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Research Article

Changes in abiotic characteristics of water in the Paranapanema River and three lateral lagoons at mouth zone of the Jurumirim Reservoir during the flood period, São Paulo, Brazil

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ABSTRACT. Floods increase the similarity of the abiotic water characteristics of the rivers with those of the surrounding floodplains and are the main factors that influence the ecosystem dynamics. The aim of this paper was to examine the alterations in abiotic characteristics of the Paranapanema River and three lateral lagoons with different degrees of connectivity to the river during the flood period. Samplings were performed twice a week during a three-month period. Water quality in the Camargo and Coqueiral lagoons, connected to the Paranapanema River, presented patterns of variation similar to those of the lotic ecosystem, evidenced by the principal component analysis. In Cavalos Lagoon, changes in water quality were observed in all the environments, such as a function of dilution after the water level increased and greater nutrients resulting from littoral plant decomposition after submersion. In conclusion, the marginal lagoons and river were influenced by two anthropogenic actions: water storage in a dam reservoir, which acted like a buffer against hydrological pulses, and the widening of the channel uniting Camargo Lagoon with the river, changing the connectivity level and causing an ever-greater similarity of the lagoon with the lotic system.

Keywords: floodplains, lateral lagoons, water characteristics, flood period, connectivity, Brazil.

Cambios de las características abióticas del agua del río Paranapanema y de tres lagunas laterales en la zona de la boca de la Reserva de Jurumirim durante el periodo de inundación, São Paulo, Brasil

RESUMEN. Las inundaciones asemejan las características abióticas del agua de los ríos a la de los entornos de planicies aluviales y son los principales factores que influyen en la dinámica del ecosistema. El objetivo de este trabajo fue analizar las alteraciones en las características abióticas del río Paranapanema y de tres lagunas laterales con distintos niveles de conectividad al río durante el período de inundación. Los muestreos se realizaron dos veces por semana durante un período de tres meses. La calidad del agua en las lagunas Camargo y Coqueiral, conectadas al río Paranapanema, presentó patrones de variación similar a aquellos del ecosistema lótico, demostrado por medio de análisis de componentes principales. En la laguna de Cavalos se observaron cambios en la calidad del agua de todos los ambientes, tales como una función de dilución después del aumento del nivel de agua y del incremento de nutrientes como resultado de la descomposición de las plantas litorales después de la inmersión. En conclusión, las lagunas marginales y el río fueron influenciados por dos acciones antropogénicas: el almacenamiento de agua en la presa, que actúa como un sistema de amortiguación de pulsos hidrológicos y la ampliación del canal de la asociación de la laguna Camargo con el río, cambiando el nivel de conectividad, y causando una similitud cada vez mayor de la laguna con el sistema lóticos.

Palabras clave: planicies aluviales, lagunas laterales, características del agua, periodo de inundación, conectividad, Brasil.

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INTRODUCTION

Many studies evidence the importance of hydrologic regime for the water abiotic characteristics in floodable areas where inundation pulses are the main power functions that affect the dynamics of these complex ecosystems (Junk *et al.*, 1989; Neiff, 1990; Thomaz *et al.*, 1997; Rodrigues *et al.*, 2002; Taniguchi *et al.*, 2004, 2005; Roberto *et al.*, 2009).

Inundation events increase the water quality similarity of the river to that of environments of floodable plains, because of the great exchanges of water, sediment, nutrients, and organisms between the different floodplain habitats during these events (Neiff, 2001; Carvalho *et al.*, 2001; Rodrigues *et al.*, 2002; Domitrovic, 2003; Britto, 2006; Thomaz *et al.*, 2007).

Annual inundation is considered the most important ecological phenomenon of the Pantanal in Mato Grosso (Brazil), since in high water periods, around 80% of the surface is covered by water. The metabolism of this biome is greatly influenced by hydrology and nutrient enrichment, which affect the aquatic food chains and terrestrial communities (Abdo & Silva, 2004; Alho, 2008). Water inflow from rivers into lateral plains results in diminished concentration of dissolved oxygen, in carbon dioxide and methane super-saturation, and in intense increase in amounts of suspended solids, mainly of detritus and algae. Suspended organic matter gives a dark color to water and shapes the natural phenomenon of water quality degradation, which is regionally known as "dequada". This phenomenon is caused by the decomposition of submerged terrestrial vegetation and has as a consequence a high rate of fish mortality (Oliveira & Calheiros, 2000; Alho, 2008).

Junk (1980) also reported on the water quality degradation after the rise periods in Amazonian lakes of the "várzea" related to organic matter increase after the inundation of terrestrial vegetation. In some periods, anoxia that resulted in fish death was observed in the aquatic environments.

Diminution in values of some limnological variables, such as electrical conductivity and nitrogen and phosphorus concentrations, both caused by dilution after the water level increase, appears to be a common pattern for the river-floodplain systems during the rise periods. Nevertheless, fertilization after inundation events by nutrients from inundated littoral zones is also observed, as was evidenced by Rodrigues *et al.* (2002) and Rocha & Thomaz (2004) in lateral lakes of the Upper Paraná River and by Britto (2006) in Catalão Lake in the floodplain of the Solimões River in the Amazon floodplain.

Although the homogenizing effect of the flood pulse in landscape is apparently a consensus (Pringle, 2001; Rocha & Thomaz, 2004; Roberto *et al.*, 2009), the connectivity had an important role on fluctuation of the abiotic variables of water in lagoons. According to Ward & Stanford (1995), connectivity had a great importance on energetic transformations of fluvial landscape, in three dimensions: the longitudinal (headstream to mouth zone), lateral (river-inundation plain) and vertical (river-underground waters). Lateral dimension can be considered as one of the main attributes of the plains affecting the dynamics of floodable ecosystems.

Hydro-electric reservoirs in equatorial regions have modified the local inundation regime and affected the plains located upstream and downstream of the dams (Junk, 1997). In Brazil, the main hydrographic basins have been altered by reservoir construction (Tundisi *et al.*, 2006) carried out to meet the continuous energy demand. They are also used for discharge control, recreation, navigation, water supply, and effluent removal (Julio-Junior *et al.*, 2005). According to Henry (2003), dams in rivers produce a fluvial discontinuity of anthropic origin that leads to serious ecological implications, because water damming causes organic matter, energy, and nutrient retention.

Mouth zones of tributaries into reservoirs present characteristics similar to wetland areas. However, amplitude, duration, and frequency of inundation pulses throughout the year are affected by dam operation, because water storage in reservoirs acts as a "plug system" of hydrologic pulses of the tributaries (Henry, 2005; Henry *et al.*, 2006). Although the Paranapanema River has been transformed into a series of reservoirs in cascade, the study area retains several lagoons with similar ecological characteristics to a flood plain, but also submitted to hydrological regime of the operation of Jurumirim dam.

The aim of this paper was to recognize the reservoir influence and verify possible modifications in abiotic variables of water in the Paranapanema River and three lateral lagoons with different connectivity to the lotic system in the mouth zone into the Jurumirim Reservoir during the inundation period.

MATERIALS AND METHODS

The Paranapanema River-Jurumirim Reservoir transition zone (located between 23°08'S and 23°35'S; 48°30'W and 49°13'W) and studied lagoons (Camargo, Coqueiral and Cavalos lagoons) are located in the southeast region of São Paulo State, Brazil (Fig. 1). The site is characterized by significant reduction

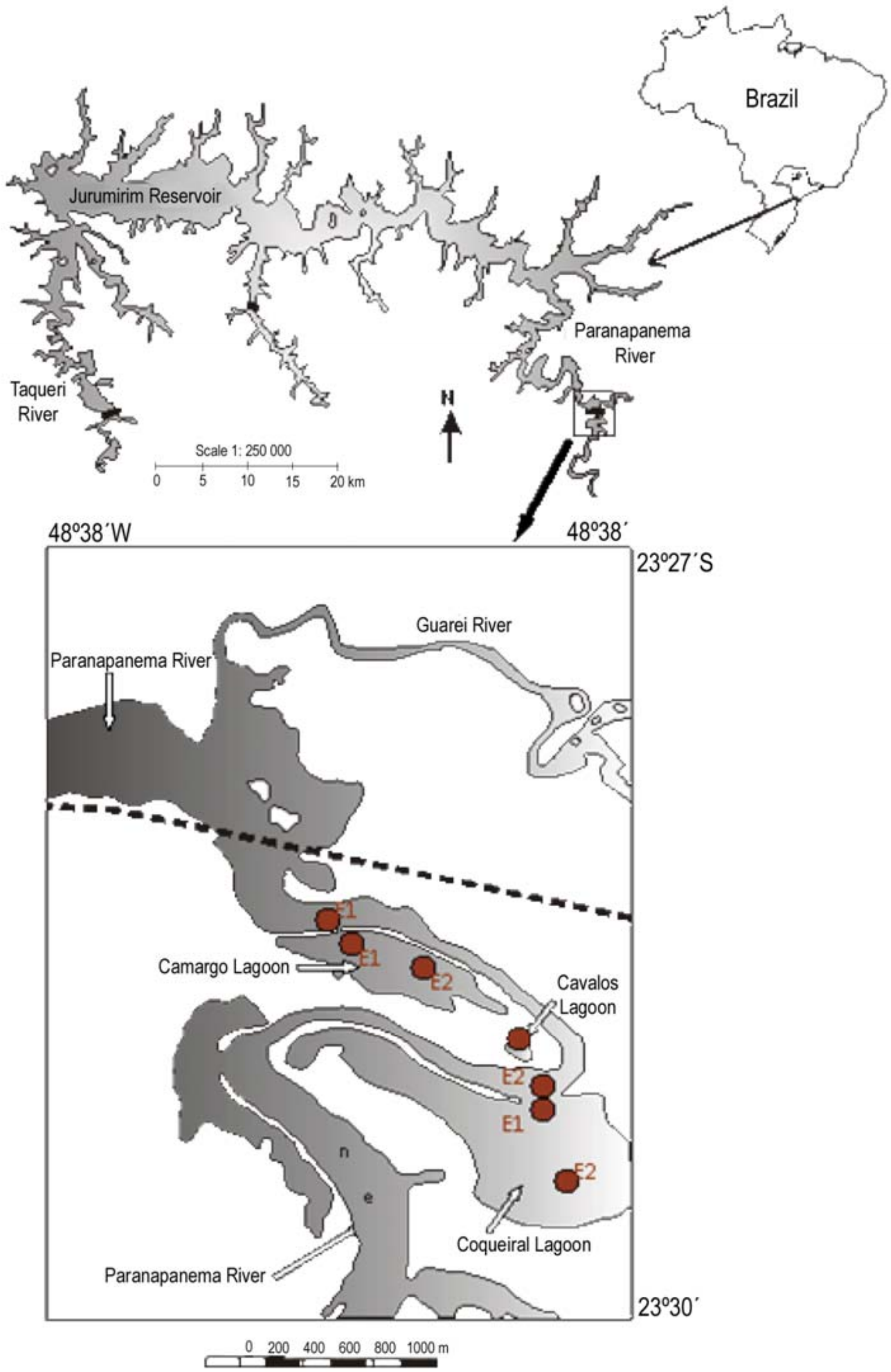

Figure 1. Sampling stations (in red) in the studied lateral lagoons in transition region of the Paranapanema River-Jurumirim Reservoir (São Paulo, Brazil).

Figura 1. Estaciones de muestreo (en rojo) en las lagunas laterales estudiadas en la zona de transición del río Paranapanema-Represa Jurumirim (São Paulo, Brasil).

in water flow (Casanova & Henry, 2004) and by a great sedimentation rate of allochthonous material conveyed by the river (Henry & Maricato, 1996). Camargo, Coqueiral, and Cavalos lagoons present distinct morphometric characteristics (Table 1) and different degrees of connectivity with the Paranapanema River.

For three months (from November 11, 2004 to February 10, 2005), sub-surface water samples were collected at two stations in the Paranapanema River

Table 1. Minimum, maximum, means, and standard deviations of abiotic variables at stations 1 and 2 of the Paranapanema River and Camargo, Coqueiral, and Cavalos lagoons during the intensive study period. The letters correspond to months of sampling (N: November, D: December, J: January, F: February).

Tabla 1. Mínimos, máximos, medias y desviaciones estándar de las variables abióticas en las estaciones 1 y 2 del río Paranapanema y de los lagunas Camargo, Coqueiral y Cavalos durante el período de estudio intensivo. Las letras corresponden a los meses de muestreo (N: noviembre, D: diciembre, J: enero, F: febrero).

Variables		River		Camargo Lagoon		Coquerial Lagoon		Cavalos Lagoon
		1	2	1	2	1	2	
Temperatura (ºC)	Min./Month	20.9/D	21.1/D	20.9/D	20.6/D	20.3/D	20.4/D	20.5/D
	Max./Month	24.9/J	24.7/J	27.5/J	27.7/J	26.7/J	28.1/J	27.3/J
	X/SD	22.8/1.0	22.8/1.1	24.1/1.7	24.0/1.7	24.0/1.7	24.3/1.9	24.5/1.6
Condutivity (µS cm^{-1})	Min./Month	40/J,F	40/J,F	47/J	47/J	48/J	50/J,F	54/D
	Max./Month	82/D	82/D	67/N	67/N	72/N,D	77/N	122/F
	X/SD	55/11	55/10	56/6	56/6	59/7	61/8	75/18
Transparency (m)	Min./Month	0.17/J	0.17/J	0.28/D	0.31/N	0.32/J	0.34/J	0.40/F
	Max./Month	0.76/D	0.72/D	0.59/F	0.55/F	0.73/J	0.74/J	1.10/F
	X/SD	0.47/0.2	0.48/0.2	0.39/0.1	0.40/0.1	0.48/0.1	0.52/0.1	0.86/0.2
Suspended Matter (mg^{-1} L)	Min./Month	10/D	12/D	9/D	8/D	7/F	5/N	1/D
	Max./Month	78/J	91/J	31/N	41/F	32/N	53/N	38/F
	X/SD	35/23	35/23	17-jun	17-jul	16-jun	16-sep	09-oct
Alcalinity (meq^{-1} L)	Min./Month	0.256/J	0.248/J	0.282/J	0.294/J	0.312/F	0.306/F	0.376/D
	Max./Month	0.460/D	0.457/N	0.416/D	0.406/N	0.465/D	0.481/D	0.801/F
	X/SD	0346/0.1	0.349/0.1	0.355/0.1	0.355/0.1	0.385/0.1	0.396/0.1	0.525/0.1
Disolved oxygen (mg^{-1} L)	Min./Month	3.1/D	5.7/D	4.4/J	5.7/D	3.5/D	2.5/D	0/F
	Max./Month	11.2/N	10.9/N	10.7/N	10.3/N	8.5/N	7.4/D	4.7/N
	X/SD	8.0/1.3	8.1/1.0	7.5/1.3	7.5/1.1	6.5/1.3	5.8/1.2	2.8/1.5
Total phosphorus (µg^{-1} L)	Min./Month	20/F	14/F	21/F	20/F	13/F	19/F	25/J
	Máx./Mopnth	85/J	100/J	125/D	88/N	102/J	90/J	260/J
	X/SD	42/15	47/20	45/21	48/17	48/23	43/20	69/57
Total nitrogen (µg^{-1} L)	Min./Month	288/J	306/D	208/D	231/J	193/F	202/J	348/J
	Max./Month	791/J	794/J	667/J	614/N	915/N	890/N	1597/F
	X/SD	496/178	493/183	428/121	433/112	515/202	431/186	836/313
Nitrate (µg^{-1} L)	Min./Month	47/J	69/F	26/D	17/J	16/D	0/J,F	0/N,D
	Max./Month	180/D	338/N	208/N	149/N	200/N	287/N	100/J
	X/SD	123/31	133/51	64/37	58/32	76/45	64/62	13/28
Nitrite (µg^{-1} L)	Min./Month	5/J	5/J	3/J	0/J	0/J	5/J	0/J
	Max./Month	47/N	45/N	22/D	23/D	32/D	39/N	49/F
	X/SD	18-oct	18-sep	14-may	14-jun	17-jul	18-jul	20/13
Ortophosphate (µg^{-1} L)	Min./Month	13/N	12/F	18/J	1/F	8/F	3/F	18/J
	Max./Month	65/J	56/J	115/D	76/D	88/J	82/J	161/F
	X/SD	33/12	32/12	38/19	35/14	35/18	33/16	49/37
Inorganic phosphate (µg^{-1} L)	Min./Month	9/F	5/N	8/N	0/F	7/F	3/F	6/J
	Max./Month	56/J	38/D	52/D	42/D	38/D	32/D	107/F
	X/SD	22-nov	20-sep	24-oct	23-sep	19-ago	19-ago	29/24
Silicate (mg^{-1} L)	Min./Month	0.9/F	1.0/F	0.9/F	0.9/F	1.0/F	0.9/F	1.8/N
	Max./Month	6.7/N	7.3/N	7.5/N	8.0/D	6.8/N	6.9/	10.6/F
	X/SP	4.2/1.6	4.7/1.5	5.4/1.5	5.4/1.8	4.5/1.5	4.9/1.4	3.7/1.9

and in Camargo and Coqueiral lagoons each and at one station in Cavalos Lagoon for the determination of temperature (with a Toho Dentam ET-3 thermistor), electrical conductivity (with a Hatch conductivity meter, values corrected to 25°C, according to Golterman *et al.*, 1978), water flow (with an ELE current meter), water transparency (with a Secchi disk), suspended matter (Teixeira & Kutner, 1962), alkalinity (Mackereth *et al.*, 1978), pH (with a Micronal B380 pHmeter), dissolved oxygen (Winkler method, described in Golterman *et al.*, 1978), total nitrogen, nitrite, and nitrate (Mackereth *et al.*, 1978), ammonium (Koroleff, 1976), total phosphorus, total dissolved and inorganic phosphates (Strickland & Parsons, 1968), and reactive silicate (Golterman *et al.*, 1978). To obtain vertical thermal profiles of the environments, temperature was measured at every 0.1 m up to 1.0 m of depth in the Paranapanema River and down to the bottom of the lagoons.

Rainfall data from the E-5-017 pluviometric station located at the town of Angatuba (approximately 30 km from the study area) were supplied by the Departamento de Águas e Energia Elétrica-DAEE (Department of Water and Electric Energy). Water level values were supplied by the operation division of the Jurumirim Reservoir dam of the Duke Energy Company. According to Pompêo *et al.* (1999), a correspondence between variation patterns of water level in dam and mouth zones of the Paranapanema River into the Jurumirim Reservoir can be observed.

A Principal Component Analysis (PCA) was performed, in which all variables were used, except the concentration of dissolved nutrients, which already embedded in the values of concentrations of total nitrogen and phosphorus. Data were conducted from covariance matrixes with data transformed by ranging of variation amplitude ($[(x - x_{min})/(x_{max} - x_{min})]$) to verify the temporal and spatial distribution of sample unities as a function of the analyzed limnological variables. Data were transformed with the FITOPAC program (Shepherd, 1996) and multivariate analyses with the program PCORD version 3.1 for Windows (McCune & Meford, 1997).

Preliminary analyses were carried out with data from all study stations, but due to the great number of overlapping sampling unities, the graph was extremely polluted. Data of the two stations in each environment was grouped; thus, to conduct a PCA, data of station 2, which is located in the middle of each water body, were selected.

RESULTS

Sampling began on November 11, after the first rains in October 2004. Frequency and intensity of rainfall increased of the November at January. In February 2005, no rainfall episode was observed in the sampling site (Fig. 2). The water flow of the Paranapanema River increased from November 2004 to February 2005). From the middle of January 2005,

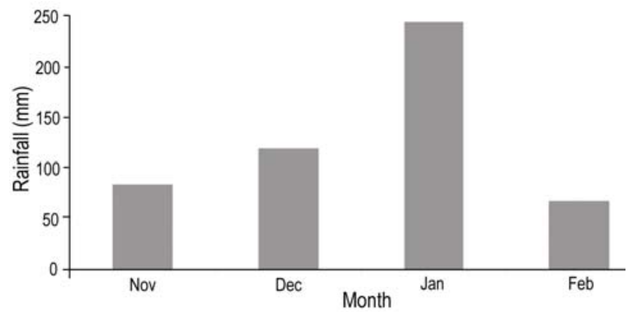

Figure 2. Monthly values of rainfall (mm) during the intensive study period.

Figura 2. Valores mensuales de precipitaciones (mm) durante el período de estudio intensivo.

high values (> 0.7 m s^{-1}) were always observed (Fig. 3). Hydrologic level variation of the Paranapanema River was 2 m during the intensive study period. At the beginning (November 11, 2004), the recorded stage value increased continuously, with the greatest value was attained in the last measurement of the intensive study (February 2005) (Fig. 4).

The temperature fluctuated at the surface of the water bodies, the lowest and highest values were recorded in December 2004 and January 2005, respectively (Table 1). In Camargo Lagoon, isothermy predominated during the study, and in Coqueiral Lagoon during half of the period. In this environment, however, the thermal gradient between the surface and bottom was up to 3°C in some episodes. In Cavalos Lagoon, temperature differences attaining 3°C in the vertical profile were observed in 16 of the 27 measurements.

In the Paranapanema River, the lowest values of the water electrical conductivity were recorded at the beginning of the study and the highest at the end of January 2005. In Camargo and Coqueiral, values fluctuated similarly to those of the river. In Cavalos Lagoon, mean electrical conductivity in the study period was 74.5 µS cm^{-1}, increased in February 2005, the values were higher than 110 µS cm^{-1} (Table 1). In this lake, the highest values of water transparency were observed, among all ecosystems (Table 1). The highest suspended matter values were obtained in December, 2004, in all water bodies. The highest mean and maximum concentrations were observed in the river; in the lagoons, the values did not exceed 17 mg L^{-1} (Table 1). In the Paranapanema River and connected lagoons (Camargo and Coqueiral), the lowest water alkalinity values was observed in January-February 2005 and the highest in November and December 2004; the variation was small, while in Cavalos Lagoon, the variation was more intense (Table 1). In this isolated lagoon, the concentration

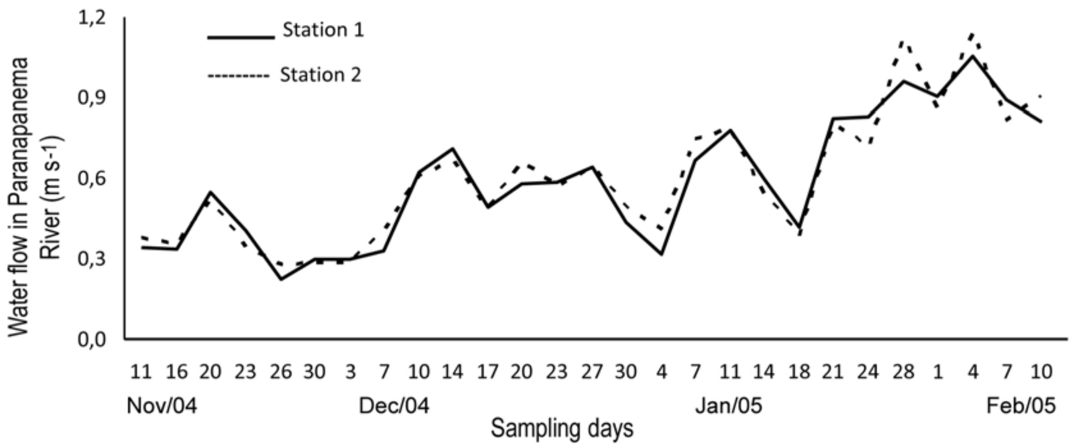

Figure 3. Water flow (m s^{-1}) at stations 1 and 2 of the Paranapanema River during the intensive study period.

Figura 3. Velocidad del flujo de agua (m s^{-1}) en las estaciones 1 y 2 del río Paranapanema durante el período de estudio intensivo.

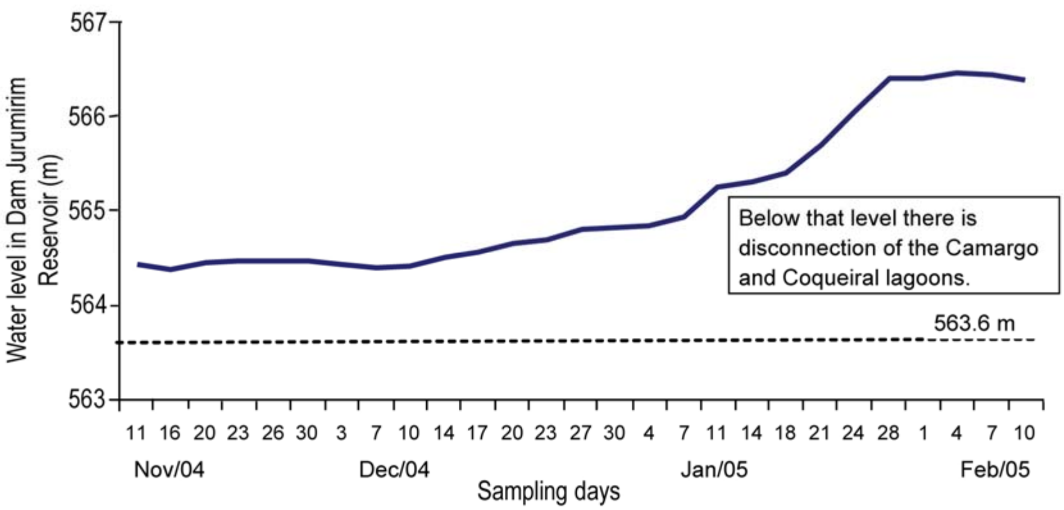

Figure 4. Water level (m) variation at the dam zone of the Jurumirim Reservoir. The horizontal line at the 563.6 m stage corresponds to the frontier between the separation and connection of lagoons with the river.

Figura 4. Variación del nivel de agua (m) en la zona del embalse de la Represa de Jurumirim. La línea horizontal en la etapa de los 563,6 m corresponde a la frontera entre la separación y conexión de las lagunas con el río.

of dissolved oxygen was lower; in some periods was zero. In the Paranapanema River and connected lagoons, the values of dissolved oxygen was higher. The highest mean (around 8.0 mg L^{-1}) was observed in the river (Table 1). In the isolated lagoon (Cavalos Lagoon), high nutrient concentrations were recorded in January, except for total phosphorus and nitrate. The highest mean nutrient concentrations were found in Cavalos Lagoon, except for nitrate (Paranapanema River) and silicate (Camargo Lagoon). The minimum concentrations predominated in January and February, 2005, and the maximum was observed at the beginning of the study (Table 2).

The Principal Component Analysis (PCA) revealed the mean tendencies in temporal and spatial scales and showed that data from Cavalos Lagoon presented behavior which was distinct from the other environments. All measurements of Cavalos Lagoon were distributed on the right side of axis 2, where some data of Coqueiral Lagoon were also inserted (Fig. 5). On the left side, the sample unities of Camargo Lagoon and Paranapanema River were concentrated. Above axis 1, the majority of values from the river and data from the end of January and beginning of February of the connected lagoons (Camargo and Coqueiral) are evidenced and are linked to high levels of suspended

Table 2. Pearson Correlation coefficients of abiotic variables measured during the intensive study period with the first two axes of Principal Component Analysis (n = 108).

Tabla 2. Coeficientes de correlación de Pearson de las variables abióticas medidas durante el período de estudio intensivo con los primeros dos ejes del Análisis de Componentes Principales (n = 108).

Variables	Abbreviatures	Principal components	
		Axis 1	Axis 2
Alcalinity	Alk	0.939	-0.039
Electrical condutivity	Cond	0.893	-0.001
pH	pH	0.023	-0.682
Dissolved oxygen	OD	-0.832	-0.019
Suspended matter	SST	-0.338	0.648
Temperature	Temp	0.282	-0.524
Transparency of water	Transp.	0.563	-0,411
Nitrogen	NT	0.767	0.304
Phosphate	PT	0.632	0.542
Hidrometric level	Cota	0.083	0.639
Explicability		35.3%	19.5%

matter and dissolved oxygen concentrations. The majority of values from November and December 2004, and January 2005, of the three marginal lagoons are below axis 1 and are associated with low levels of the river. Data from the end of the study, especially from Cavalos Lagoon, were separated from the rest due to the high nitrogen and phosphorus concentrations. The first two axes of PCA corresponded to 54.8% of the variability of abiotic data (Fig. 5, Table 2).

DISCUSSION

Mixing processes of lentic systems are mainly associated with thermal structure in a water column. In lagoons of floodable areas, mixing mechanisms are also influenced by water input from adjacent rivers during the rise and high water phases (Huszar, 1994). lagoons located at the mouth of the Paranapanema River into the Jurumirim Reservoir presented a distinct thermal pattern because of several characteristics. In Camargo Lagoon, isothermy predominated due to the great influence of water inflow from the Paranapanema River after the channel enlargement of the connection between the two environments at the beginning of the study by a fisherman, to make it easier for his boat to enter the lake. Coqueiral Lagoon remained isothermic during half of the study, but both lentic systems (Camargo and Coqueiral) presented thermal gradients form surface to bottom on some days related to increases in air temperatures. In the isolated environment (Cavalos), thermal stratification was evidenced during half of the study and could be linked to low depth of the lagoon (Panarelli, 2004). It is likely that thermal gradients in Cavalos Lagoon present a short duration, since in shallow tropical lagoon, daily temperature differences are higher than seasonal variations (Esteves, 1998).

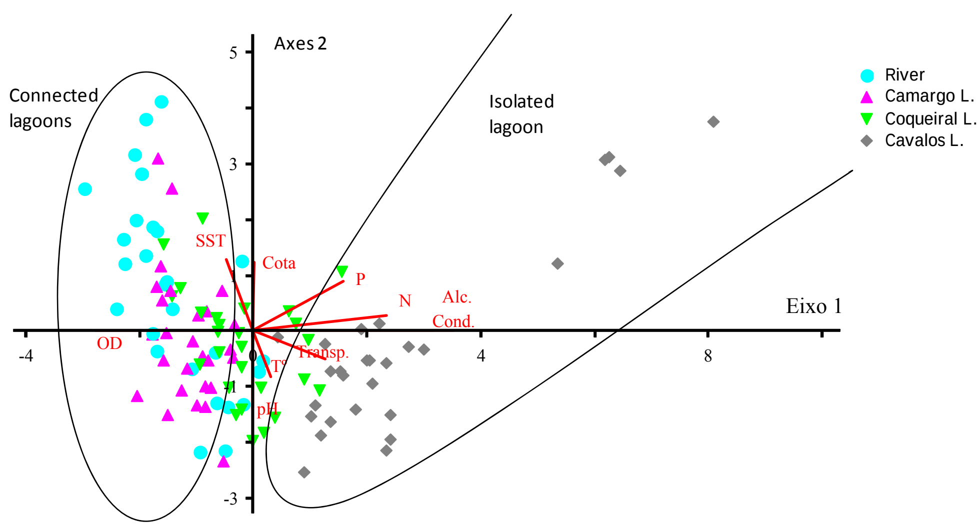

Figure 5. Ordination by Principal Component Analysis on axes 1 and 2 of abiotic characteristics in the sampling station (Paranapanema River and Camargo, Coqueiral, and Cavalos lagoons). Abbreviations of abiotic variables are presented in Table 2.

Figura 5. Ordenación por medio del análisis de componentes principales, en ejes 1 y 2 de las características abióticas en los ambientes de muestreo (Paranapanema y en los lagunas Camargo, Coqueiral y Cavalos). En Tabla 2 se presentan las abreviaturas de las variables abióticas.

In the southeast of Brazil, the rainfall period occurs in the hottest season of the year. During the study, the more intense rains occurred in January. Slow increases in water level were observed in December with a further increase in January. Effects of inundation pulses were recorded from the middle of the month on.

In the Paranapanema River, the main alterations related to water level were the increase in suspended matter concentrations and the decrease in Secchi disk readings from January 7 2005, and the increase in current velocity from January 21st. Modifications of these variables associated with water area were related to rainfall increase, as was also observed by Moccellin (2006) and Benassi (2006) in the floodplain of Jacupiranga River (São Paulo). The high suspended matter concentrations and the reduced transparency values are due to allochthonous material inputs from adjacent areas and from watershed, especially during rainfall episodes and the rise period. Similar findings were reported in other studies of floodplains (Oliveira & Calheiros, 2000; Rodrigues *et al.*, 2002; Taniguchi *et al.*, 2004, 2005; Alho, 2008). Reductions in water alkalinity, electrical conductivity, and dissolved oxygen were observed at the end of January, 2005, in the Paranapanema River and connected lagoons (Camargo and Coqueiral). Alkalinity and conductivity diminutions were related to dilution effect due to water level increase and the decrease in dissolved oxygen, due to the degradation process of organic matter conveyed from a lateral plain.

Variations in abiotic factors of connected lagoons presented a similar behavior to that of the Paranapanema River. PCA confirmed similarity, since the majority of sample units of the three environments were assembled (Fig. 5). Measurements from the beginning of the study were related to low water levels and measurements from the end were linked to high stage values. No evident influence of inundation pulses was observed on water physical and chemical variables, a fact that can be related to turbinated water discharge control from the operation sector of the Jurumirim Reservoir, since the studied lacustrine environments are submitted to control of the dam division (Costa & Henry, 2002). However, a reduction in the majority of abiotic characteristics was verified at the end of January, when a significant increase in water level of the environments was observed. The values, however, then became similar to those recorded in the period before the water level increases.

According to PCA, significant modifications in the majority of abiotic variables were found in Cavalos Lagoon after the increase of water volume in the lagoon by underground flow from the river (Carmo, 2007). A reduction in dissolved oxygen concentrations (from a mean value corresponding to 3.3 mg L^{-1} to an anoxic condition) due to an increase in oxygen biochemical demand for the degradation of organic matter from submerged plants of the littoral zone was then observed. Costa & Henry (2002) also recorded a drastic diminution of dissolved oxygen to a mean value of 1.5 mg L^{-1} in Cavalos Lagoon in the rainy season. However, Martins & Henry (2004) did not find a significant reduction in dissolved oxygen in Cavalos Lagoon during the water rise period, despite the high amounts of suspended matter associated with decomposition of submerged organic matter. Significant increases in alkalinity values (from 0.471 to 0.809 meq L^{-1}) were recorded due to an increase in carbon dioxide contents released after the decomposition of flooded plants. Similarly, Costa & Henry (2002) found, during the dry period, an increase in mean values from 0.28 to 0.85 meq L^{-1}. Similar increases were observed for electrical conductivity, from 66.6 to 122.4 µS cm^{-1} (this study) and from 46.2 to 92.3 µS cm^{-1} (Costa & Henry, 2002), and were also due to the decomposition of submersed littoral vegetation of Cavalos Lagoon. Martins & Henry (2004), however, found a reduction in water electrical conductivity during the rise period that was attributed to dilution effect by the water stored in the isolated lagoon.

The similar pattern of variation of water abiotic attributes between the Paranapanema River and the connected water bodies (Camargo and Coqueiral lagoons) could be explained by the permanent association of the lagoons with the river, because the connectivity increase produces water, sediment, nutrient and organism exchanges between the floodplain environments (Neiff, 2001; Domitrovic, 2003).

As in Thomaz *et al.* (2007), inundation connects water bodies with different hydrologic characteristics within the landscape, resulting in a similarity of ecological processes and biotic communities in the different environments. Habitat homogeneity after inundation can be considered to be a general pattern for the river floodplain systems in the High Paraná floodplain (Thomaz *et al.*, 2007) and other sites (Carvalho *et al.*, 2001).

After a study of seasonal variation in chemical and physical factors in the same ecosystems, Granado & Henry (2008) also observed that Camargo and Coqueiral lagoons presented a similar fluctuation pattern to that of the lotic system, while in the isolated lagoon (Cavalos), a distinct behavior with great fluctuation in the abiotic parameters was recorded. Despite the fact that management of Jurumirim Reservoir causes modifications in the natural hydrologic regime of the river, alterations in physical and chemical factors are comparable to those described for the floodplains. During the inundation episodes, changes in water quality were affected, initially by dilution resulting from the increase in hydrologic level, and later by the increase in nutrient concentrations from the decomposition of submersed littoral vegetation.

Dilution process caused by lateral water from the river, followed by the fertilization of water together with the decomposition of flooded vegetation has been observed in several studies, it shows by the Rodrigues *et al.* (2002) and Rocha & Thomaz (2004) data in the backwaters of the Upper Paraná River and, Britto (2006) data in Amazonian floodplain lagoons. In this study, the dilution process followed by a great fertilization on waters was observed in the Cavalos lagoon. Highest concentrations of total and dissolved nutrients was recorded in all the sampling period comparing the three lagoons, as well as the highest values of alkalinity and conductivity and the lowest concentrations of dissolved oxygen. In connected lagoons (Camargo and Coqueiral), the effects of increasing the volume of water in physical and chemical variables were little evident, since that Jurumirim reservoir acts as a buffer of hydrologic pulses (Henry, 2003, 2005). Similarity on abiotic characteristics of waters in Camargo and Coqueiral lagoons with Paranapanema River can be attributed to lateral connectivity during the major part of study, as it was seen in PCA. Similar observations were made by Rodrigues & Bicudo (2001), Rocha & Thomaz (2004), Abdo & Silva (2004) and Roberto *et al.* (2009).

According to Henry (2005), lagoons lateral to the Paranapanema River in the mouth region into Jurumirim Reservoir can be classified as one of three types: lagoons with great connectivity with the river (Coqueiral Lagoon), lagoons with low connectivity (Camargo Lagoon) and lagoons isolated from the river (Cavalos Lagoon). Panarelli (2004) and Casanova *et al.* (2009) related the structural and functional differences between the three lacustrine environments during a drought period and after the recovery of connectivity with the river. However, an increase of the channel width by human alteration between Camargo Lagoon with Paranapanema River, changing the connectivity from low to high, resulted in a similarity in the water physical and chemical variables of this lagoon with Coqueiral and Paranapanema River.

In conclusion, during the inundation episodes, changes in water quality were affected, initially by dilution resulting from the increase in hydrologic level, and later by the increase in nutrient concentrations from the decomposition of submersed littoral vegetation observed in the Cavalos Lagoon. In connected lagoons (Camargo and Coqueiral), the similarity on abiotic characteristics of waters with Paranapanema River can be attributed to lateral connectivity; the effects of increasing the volume of water in limnological variables were little evident, since that Jurumirim reservoir acts as a buffer of hydrologic pulses. Thus the flutuations on water physical and chemical characteristics during the study period in marginal lagoons and Paranapanema River were influenced by two anthropic actions of different scales. The first, the oldest at regional level, is a result from water storage in Jurumirim Reservoir and from the buffer effect in the hydrological regime at study area. The second, at local level, is characterized by the channel widening of association of Camargo Lagoon with the river, changing the connectivity level, increased similarity of the lagoon with the lotic system.

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