Physical and chemical characteristics of Lavapés and Capivara rivers, tributaries of Barra Bonita Reservoir (São Paulo – Brazil).

MORETTO, E.M.[1] & NOGUEIRA, M.G.[1]

[1] **Department of Zoology, Institute of Biosciences, UNESP, Rubião Junior, 18618-000, Botucatu, São Paulo, Brazil.**

ABSTRACT: Physical and chemical characteristics of Lavapés and Capivara rivers, tributaries of Barra Bonita reservoir (São Paulo – Brazil). **A limnological study was carried out during winter (dry period) and summer (rainy period) in the lower stretches of the rivers Capivara and Lavapés, as well in the transitional zone of these rivers mouth into Barra Bonita reservoir (river Tietê, SP). Water quality differences between the rivers and rivers-reservoir system were efficiently detected by variations in the values of conductivity, dissolved oxygen, dissolved and total phosphorus, total nitrogen, nitrite, ammonium and suspended solids. The limnological conditions in the Lavapés are strongly conditioned by the untreated sewage loads received from the city of Botucatu in the river upper stretches. The significative altitudinal difference between the upstream and downstream regions certainly increases the natural capacity of the river self-purification. However, the water observed in the lower stretch is still very rich in nutrient making this river an important contributing factor for the eutrophication of Barra Bonita reservoir. Despite of the siltation, the summer rains promote a dilution on the nutrient concentration. The conservation of native vegetation is critical for both basins, but the problem is even worst for Lavapés. In case of Capivara other important factor of degradation is the drainage of original wetland areas ("várzeas") for agricultural purposes. Thus, during the rainy season there is a remarkable increase of solids concentrations in both rivers. As a consequence high loads are introduced into the reservoir. In this process the contribution of Capivara is higher as its volume increases more in summer. This is because the Capivara watershed is larger and also receives a higher number of small tributary streams. The precipitation cycle has not the same direct effects in the reservoir main channel. At least in terms of hydrodynamics, as the reservoir depth showed higher dependence on the dam operation. The limnological conditions in the region of the reservoir located in front of the rivers mouths were different from the ones found in the rivers themselves. Therefore, the rivers influence is limited, probably due to the small contribution in terms of volume. Nevertheless, on a long-term scale it can not be neglected their cumulative impact on Barra Bonita reservoir, which is already an eutrophic system.**
Key-words**: reservoir tributaries, physical and chemical variables, spatial and temporal variation.**

RESUMO: Características físicas e químicas dos rios Capivara e Lavapés, tributários do reservatório de Barra Bonita (São Paulo, Brasil). **Um estudo limnológico foi realizado nos trechos inferiores dos rios Capivara e Lavapés, bem como na região de suas desembocaduras junto ao reservatório de Barra Bonita (rio Tietê, SP). As amostragens foram feitas em duas épocas do ano, inverno (período seco) e verão (período chuvoso). Diferenças na qualidade de água entre os rios e destes com a zona sob influência do reservatório foram eficientemente detectadas pela variação dos valores de condutividade elétrica, oxigênio dissolvido, fósforo dissolvido e total, nitrogênio total, nitrito, amônio e sólidos em suspensão. As condições limnológicas no rio Lavapés são fortemente condicionadas pela entrada, ainda no trecho superior, de todo o esgoto não tratado da cidade de Botucatu. A considerável diferença altitudinal**

entre as zonas de cabeceira e desembocadura certamente contribui para uma maior capacidade de auto-depuração do sistema. Contudo, a água observada no trecho inferior ainda apresenta elevadas concentrações de nutrientes, o que torna este rio um importante fator contribuindo para a eutrofização do reservatório de Barra Bonita. Apesar do aumento da turbidez, o aumento das chuvas no verão promove uma diluição na concentração de nutrientes. O estado de conservação da vegetação é crítico em ambas as bacias, sendo ainda pior para o Lavapés. No caso do Capivara outro importante fator de degradação é a drenagem de áreas de várzea originalmente presentes ao longo da bacia, para fins de ocupação agrícola. Assim, durante a estação das chuvas há um considerável incremento na concentração de sólidos suspensos em ambos os rios. Como conseqüência elevadas cargas são introduzidas no reservatório. Neste processo a contribuição do Capivara é maior, já que seu volume aumenta muito mais no verão devido a maior extensão de sua bacia e número de tributários. O ciclo sazonal de precipitações não tem o mesmo efeito direto no reservatório. Pelo menos em termos hidrodinâmicos, já que a profundidade no compartimento estudado mostrou-se mais influenciada pelos mecanismos de operação na barragem. As condições limnológicas na região do reservatório localizada em frente as zonas de desembocadura mostraram-se diferenciadas daquelas encontradas nos próprios rios. Assim, a influência dos mesmos sobre o reservatório é limitada, devido a pequena contribuição em termos de volume. Contudo, o impacto cumulativo destes tributários sobre Barra Bonita não pode ser negligenciado.
Palavras-chave: **reservatório, tributários, variáveis físicas e químicas, variação espaço-temporal.**

Introduction

Several studies carried out in the reservoir of Barra Bonita (middle Tietê river, São Paulo, Brazil) have covered different limnological aspects (Esteves et al., 1981; Tundisi, 1981; Matsumura-Tundisi et al., 1981; Henry et al., 1985; Henry, 1986; Henry & Simão, 1988; Tundisi, 1988; Calijuri & Tundisi, 1990; Matsumura-Tundisi et al., 1990; Tundisi, 1990; Tundisi & Matsumura-Tundisi, 1990, Novo et al., 1993). In terms of the reservoir spatial structure the main considered characteristics are the ones related to the longitudinal processes associated to the influence of the Piracicaba and Tietê rivers. However, there is little information on the influence of other tributaries. In terms of water fluxes, the role of these small or middle rivers is limited, but the regional contribution can be significant as they came from different rural and urban areas.

In addition to the typical longitudinal gradients in physical, chemical and biological characteristics observed in river-valley reservoirs (Kimmel et al., 1990; Urabe, 1990; Armengol et al., 1999), the presence of lateral compartments, such as the ones created by the entrance of tributaries, can affect significantly the spatial structure of this kind of ecosystem (Wetzel, 1990; Straskraba et al., 1993; Tundisi, 1994; Betsil & Van Den Avyle, 1994; Oliveira & Calijuri, 1996; Nogueira et al., 1999). The presence of either permanent or periodic wetlands in the mouth zones of tributaries is another contributing factor that can have a relevant ecological role in large compartments of the reservoirs, or even in the whole ecosystem. In general, such areas are important in the cycling of nutrients and in the maintenance of trophic resources and aquatic biodiversity (Tundisi, 1988).

The characteristics of the river waters depend on the soil type, the extension and composition of the vegetation and the human interference in the watershed (Pedroso et al., 1988). Thus, the water quality of reservoirs will be determined by their tributaries. In case of large reservoirs, a spatial variability in a macro geographical scale can be identified when major rivers contribute with diverse sources of particulated and dissolved material. This seems to be the case of large reservoirs in the State of São Paulo, such as Barra Bonita (Tundisi, 1994).

On the left side of Barra Bonita reservoir, approximately 27 km upstream the dam, there is a large lateral compartment (6 km long) originally corresponding to the lower stretches of Capivara and Lavapés rivers. Presently, this area is a typical wetland landscape functioning as a transition zone between the river mouths and the reservoir. In this study, it was analysed some water physical and chemical characteristics of Capivara and Lavapés rivers in their lower stretches as well as the region of the reservoir adjacent to their mouth zones. The aim was to determine the role of lateral tributaries coming from areas under different agriculture and urban influences on the limnology of Barra Bonita reservoir.

Study Area

The study area is located in a district of Botucatu, central region of São Paulo State, between 22°43'12"/22°56'03" S and 48°22'36"/48°29'43" W (Fig. 1). Most of the Capivara (99 km^2 area) and Lavapés (62.5 km^2 area) watersheds are located in a region where the predominant relief is the Basaltic Cuesta of Botucatu. The rivers Lavapés (22.8 km long) and Capivara (21 km long) flow into Barra Bonita reservoir and their mouth zones are nearly positioned (Fig. 1). A remarkable feature of these river basins is the high altimetrical difference when compared with their relatively short extension. The headwaters are located at 900 m (a.s.l.) and the mouth zones at 450 m (a.s.l.).

Despite of the fact that the rivers drain similar areas in terms of geology and geomorphology they are exposed to different human impacts. The whole urban area of Botucatu, with 130,000 inhabitants approximately, are located in the upper zone of the Lavapés watershed and the river receives the domestic and industrial sewage from the city without any treatment. The Capivara river drains rural areas of the municipality.

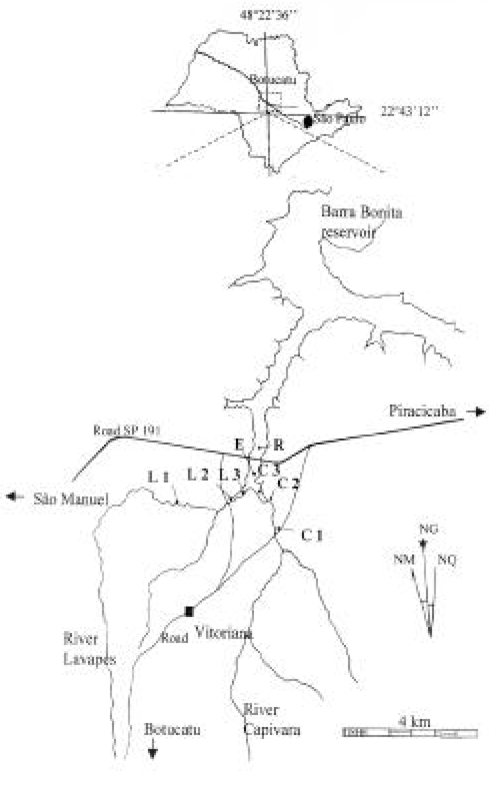

Figure 1: Map of the study area (Source: IBGE 1969) and position of the sampling stations.

Material and Methods

For water sampling and measurements, seven stations were selected: three in the lower stretch of Capivara river (C1, C2 and C3), three in the lower stretch of Lavapés river (L1, L2 and L3) and two in the lateral arm of the reservoir originated by the junction of both river mouths (E and R) (Fig. 1).

Samplings on water surface were carried out in August 1996 (winter/dry period) and in February 1997 (summer/rainy period).

The following limnological variables were determined: transparency (Secchi disk); temperature (mercurial thermometer); dissolved oxygen (Winkler method according to Golterman et al., 1978); pH (pH meter Micronal B-380); electric conductivity (conductivity meter Hach 2511); nitrite (Golterman et al., 1978); nitrate (Mackereth et al., 1989); ammonium (Koroleff, 1976); total and inorganic dissolved phosphate (Strickland & Parsons, 1960); silicate (Golterman et al., 1978); total nitrogen and total phosphorus (Valderrama, 1981). Total, inorganic and organic suspended solids were determined by gravimetry (Millipore AP40 membranes, Mettler analytical balance H20T 0.01 mg) (Cole, 1979) and chlorophyll-*a* of phytoplankton by extraction in cold 90% acetone (Golterman et al., 1978).

The rivers flow was estimated using the floating technique to determine velocities and direct measurements of the transversal section (Linsley, 1978).

The Electric Generation Company (CESP) supplied data on precipitation, reservoir volume, inflow and outflow rates.

A PCA analysis (Statitcf) using log transformed (lnx + 1) values of the limnological data was performed. The variables with correlation higher than 0.80 with the components 1 and 2 of the analysis are presented.

Results

A seasonal regime of precipitation, with concentration of rains in spring and summer and a dry period in autumn and winter was observed (Fig. 2). The peak of rains occurred in January, reaching 517.5 mm in the top of the "Cuesta" (Botucatu station). The anual precipitation in this area (1,692 mm) was relatively higher as compared with the value at the Barra Bonita dam (1,280 mm). July was the driest month, with the minimum of 1.5 mm precipitation found near the dam.

The same temporal pattern was observed for the flow rates, as in the reservoir (Fig. 3) as in the rivers (Tab. I). The highest reservoir inflow (1,231 m^3/s) and outflow (1,072 m^3/s) were observed in January and February, respectively (Fig. 3). The lowest

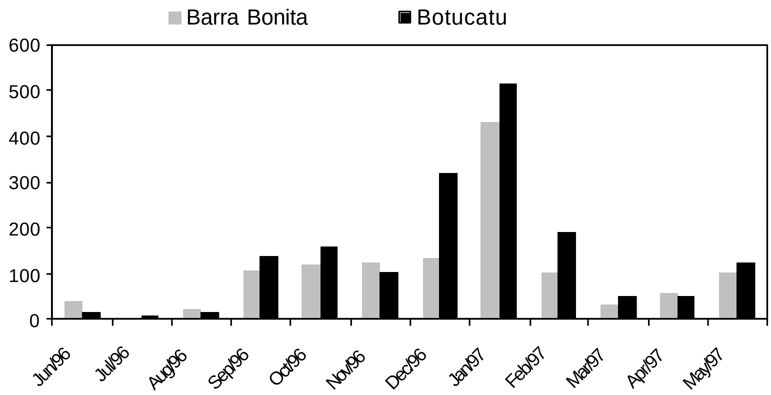

Figure 2: Precipitation (mm) at the CESP-Botucatu and CESP-Barra Bonita during the study period.

outflow (270 m³/s) occurred in July and the lowest inflow (219 m³/s) in August. As a consequence of the flow variation an inverse seasonal tendency was recorded for the water retention time in the reservoir (Fig. 3).

The water column depth ranged from 0.48 m at the C1 station (winter) to 5.97 m at the R station in winter (Tab. I).

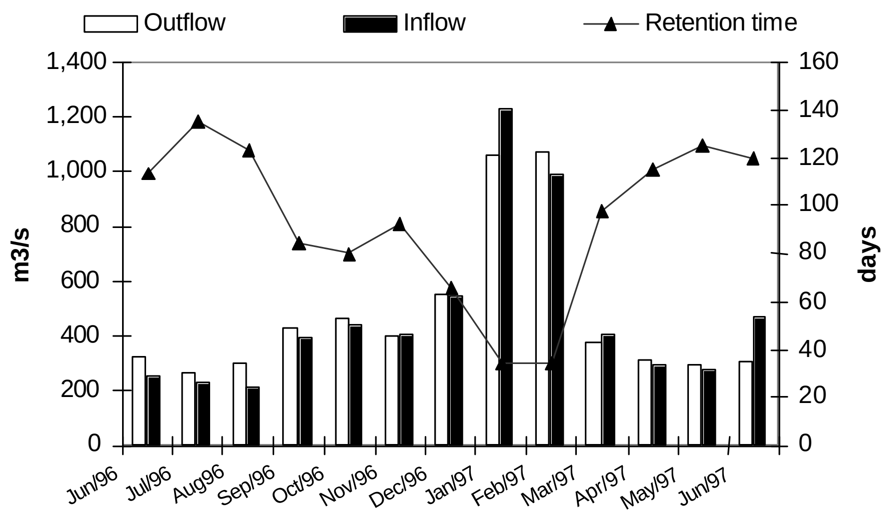

Figure 3: Monthly means of the inflow, outflow and theoretical retention time in Barra Bonita reservoir during the study period.

Table I: Physical variables at the Lavapés (L) and Capivara (C) sampling stations and in Barra Bonita reservoir (station E and R).

Sampling stations	Temperature (°C)		Depth (m)		Transparency (m)		Flow (m³/s)	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
L1	**21.0**	**24.0**	**2.70**	**3.52**	**0.50**	**0.16**		
L2	**19.0**	**22.9**	**1.44**	**3.42**	**0.60**	**0.16**	**2.8**	**4.8**
L3	**19.0**	**22.9**	**1.63**	**0.86**	**0.70**	**0.16**		
C1	**21.0**	**24.2**	**0.48**	**1.75**	**0.48**	**0.37**		
C2	**19.0**	**23.3**	**1.70**	**1.42**	**0.70**	*	**1.2**	**10.2**
C3	**19.0**	**23.3**	**2.50**	**2.68**	**0.80**	*		
E	**19.0**	**23.4**	**1.50**	**1.35**	**0.80**	**0.50**		
R	**19.0**	**26.7**	**5.97**	**3.40**	**1.40**	**0.43**		

*** Missing data**

The variation of water temperature among the sampling stations was higher in the summer (22.9 to 26.7 °C) as compared to the winter (19.0 to 21.0 °C) (Tab. I). There was an increase between 3 and 4 °C in summer temperatures and the maximum was measured at the R station (26.7 °C).

The water transparency in the sampling stations was relatively low and a reduction was observed in the summer (Tab. I). The river Lavapés showed the lowest value (0.16 m, in summer) and the maximum transparency (1.40 m) was observed at the R station in winter. An increase of transparency into downstream direction occurred for both rivers in winter.

pH values near to neutrality in winter, having a range between 6.9 at the L3 station and 7.2 at the R station, were found (Fig. 4). A decreasing upstream-downstream tendency was observed for the Lavapés river in winter. Except for the E station (pH 7.1), a decrease in pH was observed in the summer and the lowest value (pH 6.6) occurred at the C1 station.

Different conductivity ranges among the three sampling sites (Capivara and Lavapés rivers and reservoir) were obtained for both study periods (Fig. 5). Higher values were observed in winter, with the maximum registered at R station (252 mS/cm). In winter the

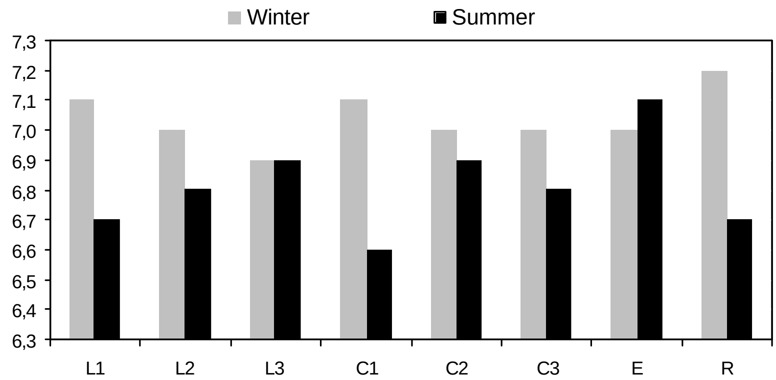

Figure 4: Variation of pH at the Capivara and Lavapés sampling stations and in Barra Bonita reservoir (E and R stations) during the study period.

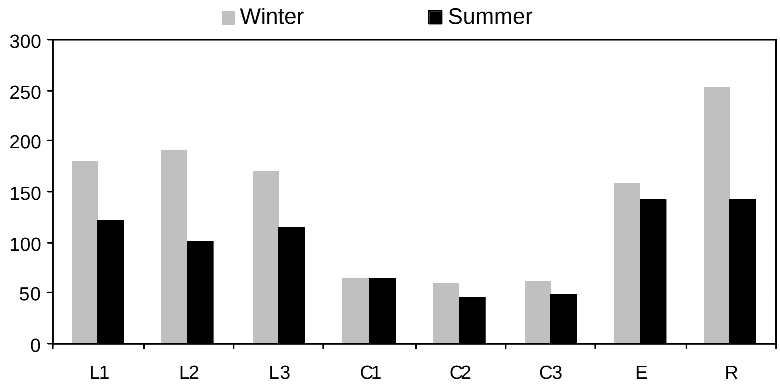

Figure 5: Variation of conductivity (μS/cm) at the Capivara and Lavapés sampling stations and in Barra Bonita reservoir (E and R stations) during the study period.

mean conductivity was 180 μS/cm for Lavapés and 63 μS/cm for Capivara stations. During summer, the mean values were 112 μS/cm for Lavapés, 52 μS/cm for Capivara stations and 142 μS/cm for E and R stations.

Relatively lower variation on dissolved oxygen was recorded in summer (Fig. 6). The lowest concentration was measured at the L1 station (3.91 mg/l) and the maximum at the R station (7.65 mg/l). But in the winter, higher values in river Capivara (mean of 8.33 mg/l) and lower in river Lavapés (mean of 2.97 mg/l) were observed.

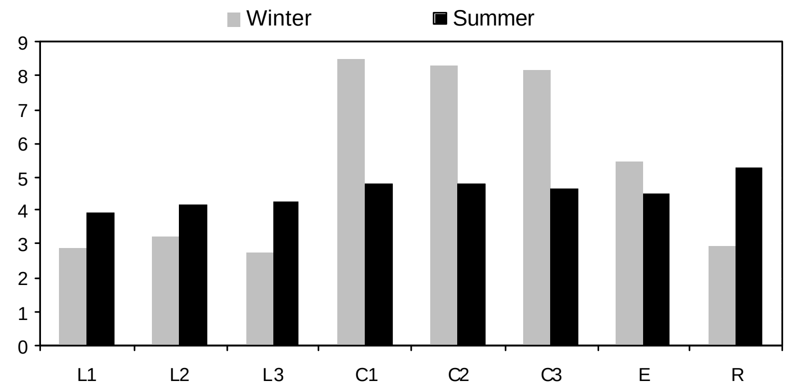

Figure 6: Variation of dissolved oxygen (mg/l) at the Capivara and Lavapés sampling stations and in Barra Bonita reservoir (E and R stations) during the study period.

The nutrient concentrations were higher in winter, except for nitrite (Tab. II). Major nutrient concentrations were found in the Lavapés. But for silicate the values were similar for both rivers, which were higher than the ones in E and R stations.

In summer, nutrient concentrations in Lavapés were also higher than the ones in Capivara for silicate, nitrite, nitrate, ammonium, total nitrogen and total phosphorus.

The nutrient concentrations at R station were relatively high, and for nitrate and total nitrogen, the values were higher than the ones in Lavapés for both periods.

A high increase in the concentration of suspended solids was observed from winter to summer (Tab. III). In winter, a higher proportion of organic matter in Lavapés and reservoir stations was found whereas the inorganic fraction predominated in Capivara stations (Fig. 7). During summer, the proportion of inorganic solids was significatively higher in all sampling stations (Fig. 7).

Table II: Total and dissolved nutrients at the Lavapés (L) and Capivara (C) sampling stations and in Barra Bonita reservoir (station E and R).

Period	Sampling stations	Silicate (mg/l)	Nitrite (μg/l)	Nitrate (μg/l)	Ammonium (μg/l)	Total Nitrogen (μg/l)	Total Dissolved Phosphorus (μg/l)	Inorganic Dissolved Phosphorus (μg/l)	Total Phosphorus (μg/l)
	L1	7.0	13.6	493	1,030	2,304	528	487.3	*
	L2	6.6	14.3	704	908	2,527	385	369.4	*
	L3	5.3	12.7	557	603	3,425	605	507.8	*
Winter	*C1*	6.2	0.3	89	35	537	25	4.4	*
	C2	6.2	0.3	112	30	486	20	2.3	*
	C3	6.4	0.2	1244	9	2,056	106	38.6	*
	E	5.1	5.4	448	284	470	171	119.3	*
	R	3.8	12.2	3298	531	3,353	51	17.6	*
	L1	4.7	26.9	452	42	*	62	25.9	235.4
	L2	5.5	25.7	358	34	793	72	29.4	228.0
	L3	5.6	25.7	343	29	*	73	30.5	293.0
Summer	*C1*	4.5	4.2	4	7	233	63	38.6	126.4
	C2	3.9	3.9	6	7	163	54	25.4	156.7
	C3	3.3	4.5	2	6	70	51	26.7	135.0
	E	2.3	0.8	47	7	68	5	0.1	148.1
	R	4.2	14.9	2698	48	3027	9	5.5	158.7

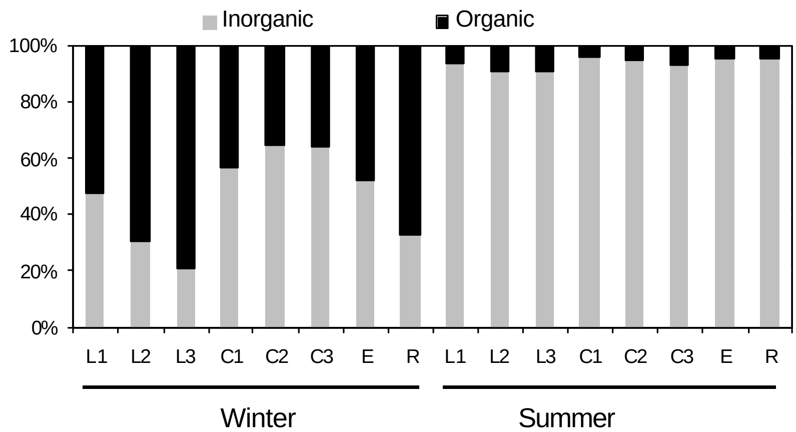

Figure 7: Variation of organic and inorganic fractions percentage in the suspended solids at the Capivara and Lavapés sampling stations and in Barra Bonita reservoir (E and R stations) during the study period.

Chlorophyll-*a* values were higher in the winter (Tab. III). For both periods, concentrations in the rivers were much lower than in the E and R stations and between the rivers, chlorophyll-*a* was higher in Capivara.

The PCA analysis shows an evident difference on the position of the sampling stations for both periods (Fig. 8).

Table III: **Suspended solids and chlorophyll-*a* concentrations at the Lavapés (L) and Capivara (C) sampling stations and in Barra Bonita reservoir (station E and R).**

Sampling stations	Suspended solids (mg/l)		Chlorophyll-*a* (µg/l)	
	Winter	Summer	Winter	Summer
L1	**7.2**	**72.7**	**1.3**	**2.0**
L2	**4.5**	**82.6**	**1.3**	**0.3**
L3	**3.9**	**83.4**	**1.4**	**1.0**
C1	**5.6**	**67.4**	**2.4**	**0.8**
C2	**10.3**	**72.1**	**2.4**	**3.2**
C3	**8.7**	**71.4**	**3.1**	**3.6**
E	**7.4**	**70.5**	**4.6**	**0.8**
R	**6.0**	**68.2**	**18.6**	**12.2**

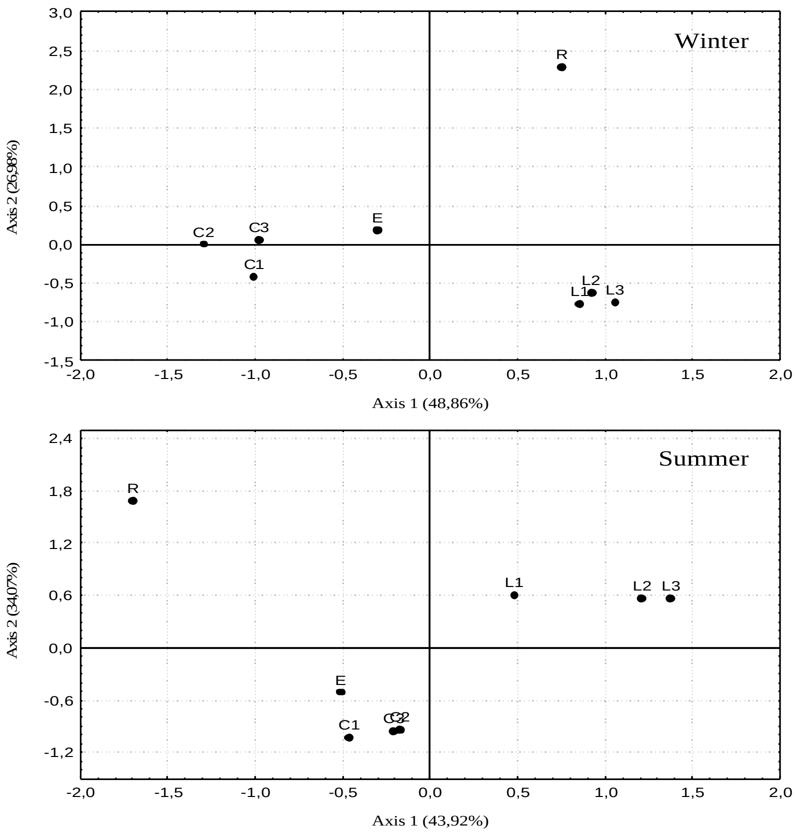

Figure 8: **Data of the PCA analysis showing the sampling stations position in relation to the first and second components.**

In the winter, the first component of the analysis (48.86 % of variance) was positively correlated with nitrite (0.96), conductivity (0.95), ammonium (0.85) and total nitrogen (0.85). Dissolved oxygen (-0.98) and inorganic suspended material (-0.80) had the best negative correlations. The second axis (26.98 % of the variance) was positively correlated to transparency (0.90) and chlorophyll-*a* (0.89).

During the summer, the first component (45.17% of the variance) was positively correlated to total dissolved phosphate (0.84), total phosphorus (0.83), inorganic suspended solids (0.88) and organic suspended solid (0.88). Transparency (-0.92) and dissolved oxygen (-0,83) were negatively correlated to the first component. The second component (30.11% of the variance) was positively correlated to nitrate (0.87), ammonium (0.97) and total nitrogen (0.87).

Discussion

The main limnological differences between Lavapés and Capivara rivers are related to the land uses and direct human impacts in each watershed. In case of Lavapés, 45.7% of the basin is inserted in the Botucatu urban perimeter and according to Leopoldo (1989) the sewage discharge into the river during the 80's, was estimated in 30,000 m^3/day. This amount is certainly higher nowadays as a consequence of the city growth in the last years.

The deforestation of native areas for agriculture purposes in both watersheds is also another important aspect to be considered in the ecological studies of these rivers. The loss of vegetation cover is higher in the Lavapés surroundings (Simões, 1996), what contributes to the increase of river siltation.

However, despite of the dramatic scenery of environmental degradation for the river Lavapés, Kikuchi (1989) suggested that the waters could reach the Barra Bonita reservoir in a relatively better condition. The water quality improvement along the river would be a consequence of an effective self-purification process due to the high difference in altitude between the headwaters and the lower stretches (about 450 m). Silva et al. (1998), based on chemical and microbiological analysis, showed a partial autopurification capacity along a 29 km stretch of river Pardo, that is the main drinking water source for Botucatu.

The rain cycle showed to be another important factor for the limnological functioning of this rivers-reservoir system. A significant increase in the flow was observed during summer. The values were 8.5 and 1.7 higher for Capivara and Lavapés rivers, respectively, as compared to the winter period. The differences in the increase magnitude between the rivers are related to the drainage capacity for each basin. The higher increase in volume of water for the river Capivara is explained by the fact that its watershed is 1.6 times larger than the Lavapés watershed.

In the reservoir the inflow (from Piracicaba and Tietê rivers) and outflow rates in winter were 5.6 and 3.9 times lower, respectively, as compared to the summer peaks. As a consequence the water retention time in the reservoir was fourfold higher in the winter, varying from 34.1 days in February to 135.5 days in July. During the autumn, winter and spring the reservoir outflow overcame the inflow, what reveal the influence of the dam operation in the hydrological dynamics of the system. Nevertheless, as the inflow is measured at the entrance of the main rivers, it should be considered that compensations can occur by contribution of underflow, lateral rivers (e.g. Lavapés and Capivara) and direct precipitation on the surface of the reservoir.

The increase of 2.6 m in the water column observed at the R station during the dry season reflects the reservoir management practices. But at the rivers sampling stations the higher depth were verified in the wet period, as expected.

Tundisi & Matsumura-Tundisi (1990) estimated the theoretical water retention time for Barra Bonita in 1 month, between November and March, and 6 months between April and September. During our study there was lower fluctuation of the retention time, that was calculated in 3.7 and 2.2 months for the same periods of the year. A higher hydrological stability could lead to persistent horizontal gradients. Nogueira et al. (1999) verified that spatial gradients in Jurumirim reservoir (Paranapanema river) are more conspicuous during the dry season. In this period the physical conditions are probably less variable, as the flow rates are lower and the theoretical water retention time is very high (about 18 months).

In summer a relatively higher water temperature was observed at the R station as compared to the stations located in the rivers (maximum difference of 3.8 °C). Nogueira et al. (1999) also verified differences of up 4 °C between riverine and lacustrine zones of the Jurumirim reservoir. Such differences of temperature between the main water body and the tributaries probably generate distinctive processes of advective water displacement into the reservoir.

A general increase of transparency into the reservoir direction was observed during the dry season. This tendency could be associated to the decrease of the rivers velocity in the wetland area, which increases the sedimentation rates of suspended solids. Henry & Maricatto (1996) observed, experimentally, such pattern of longitudinal variation in the upstream zone of Jurumirim reservoir.

A decrease in the water transparency was observed during the rainy period, due to the input of large amounts of allochthonous material from the watershed. The lowest values in Lavapés river may be related to the occurrence of laminar erosion processes as the deforestation was more intensive in this basin (Simões, 1996).

Lower values of conductivity at the sampling stations of the river Capivara, for both periods, confirmed the less eutrophic condition as compared to Lavapés and reservoir compartments. Except for the C1 station, there was a reduction of the conductivity during summer in all sampling stations, as a consequence of ions dilution by the rain.

Despite of the high concentration of chlorophyll at the R station during the winter (18.6 mg/l) and relatively high pH (7.2), the dissolved oxygen concentration was low (2.95 mg/l). As the sampling was performed early in the morning this result probably reflects the nocturnal oxygen consumption, which tend to be high in eutrophic ecosystems. In the winter the river Capivara had significatively higher concentration of dissolved oxygen, despite of the very low flow rate observed in the period. This could be related to the oxygen introduction by turbulence due to the high declivity and lower temperature.

A certain decrease of the pH in summer can be related to a reduction of the phytoplankton abundance, as indicated by lower values of chlorophyll. Humic substances inputs from terrestrial ecosystems by the rains can also affect the pH values.

Major differences were observed for the distribution of nutrients at the temporal and spatial scales. The highest values were associated to the river Lavapés and to the reservoir. A decreasing trend in the concentrations during winter was recorded.

For dissolved phosphorus the concentrations were more similar among the rivers sampling stations during summer. In the rainy period, there was a reduction in the concentrations for the river Lavapés. At the C1 and C2 stations it was observed an increase of 2.6 and 9.5 times for total and inorganic dissolved phosphorus, respectively. Allochthonous material input promotes an increase of phosphorus. In case of Lavapés, despite of the increase of suspended solids, the predominant effect of rains seems to be the dilution of phosphorus due to its very eutrophic condition.

The remarkable reduction of dissolved phosphorus at the E station during the summer may be a consequence of the intensive macrophytes growth. Donk et al. (1993), studying the fate of nutrient loads introduced into the Lake Zwenlust (The Netherlands) by an eutrophic river, observed that the presence of macrophyte stands reduces significatively the concentrations of nitrogen and phosphorus, which are incorporated in the local food webs.

The highest concentrations of nitrate and total nitrogen were observed at the R station. Thus for the nitrogen compounds, the tributaries contribution, even in case of Lavapés, seems to be less important than the internal loads in the reservoir. This could be indicating a high rate of nitrogen fixation, probably by blue-green algae, or sediment releases. A decrease of ammonium into downstream direction was observed in summer and winter for both rivers and probably is associated to dilution effects.

An increase of suspended solids was observed for all sampling stations in summer. Comparatively, the increase was higher at the L2 and L3 stations with 20 times more inorganic solids as compared to the winter amounts. The lowest increases occurred at the C2 and C3 stations, respectively 7 and 8 times. In the winter most of suspended solids were organic, but in summer the concentrations of inorganic were higher. This indicates that the mineral fraction predominates in the allochthonous material introduced during he rainy season.

The increasing trend of organic compounds into downstream direction for both rivers during the summer could be associated to detritus released from macrophytes stands in the area.

In terms of chlorophyll-*a* the values at the R station were the highest in both periods. This indicates that the increase of water retention in the reservoir provides better conditions for the phytoplankton development. In the winter there was a clear spatial variation among the study areas related to chlorophyll-*a*, with the lowest values in the river Lavapés, followed by Capivara and then by the sampling stations E and R under influence of the reservoir.

The PCA analysis showed that nutrient concentration was the main factor influencing on the stations disposition. The C and E stations were negatively correlated to total and dissolved nutrients. Capivara and Lavapés characteristics were clearly discriminated by this analysis in both periods. The lacustrine zone (the E station) was more associated to the Capivara river.

Acknowledgements

We wish to thank Hamilton Rodrigues and Nelson Carneiro for the help in field work, to Professor Raoul Henry for laboratory facilities and suggestions, to CESP (Botucatu and Barra Bonita) for hydraulic and precipitation data and to FAPESP for the scholarship to the first author (Proc. 96/11966-8).

References

Armengol, J., Garcia, J. C., Comerma, M., Romero, M., Dollz, J., Roura, M. Han, B. H., Vidal, A. & Šimek, K. 1999. Longitudinal Processes in Canyon Type Reservoirs: The Case of Sau (N.E. Spain). In: Tundisi, J. G. & Straskraba, M. (eds). Theoretical Reservoir Ecology and its Applications. Backhuys Publishers, Leiden. p.313-345.

Betsil, R. & Van Den Avyle, M. J. 1994. Spatial heterogeneity of reservoir zooplankton: a matter of timming? Hydrobiologia, 277:63-70.

Calijuri, M. C. & Tundisi, J. G. 1990. Limnologia Comparada das Represas do Lobo e Barra Bonita - Estado de São Paulo: Mecanismos de Funcionamento e Bases para o Gerenciamento. Rev. Bras. Biol., 49:83-95.

Cole, G. A. 1979. Textbook of Limnology. 2nd ed. Mosby Company, Saint-Louis. 283p.

Donk, E. V., Gulati, R. D., Iedema, A. & Meulemans, J. T. 1993. Macrophytes - related shifts in the nitrogen and phosphorus contents of the difference tropic levels in a biomanipulated shallow lake. Hydrobiologia, 251:19-26.

Esteves, F. A., Ferreira, J. R., Pessenda, L. C. R. & Mortatti, J. 1981. Análises preliminares sobre o teor e a distribuição de metais em sedimentos de represas do Estado de São Paulo. In: II Simpósio Regional de Ecologia. UFSCAR, São Carlos. p.323-345.

Golterman, H. L., Clymo, R. S. & Ohnstad, M. A. 1978. Methods for physical & chemical analysis of Fresh Waters. 2nd ed. Blackwell Scientific Publications, Oxford. 213p. (IBP, 8).

Henry, R. 1986. O crescimento potencial do fitoplâncton de Barra Bonita (Rio Tietê, SP): uma comparação sazonal dos efeitos de enriquecimento artificial em amostras de seus tributários. Ciênc. Cult., 38:1553-1564.

Henry, R., Hino, K., Gentil, J. G. & Tundisi, J. G. 1985. Primary production and effects of enrichment with nitrate and phosphate on phytoplankton in the Barra Bonita Reservoir (State of São Paulo, Brazil). Int. Rev. Gesamten Hydrobiol., 70:561-573.

Henry, R & Maricatto, F. E. 1996. Sedimentation rates of Tripton in Jurumirim Reservoir (São Paulo, Brazil). Limnologica, 26:15-25.

Henry, R. & Simão, C. A. 1988. Aspectos sazonais da limitação potencial por N, P e Fe no fitoplâncton da Represa de Barra Bonita (Rio Tietê, SP). Rev. Bras. Biol., 48:1-14.

IBGE. 1969. Carta do Brasil. Mapa, Folha SF-22-R-IV-3 (Botucatu). 1.ed. Escala 1:50.000.
Kikuchi, R. M. 1989. Caracterização de alguns parâmetros físico-químicos e biológicos do Ribeirão Lavapés. Botucatu, UNESP, 50p. (Monografia)
Kimmel, B. L., Lind, O. T. & Paulson, L. J. 1990. Reservoir primary production. In: Thorthon, K. W., Kimmel, B. L. & Payne. E. F. (eds). Reservoir Limnology: ecological perspectives. John Wiley & Sons, New York. p.133-192.
Koroleff, F. 1976. Determination of nutrients. In: Grasshoff, K.(ed). Methods of seawater analysis. Verlag, Weinhein. p.177-181.
Leopoldo, P. R. 1989. Aspectos hidrológicos da Região de Botucatu. In: Encontro de Estudos sobre a Agropecuária na Região de Botucatu. Botucatu. v.1, p.57-70.
Linsley, R. K. 1978. Engenharia de Recursos Hídricos. Mc Graw-Hill, São Paulo. 789p.
Mackereth, F. J. H., Heron, J. & Talling, F. J. 1989. Water analysis: Some revised methods for limnologists. 2.ed. Titus Wilson & Sons, Kendall. 120p. (Freshwater Biological Association Scientific Publication,36).
Matsumura-Tundisi, T., Hino, K. & Claro, S. M. 1981. Limnological studies in 23 reservoirs in Southern part of Brazil. Verh. Int. Verein Limnol., 21:1040-1047.
Matsumura-Tundisi. T., Leitão, S. N., Aguena, L. S. & Miyahara, J. 1990. Eutrofização da Represa de Barra Bonita: estrutura e organização da comunidade de Rotifera. Rev. Bras. Biol., 50:923-935.
Nogueira, M. G., Henry, R. & Maricatto, F. E. 1999. Spatial and temporal heterogeneity in the Jurumirim Reservoir, São Paulo, Brazil. Lakes & Reserv. Res. Manag., 4:107-120.
Novo, E. M. L. M., Braga, C. Z. F. & Tundisi, J. G. 1993. Remote sensing estimation of total chlorophyll pigment distribution in Barra Bonita reservoir, Brazil. In: Straskraba, M., Tundisi, J. G. & Duncan, A. (eds). Comparative Reservoir Limnology and Water Quality Management. Kluwer Academic Publishers, Dortrecht. p.147-152.
Oliveira, M. D. & Calijuri, M. C. 1996. Estimate of Rate of Primary Production in two Lotic systems, based on hourly change of dissolved oxygen – Itaqueri and Lobo Rivers (São Paulo State). An. Acad. Bras. Cienc., 68:103-111.
Pedroso, F., Bonetto, C. A. & Zalocar, Y. 1988. A comparative study on phosphorus and nitrogen transport in the Parana, Paraguay and Bermejo rivers. In: Tundisi, J. G. (ed.). Limnologia e manejo de represas. EESC-USP/CRHEA/ACIESP, São Carlos. v.1, t.1, p.91-117. (Monografias em Limnologia)
Silva, A. M. M., Henry, R., Carvalho, L. R. & Santini, J. A. J. 1998. A capacidade de autopurificação de um curso d'água: um estudo de caso no rio Pardo (Botucatu, SP). Acta Limnol. Bras., 10:83-99.
Simões, L. B. 1996. Avaliação das Áreas de Preservação Permanente da Bacia do Ribeirão Lavapés, Botucatu, SP, através de Sistema de Informações Geográficas (SIG-IDRISI). Botucatu, UNESP, 145p (Dissertação)
Strickland, J. D. & Parsons, T. R. 1960. A manual of sea water analysis. Bull. Fish. Res. Bel. Can., 125:1-185.
Straskraba, M., Tundisi, J. G. & Duncan, A. 1993. State-of-the-art of reservoir limnology and water quality management. In: Straskraba, M., Tundisi, J. G. & Duncan, A. (eds). Comparative reservoir limnology and water quality management. Kluwer Academic Publishers, Dordrecht. p.213-288.
Tundisi, J. G. 1981. Typology of reservoirs in Southern Brazil. Verh. Int. Verein. Limnol., 21:1031-1039.
Tundisi, J. G. 1988. Impactos ecológicos da construção de represas: aspectos específicos e problemas de manejo. In: Tundisi, J. G. (ed.) Limnologia e Manejo de Represas. Série: Monografias em Limnologia. EESC-USP/CRHEA/ACIESP, São Carlos. v.1, t.1, p.1-75.
Tundisi, J. G. 1990. Distribuição espacial, sequência temporal e ciclo sazonal do fitoplâncton em represas: fatores limitantes e controladores. Rev. Bras. Biol., 50:937-955.
Tundisi, J. G. 1994. Tropical South America: present and perspectives. In: Margalef, R. (ed.) Limnology now: a paradigm of planetary problems. Elsevier Science, Amsterdam. p.353-424.

Tundisi, J. G. & Matsumura-Tundisi, T. 1990. Limnology and eutrophication of Barra Bonita Reservoir, São Paulo State, Southern Brazil. Arch. Hydrobiol. Beih. Ergeb. Limnol., 33:661-667.

Urabe, J. 1990. Stable horizontal variation in the zooplankton community structure of a reservoir maintened by predation and competition. Limnol. Oceanogr., 35:1703-1717.

Valderrama, J.G. 1981. The simultaneous analysis of total nitrogen and phosphorus in natural waters. Mar. Chem., 10:109-122.

Wetzel, R. G. 1990. Reservoir ecosystem: conclusions and speculations. In: Thorthon, K. W., Kimmel, B. L. & Payne. E. F. (eds). Reservoir Limnology: ecological perspectives. New York, John Wiley & Sons. p.227-238.

Received: **31 July 2000**
Accepted: **12 November 2002**