was present in the whole reservoir, with superior density. In the dry period the dominance of Cyclopoida among the copepods was evident, however its distribution didn't present a defined pattern (Fig. 5).
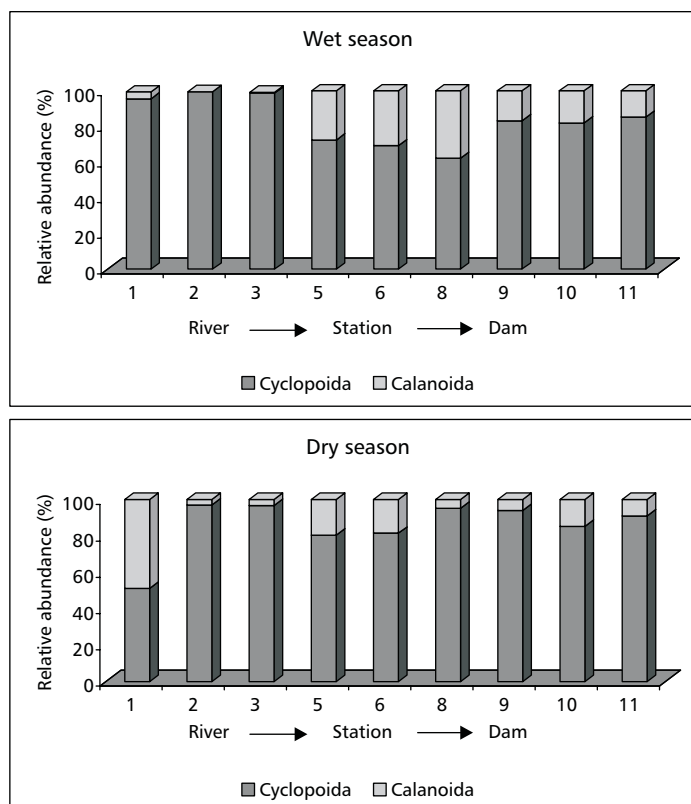

Fig. 5 — Longitudinal distribution of the relative abundance between Cyclopoida and Calanoida in the Salto Grande reservoir.

The density of organisms was also related with the water retention time in the reservoir. As for Copepoda, Rotifera and Cladocera, the density of organisms was directly proportional to the time of retention, in other words, the larger the time of retention the higher the density of organisms. As discussed above, the communities are sensitive to the operational regime, mainly the smallest ones, such as rotifers (Rocha *et al*., 1999). In that way, it is possible that the numeric likeness between rotifers and copepods in the rainy period has occurred due to the effect of the intense water flow being more negative on rotifers than on copepods. In the dry period, when the time of retention was larger, the dominance of rotifers on other groups was more evident.

In relation to the cladocerans, it was observed that this group did not numerically dominate the zooplanktonic community in any of the stations during the studied periods and they were better adapted in the stations distant to the entrance of the Atibaia river, where the characteristics of the system are more similar to a lake.

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