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Differential environmental impacts on small and medium size rivers from center of São Paulo State, Brazil, and regional management perspectives

Efeitos de diferentes tipos de impactos ambientais em rios de pequeno e médio porte do centro do Estado de São Paulo, Brasil, e perspectivas de manejo.

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Abstract: Aim: This study aimed to evaluate, comparatively, the influence of distinct environmental impacts in the watershed on the rivers Capivara, Lavapés, Araquá and Pardo and the transference of effects downstream. **Methods**: The limnological/water quality study was carried out in rainy (March/2007) and dry (September/2007) seasons, considering 17 sampling stations. **Results**: Variables such as channel width and depth, water velocity and temperature increased towards the river's mouth; water transparency, velocity and dissolved oxygen were higher in the upstream regions. Light penetration was total at most sampling stations and pH was predominantly acid. The sampling stations impacted by pollution sources, Lavapés and Araquá Rivers, exhibited higher values of electric conductivity, suspended solids, total nitrogen, nitrate, nitrite, ammonium, total dissolved phosphorus, BOD, and thermotolerant coliforms. Higher values of electric conductivity, turbidity and suspended solids were observed in the rainy season, whereas higher chlorophyll concentrations occurred in the dry season. The Lavapés River exhibits the worst environmental condition, while Capivara River is under better state of conservation. This study shows that it is urgent the implementation of measures for preservation and restoration of these regional aquatic ecosystems. All studied rivers were influenced by seasonal variation, sewage discharges and by watershed use and occupation. The TSI is a good analysis tool. The studied rivers export organic matter and TN, TP and SS loads to Tietê and Paranapanema rivers. **Conclusions**: This study show the importance of river management and that the accelerated degradation of the river systems indicates the little progress of the Brazilian legislation in terms of preservation and good management practices and that the interface between science, law, management and conservation need to be improved.

Keywords: pollution, CONAMA 357, trophic state index, loads.

Resumo: Objetivo: O presente trabalho buscou avaliar, comparativamente, a influência dos distintos tipos de impactos ambientais na bacia hidrográfica sobre os rios Capivara, Lavapés, Araquá e Pardo, e transferências de efeitos para a jusante. **Métodos**: O estudo limnológico/qualidade de água foi realizado nos períodos chuvoso (março/2007) e seco (setembro/2007), sendo consideradas 17 estações de amostragem. **Resultados**: Variáveis como largura, profundidade, vazão e temperatura da água aumentaram a jusante; velocidade, transparência e oxigênio dissolvido foram maiores nos trechos superiores. A penetração de luz na água foi total em quase todas as estações de amostragem e o pH predominantemente ácido. Os rios que sofrem impacto da área urbana, com fontes pontuais de poluição foram Lavapés e Araquá, apresentando maiores valores de condutividade elétrica, material em suspensão, nitrogênio total, nitrato, nitrito, amônia fósforo total, fosfato total dissolvido, DBO e coliformes termotolerantes. No período chuvoso foram observados maiores valores de condutividade elétrica, turbidez e material em suspensão, enquanto que concentrações mais elevadas de clorofila-*a* ocorreram no período seco. O rio Lavapés foi o que apresentou a pior condição ambiental, em contraste com o rio Capivara em melhor estado de conservação. Os rios estudados foram fortemente influenciados pela variação sazonal e por despejos de esgoto e uso e ocupação da bacia hidrográfica. O IET mostrou ser uma boa ferramenta de análise. Os rios estudados impactam a jusante com a exportação de matéria orgânica e cargas elevadas de NT, PT e SS para os rios Tietê e Paranapanema. **Conclusões**: O estudo mostrou a importância da gestão desses ambientes e que a degradação dos rios demonstram que a legislação brasileira avançou pouco na preservação, gestão e manejo dos ecossistemas aquáticos e que a interface entre ciência, legislação, gestão e preservação de ecossistemas aquáticos precisa ser melhorada.

Palavras-chave: poluição, CONAMA 357, índice de estado trófico, cargas.

1. Introduction

The increasing multiple uses of the water resources have caused major modifications on the aquatic ecosystems. Nevertheless, it is very difficult to determine precisely the effects of the environmental impacts due to the human activities, as they are continuous and ubiquitous with multiple direct and indirect consequences (Tundisi, 2003; Allan, 2004; Heathwaite, 2010).

Medium and small size rivers can be considered as highly representative freshwater ecosystem in the State of São Paulo, if considered their wide distribution and high frequency in the local and regional landscapes. Due to the differential positioning among other Brazilian States, in terms of higher economic production and higher demographic density, in addition to the limited efficiency of the public environmental conservation policies, a severe degradation of the surface waters is widely disseminated in São Paulo State.

The small rivers flowing in different Brazilian biomes constitute a dense and widespread structural collecting net of all kind of allochthonous material, which is transported to higher order river systems (Tundisi, 2003). In urbanized and in mono-cultured areas (e.g. vast sugar-cane plantation) the small rivers transport high loads of nutrient, sediments and contaminants, due to the intensive use and occupation of each individual watershed. This process can result in a considerable impact (magnification of loads introduction) on larger rivers or reservoirs downstream located, as already observed for southeast (Paranapanema River in São Paulo State - Ferrareze et al., 2006) and central (savanna-cerrado streams – Fonseca et al., 2014) Brazil.

Water physical and chemical characteristics are good indicators of the environmental health and integrity, as they are key factors determining the ecosystem functioning. Additionally, there is also a practical applicability for this kind of measurements, as they are primarily considered by the Brazilian government for the assessment of the water quality standards (Brasil, 2005).

The increase in nutrient concentration, such as nitrogen and phosphorus, is usually associated to pollution from domestic and industrial activities. Therefore the analysis of these compounds in river systems is necessary for environmental diagnostics.

Data from river sediments are also of fundamental importance. The superficial sediment of freshwater ecosystems is the compartment where intense decomposition of the organic matter and the nutrient cycling occur and it is also inhabited by a diversified and numerous benthic fauna (Håkanson and Jansson, 1983; Mozeto et al., 2006).

Despite the growing demand from the Brazilian society for the maintenance of satisfactory environmental standards of the freshwater ecosystems, there is a weak linkage between legislation, practical management and science, with many technical difficulties and lack of appropriate framework for classifying rivers according to the specific legislation (Brasil, 2005). It is also important to keep as a reference that the eutrophication process promotes drastic changes in aquatic ecosystems, which will be hardly mitigated.

This investigation aimed: (a) to assess the water quality condition of Araquá, Capivara, Lavapés and Pardo Rivers by analysis of physical and chemical variables of water and sediment; (b) to assess the downstream impact of medium and small size rivers on higher order aquatic systems, in terms of transportation of phosphorus, nitrogen and suspended solids loads.

2. Material and Methods

The studied rivers, Araquá, Capivara, Lavapés and Pardo, are located in the municipality of Botucatu, center region of São Paulo State (Figure 1). Geographic positioning and general characteristics of each sampling point are shown in Table 1.

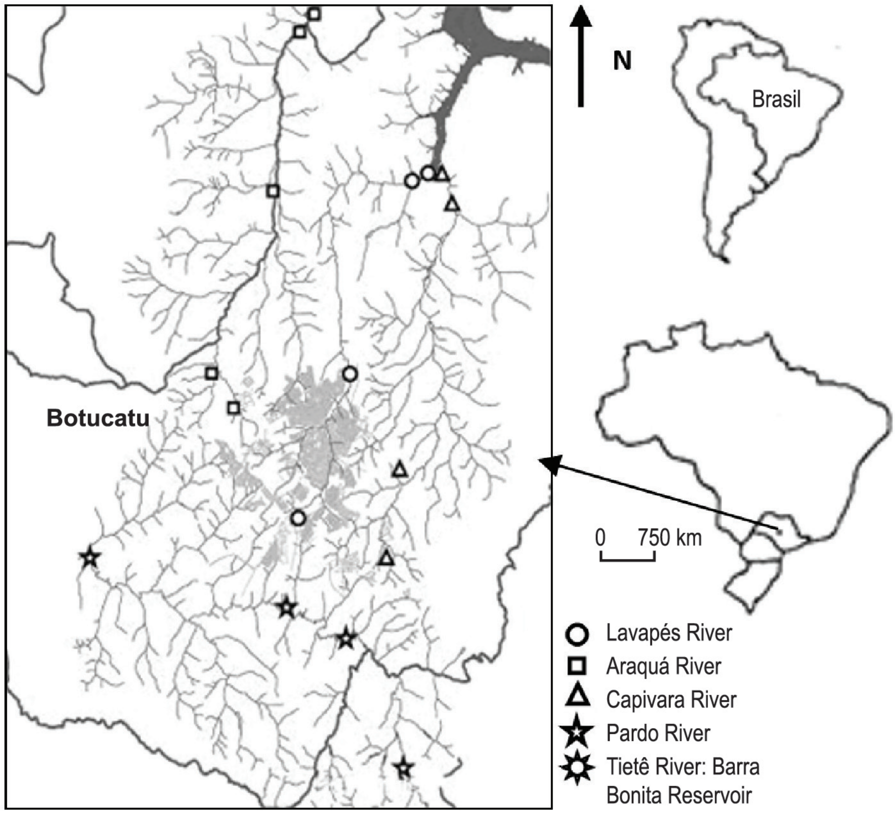

Figure 1. Study area and sampling stations locations. In gray, the urban area of Botucatu, São Paulo, State.

Table 1. List of the sampling stations, geographic positioning and some general environmental characteristics.

Stations	Bank Characteristics	Geographic Coordinate		Elevation (m)	Stream Order
Araquá 1	no gallery forest; no pollution evidency; erosion	22° 50' 46.6"	48° 30' 37.45"	719	3º
Araquá 2	no gallery forest; sewage evidency; erosion	22° 52' 02.8"	48° 29' 51.8"	777	3º
Araquá 3	no gallery forest; no pollution evidency; erosion	22° 44' 50.4"	48° 28' 31.1"	470	4º
Araquá 4	no gallery forest; no pollution evidency	22° 39' 27.7"	48° 27' 25.7"	453	4º
Araquá 5	floodplain; no pollution evidency; erosion	22° 39' 04.1"	48° 27' 11.1"		4º
Capivara 1	no gallery forest; dairy sewagw; erosion	22° 56' 22.8"	48° 24' 04.8"	814	2º
Capivara 2	no gallery forest; no pollution evidency; erosion	22° 53' 54.4"	48° 23' 11.2"	557	4º
Capivara 3	no gallery forest; no pollution evidency; erosion	22° 45' 23.6"	48° 21' 57.9"	446	5º
Capivara 4	no gallery forest; no pollution evidency; erosion	22° 41' 15.2"	48° 22' 26.2"	450	5º
Lavapés 1	gallery forest; no pollution evidency; erosion	22° 55' 29.7"	48° 27' 31.4"	797	1º
Lavapés 2	gallery forest; sewage evidency; erosion	22° 50' 46.0"	48° 25' 36.1"	733	3º
Lavapés 3	gallery forest; no pollution evidency; erosion	22° 44' 32.5"	48° 23' 18.0"	453	3º
Lavapés 4	gallery forest; no pollution evidency; erosion	22° 44' 13.7"	48° 22' 47.5"	460	4º
Pardo 1	no gallery forest; dairy sewagw; erosion	23° 03' 33.2"	48° 23' 19.0"	861	2º
Pardo 2	no gallery forest; no pollution evidency; erosion	22° 59' 26.7"	48° 25' 42.2"	814	4º
Pardo 3	no gallery forest; no pollution evidency; erosion	22° 58' 26.2"	48° 27' 56.0"	801	4º
Pardo 4	gallery forest; no pollution evidency	22° 56' 57.5"	48° 35' 16.1"	767	4º

Araquá, Capivara, Lavapés belong to the Tietê River basin and Pardo to the Paranapanema River basin, both important rivers of Paraná-La Plata basin upper region. The considered rivers receive different kind and intensity of human interferences. The Lavapés River, right after its headwater zone, receives almost all the urban discharges, partially treated, from Botucatu (ca. 130.000 inhabitants). The other rivers have their courses integrally located in rural areas, but one sampling point of the Araquá River (station A2) is influenced by a small tributary that receives the effluent of a sewage treatment plant from a campus of the State University of São Paulo (UNESP), with large human and a veterinarian hospitals.

Samplings were taken in the upstream, middle and low stretches of each river, except for Pardo, which is a much longer river and the lower stretch was not analyzed. Water and sediment were collected in 17 sampling stations during the rainy (March /2007, late summer) and dry (September/2007, late winter) periods (Figure 1; Table 1).

Table 2 presents the list of the measured variables and parameters and the methods used for determinations.

A Principal Component Analysis (Pcord-win) was performed in order to ordinate the sampling points distribution according to the limnological/ water quality factors.

Instantaneous loads of nutrient (total nitrogen and total phosphorus) and suspended solids were calculated (kg/day) through the multiplication of concentrations by flow.

3. Results

The data variance explicability of the principal components analysis (PCA) (Figure 2) was high, 54.69% in the axis 1, 14.66% in axis 2. Water variables were mainly related with axis 1, and sediment variables with axis 2. The water variables better correlated with the axis 1 were electric conductivity (r=0.72), suspended organic solids (r=0.579), chlorophyll-*a* (r=0.532), total (r=0.668) and thermotolerant (r=0.759) coliforms, TN (r=0.924) and TP (r=0.9), ammonium (r=0.796), nitrite (r=0.869), nitrate (r=0.913), organic (r=0.606) and inorganic (r=0.927) dissolved phosphorus and total dissolved phosphorus (r=0.93) and silicate (r=0,509). The sediment variables better correlated with the axis 2 were organic matter (r=-0.823), NT (r=-0.784) and PT (r=-0.693) and grain size (r=-0.690).

Electric conductivity was a water variable that showed a wide variation between studied places (Figure 3), with very high values measured in sampling stations under direct influence of sewage

Table 2. Analyzed variables and methodology.

Environmental variables	Methodology
Pluviosity	Meteorological Post -UNESP
Air temperature	Hg Thermometer
Luminosity	Luximeter Panlux eletronic gossen
Channel width and deepness	Manual measurements (graduated rule)
Velocity	Curent meter flowatch and displacement of floating object
Flow	Area x velocity integration - Linsley et al. (1982)
Water transparency	Secchi disc
Turbidity	Turbidímetro MS Tecnopon
*Water analysis**	
Dissolved oxygen, pH and electric condutivity	Horiba- Mod. U22
Suspended solids	Cole (1979)
Total nitrogen and phosphate	Valderrama (1981)
Nitrite	Bendchreider and Robinson (1952) (apud Golterman et al., 1978)
Nitrate	Mackereth et al. (1989)
Ammonium	Koroleff (1976)
Phosphate	Strickland and Parsons (1960)
Silicate	Golterman et al. (1978)
Chlorophyll-*a*	Talling and Driver (1963)
Thermotolerants and total coliforms	APHA (1998) e tabela de Colilert 18®
Biochemical oxygen demand	APHA (1998)
IET	Lamparelli (2004)
Phosphorus, nitrogen and solids loads (Kg/ day)	(P4,A4,C3,L3) loads (Kg/l) * (P4,A4,C3,L3) discharge (L/day)
*Sediment analysis***	
Grain size, organic matter and water percentage	Håkanson and Jansson (1983).
Total nitrogen	Kjeldhal
Total phosphorus	Andersen (1976)

*Samples were collected os surface in the middle of the channel. For dissolved nutrients the samples were filtered in Millipore AP40 membranes; **Samples collected with Van Veen dredge.

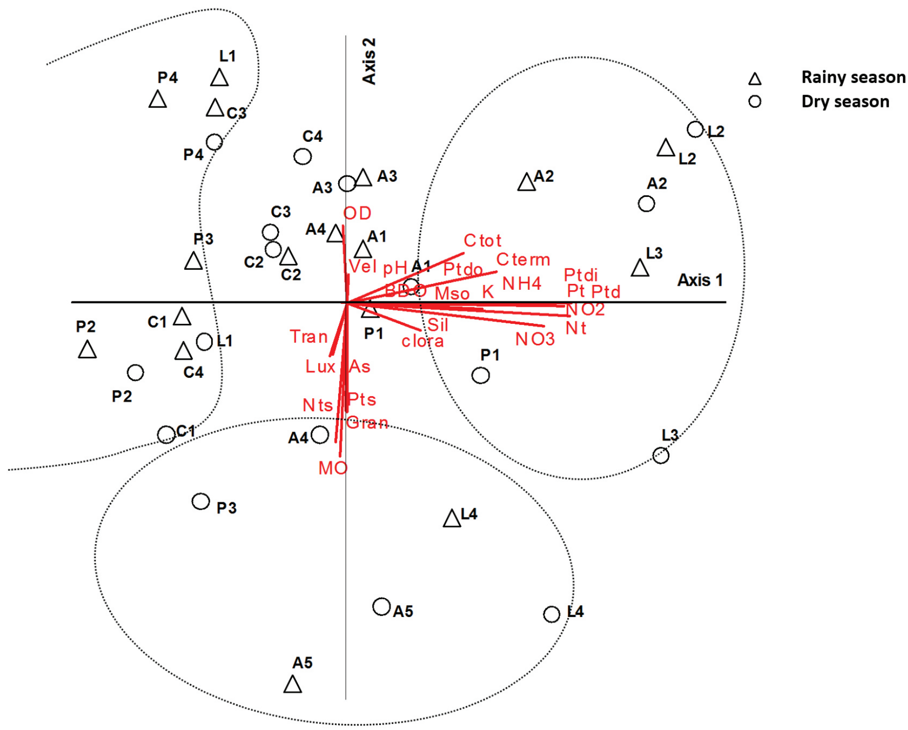

Figure 2. Principal component analyses of Araquá, Capivara, Lavapés and Pardo Rivers on the basis of studied variables measured in rainy and dry seasons.

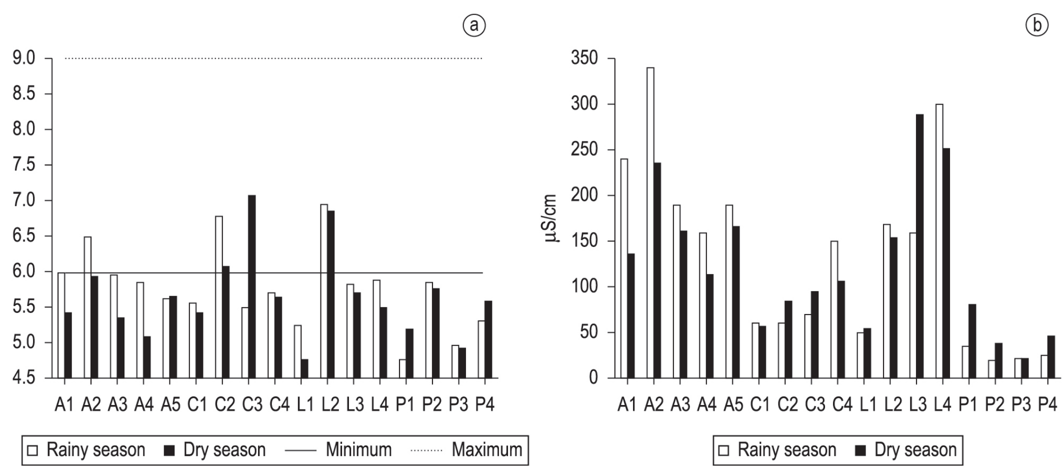

Figure 3. Variation of pH (b) and electric conductivity (a) in Araquá, Capivara, Lavapés and Pardo Rivers in rainy and dry season and rivers classification limit (class 1,2, 3 and 4) according to CONAMA 357

discharges (A2, L4). Lower values were measured in Pardo River.

The suspended solids values in the studied river are low, mainly in the dry season. Higher values of organic and inorganic fractions of suspended solids were observed at station L3. Inorganic solids predominate compared to organic (Table 3).

The highest value of chlorophyll-*a*, 91 µg/L at A2 (Table 3), is related to phytoplankton exportation from an upstream sewage treatment plant (stabilization lagoons) located in a small upstream tributary (Cintra River) (Gralhóz and Nogueira, 2006). Relatively high values were also observed in the final stretches of Araquá (A5) and Lavapés (L4) rivers, were the terrain declivity is low and under influence of the eutrophic influence of Barra Bonita reservoir (Tietê River) (Moretto and Nogueira, 2003).

Total and thermotolerant coliforms were higher in dry season (Figure 4), especially in Araquá and Lavapés Rivers. For thermotolerant coliforms the highest values occurred in the middle and low

Table 3. Water temperature, dissolved oxygen (D.O.), suspended solids (organic and inorganic), turbidity, Chlorophyll - *a* and biochemical oxygen demand (BOD) measured in Araquá, Capivara, Lavapés and Pardo Rivers during the rainy and dry (in bold) periods of 2007.

Sample Station	Temperature °C		D.O. mg/L		Suspended Solids mg/L				Turbity NTU		Chlorophyll-*a* µg/L		BOD mg/L	
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Araquá1	21.0	**18.2**	9.0	**9.5**	0.25	**0.15**	0.12	**0.13**	11.9	**6.14**	2.87	**4.16**	23	**9**
Araquá2	23.1	**18.3**	9.0	**9.3**	0.14	**0.03**	0.20	**0.95**	8.2	**7.76**	17.87	**91.20**	21	**14**
Araquá3	22.4	**18.2**	8.5	**9.4**	1.17	**0.60**	0.29	**0.22**	25.3	**14**	3.26	**1.69**	25	**14**
Araquá4	25.2	**19.3**	6.0	**8.6**	1.09	**0.93**	0.38	**0.36**	33.0	**17.6**	5.14	**2.90**	26	**13**
Araquá5	26.8	**23.3**	4.7	**5.6**	0.22	**0.29**	0.33	**0.48**	13.2	**11**	14.37	**15.89**	27	**12**
Mean	*23.7*	**19.5**	*7.4*	**8.5**	*0.6*	**0.40**	*0.3*	**0.43**	*18.3*	**11.3**	*8.7*	**23.17**	*24*	**12**
Capivara1	25.3	**21.7**	3.2	**6.5**	0.65	**0.28**	0.33	**0.20**	19.8	**8**	1.12	**2.72**	11	**8**
Capivara2	26.8	**18.3**	9.2	**10.5**	0.17	**0.14**	0.13	**0.13**	10.8	**4.2**	2.02	**3.31**	15	**13**
Capivara3	24.5	**19.5**	7.6	**9.9**	1.44	**0.56**	0.49	**0.20**	29.2	**13.3**	0.24	**2.81**	18	**14**
Capivara4	24.7	**20.8**	6.6	**8.9**	0.33	**0.73**	0.16	**0.28**	16.1	**14.8**	2.42	**2.89**	22	**13**
Mean	*25.3*	**20.1**	*6.7*	**9.0**	*0.6*	**0.43**	*0.3*	**0.20**	*19.0*	**10.1**	*1.5*	**2.93**	*17*	**12**
Lavapés1	22.3	**20.6**	7.9	**8.6**	0.23	**0.61**	0.23	**0.47**	6.0	**3.96**	1.74	**1.56**	12	**8**
Lavapés2	26.3	**22.8**	8.2	**9.5**	0.68	**0.13**	0.52	**0.27**	22.9	**6.25**	1.76	**3.28**	19	**17**
Lavapés3	28.7	**20.5**	6.1	**5.7**	3.16	**1.21**	1.02	**0.51**	50.1	**19.1**	4.38	**4.61**	18	**18**
Lavapé 4	28.2	**19.7**	5.2	**5.1**	0.56	**0.77**	0.49	**0.48**	18.0	**14.5**	27.53	**6.97**	22	**15**
Mean	*26.3*	**20.9**	*6.9*	**7.2**	*1.2*	**0.68**	*0.6*	**0.43**	*24.2*	**11.0**	*8.9*	**4.10**	*18*	**15**
Pardo1	20.0	**20.6**	7.4	**6.3**	0.50	**0.10**	0.25	**0.15**	16.2	**6.24**	4.04	**2.15**	8	**8**
Pardo2	22.1	**21.8**	9.6	**9.8**	0.27	**0.19**	0.14	**0.12**	10.5	**9.39**	0.22	**2.81**	10	**7**
Pardo3	22.3	**19.5**	8.8	**8.0**	0.47	**0.15**	0.20	**0.15**	15.1	**9.11**	0.22	**3.05**	12	**10**
Pardo4	21.1	**20.4**	9.4	**10.1**	0.63	**0.09**	0.24	**0.10**	24.1	**6.6**	1.24	**2.09**	13	**8**
Mean	*21.4*	**20.6**	*8.8*	**8.6**	*0.5*	**0.13**	*0.2*	**0.13**	*16.5*	**7.8**	*1.4*	**2.52**	*11*	**8**

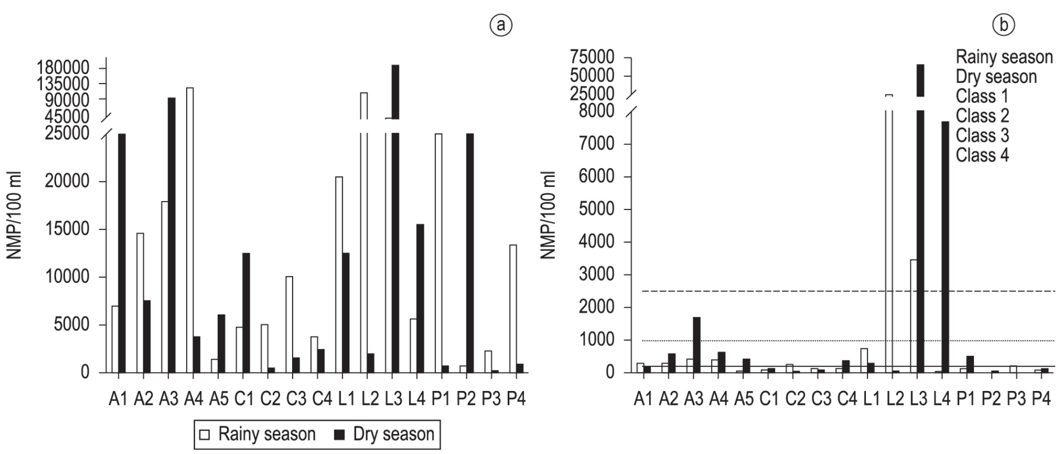

Figure 4. Variation of total coliforms (a) and thermotolerant (b) in Araquá, Capivara, Lavapés e Pardo Rivers in rainy and dry season and the rivers classification limit (class 1,2, 3 and 4) according to CONAMA 357.

Lavapés, showing the direct influence of domestic effluent discharges.

The water variables most strongly related to axis 1 were dissolved phosphorus, TN, nitrate, TP and nitrite. The highest nitrogen concentrations were observed in Lavapés River and the lowest in the Pardo River (Table 4). Nitrate (Table 4) was not analytically detected at C1, L1, P2 and P4 in the rainy season and at L4 the concentration was the highest. The lowest nitrate concentration was measured in Capivara River and the Lavapés headwater (L1). Nitrite (Table 4) concentration was lower at P2 and L1 in the dry season and higher at L3 in the rainy season. The lowest nitrite concentration occurred in Pardo River and Lavapés River exhibited the highest value. Nitrate was frequently the main nitrogen compound. This pattern is expected in lotic ecosystem with oxygen availability (Hynes, 2001; Pérez, 2003).

The results of TP, IP and OP are shown in Table 4. The lowest TP mean value was determined for Pardo River in rainy-summer and the highest in

Table 4. Dissolved (ammonium, nitrate, nitrite, organic and inorganic phosphate and silicate), total (phosphorus and nitrogen) nutrients in the water samples and TSI of Araquá, Capivara, Lavapés and Pardo Rivers during the rainy and dry (in bold) periods of 2007.

Sample Station	Ammonium µg/L		Nitrate µg/L		Nitrite µg/L		Total Nitrogen µg/L		Total Phosphorus µg/L		Inorganic Phosphate µg/L		Organic Phosphate µg/L		Silicate mg/L		TSI	
Araquá1	7.2	**26.3**	221.8	**466.1**	4.9	**4.9**	370.2	**612.5**	27.3	**38.5**	22.6	**33.5**	4.8	**5.0**	15.2	**16.5**	**55**	**58**
Araquá2	19.2	**54.3**	461.5	**1437.5**	23.0	**117.2**	1776.6	**1793.7**	243.0	**547.3**	206.0	**535.1**	37.0	**12.2**	15.2	**16.3**	**69**	**78**
Araquá3	15.2	**26.3**	132.7	**109.1**	3.6	**3.7**	246.8	**293.3**	19.8	**22.6**	17.5	**21.8**	2.3	**0.8**	15.1	**20.5**	**55**	**52**
Araquá4	10.6	**29.4**	39.8	**87.2**	3.7	**2.7**	333.7	**269.6**	15.3	**23.3**	13.6	**19.8**	1.7	**3.5**	16.1	**16.8**	**56**	**55**
Araquá5	4.7	**51.4**	162.0	**280.1**	12.7	**10.6**	921.6	**923.5**	18.3	**25.1**	10.3	**14.3**	8.0	**10.8**	12.0	**14.1**	**61**	**62**
Mean	*11.4*	**37.5**	*203.6*	**476.0**	*9.6*	**27.8**	*729.8*	**778.5**	*64.7*	**131.4**	*54.0*	**124.9**	*10.8*	**6.5**	*14.7*	**16.8**	**59**	**61**
Capivara1	44.9	**11.8**	0.0	**12.9**	1.2	**1.3**	87.9	**197.0**	10.2	**8.7**	4.3	**8.0**	5.9	**0.8**	13.0	**8.1**	**49**	**52**
Capivara2	42.7	**9.4**	30.3	**79.7**	1.9	**2.0**	126.6	**320.8**	20.0	**18.2**	7.5	**17.4**	12.5	**0.8**	15.9	**11.2**	**53**	**55**
Capivara3	8.3	**13.7**	0.2	**21.3**	3.1	**2.1**	145.6	**257.7**	27.0	**18.3**	10.3	**17.7**	16.7	**0.6**	12.6	**9.8**	**44**	**54**
Capivara4	3.9	**29.8**	0.0	**20.4**	2.3	**1.9**	147.8	**303.5**	25.0	**17.5**	9.2	**15.3**	15.8	**2.2**	14.7	**8.8**	**54**	**54**
Mean	*24.9*	**16.2**	*7.6*	**33.6**	*2.1*	**1.8**	*127.0*	**269.8**	*20.5*	**15.7**	*7.8*	**14.6**	*12.7*	**1.1**	*14.1*	**9.5**	**50**	**54**
Lavapés1	18.5	**26.1**	0.0	**19.0**	1.5	**0.7**	153.6	**135.8**	10.8	**10.0**	7.9	**4.7**	3.0	**5.3**	3.0	**3.6**	**51**	**50**
Lavapés2	1681.7	**1291.8**	354.3	**1730.1**	181.2	**76.0**	3940.9	**3519.5**	174.3	**155.2**	94.8	**137.8**	79.5	**17.4**	12.9	**13.3**	**58**	**60**
Lavapés3	227.7	**859.7**	1993.4	**2478.6**	292.1	**68.0**	3375.5	**4621.0**	148.2	**400.5**	109.2	**382.6**	39.0	**17.9**	15.0	**12.1**	**61**	**64**
Lavapé 4	8.6	**580.2**	1297.3	**2884.5**	101.0	**44.8**	1590.0	**5277.7**	46.8	**146.9**	32.5	**132.9**	14.3	**14.0**	12.6	**11.7**	**66**	**63**
Mean	*484.1*	**689.4**	*911.3*	**1778.0**	*144.0*	**47.4**	*2265.0*	**3388.5**	*95.0*	**178.1**	*61.1*	**164.5**	*33.9*	**13.6**	*10.9*	**10.2**	**59**	**59**
Pardo1	111.3	**289.4**	138.9	**858.5**	8.4	**85.6**	439.1	**1109.5**	20.2	**77.5**	9.3	**74.5**	10.8	**3.0**	6.6	**8.4**	**56**	**57**
Pardo2	5.7	**14.2**	0.0	**23.7**	1.6	**0.7**	93.7	**271.2**	10.6	**6.6**	6.7	**2.1**	3.9	**4.5**	4.8	**4.0**	**42**	**51**
Pardo3	2.7	**12.2**	6.8	**35.8**	2.2	**1.2**	138.7	**267.4**	14.2	**8.4**	10.8	**5.4**	3.4	**3.0**	3.2	**3.3**	**42**	**52**
Pardo4	0.5	**7.8**	0.0	**3.2**	2.3	**2.2**	165.7	**211.9**	11.2	**10.7**	5.8	**7.3**	5.4	**3.4**	10.1	**6.4**	**49**	**51**
Mean	*30.0*	**80.9**	*36.4*	**230.3**	*3.6*	**22.4**	*209.3*	**465.0**	*14.1*	**25.8**	*8.2*	**22.3**	*5.9*	**3.5**	*6.2*	**5.5**	**47**	**53**

Lavapés River during the dry-winter. The inorganic phosphate was lowest in P2 and highest in A2. The organic phosphate was lowest in C3 and highest in L2. Lavapés River had the highest inorganic and organic phosphate concentration. Capivara River showed the lowest inorganic and organic phosphate concentrations

Total and dissolved nutrient concentration were higher in dry period (Table 4). Sampling stations with domestic and industrial sewage impact were the ones with higher nutrient concentration (A2, L2, L3, L4 and P1). Lavapés River always showed high nutrient concentration, mainly in the medium river stretch, right after the headwater stretch (L1), and concentrations in Capivara River were generally lower.

DBO, pH and OD are important water variables that do not show up in PCA analysis. The BOD values were high in Lavapés and Araquá rivers, especially in the rainy season (Table 3). Acid conditions predominated in the studied rivers, mainly in dry season (Figure 3). In the sampling station L2, with a direct influence of domestic sewage discharges, the pH values were high in both periods. Higher concentrations of OD were observed during the dry season, due to a positive influence of lower temperatures. In summer higher differences were observed among the rivers mean values.

Concerning the sediment analysis, some upstream stations exhibited consolidated sediment like coarse gravel (A2 and C2) or even a continuous rock bed (L2 and P1) (Table 5). In the lower river stretches the sediment was fine sand (A4, A5, C4, L3, L4 and P3), due to the continuous erosional process and soil transportation along the basins. The sediment of the other sampling stations was classified as medium sand.

The organic matter percentage (Table 5) and nitrogen concentration (Figure 5) in the sediments were influenced by the predominant particle size. Thus, the stations A5, C4, L3, L4 and P3, with finer sediment particles, exhibited higher organic matter percentage and nitrogen concentration. There was no clear correlation between nitrogen concentration in water and sediment.

3.1. *The trophic index*

The trophic index – TSI was also calculated in this study aiming to classify rivers according to their eutrophication degree (Table 4). Higher values of TSI were determined for the sampling station A2, considered hypereutrophic due to the excessive concentration of chlorophyll-*a*. The lowest TSI was determined for P2, considered ultra-oligotrophic, which may be related to low nutrient availability in the water. The TSI was generally higher in dry season with an increase downstream tendency, except in A2 and P1 directly under influence of sewage discharges. Lower TSI was calculated for Pardo River in the rainy-summer period.

3.2. *Loads*

Higher loads of TN and TP are transported by Lavapés River and lower by Pardo River (Figure 6). Nutrient loads were higher in the rainy season, except for TP in Lavapés River that should be related to sewage concentration in dry season.

Table 5. Grain size, organic matter and water percentage in the sediment samples of Araquá, Capivara, Lavapés and Pardo Rivers during the rainy and dry (in bold) periods of 2007.

Sample Station	Grain size (Φ)		Organic Matter %		Water percentage	
Araquá1	1.716	1.600	0.38	0.34	24.30	10.30
Araquá2	1.716	1.630	0.65	0.31	8.20	4.69
Araquá3	1.760	1.600	0.85	1.18	18.96	21.25
Araquá4	1.600	3.130	2.24	12.11	23.14	53.91
Araquá5	2.360	4.360	47.24	43.66	85.66	45.34
Mean	*1.830*	**2.464**	*10.27*	**11.52**	*32.05*	**27.10**
Capivara1	2.050	1.760	9.96	6.56	29.74	30.35
Capivara2	1.750	1.050	7.66	1.25	18.28	7.63
Capivara3	1.983	1.530	0.29	0.34	16.94	42.41
Capivara4	3.883	1.583	12.38	0.81	44.12	0.00
Mean	*2.417*	**1.481**	*7.57*	**2.24**	*27.27*	**20.10**
Lavapés1	1.516	1.716	1.29	3.76	22.63	47.79
Lavapés2	1.160	1.300	0.68	0.89	17.14	22.72
Lavapés3	1.983	3.983	2.09	10.27	22.04	63.54
Lavapé 4	2.483	2.800	4.56	6.16	28.44	29.14

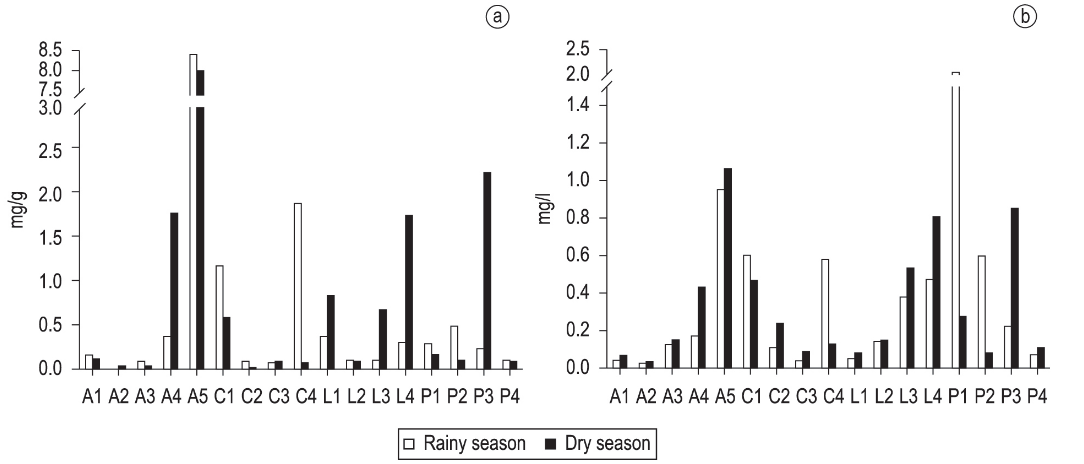

Figure 5. Variation of nitrogen (a) and phosphorous (b) concentration in sediment samples of Araquá, Capivara, Lavapés and Pardo Rivers in rainy and dry season.

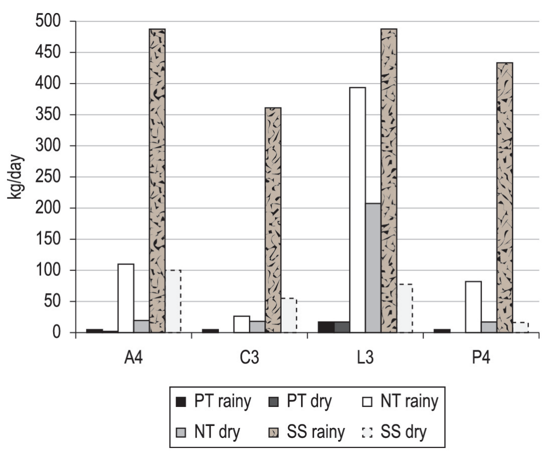

Figure 6. PT, NT and SS loads in Araquá (A4), Capivara (C3), Lavapés (L3) and Pardo (P4) rivers.

For nitrogen the increase between rainy and dry period was proportionally higher in Araquá River, 5.3 times. This result is related to sewage impact in the upstream and intensive agricultural land use in the watershed area (63%) (Figure 7). Suspended solids were higher in Araquá and Lavapés rivers in the rainy season. Lower SS load was calculated for Pardo River during dry season.

The rivers Lavapés, Capivara and Araquá together export 27.42 kg.day^{-1} of TP in the rainy season and 21.11 kg.day^{-1} in the dry season. The largest contribution is from Lavapés River (63% in rainy season and 85% in dry season). The considered rivers TN exportation is 531.73 kg.day^{-1} in rainy season and 247.05 kg.day^{-1} in dry season, with higher contribution also from Lavapés River (74% in rainy and 84% in dry season). The total (Araquá, Capivara, Lavapés and Pardo) SS load was 1337.12 kg.day^{-1} in rainy season and 231.63 kg.day^{-1} in dry season. Capivara, with higher percentage of forests in the watershed (47%) (Figure 7) is the river with the lowest contribution of SS exportation.

4. Discussion

Based on the integrated analysis (PCA) of data, which discriminated the main tendencies of variation, the discussion of the results was organized in the following topics: seasonality, longitudinal variation, impacts and management.

4.1. Seasonality

The rivers width, depth, velocity, flow, suspended solids, electric conductivity, turbidity and BOD at the different sampling stations were generally higher in summer/rainy season (Table 6). The rain effects on soil material transportation into the rivers are amplified by diminution of retention mechanisms (low permeability, soil compactness and deforestation). Similar results were observed by Moretto and Nogueira (2003) in a previous comparative study of Capivara and Lavapés rivers.

According to Brigante and Espíndola (2003) most Brazilian rivers are naturally turbid, due to the geological characteristics of the basins and effects of the strong tropical rains. Additionally, the suppression of the vegetal coverage, increasing soil susceptibility to erosion, is the most frequent human activity that causes turbidity increases of freshwater ecosystems (Pérez, 2003).

High variation in chlorophyll and dissolved oxygen concentration between rainy and dry season was also observed (Table 3). The chlorophyll-*a* and DO were higher in dry season, probably because

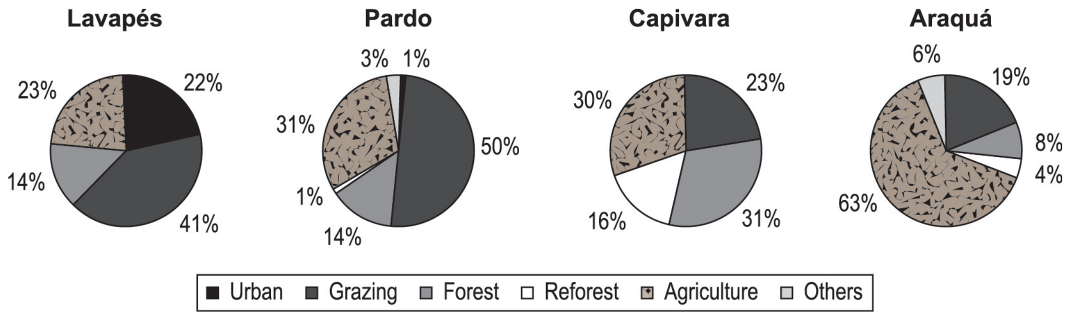

Figure 7. Lavapés (Orsi, 2004), Pardo (Ribeiro and Campos, 2007), Capivara (Araújo Junior et al., 2002) and Araquá (Refosco, 1996) catchment uses.

Table 6. Channel width, depth (transversal section mean value), flow and velocity (transversal section mean value) measured in Araquá, Capivara, Lavapés and Pardo Rivers during the rainy and dry (in bold) periods of 2007.

Sampling stations	Width (m)		Depth (m)		Velocity (m/s)		Flow (m³/s)	
Araquá1	2.00	**2.34**	0.32	**0.33**	0.42	**0.30**	0.29	**0.17**
Araquá2	1.65	**2.60**	0.19	**0.10**	0.32	**0.30**	0.10	**0.29**
Araquá3	8.50	**6.00**	0.42	**0.24**	0.49	**0.35**	1.26	**0.52**
Araquá4	7.30	**6.90**	1.11*	**1.43***	0.25	**0.14**	3.84	**0.89**
Araquá5	-	**-**	2.10*	**1.60***	-	**-**	-	**-**
Mean	5.11	**4.46**	0.83	**0.74**	0.37	**0.27**	1.37	**0.47**
Capivara1	1.00	**0.60**	0.24	**0.39**	0.76	**0.25**	0.13	**0.06**
Capivara2	6.00	**7.95**	0.29	**0.14**	0.36	**0.44**	0.55	**0.46**
Capivara3	13.00	**11.00**	0.57	**0.30**	0.37	**0.30**	2.17	**0.84**
Capivara4	-	**10.00**	1.10*	**1.50***	-	**0.06**	-	**1.43**
Mean	6.67	**7.39**	0.55	**0.58**	0.50	**0.26**	0.95	**0.70**
Lavapés1	0.25	**0.25**	0.04	**-**	0.03	**0.05**	0.00	**0.00**
Lavapés2	10.70	**9.50**	0.13	**0.11**	0.84	**0.67**	0.90	**0.74**
Lavapés3	1.20	**1.20**	2.48*	**0.67**	0.13	**0.51**	1.35	**0.52**
Lavapé 4	-	**-**	2.50*	**2.40***	-	**-**	-	**-**
Mean	4.05	**3.65**	1.29	**1.06**	0.33	**0.41**	0.75	**0.42**
Pardo1	2.30	**2.40**	0.45	**0.31**	0.60	**0.29**	0.48	**0.16**
Pardo2	4.87	**2.40**	0.55	**0.17**	1.15	**0.63**	2.96	**0.20**
Pardo3	8.50	**13.50**	1.83*	**1.93***	0.05	**0.11**	1.54	**2.03**
Pardo4	10	**10**	1.08*	**0.51**	0.306	**0.20**	5.77	**0.97**
Mean	6.42	**7.08**	0.98	**0.73***	0.52	**0.31**	2.69	**0.84**

the diminution of the washout effect, in case of chlorophyll-*a*, and lower temperature, favoring oxygen solubility.

The TN, nitrite, nitrate and ammonium concentration in the water increased in dry season, directly related with water flow decrease and diminution of dilution effect. König et al. (2008) also observed higher values of nutrients during winter, in small streams from south Brazil, superior than the values of total phosphorus accepted by CONAMA/357 (Brasil, 2005). Phosphates concentration was approximately twice higher in the dry season, with the predominance of the organic fraction. Similar trend was observed by Gralhóz and Nogueira (2006) in a small and heavily polluted tributary of Araquá River.

The nutrient concentration and also the trophic (TSI) state was higher in dry season, that is related to chlorophyll-*a* and TP increase; however loads of TP, TN and SS were higher in rainy season due to the considerable increase in the rivers flow rate. Pérez (2003) considers that water nitrogen main sources are associated to organic effluents and agriculture activities and nitrite and ammonium indicate recent contamination (organic).

In Pardo River the loads transportation increase 6.2 times for TP and 27 times for SS in rainy season when compared to dry the season. The Lavapés, Capivara and Araquá rivers loads exportation of TP to Tietê River were 1.3 times higher in rainy season and for TN it was 2.15 higher.

The dilution effect is remarkable in rainy season, but the runoff contributes to higher P, N and SS loads during this season. Kuhlmann et al. (2014) considered that the transport of erosional material from surface runoff to the upstream section of Paraibuna and Ipiranga rivers (SP), were positively correlated with rainfall. Banner et al. (2009), studying phosphorus dynamics in streams of Kansas - USA, found that 88% of the total annual load is transported during flows that occur only in 10% of the time.

4.2. Longitudinal variation

The upstream stations exhibited higher velocity, water transparency and dissolved oxygen and also gravel substrate. Downstream stations had higher width, depth and water temperature, fine sediment and higher organic matter percentage and nitrogen in the sediment. The TSI tend to be lower in upstream sampling stations.

The electric conductivity, suspended solids and turbidity have a tendency to increase downstream in Capivara and Lavapés rivers and the temperature and BOD in all studied rivers (Table 3). The PCA also evidenced a better environmental condition in the upstream sampling stations (L1, C1 and P2). This is a result of longitudinal accumulated impacts from agriculture, deforestation, soil erosion and domestic sewage discharges. Dodds and Oakes (2008) pointed out the important role of headwater riparian areas on the downstream water quality maintenance. The nutrient and sediments loads results demonstrate the impact of small and medium size rivers on higher order rivers and reservoirs downstream located.

In Araquá, Capivara and Lavapés rivers DO decreased towards the mouth due to the turbulence decrease (lower declivity) and increase in decomposition processes, higher temperature and lentic characteristic due to the influence of Barra Bonita reservoir. High increase in chlorophyll-*a* concentration at A5 and L4 stations and the reduction of the sediment size in the river mouths stations was influenced by the lentic characteristics of Barra Bonita reservoir, appropriated to phytoplankton development. In Lavapés river is noteworthy the DO concentration decline in L3 station, after the sewage discharge (L2), diminution of the water velocity and the replacement of lotic by lentic characteristics.

Stations downstream located, with lower river declivity, showed higher organic matter percentage and nitrogen concentration in the sediment (A4, A5, L3, L4 and P3). These stations were also grouped in the PCA because of the sediment organic matter, NT, PT and grain size (axis 2). The downstream accumulation of fine sediment and its negative impact on benthic invertebrates is a clear impairment indicative (Buendia et al., 2013; Suriano et al., 2011).

In streams impacted by sewage effluents (Araquá and Lavapés) the amount of nutrients is probably much higher than the biota consumption, and phosphorus tends to accumulate downstream in the bottom sediment. In streams with no significant organic sewage discharges (Pardo and Capivara) there is an opposite tendency, phosphorous concentration in the sediments decreases downstream, probably related to biota incorporation. Kuhlmann et al. (2014) considered that organic pollution and erosion impacts in the Paraibuna River were buffered by the depuration process and protective action of the riparian vegetation of the surrounding area.

4.3. Impacts

The analyzed rivers undergo distinct environmental impacts that are related with point and non-point sources impairments, such as urban sewage and intensive soil use for agriculture.

The PCA analysis grouped the river stretches under direct influence of punctual sources of pollution - Lavapés (L2, L3), Araquá (A2) and Pardo (P1). It is related with the sewage discharges that promoted the increase of SS, EC, chlorophyll-*a,* total and thermotolerant coliforms, TN and TP, ammonium, nitrite, nitrate, organic and inorganic dissolved phosphorus and total dissolved phosphorus in water, that were water variables better correlated with this axis 1.

In polluted waters there is a conspicuous increase of conductivity due to the direct effect of higher ions concentration (Brigante and Espíndola, 2003; Gralhóz and Nogueira, 2006; Lussier et al., 2008). Ternus et al. (2011) observed significant conductivity increase in river courses passing through urban areas with no marginal vegetation. Conductivity also provided to be useful to differentiate ecological conditions and correlation with biota (Braun et al., 2014; Cunha et al., 2014; Mazzoni et al., 2014; Suriano et al., 2011).

In sampling sites affected by sewage sources the organic fraction of suspended solids was much higher than the mineral one (e.g. A2 station) as observed by Brigante and Espíndola (2003) in the Mogi Guaçu River and concluded that these results reflected the sum of both natural conditions and human impacts.

Nutrient concentration in stream water is too different when compared polluted and non-polluted conditions (Strieder et al., 2006; Cunha et al., 2011; Ternus et al., 2011). According to Odum (2007) human occupation accelerated the circulation of many earth materials and the auto-regulation processes, which tend to maintain the ecosystems homeostasis, became less operational, hence the nutrients cycles tend to be imperfect or acyclic resulting in a paradoxical situation with excess in some places and scarcity in others.

Nitrogen availability, especially associated to phosphorus, can regulate or limit the productivity in freshwater ecosystems (Carmouze, 1994). The concentration of chlorophyll-*a* in the studied river, as showed in the PCA, is positively correlated with pollution and eutrophication process. According to Pérez (2003) the phosphorus amount is much lower comparing to nitrogen, but its effect for eutrophication is higher. In this study the TP concentration were about eight times lower than nitrogen. Cunha et al. (2011) consider that TP point discharges from urban centers represent a higher risk of eutrophication for São Paulo State rivers than the diffuse sources. The authors also found lower TP concentration in rivers with presence of riparian vegetation.

The loads analyses also showed that high TP, TN and SS transported by Lavapés River are strongly related to point sources of pollution. According to Moretto and Nogueira (2003) this river receives huge loads of urban sewage, partially treated, just after its headwater.

The nonpoint source impacts were the ones associated with intensive watershed uses and occupation, such as the absence of riparian forest, soil compactness, soil erosion and agriculture impact. Better water quality conditions were associated to Capivara and Pardo rivers, which were grouped in the opposite side of PCA axis 1. Regionally these rivers indicate a relatively good conservation status. Riparian forests and whole watershed land cover are significantly correlated with the water quality metrics, particularly nutrient concentrations, and the agricultural and/or urban lands are the most important predictors of water quality degradation (Dodds and Oakes, 2008; Kuhlmann et al., 2014; Mazzoni et al., 2014).

Fonseca et al. (2014) consider that agriculture and planted pasture have caused major impacts on river watersheds of Cerrado Domain, such as water pollution, streams siltation, and loss of riparian vegetation. In the United States the distinct stream segments in watersheds are classified by criteria of the Department of Agriculture Natural Resources Conservation Service (NRCS), which is comparable to the Brazilian CONAMA, searching for primary management capacity in regions of high agricultural threats (Fore et al., 2014).

The impact related with deforestation and erosion was particularly observed in Araquá River basin. As seen in Figure 7, the Araquá River has only 12% of the watershed composed by forested or reforested areas, and Capivara River has 47%, the highest forest percentage in this study. In our study Araquá and Lavapés Rivers exhibited higher spatial and seasonal amplitude of variation for temperature. Differences in temperature can be related to the distinct proportion of preserved riparian forest in each basin (Ternus et al., 2011). Fonseca et al. (2014) consider that the smallest median values reported for water temperature from sites classified as "natural" is a consequence of shading effects promoted by riparian vegetation.

The sampling station A2 (Cintra River) showed the highest chlorophyll–*a* concentration, due to the direct influence of upstream phytoplankton inoculums derivate from primary sewage treatment lagoons. The survival of the phytoplankton populations along the downstream stretches could be favored by increasing tendency of light penetration, as the marginal forest has been removed. Harding et al. (2006) observed increase about 100 to 600% of periphyton growth in impacted sites of agriculture areas with low riparian forest.

The loads results are related to the characteristic of the watershed area as for Pardo River where 50% is pasture, 31% agriculture and 14% forest. For Dodds and Oakes (2008) the land use characteristics are the main stressor for water quality variation among watersheds. In Araquá and Pardo rivers the runoff impact that carries TN, TP and SS from the soil to the water is mainly associated to the watershed use and occupation and loads, especially of TN, increased in the rainy season. Silicate higher concentrations are also associated to intensive soil use/deforestation for agriculture, as observed by Moretto and Nogueira (2003). According to Liu et al. (2014), the losses of P and N in farmland plains are positively correlated with the rainfall intensity and the antecedent conditions of soil moisture, and negatively correlated with the vegetation cover. Longer and more intense rainfall resulted in a higher loss of N and P.

Violin et al. (2011) consider that pollutant concentrations increase not only due to higher inputs from point and non-point sources but also as a result of decreased nutrient removal efficiency in hydrological disconnected riparian zones and streambeds. Changes in riparian vegetation are notorious in the studied rivers. In case of Araquá River it is observed only 12% of forested areas in the watershed, with the predominance of pasture, 19%, and agriculture, 63%.

4.4. Management

The obtained results can certainly subsidize regional environmental policies. Lavapés River is the most affected by urbanization, followed by Araquá River and they are impacted mainly by sewage, whose treatment efficiency should be urgently improved. The disposal of untreated sewage into rivers is still a common practice in Brazil and generates large impact downstream.

The Lavapés River passes through the city of Botucatu and the population is in contact with very polluted stretches of the river, providing an unhealthy environment, taking off aesthetics scenarios, preventing the water to be used for water supply, irrigation, fishing and leisure despite its great potential. Moreover this study also shows the river exports large amounts of N, P and SS to Tietê basin, increasing its eutrophication and siltation. Therefore, the Lavapés River pollution surpasses municipality borders and impacts cities downstream.

Pardo, Araquá, Lavapés and Capivara rivers are impacted by rural uses of the watershed, mostly monocultures (especially sugar-cane plantation) and cattle pastures without proper soil conservation practices and native forest preservation.

For effective management Carpenter et al. (1998) consider essential to understand the hydrological processes of retention, related to the mechanisms of nutrient mobilization and transport. It is important developing a strategic environmental assessment that aims to integrate environmental and sustainability considerations into strategic decision making (Bidstrup and Hansen, 2014).

The P and N soil losses and transport to surface waters by erosion and runoff occurs over larger spatial scales or landscape scale and may be reduced by increasing vegetation cover and gallery forest, maintaining buffers zones or other passive land uses in headwater streams, regulate the land uses, conservation and restoration of wetlands and reduced applications to match crop needs (Allan, 2004; Carpenter et al., 1998; Dodds and Oakes, 2008; Hoffmann et al., 2009; Fore et al., 2014; Kuhlmann et al., 2014; Liu et al., 2014).

The legislation is also an important management instrument, because it establishes norms and standards to be followed for good practices in water use and conservation (Kuhlmann et al., 2014). The interpretation of particular water variables, such as DO and BOD, is commonly made for water supply and sewage companies in Brazil, but it can generate deficient interpretations. In this study the DO and BOD did not show strong relationship with pollution, as observed for SS, EC, chlorophyll-*a,* coliforms, Nitrogen e Phosphorus in water.

The specific resolution of the Brazilian Council for the Environment, CONAMA 357, that considers a range of standards can be considered an advance for the Brazilian environmental policy. It establishes limits for water variables according to the current and future uses, and classifies freshwater systems in five classes (especial, 1, 2, 3 and 4).

The results of some studied variables were confronted with the standards of the CONAMA 357 resolution for class 1, due to its good quality and multiple uses possibilities. Maintenance or restoration in order to achieve class 1 condition should be a target for the society distinct sectors.

In general the OD and turbidity of most sampling stations, as well as chlorophyll-*a* concentration except at stations A2, A5 and L4 (in summer), could correspond to class 1 river standards. Most of pH values were inappropriate. However, it is important to consider that acid water can be a natural condition (Odum, 2007).

All BOD values, TP concentrations, TN concentrations in L2, L3 e L4, thermotolerant coliforms in Araquá, Lavapés and P1 were higher than the permitted to class 1 rivers. According to Cunha et al. (2011), the reference standard for nutrients should be revised, e. g. nitrogen concentrations that are naturally low and limiting condition in many tropical watersheds. Fonseca et al. (2014) consider that systems classified as "very impacted" in their study presented TP values lower than the proposed for class 1 rivers.

From "Class 1" to "Class 4," water quality decreases, and upper limits for different water variables are fixed. Lavapés River that receives effluents discharge is included in class 4. Class 4 rivers are only intended for navigation and landscape harmony and its quality standards are very permissive. According to Araújo and Santaella (2001), the management concept that domestic and industrial wastewater can be disposed into water bodies due to their ability to dilute and degrade the waste and pollutants is primitive and must be more intensively fought. The law consideration that a river can receive wastewater with high concentration of pollutants is harmful to the society, especially considering that São Paulo States is presently in the worst water crisis in the history. Therefore, all the rivers should have a minimum quality for nobler purposes than only navigation and landscape harmony.

The applicability and efficiency limitations of the legislation for management purposes may be related to continuous aquatic environment degradation as observed in this study. The CONAMA/357 Resolution seems to be inadequate to different environmental impacts, not considering regional typologies and not addressing specific ecosystem features. This can mask the reality and generates false interpretations. The study also shows that the CONAMA/357 could be improved, in order to consider important variables, such as sediment quality, water electric conductivity, the influence of ecological process and be more restrictive to nitrogen concentration. In case of phosphorus it seems to be too restrictive. By assessing the general watershed condition and multiple threats, management agencies can prioritize conservation actions and investments based on the types and severity of the threats, and the degree of primary management capacity (Fore et al., 2014).

In China environmental protection policies have been implemented to prevent soil erosion and nonpoint source pollutions, resulting in a considerable percentage of change, close to 60%, of water flow, sediment, organic N, and organic P at watershed level (Ouyang et al., 2008).

The establishment of standards should be related to scientific knowledge. In Brazil, different from some more advanced experiences (e.g. USA, China and the European Union), the interface between science, law, management and conservation of aquatic ecosystems is still incipient and needs to be urgently improved.

5. Conclusion

The considered variables permitted to identify longitudinal tendencies, seasonal influences (rainy-summer and dry-winter) and the impact of point and non-point sources of pollution. The TSI was a sensitive tool to detect, in an integrated way, the environmental variations. The small and medium-sized rivers studied export large amount of NT, TP and SS, mainly to the Tietê River basin/Barra Bonita reservoir. The assessment of Araquá, Capivara, Lavapés and Pardo rivers conditions demonstrates that management measures at punctual and watershed levels are urgent and that environmental law standards should be reconsidered and improved.

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